Vehicle Data Logging Device

Group 17

Sponsored by

Dr Yiannis Papelis

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Joshua Mahaz (CpE)

Graham Smith (EE)

April 20 2007

Abstract

- Sponsored by Dr. Papelis (UCF CECS)
- Build a compact hardware device that logs data acquired by various sensors on a passenger vehicle
- Vehicle data to be logged includes: geographic location, engine RPM, throttle position, acceleration, speed, yaw rate, and forward looking video
- Device must have an easy way to retrieve the data
- Must allow for widespread data gathering usage
- Device must be portable and easy to install

Motivation

- Dr. Papelis' Motivation:
  - 45,000 automobile accident deaths each year, of which 90% involve driver error.
  - To provide real world data for input into his research.
  - Extensive amounts of logged data to study driver behavior and develop metrics for driver performance.

- Group 17's Motivation:
  - Solid-state device with current standard components
    - Working with standard hardware will be much more versatile than learning a highly specialized task to complete a project.
  - It is also encouraging that if the design is good enough, the device could be actually used after the project is done, rather than just a proof of concept.
  - Sponsored - meaning little money out of pocket.

Vehicle Data Logging Device

- **Data Requirements:**
  - Geographic position
  - Velocity
  - Throttle-position
  - Engine RPM
  - Lateral & longitudinal acceleration
  - Forward looking video images (cost dependent)
  - Yaw rate (optional)
  - Following distance (optional)

- **Administrative Requirements:**
  - Allow for easy data retrieval
  - User Interface
  - Small, portable, easy to install device
  - Maintain system cost reproduction below ~$400
  - Intelligent Power Supply
    - Draws power only when the engine is running

Project Specifications

	Capture Frequencies	
Data	Minimum	Optimal
OBDII - Speed, RPM, Throttle Position	1 Hz	3 Hz
Lateral & Longitudinal Acceleration	>10 Hz	10 Hz
GPS Position, Speed, Time	1 Hz	1 Hz
Forward Looking Video Images	>1 Hz	2 Hz
Yaw Rate	>5 Hz	10 Hz
Following Distance	>1 Hz	5 Hz

Vehicle Data Logging Device

Hardware Requirements

- OBDII Interface (On Board Diagnostics)
  - Vehicle Speed, RPM, Throttle Position (if avail.)
- Accelerometer (dual-axis)
  - Lateral and longitudinal acceleration
- GPS Sensor
  - Vehicle position and accurate time
- Data Storage Device
  - To store all the logged data

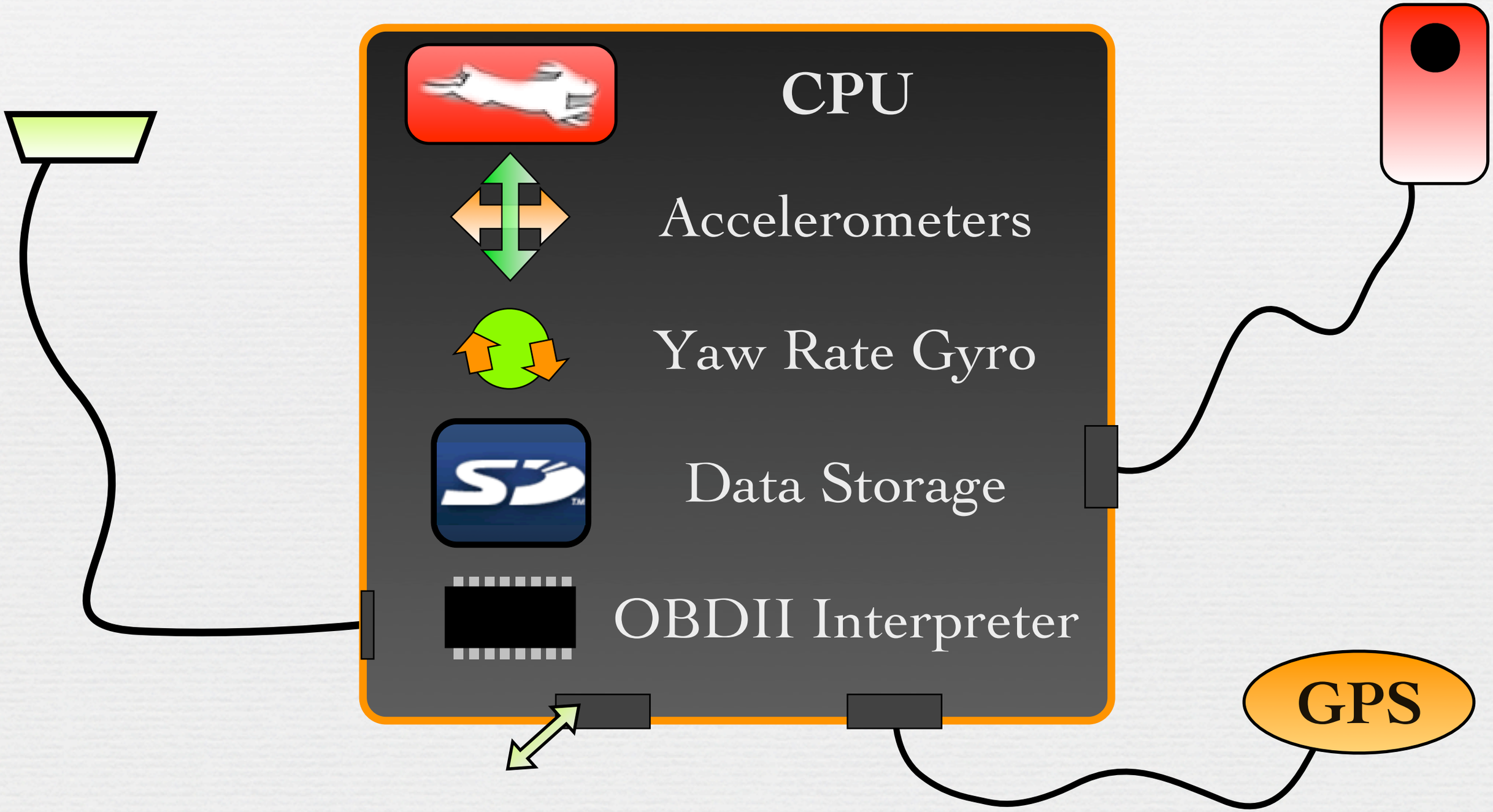
- Image Sensor
  - Captures forward looking video
- Yaw Rate Sensor
  - Measures turning rate of the vehicle
- Range-finder
  - Measures following distance

} Optional

Vehicle Data Logging Device

Hardware Components

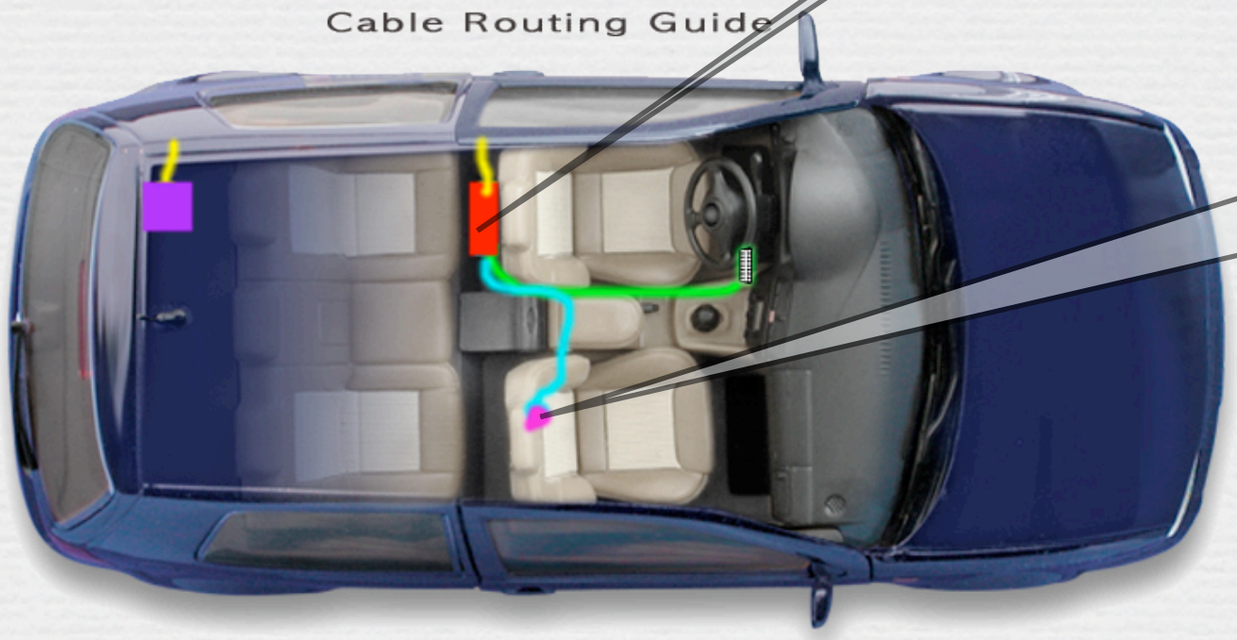
Block Diagram



Vehicle Data Logging Device

Component Layout

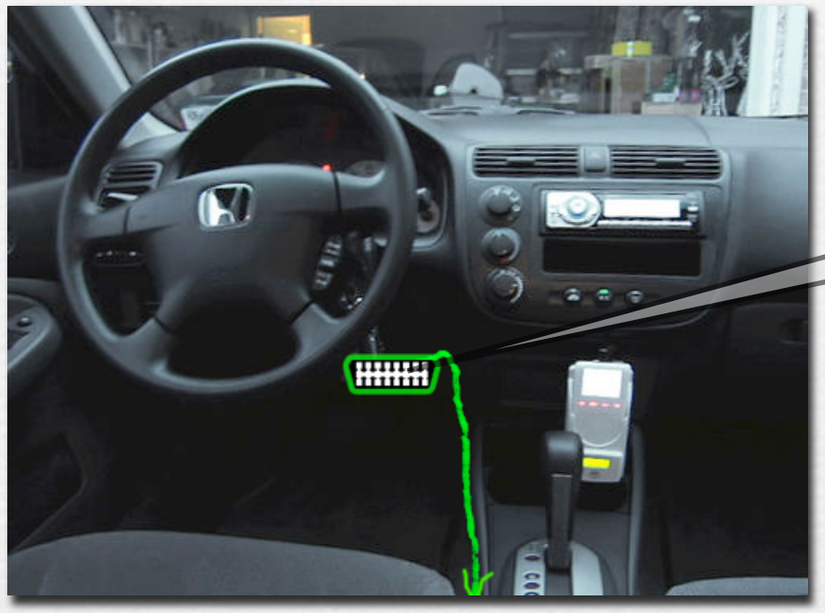
Cable Routing Guide



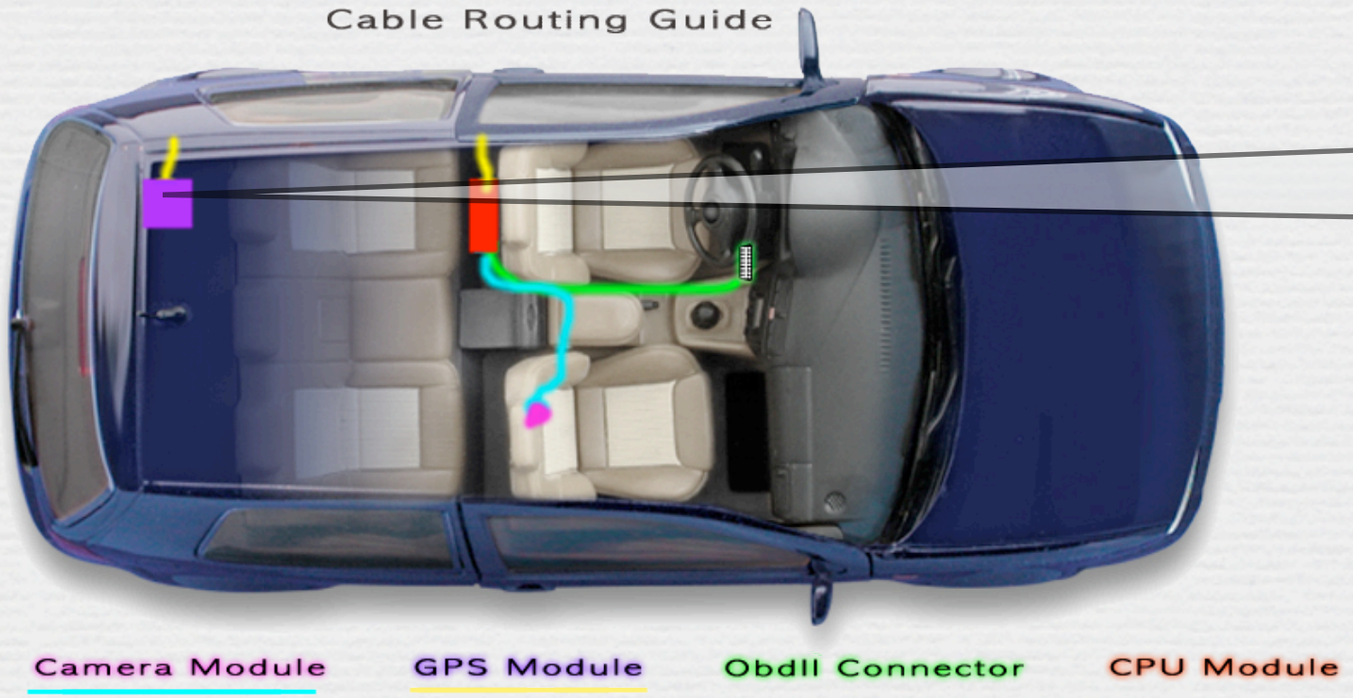
Device CPU placed on the back seat floor

Camera placed in view of driver and road; Attached to headrest of passenger seat

Component Layout

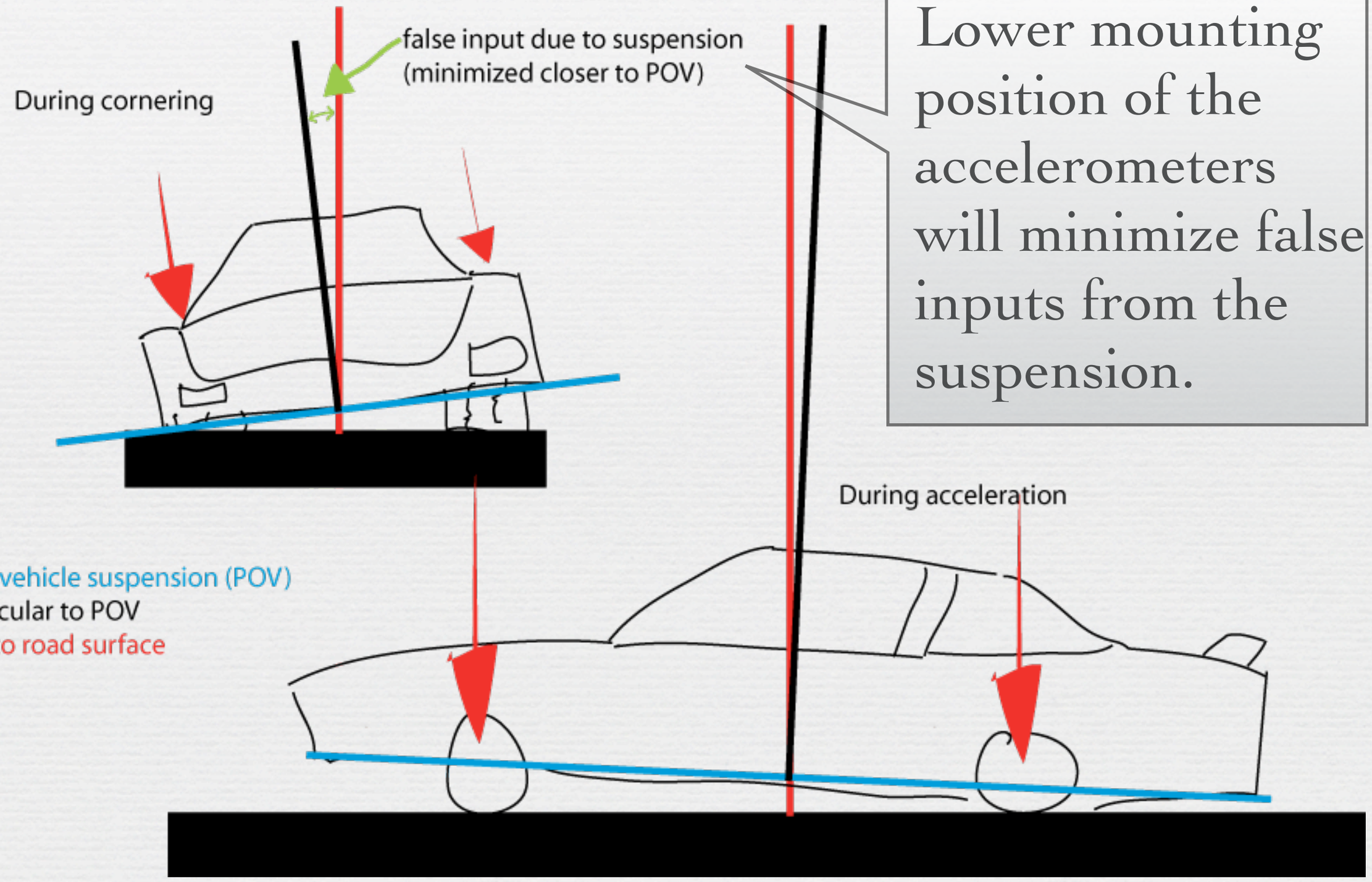


OBDII Standard requires port to be within 36” of steering wheel.



GPS device mounted on roof for clear view of sky and proper ground plane.

Mounting Location Constraints



Lower mounting position of the accelerometers will minimize false inputs from the suspension.

Data Logging Constraints

Image Capture Constraints

Resolution	Approx File Size (KB)	Approx Number of Images/Capacity(MB)				
Capacities (MB) ---->		128	512	1024	2048	4096
VGA	32.3 KB	4,058	16,232	32,464	64,927	129,855
QVGA	11.0 KB	11,967	47,869	95,739	191,477	382,954
160x120	6.8 KB	19,361	77,443	154,886	309,771	619,543
Text	0.2 KB	613,788	2,455,154	4,910,307	9,820,615	19,641,230
Hours of Image Capture @ 1Hz						
640x480	VGA	1	5	9	18	36
320x240	QVGA	3	13	27	53	106
160x120	sub-QVGA	5	22	43	86	172
Text		170	682	1364	2728	5456

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Storage Media Comparison

Media Type ->	CompactFlash		SmartMedia	MMC	
Varieties	I	II		MMC	RS-MMC
Maximum storage capacity, MB	8000	12000	128	4096	512
Theoretical maximum capacity	137 GB	137 GB		128 GB	
Data read speed, MB/s	40	40	2		
Data write speed, MB/s	40	40			
Read/write cycles	∞	∞	1,000,000	1,000,000	∞

Media Type ->	Sony Memory Stick (proprietary - not much hardware avail)			
Varieties	Standard	Pro	Pro Duo	Micro
Maximum storage capacity, MB	128	4096	4096	
Theoretical maximum capacity	128 MB	32 GB		
Data read speed, MB/s	2.5	20	20	20
Data write speed, MB/s	1.8	1.8	10	
Read/write cycles	∞	∞	∞	∞

Benefits of SD

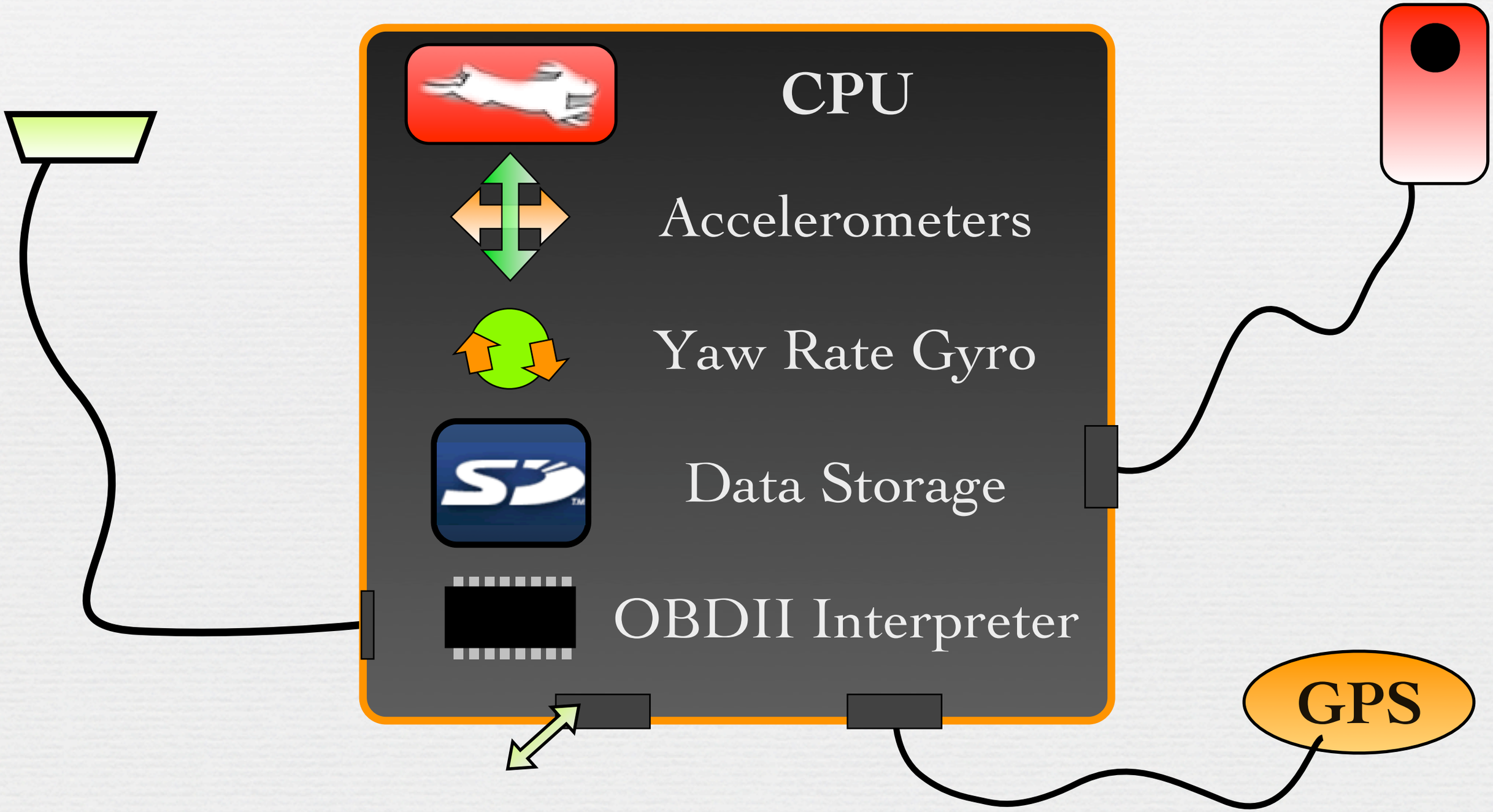
- Uses less power than CF
- Lots of 3rd party hardware available
- Smaller
- Inexpensive cards in many sizes

Media Type ->	xD			Secure Digital (SD)		
Varieties		Type M	Type H	SD	miniSD	microSD
Maximum storage capacity, MB	512	2048	1024	4096	2048	2048
Theoretical maximum capacity	512 MB	8 GB	8 GB	128 GB		
Data read speed, Mb/s	5	4	15	20		
Data write speed, Mb/s	3	2.5	9	20		
Read/write cycles	∞	∞	∞	∞		

Hardware

Hardware Components

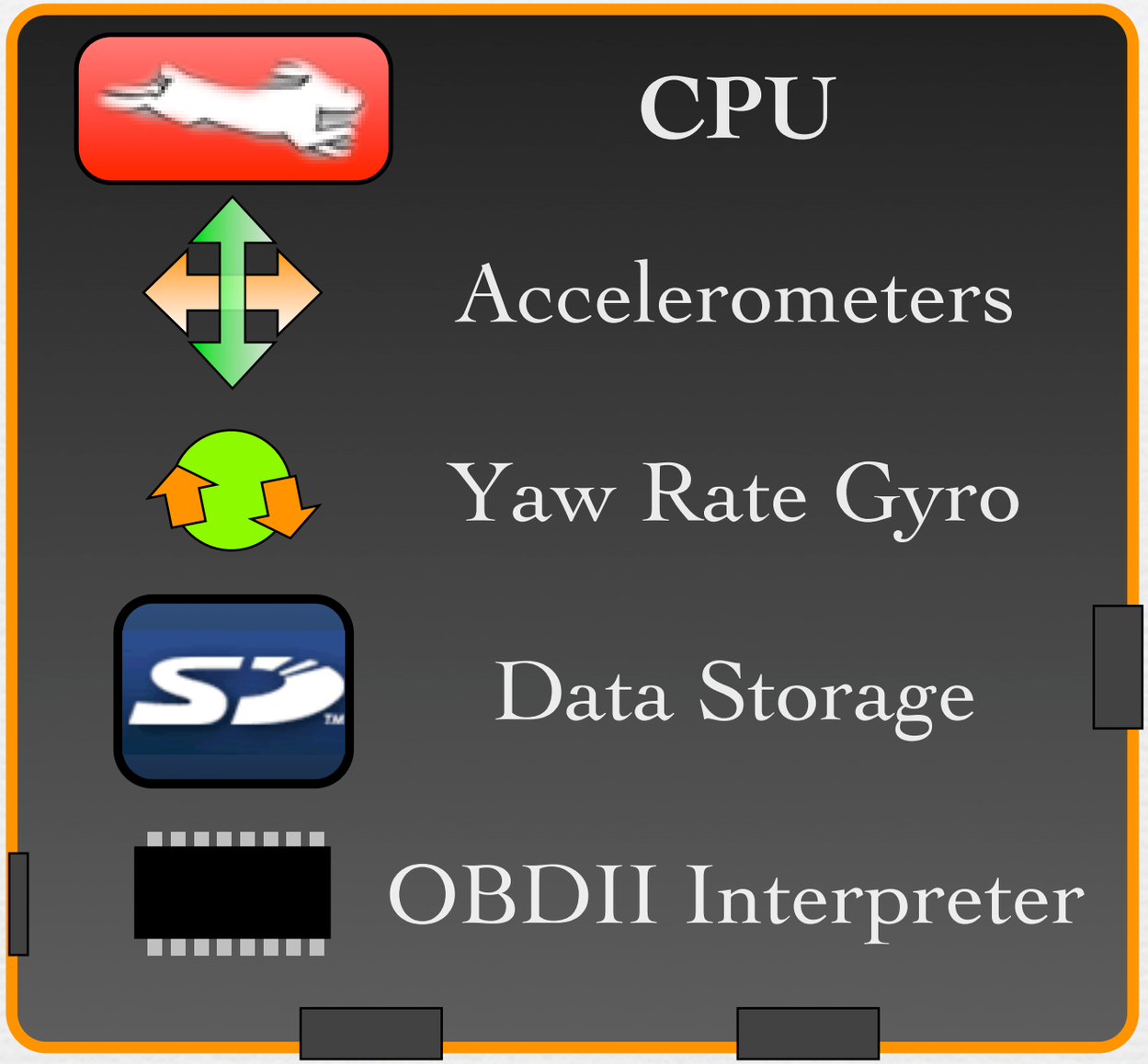
Block Diagram



Vehicle Data Logging Device

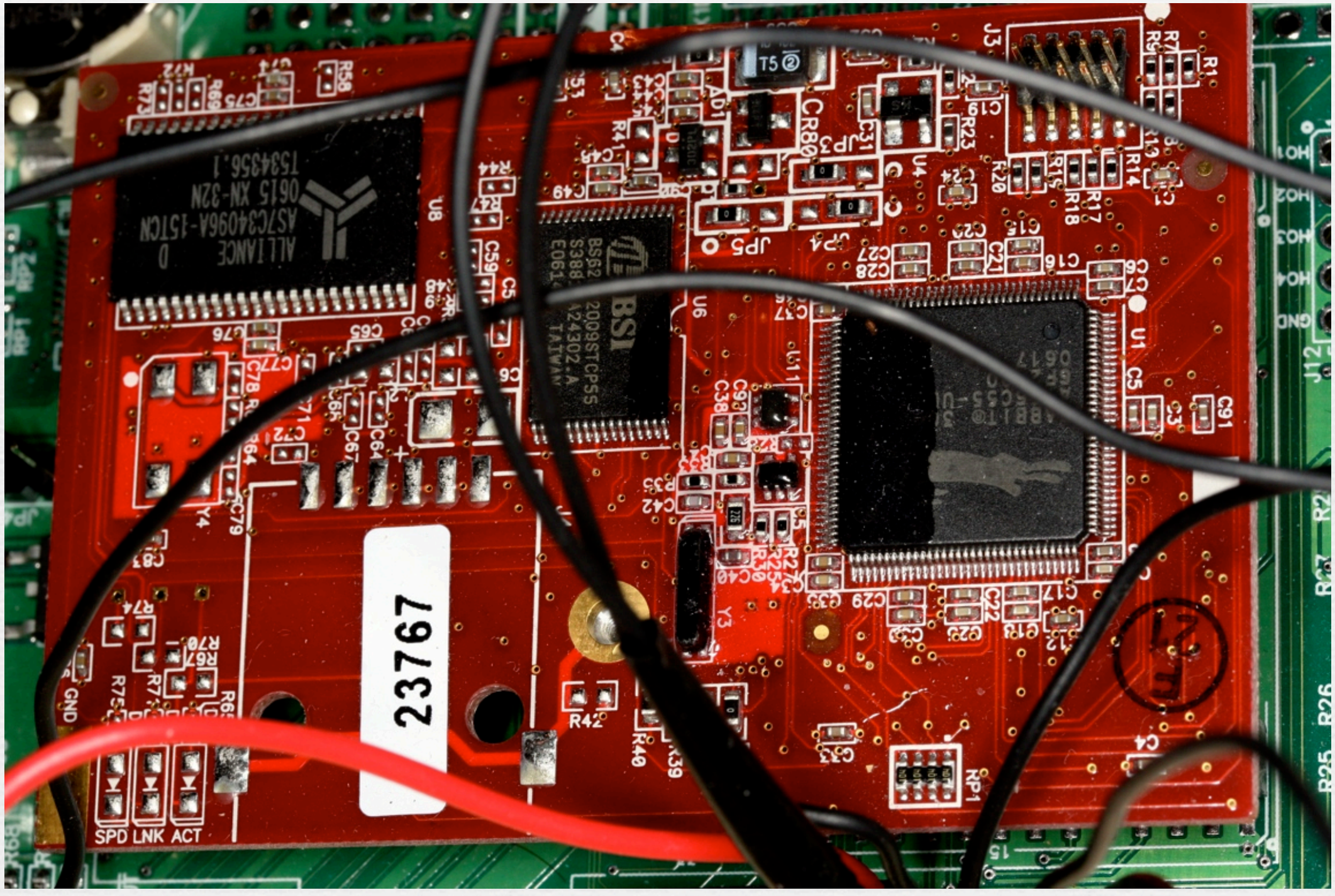
Hardware Components

Block Diagram



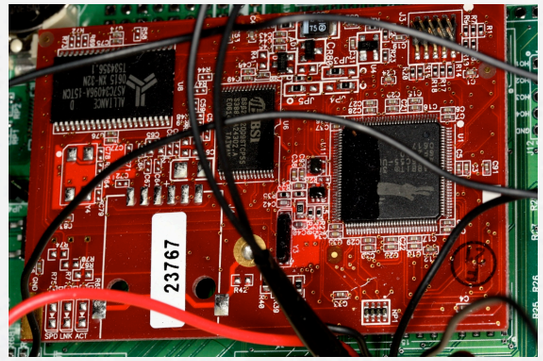
Vehicle Data Logging Device

Micro-Controller



Vehicle Data Logging Device

Micro-Controller



Rabbit 3220

Design Considerations

- **Speed - 44MHz**
  - Adequate speed for data throughput
    *Image capture is largest constraint
- **I/O Lines**
  - Must have adequate I/O lines to support all devices (33)
    Rabbit has 52 I/O Pins
- **Protocol Support**
  - I^2C, RS232, SPI, PWM Input Capture
- **Programming Language**
  - Assembly, Dynamic C
- **Cost**
  - Rabbit is actually a bit expensive, $80.00, but Dr Papelis wanted to use it.
  - PIC is a viable option at $10/unit

Input/Output Lines

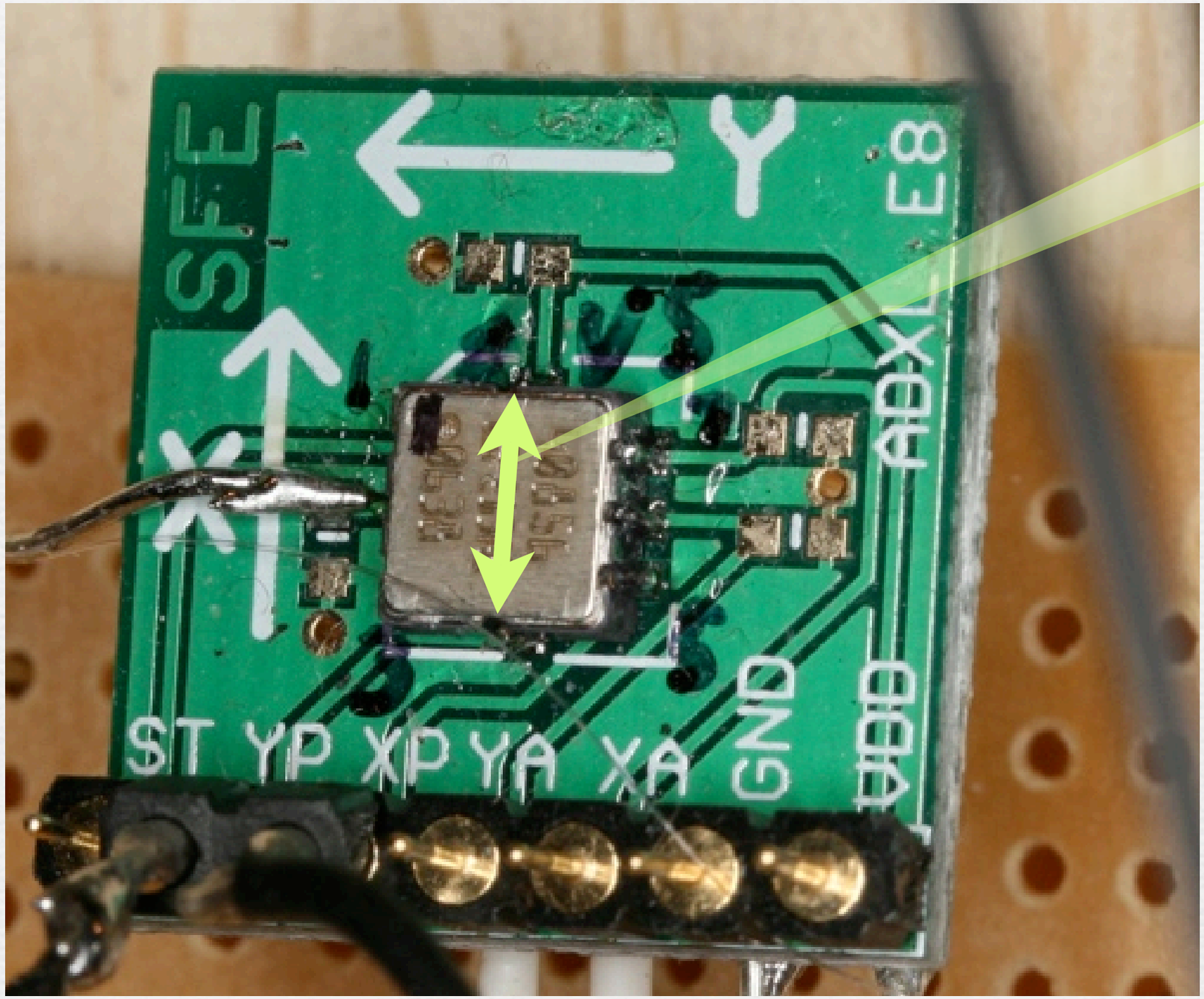
Device	Communication	Data Pins	Other	Total Req
GPS Device	Serial Data	2	0	2
Camera	UART	2	0	2
2-Axis Accelerometer	PWM	2	0	2
Yaw Rate Gyro	SPI	3	1	4
ELM327	Serial	2	2 (Busy/RTS)	4
Diagnostics Port	Serial	2	0	2
Future Expansion	Serial	4	2	6
Input Total				22
uALFAT	UART/SPI	6	0	6
UI LEDs (5)	PWM	0	5	5
Output Total				11
Total				33

Accelerometer

Lateral & Longitudinal Accelerations

ADXL213

shown on breakout board



5mm

Vehicle Data Logging Device

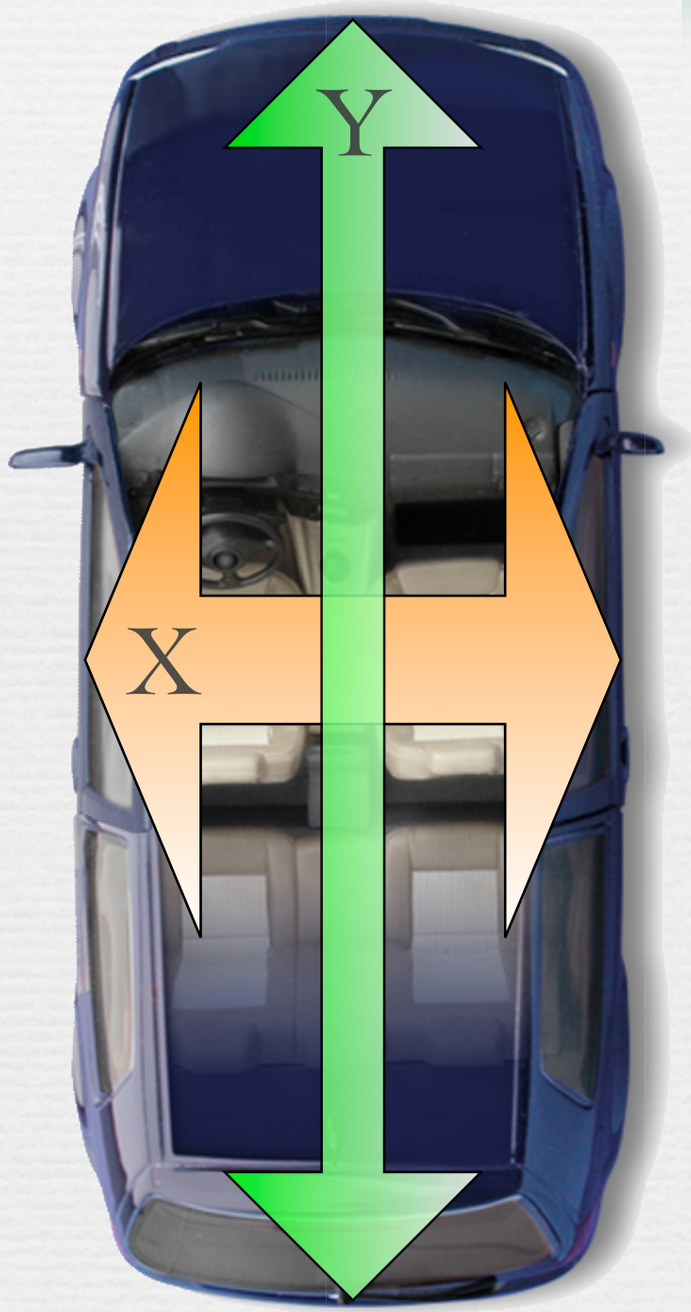
Accelerometer

Lateral & Longitudinal Accelerations

ADXL213

Design Considerations

- **Dual axis**
- **PWM output**
  - Built-in ADC
- **Range**
  - ±1.2g
- **Cost**
  - $40.00



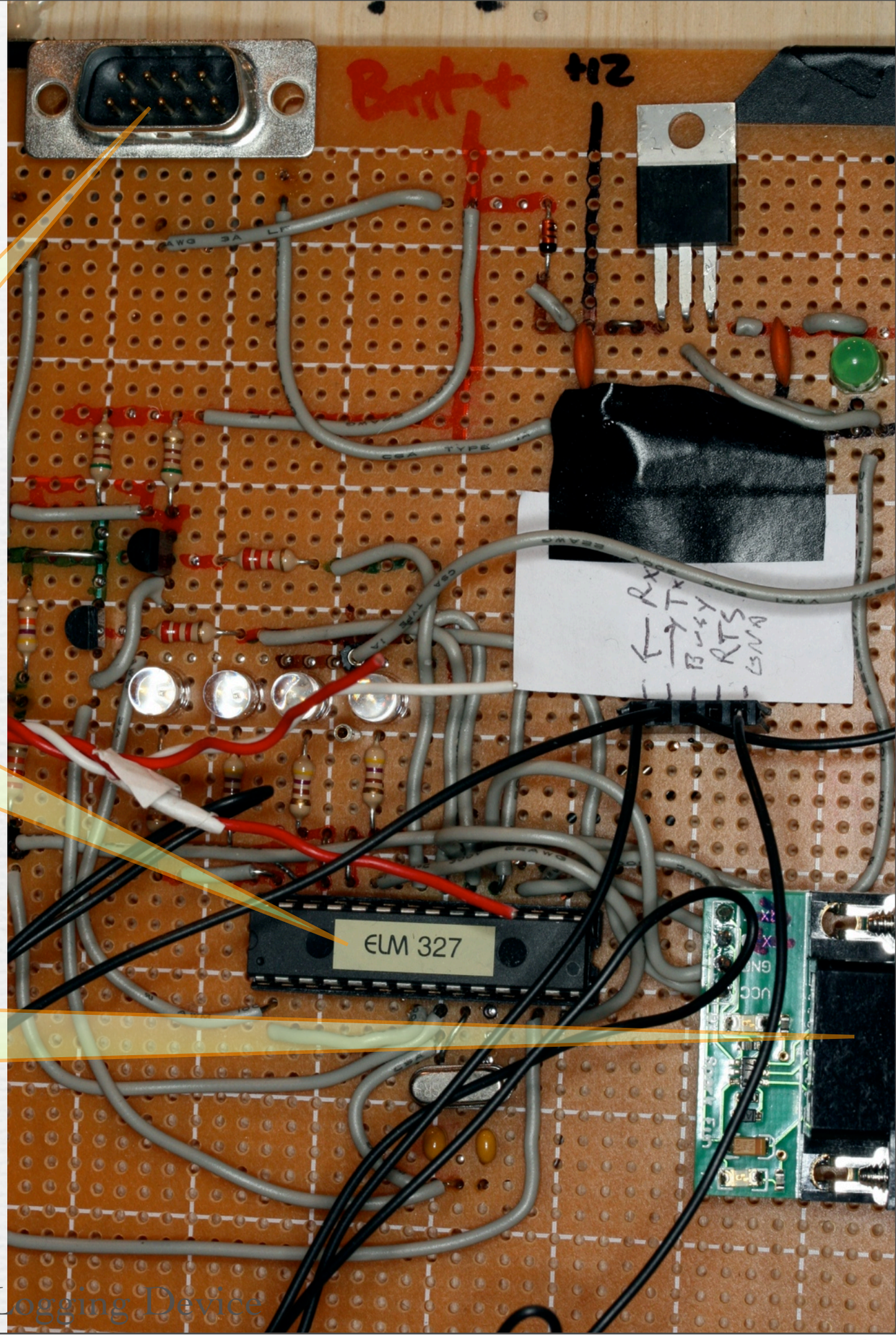
Vehicle Data Logging Device

OBDII Interface

To car's OBDII port

OBDII Interpreter

Data to µController



OBDII Interface

Vehicle RPM & Throttle Position

Design Considerations

- **Compatibility**
- **Ease of Use**
  - Uses standard AT command syntax
  - RS232
  - Handles all the bus initiation and detection itself automatically
- **Cost**
  - $30.

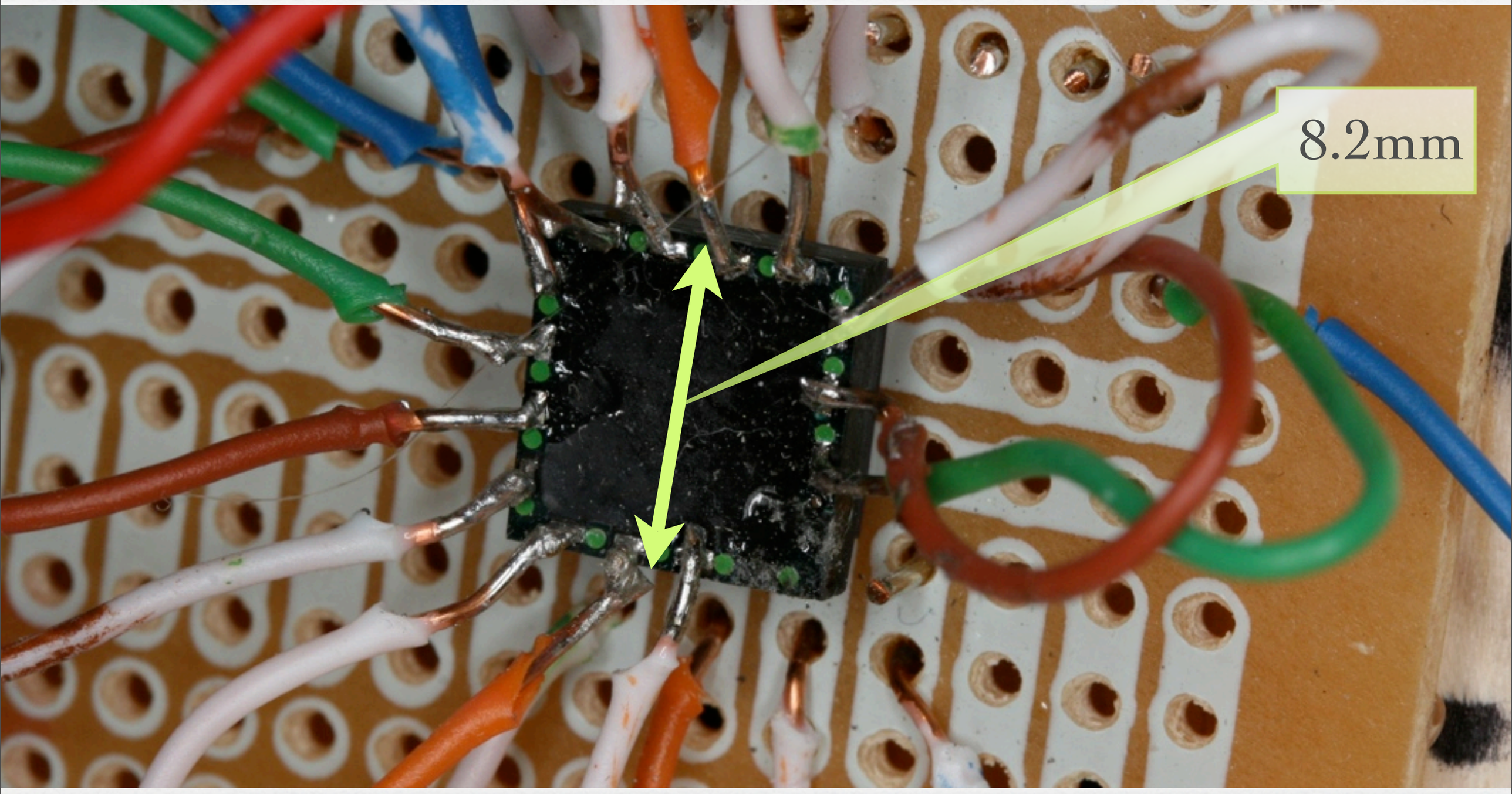
ELM327

Compatible with all OBDII standard protocols:

SAE J1850 PWM	Ford
SAE J1850 VPW	GM
ISO 9141-2	Chrysler, European, Asian
ISO 15765 CAN	all after 2008
ISO 14230	

Yaw-Rate Gyro

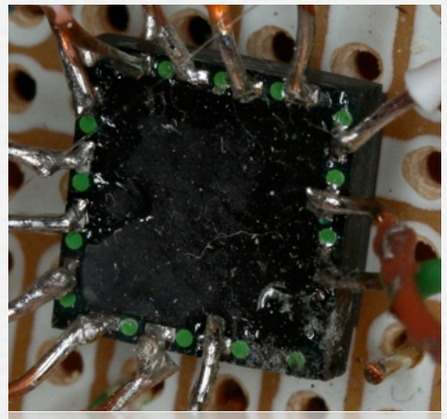
ADIS16100



Vehicle Data Logging Device

Yaw-Rate Gyro

Vehicle Turning Rate



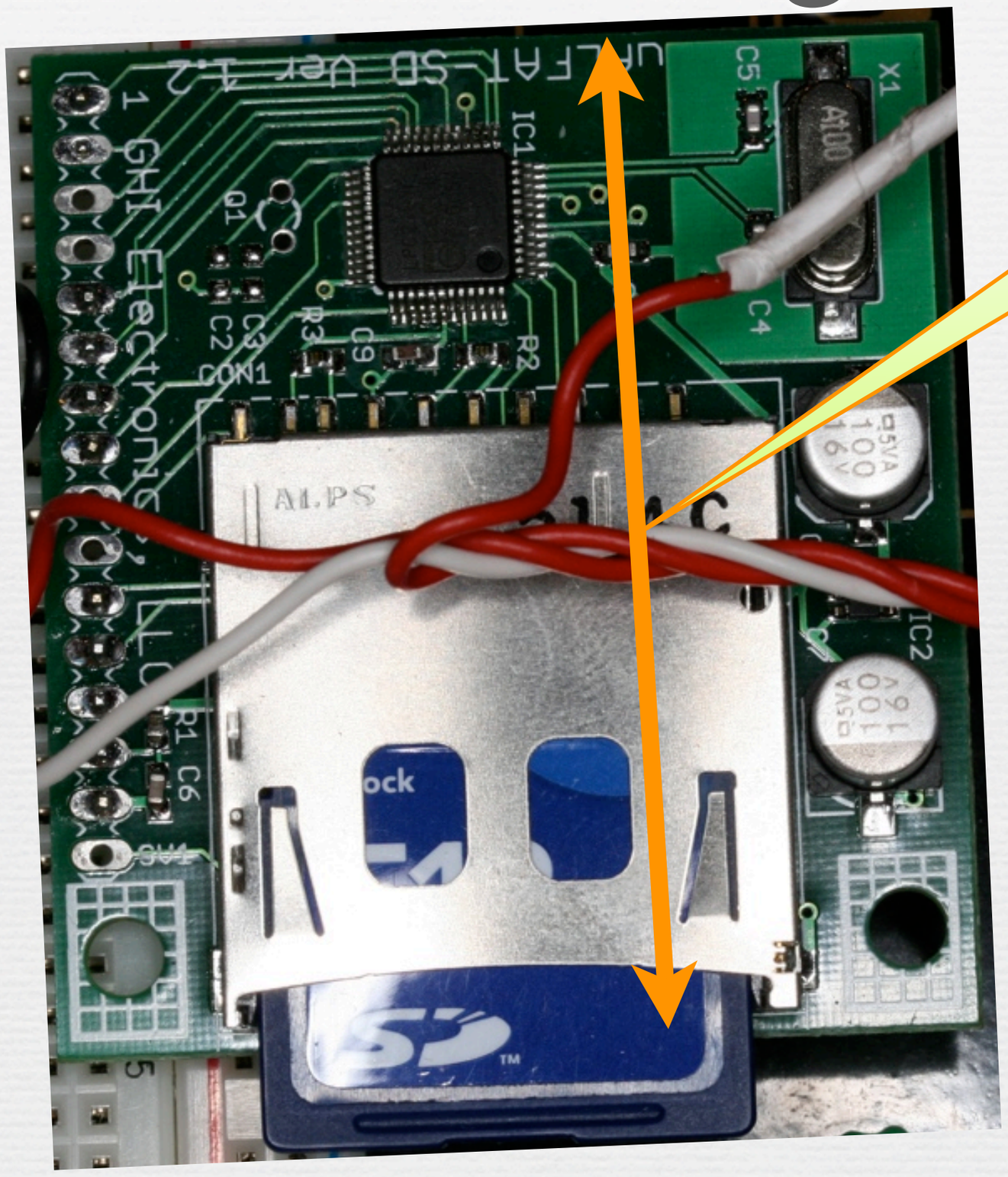
ADIS16100

Design Considerations

- **Built-in ADC**
  - Reduces number of components on the board
- **Resolution**
  - 360°/second
- **Protocol Support**
  - SPI Interface is fast and relatively easy
- **Number of Axes**
  - Single axis measurement (yaw)
- **Cost**
  - A bit expensive at $50 each
- **Difficulties**
  - LGA16

Vehicle Data Logging Device

Data Storage Device



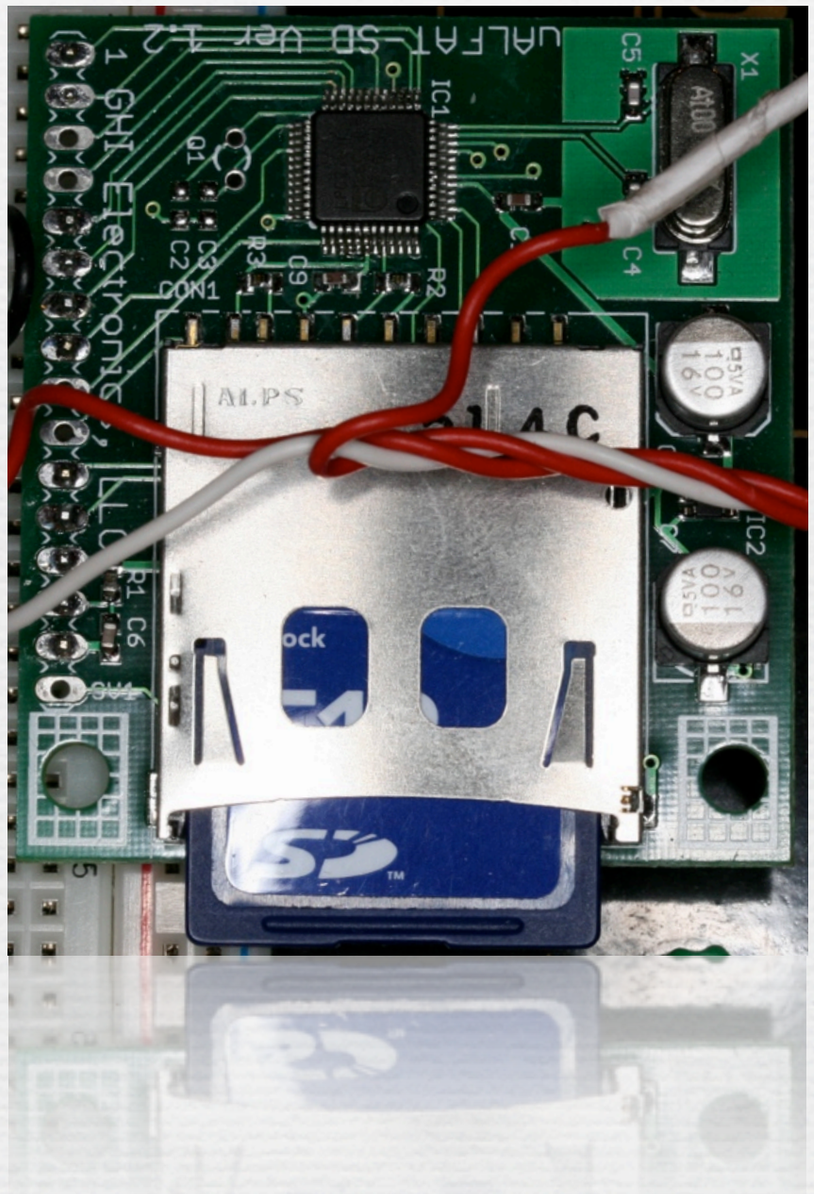
Vehicle Data Logging Device

Data Storage Device

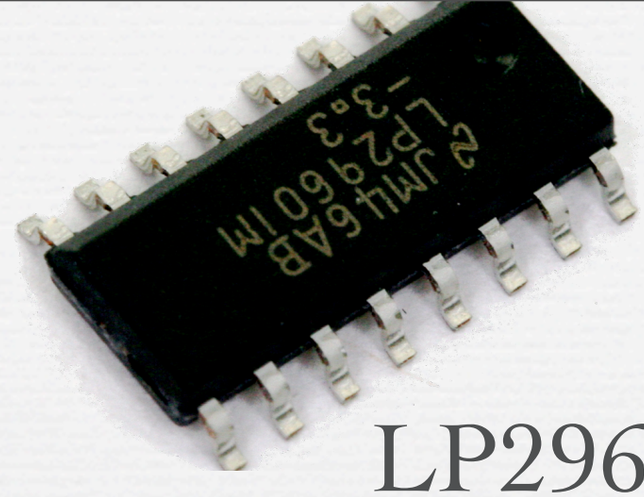
µALFAT

Design Considerations

- **File System Format**
  - FAT16
- **Speed**
  - 57.5 KB/s write speed
- **Physical Media Format**
  - Removable SD Card
- **Communication**
  - RS232
- **Cost**
  - $40.00



Power Supply

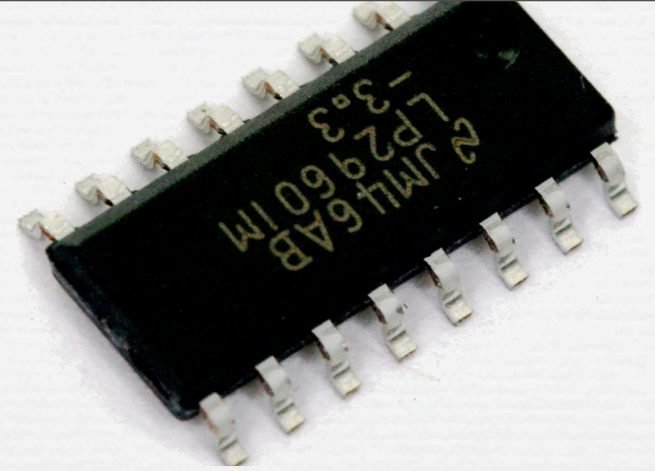


LP2960

<u>Design Considerations</u>

- **Input vs Output Voltages**
  - 11-15 VDC from OBDII port must be converted to a stable 3.3 and 5 VDC for our components.
- **Logic Level Shutdown**
  - Will shut down PSU and attached devices with one pin
- **Cost**
  - $3.50
- **Internally Fused**
  - 500mA internally limited current
- **Automatic Thermal Limiting**
  - Will shut down before heat damages components
  - A well-tested feature

Power Requirements



Part	Voltage (V)	Current (mA)	Power (mW)
Micro-Controller	3.3	255.0	841.5
Storage	3.3	5.0	16.5
Camera	3.3	15.0	49.5
Accelerometers	5.0	0.7	3.5
OBDII IC	5.0	9.0	45.0
GPS	5.0	60.0	300.0
Yaw Rate Gyro	5.0	7.0	35.0
Total			1291

Hardware Components

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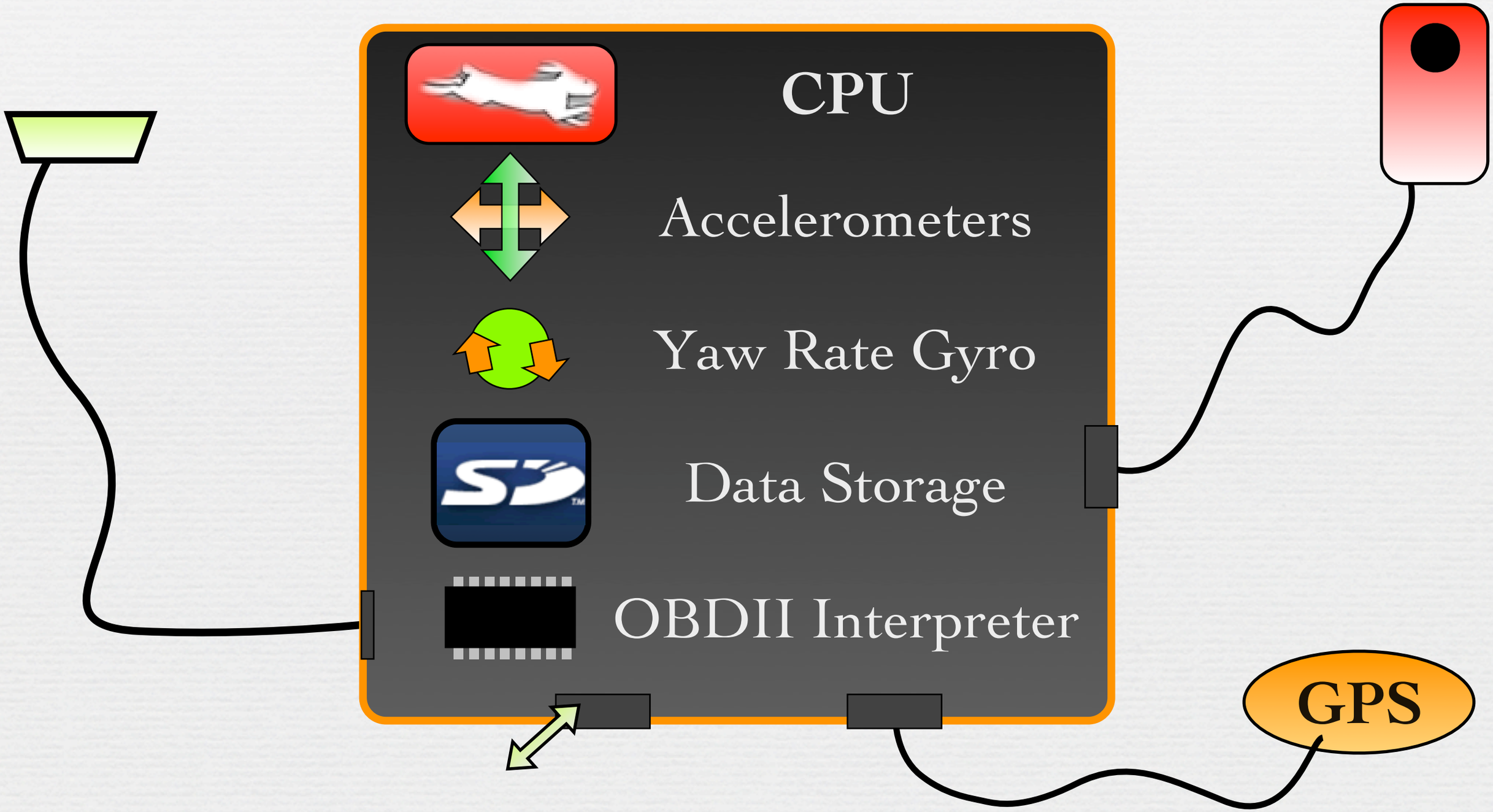

Vehicle Data Logging Device

Hardware Components

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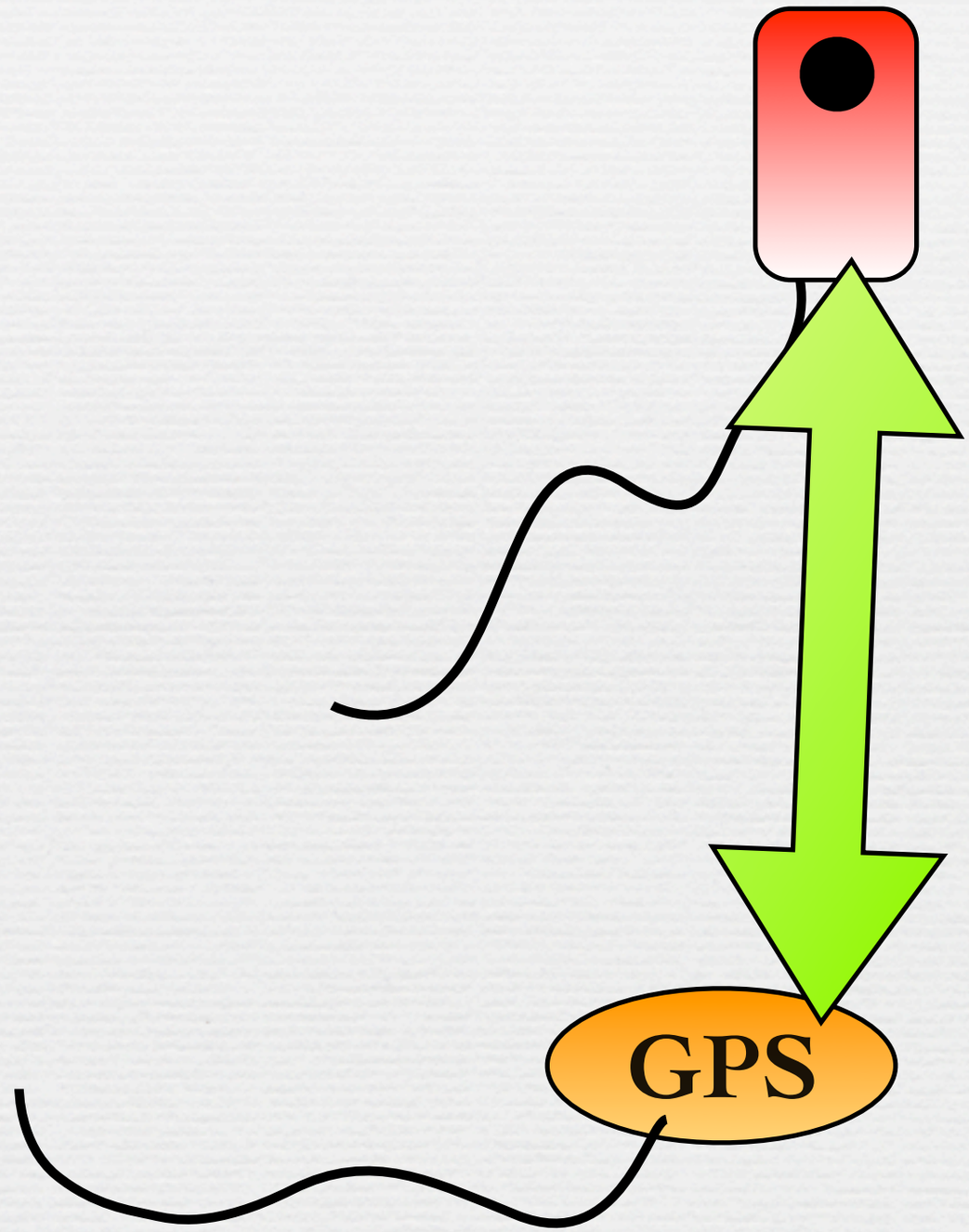


Vehicle Data Logging Device

Garmin GPS18

GPS Sensor

Geographic Position & Speed

Design Considerations

- **Update Frequency**
  - 1 Hz
- **Communication**
  - Standard NMEA over RS232
- **Time To First Fix**
  - ~40 seconds (cold start)
- **Physical Design**
  - Weatherproof, magnetic enclosure
- **Cost**
  - Already had one; $80 to buy

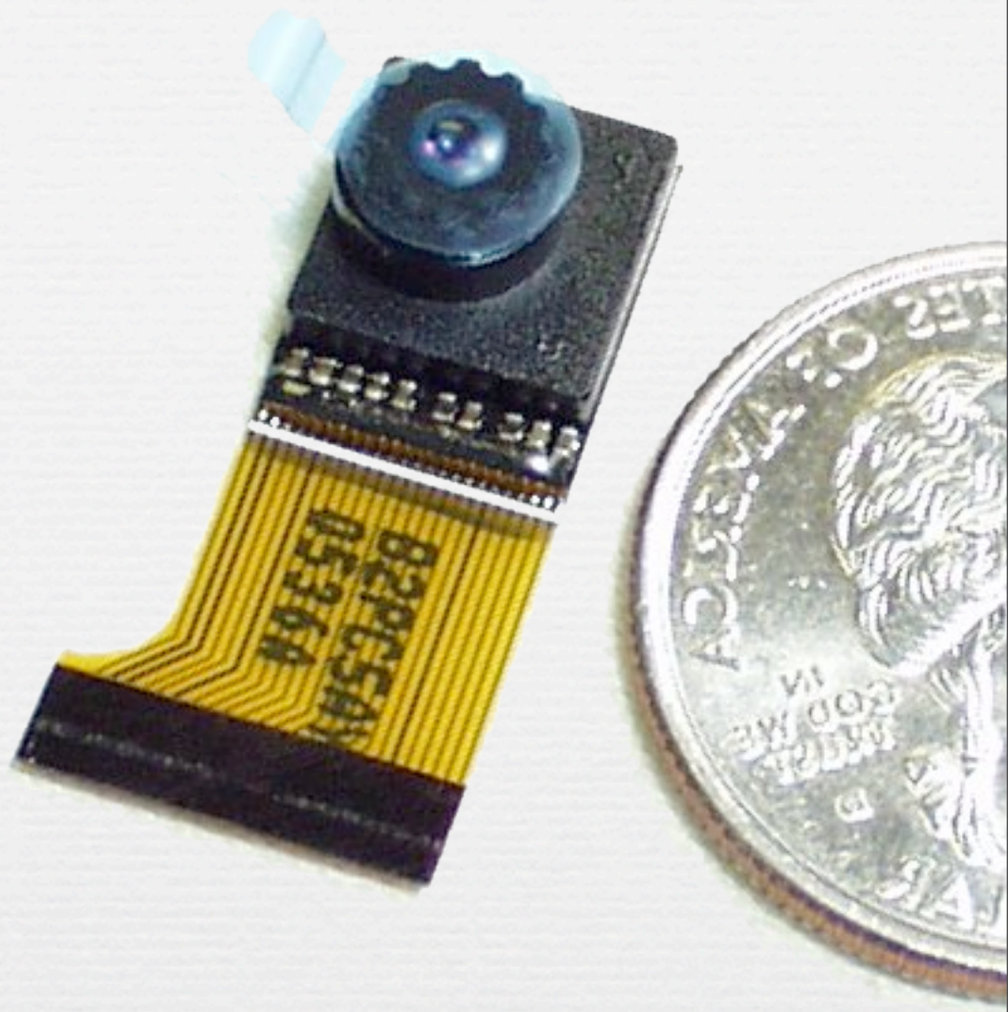
Camera / Video Capture

Design Considerations

- **Resolution**
  - VGA, QVGA, CIF, QCIF
  - Must scale to lower resolutions to enable higher frame rates with the same throughput.
  - Configurable on-the-fly

- **Frame Rate**
  - Only limited by communications speed

- **Video Format/Compression**
  - JPEG output



- **Communications**
  - RS232 @ 115.2Kb/s max
- **Cost**
  - $50./module
- **Wide Field of View**
  - 118°

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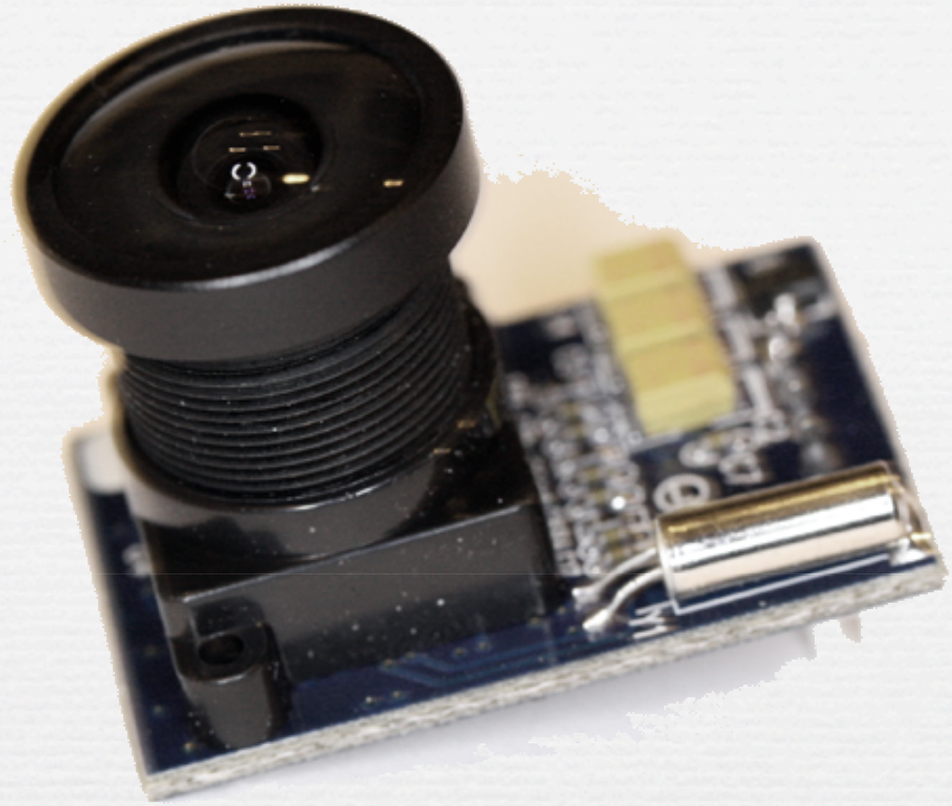


C328-2225BW

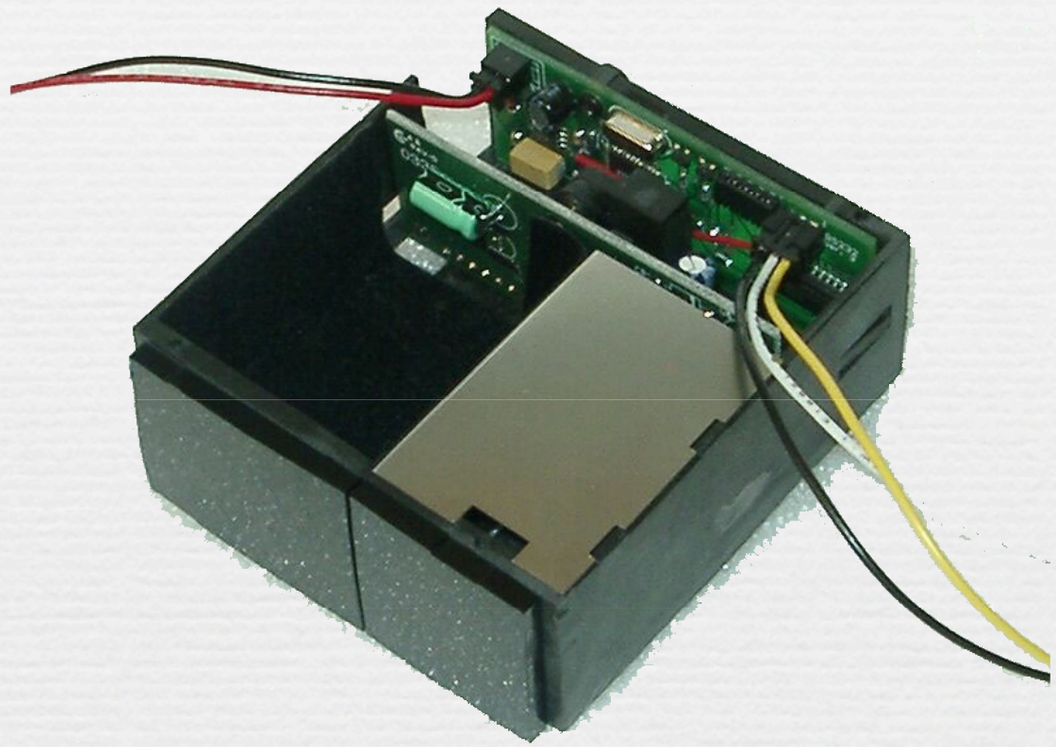
- **Frame Rate**
  - Only limited by communications speed
- **Video Format/Compression**
  - JPEG output
- **Communications**
  - RS232 @ 115.2Kb/s max
- **Cost**
  - $50./module
- **Wide Field of View**
  - **118°**

Range Finder

Following Distance

Design Considerations

- **Cost**
  - Laser - $600
  - Microwave - $10,000
  - Budget still only $400
- **FCC Regulations**



Final Product Package

- Final design is implemented on a custom fabricated printed circuit board (PCB)
- PCB is fabricated so the optional components can be added to the board or not.
  - Allows for lower cost devices with reduced functionality
- The software determines whether or not the sensors are present and log data accordingly.
  - Intelligent software control to reduce user interaction
- Enclosure includes active cooling hardware

Software

Software Design

- Sensor Boot Sequences w/ Error Handling
- User Interface
- Polling Multiple Sensors
- Store to Removable Media Device

Sensor Boot Sequence

- Error handling
- Call initialization function
- Pull test data
- Validate data
- Return passed/failed

```
while(testCounter<15)
{
    ++testCounter;
    AccelInit();
    getAccel();
    if(Accelleration.x>=-10 &&
       Accelleration.x<=10 &&
          Accelleration.y>=-10 &&
             Accelleration.y<=10)
       {
          passed=1;
          break;
       }
    }

    if(passed)
       return 1;
    else
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User Interface

- Power
- GPS Sensor
- SD Card
- OBDII Data
- Camera

- On power up system LED flashes
- each sensor LED flashes as being tested
- System LED signaled between each sensor test
- After all sensors are done testing all LEDs sequence
- A solid sensor LED with a solid system LED during testing indicates an error
- If the system light begins to flash non stop during boot up it means there is an SD failure: either not present, full, or corrupted.
- After boot up and testing each sensor flashes as it is being polled

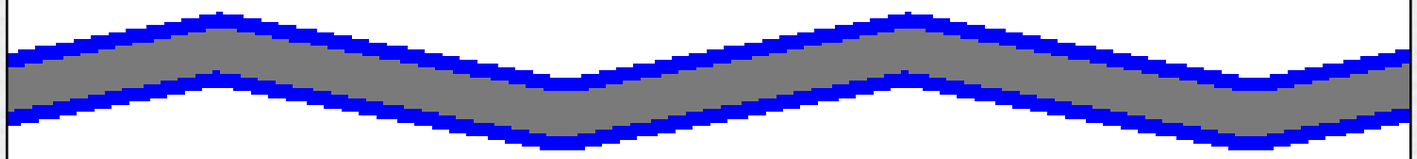
User Interface

- Software flashes sensor's LED upon activity

```
int getYawRate()
{
    int i;
    int DOUT[17];
    int decimalSum;

    DOUT[0]=0;

    WrPortI(PEB5R, NULL, 0xFF);
    BitWrPortI(PBDR, PBDRShadow,  0, 7);    //CS low
    BitWrPortI(PCDR, PCDRShadow,  1, 4);    //WRITE
```



```
    decimalSum += DOUT[5]*1024;
    decimalSum += DOUT[4]*2048;

    WrPortI(PEB5R, NULL, 0x00);

    return decimalSum;
}
/* END: YAW RATE GYRO FUNCTIONS */
```

User Interface

- Indicate sensor activity
- Mark end of boot sequence
- Notify user of any sensor initialization failures

```
printf("\nMain Function Starting");
printf("\nChecking Devices...");

OBDGTG = prepOBD();
yawGTG = prepYaw();
accelGTG = prepAccel();
GPSGTG = prepGPS();


flashLED1();
flashLED2();
flashLED3();
flashLED4();
flashLED5();


if(accelGTG==0)
   WrPortI(PEB3R, NULL, 0xFF);
if(OBDGTG==0)
   WrPortI(PEB4R, NULL, 0xFF);
if(yawGTG==0)
   WrPortI(PEB5R, NULL, 0xFF);
if(camGTG==0)
   WrPortI(PEB6R, NULL, 0xFF);
if(GPSGTG==0)
   WrPortI(PEB7R, NULL, 0xFF);
```

User Interface

- Indicate sensor activity
- Mark end of boot sequence
- Notify user of any sensor initialization failures

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if(GPSGTG==0)
   WrPortI(PEB7R, NULL, 0xFF);
```
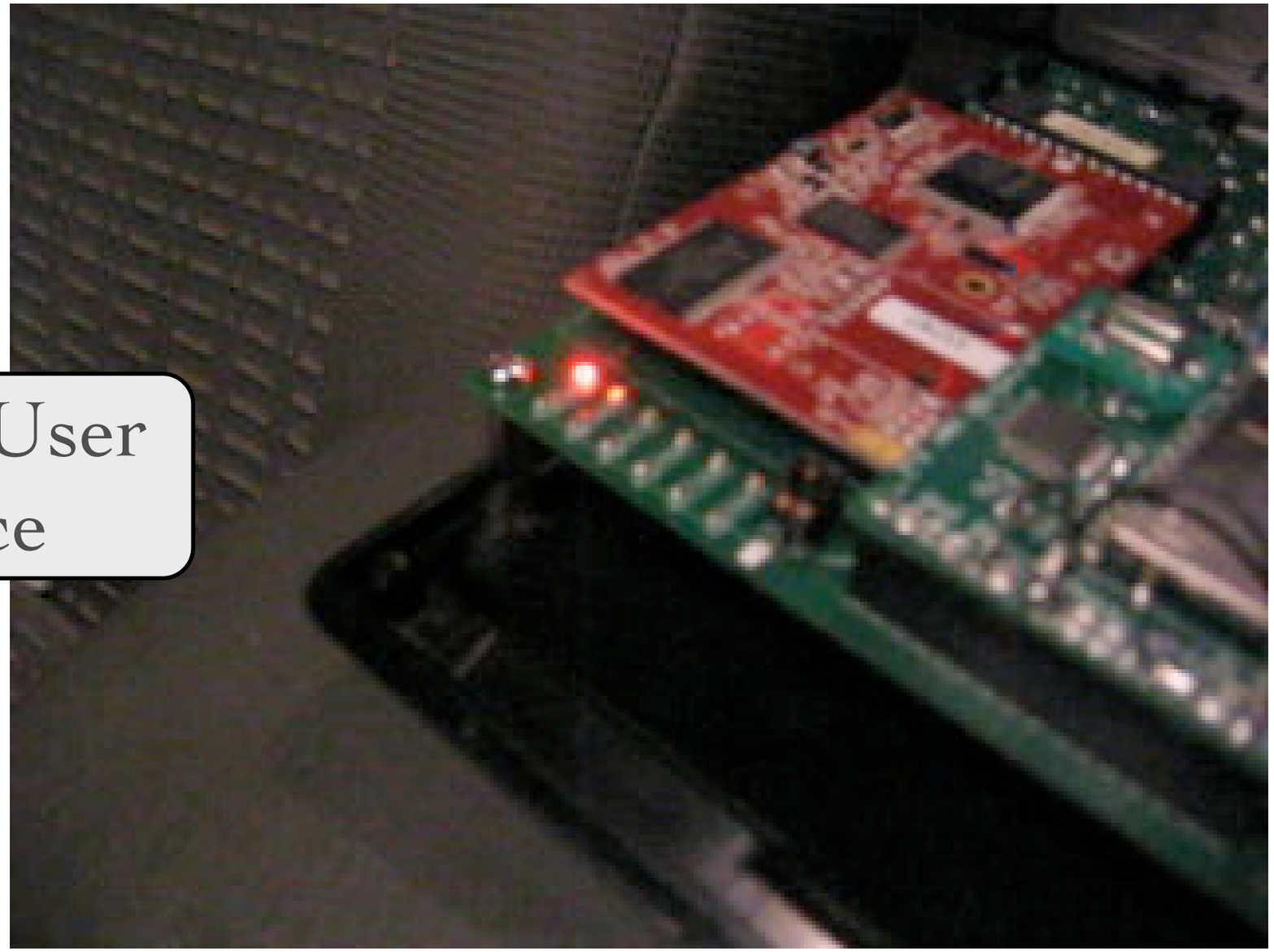

Intelligent Power Control

(Sleepy Mode)

Sleepy Mode Demo



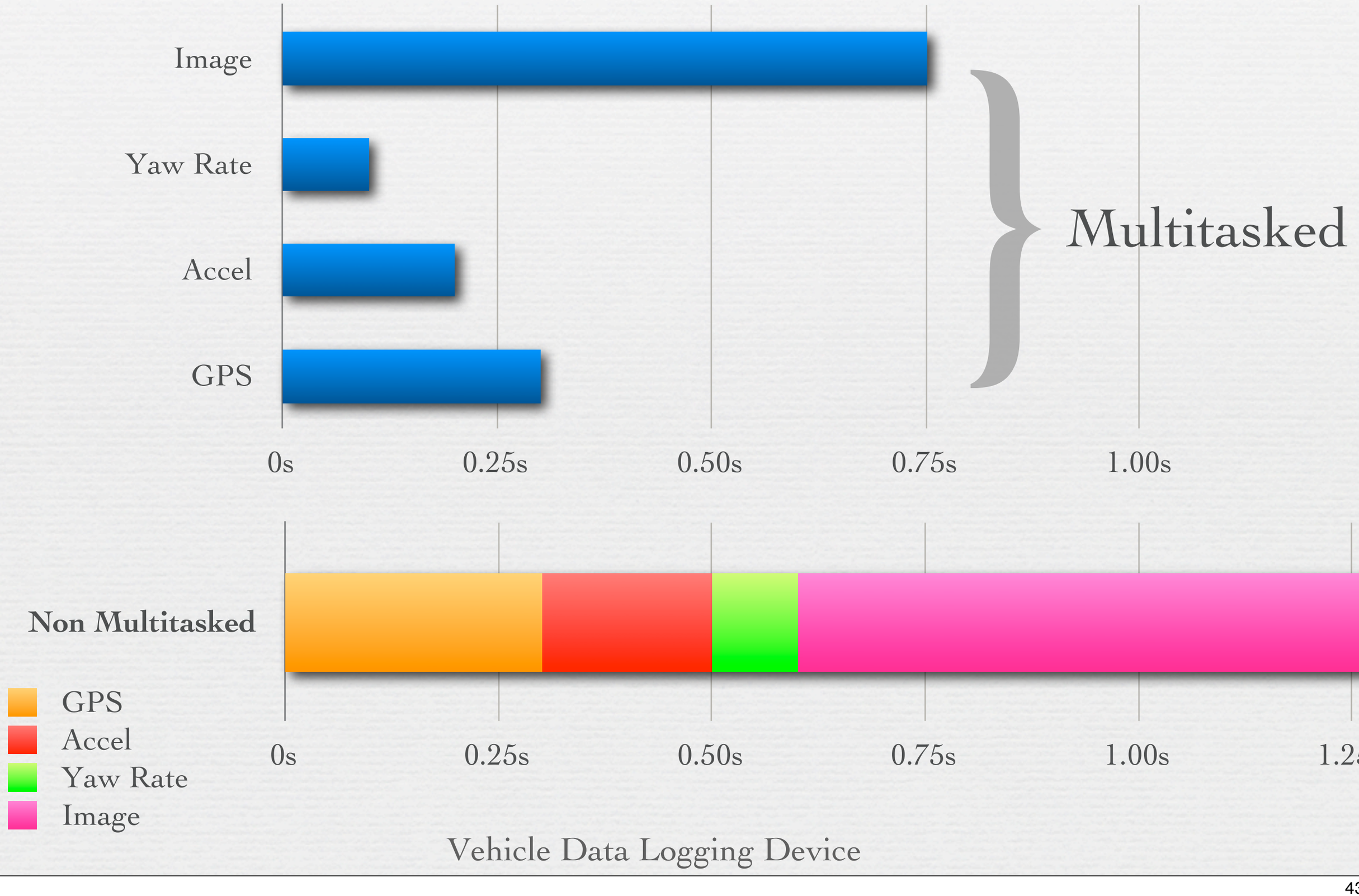
Also note User Interface

- Device powers down when RPM = 0
- Accelerations wake the unit up to check the RPM status as the accelerometer can be polled using less power

Sensor Polling

The need for multitasking.

Multitasking Timing Illustration



Polling Sensors

Multitasking

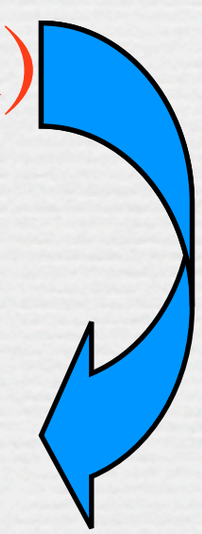
```
while(1){
  costate { … }
  costate { … }
  costate { … }
}
```

- costate descriptor
- Resides within infinite loop
- costate flow proceeds in three ways

Polling Sensors

Multitasking

```
costate{
   statement 1
   statement 2
   waitfor(condition)
   statement 3
   statement 4
}
```

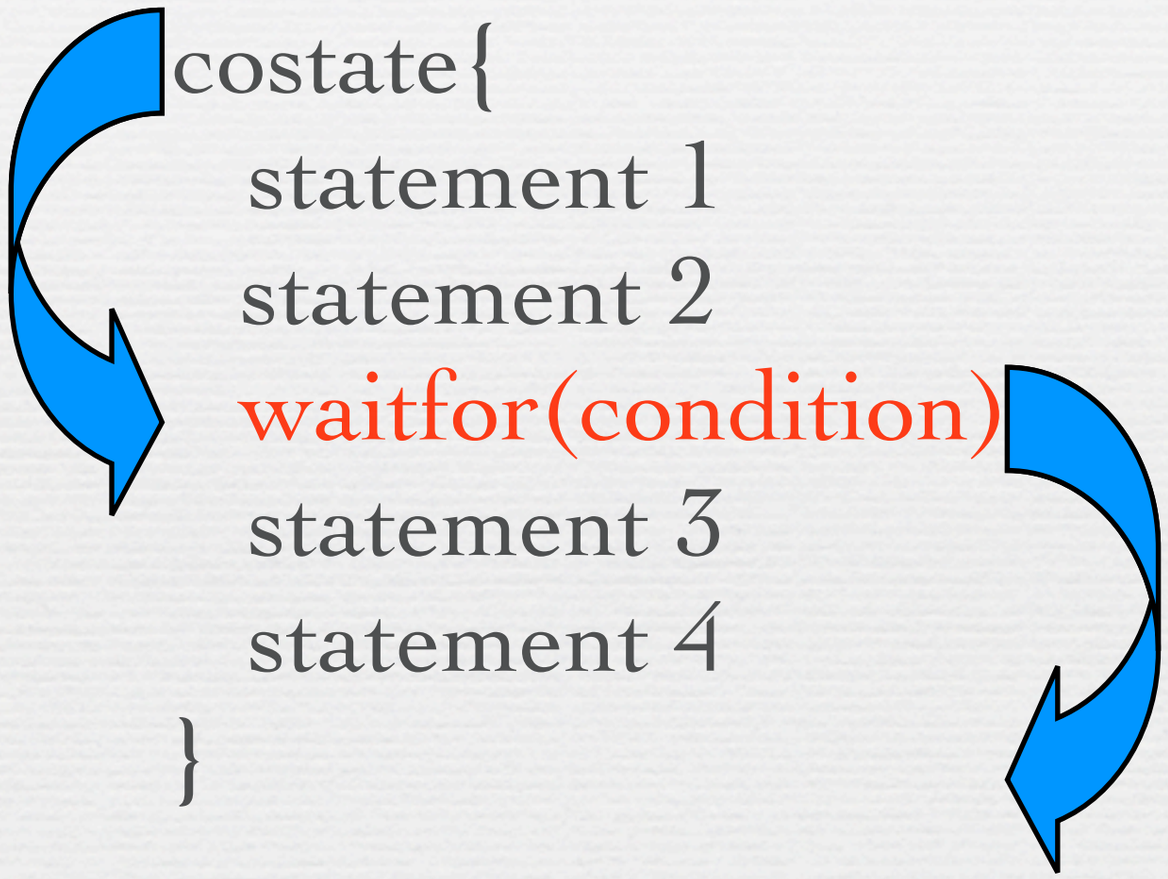


Initial entry into costate

- **Statement 1 & 2 executed**
- **waitfor evaluated to zero (0)**
- **Flow jumps out of the costate**

Polling Sensors

Multitasking



Subsequent entry into costate

- **Flow jumps directly to waitfor**
- **waitfor evaluated to zero (0)**
- **Flow jumps out of the costate**

Polling Sensors

Multitasking

```
costate{
    statement 1
    statement 2
    waitfor(condition)
    statement 3
    statement 4
}
```

Subsequent entry into costate

- **Flow jumps directly to waitfor**
- **waitfor evaluated to one (1)**
- **Statement 3 & 4 executed**
- **System reference to costate reset**

Polling Sensors

Multitasking

```
costate{
   statement 1
   statement 2
   waitfor(condition)
   statement 3
   statement 4
}
```

<u>After costate reference is reset</u>

- **Next cycle will be executed as an initial entry**
- **Cycle starts anew**
- **Statement 1 & 2 executed**
- **waitfor evaluated to zero (0)**

Polling Sensors

Multitasking

Allows Rabbit to devote time to other tasks while…

- Waiting for ELM327 Ready to Receive Flag
- Waiting for ELM327 to fill buffer with data

```
cofunc int getThrot()
{
    char readSentence[25];
    char OBDresponse[5];
    int carThrot;
    int x;

    carThrot=1;

    serErdFlush();
    serEwrFlush();
   waitfor(0==BitRdPortI(PGDR, 4));
    serEputs("01 11\r");
   waitfor(20==serErdUsed());
    serEread(readSentence, 20, 10);
```

Polling Sensors

Multitasking

Allows Rabbit to devote time to other tasks while…

- Waiting for ELM327 Ready to Receive Flag
- Waiting for ELM327 to fill buffer with data

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    waitfor(20==serErdUsed());
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Polling Sensors

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   waitfor(0==BitRdPortI(PGDR, 4));
    serEputs("01 11\r");
   waitfor(20==serErdUsed());
    serEread(readSentence, 20, 10);
```

Storing Data to SD Card

- New text file is created on system boot
  - **system boots each time ignition is cycled**
- Each cycle's data is appended to this text file

```
UTC Time              $$ UTC Position(Lat,Lon)          $$ Yaw $$ Accel(x,y)
$$ OBD(RPM,Speed,Throttle)
-------------------------------------------------------------------------------
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +01 $$  0.63 -0.55
$$ 0812 000 000
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +01 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +01 $$  0.02  0.03
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$$ 0812 000 000
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +00 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +00 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +01 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:48 $$ 28 25.463301 N 081 15.399800 W $$ +01 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:48 $$ 28 25.463301 N 081 15.399800 W $$ +01 $$  0.02  0.03
```

```
*00-00-0000
00:00:02*FFD8FFE000114A4649460001020304050607080900
785C666864FFDB00430112121216161630 1A1A306442384264
0000000000000102030405060708090A0BFFC400B510000201
36373839 3A434445464748494A535455565758595A63646566
E1E2E3E4E5E6E7E8E9EAF1F2F3F4F5F6F7F8F9FAFFC4001F01
1
3223281081442 91A1B1C109233352F015627 2D10A162434E12
999AA2A3A4A5A6A7A8A9AAB2B3B4B5B687B8B9BAC2C3C4C5C6
48E69314F229B8A0618A314B45218014B8A4CD2E6900A2A64A
A598E147535CFCD235C4CD230EBD07A5696A92958D621FC7C9
1E7DDA605FEEB1AD5AE7FC2AE5ADEE14FF000B0FEB5D054D89
8
A43466B31851499A4CD201D4F5A8F34A1A901614D4AA6AAAB5
CD2B0E1C803F0CD7454D753196E1451453 2428A28A6073C501
E14D4ADE5D9A7DE006440444792 5C7248E3A600FC7F0AECC59
71918E4567D9DB9B9620B615464D6C12ACEA57A13FD2B29EC6
39AA2B4828A291890A48EB564ADC5A2A389CBAE4AE2A4A10E4
4
BD0B5B8756B70CAA125CE1E3DD92A79F6F403FC8AF2ECD5CD3
9B3819A18F4BD56E2DE272D103C647623207E19C55A8984891
62AD8499DC9F3286033903A9C0E2B3847B9A4E5D8F53D37EEE
304D349A09A69AA2C334B494B400668CD145075FE03BF8E38
```

Image Capture

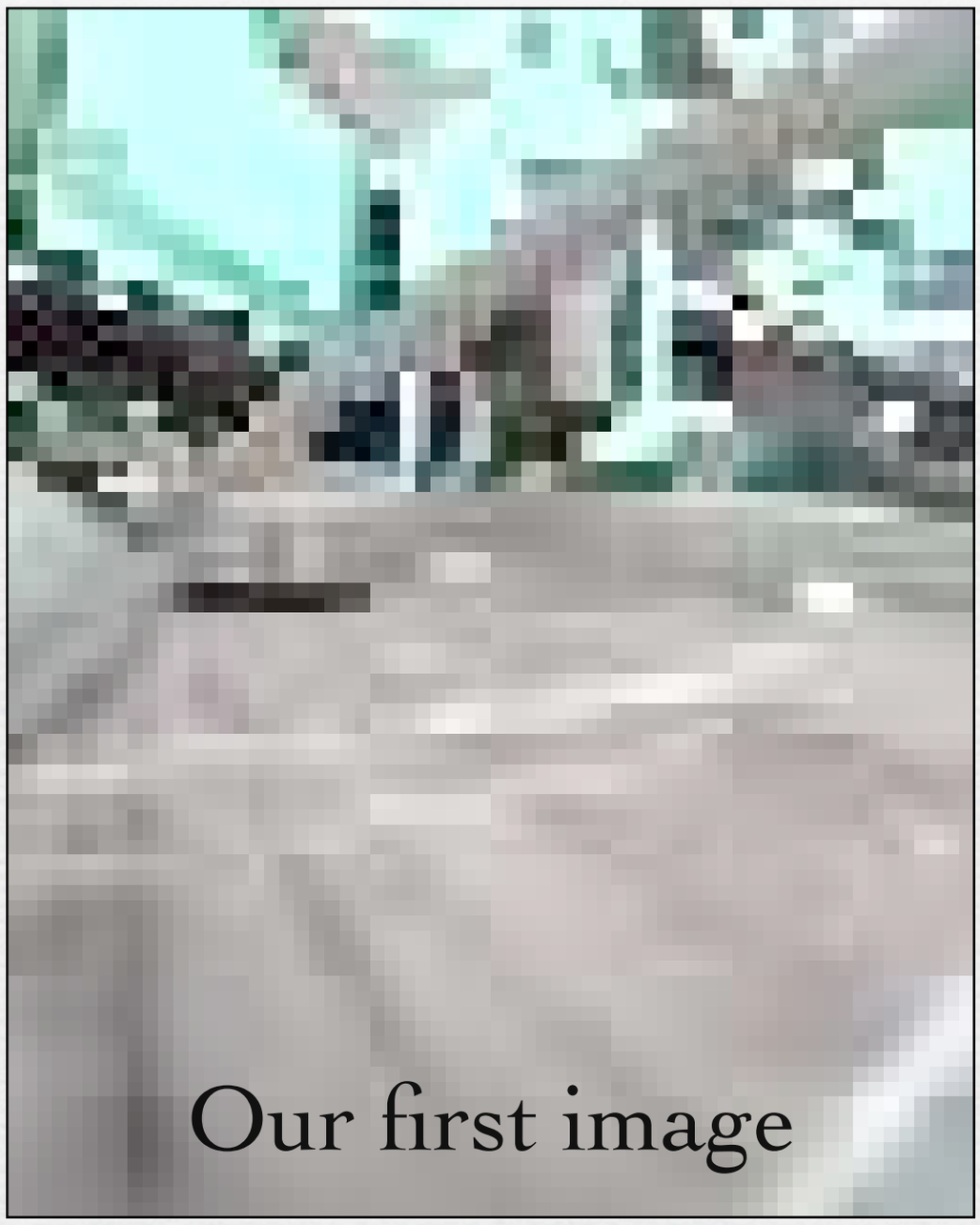
- Stored to a separate file

  - **images stored in one text file per trip**

  - **images sorted by time within text file**

- Post Processing

  - **ASCII data is sorted and converted to JPEGs via web application**

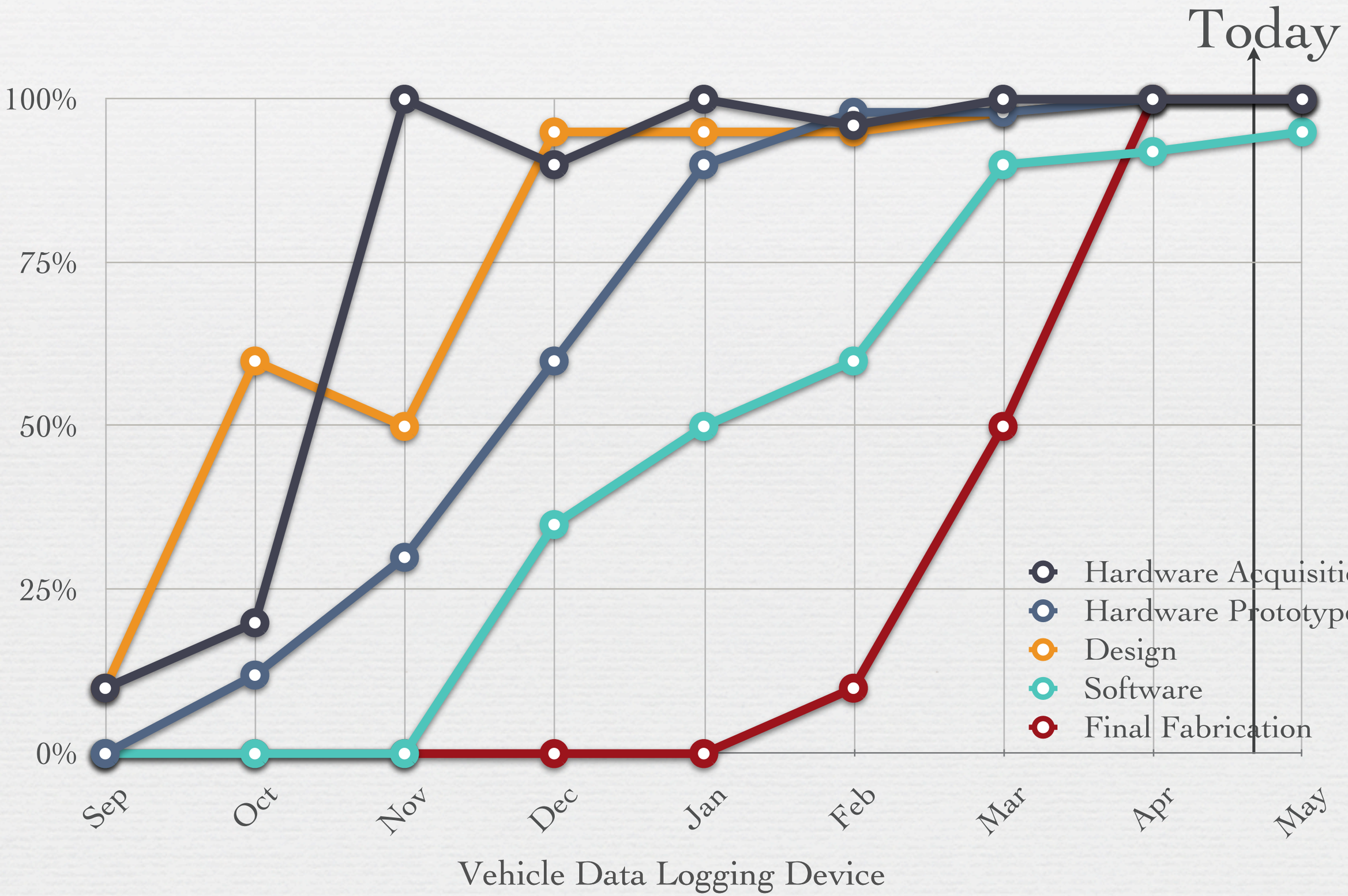


Software to Do

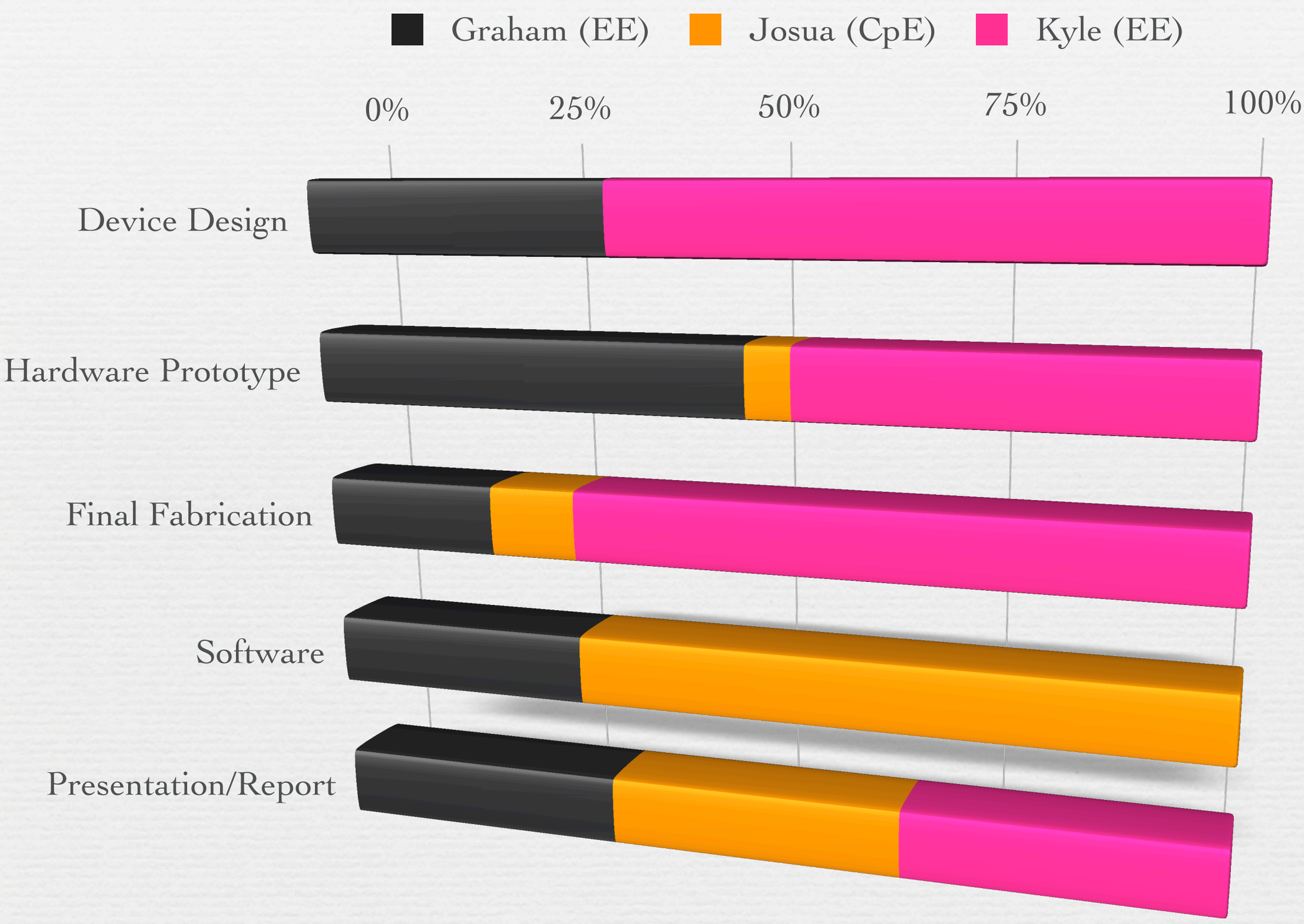
- Improve Image Capture
- Implement System Configurability
  - **Allow user to edit text file on SD to change system settings**
- Fully Incorporate Intelligent Power Supply

Progress & Budget

Project Progress

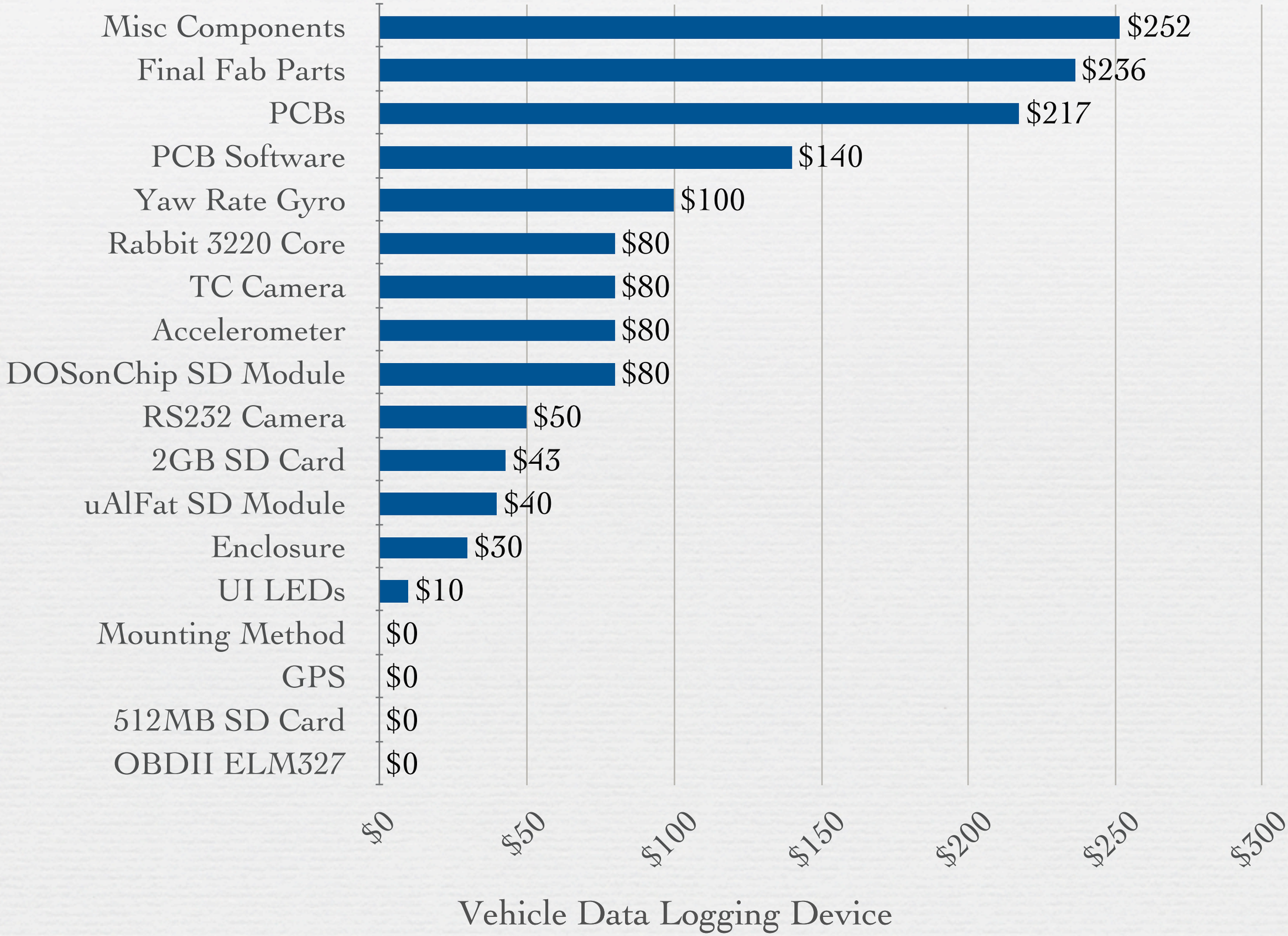


Work Breakdown



Vehicle Data Logging Device

Budget


Misc Components
$252
Final Fab Parts
$236
PCBs
$217
PCB Software
$140
Yaw Rate Gyro
$100
Rabbit 3220 Core
$80
TC Camera
$80
Accelerometer
$80
DOSonChip SD Module
$80
RS232 Camera
$50
2GB SD Card
$43
uAlFat SD Module
$40
Enclosure
$30
UI LEDs
$10
Mounting Method
$0
GPS
$0
512MB SD Card
$0
OBDII ELM327
$0
$0
$50
$100
$150
$200
$250
$300
Vehicle Data Logging Device

Miscellaneous Costs

Capacitors, power regulators, wire, perf board, tools, solder, SOIC adapters, DIP adapters, diodes, transistors, DB9 connectors, markers, PCB etching materials, pre-made breakout boards, RS232 level shifters, breadboards, test leads, and more...

Budget Specifics

Part	Actual Cost	Our Cost	# Acquired	Total Spent
GPS Device	$80.00	$0.00	2	$0.00
CMOS Image Sensor	$40.00	$40.00	2	$80.00
RS232 Camera	$50.00	$50.00	1	$50.00
2-Axis Accelerometer	$40.00	$40.00	2	$80.00
Yaw Rate Gyro	$50.00	$50.00	2	$100.00
ELM327	$35.00	$0.00	2	$0.00
DOSonChip	$40.00	$40.00	2	$80.00
uALfat	$40.00	$40.00	2	$80.00
UI LEDs (4)	$10.00	$10.00	0	$0.00
2GB SD Card	$43.00	$43.00	1	$43.00
512MB SD Card	$20.00	$0.00	1	$0.00
Rabbit 3220 Core	$80.00	$80.00	1	$80.00
Misc Components	??	$251.60	1	$251.60
Enclosure	$30.00	$30.00	0	$30.00
Mounting Method	$5.00	$5.00	0	$0.00
PCB Software	$140.00	$140.00	1	$140.00
Final Fab Parts (3)	$236.17	$236.17	1	$236.17
PCBs (5)	$217.35	$217.35	1	$217.35
Parts Totals	$455.00	$819.60	22	$1,468.12

Device Reproduction Costs

Required Parts	Actual Cost
Rabbit 3220 Core	$80.00
Accelerometer	$15.00
ELM327	$35.00
GPS Device	$80.00
512MB SD Card	$20.00
uALfat	$40.00
Misc Components	$30.00
Required Parts Total	$300.00
Camera	$40.00
Yaw Rate Gyro	$50.00
Parts Totals	$390.00

Without optional components, the total cost of fabrication is easily within the budget constraints.

With optional components we must have a large production run in order to meet the specified system cost.

We suggest in this instance the Rabbit be swapped for a PIC thereby saving $80, about the cost of the additional components.

Number of Boards	2	4	6	8	10	15
PCB Fabrication	$130.00	$130.00	$135.00	$140.00	$145.00	$155.03
Cost/Board	$65.00	$32.50	$22.50	$17.50	$14.50	$10.34
Totals	$455.00	$422.50	$412.50	$407.50	$404.50	$400.34
w/o opt components	$365.00	$332.50	$322.50	$317.50	$314.50	$310.34

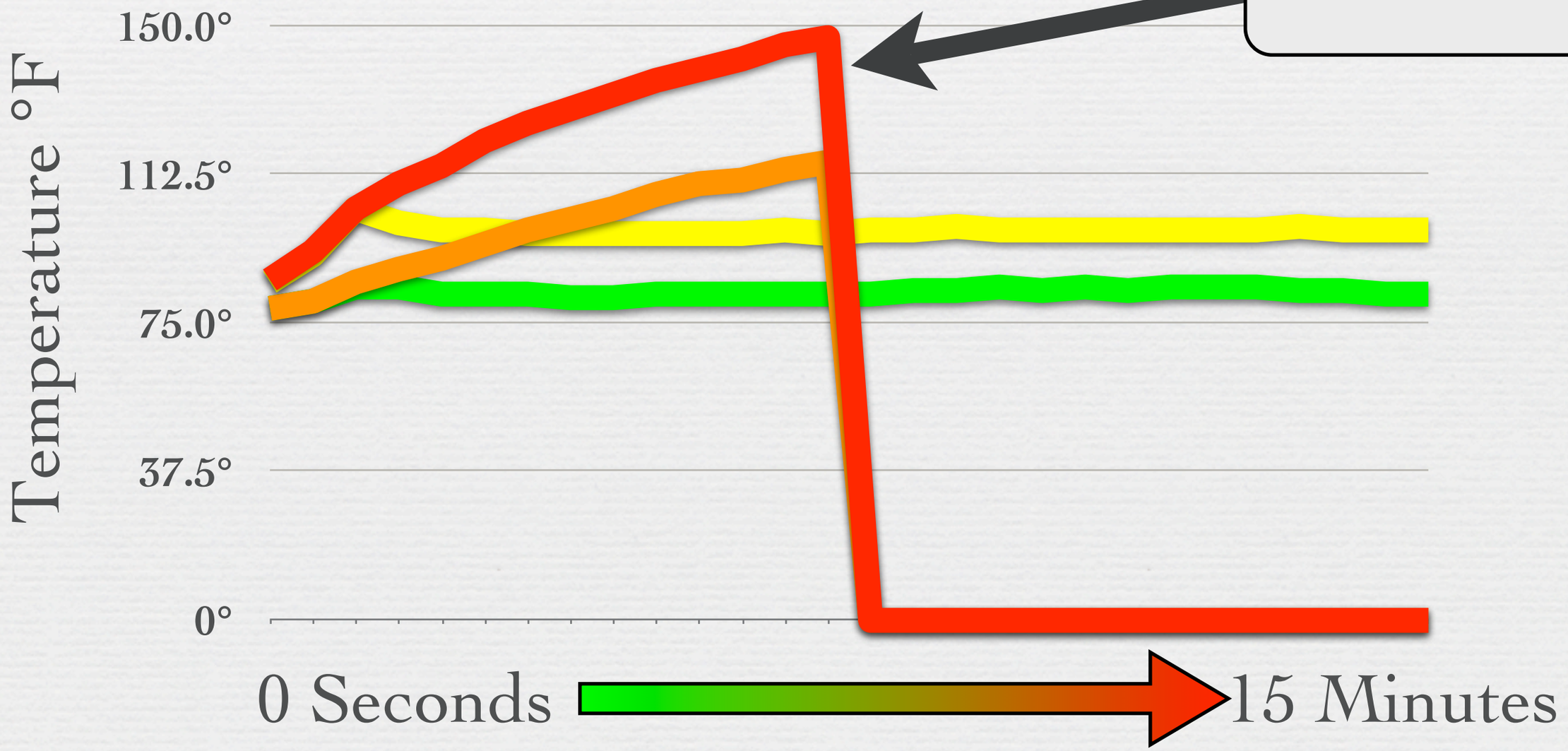
Difficulties

- LGA 16 package (yaw rate gyro) was difficult to work with
- SPI driver had to be rewritten
- 24 Pin ZIF (first camera) also difficult to work with
- Hardware discontinued mid-development (first camera)
- Reworking storage device due to insufficient write speed (DOSonCHIP)
- Thermal dissipation issues with varying voltages

Temperature Analysis

- On Heatsink No Enclosure
- Above Heatsink No Enclosure
- On Heatsink With Enclosure
- Above Heatsink With Enclosure

PSU Thermal



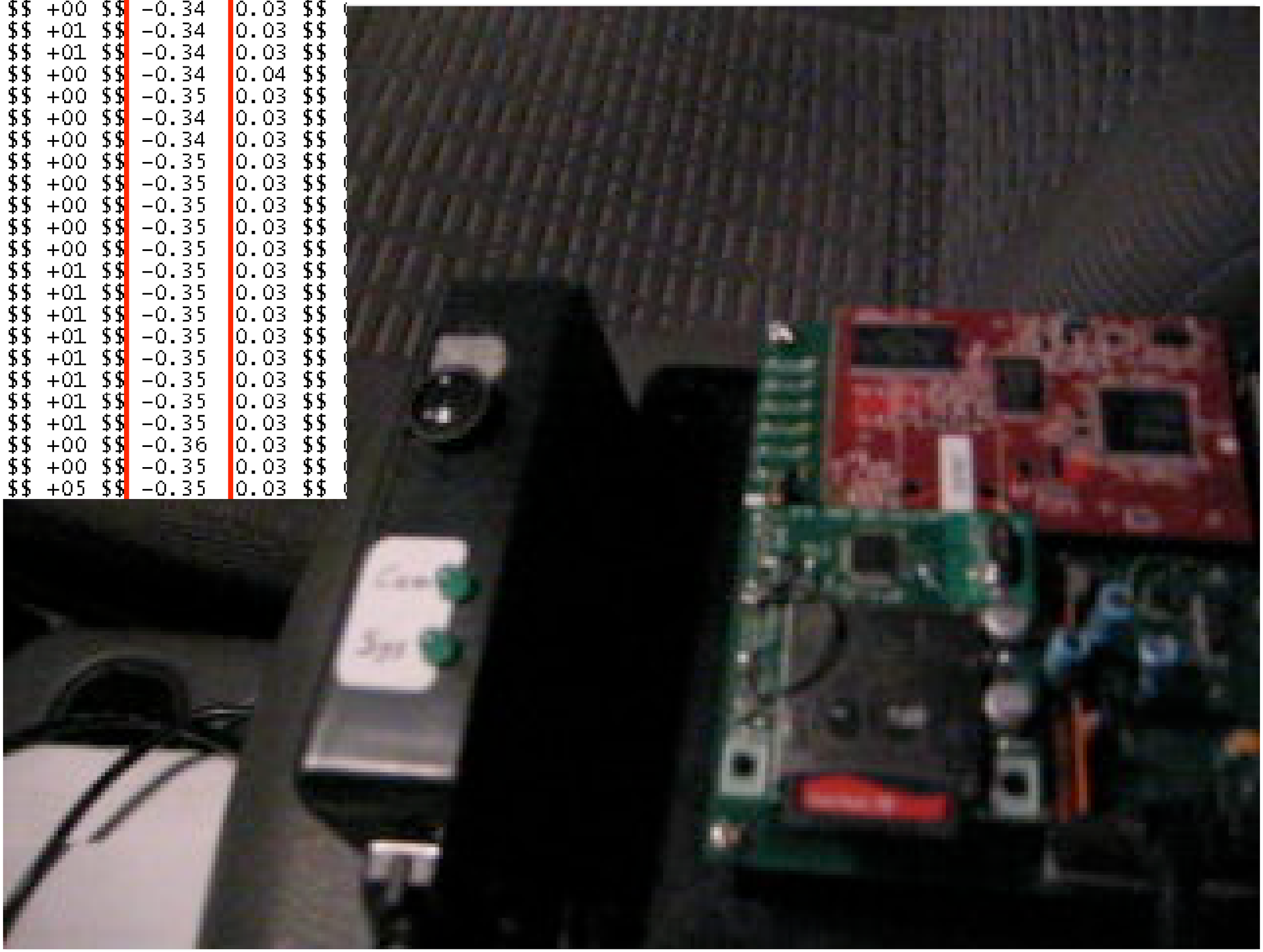
Future Progress

- Optimize Software
- Improve Image Capture
- Implement System Configurability
- Further Calibrate Sensors
- Optimize PCB for better cooling
  - ★ Reduce Size of Device

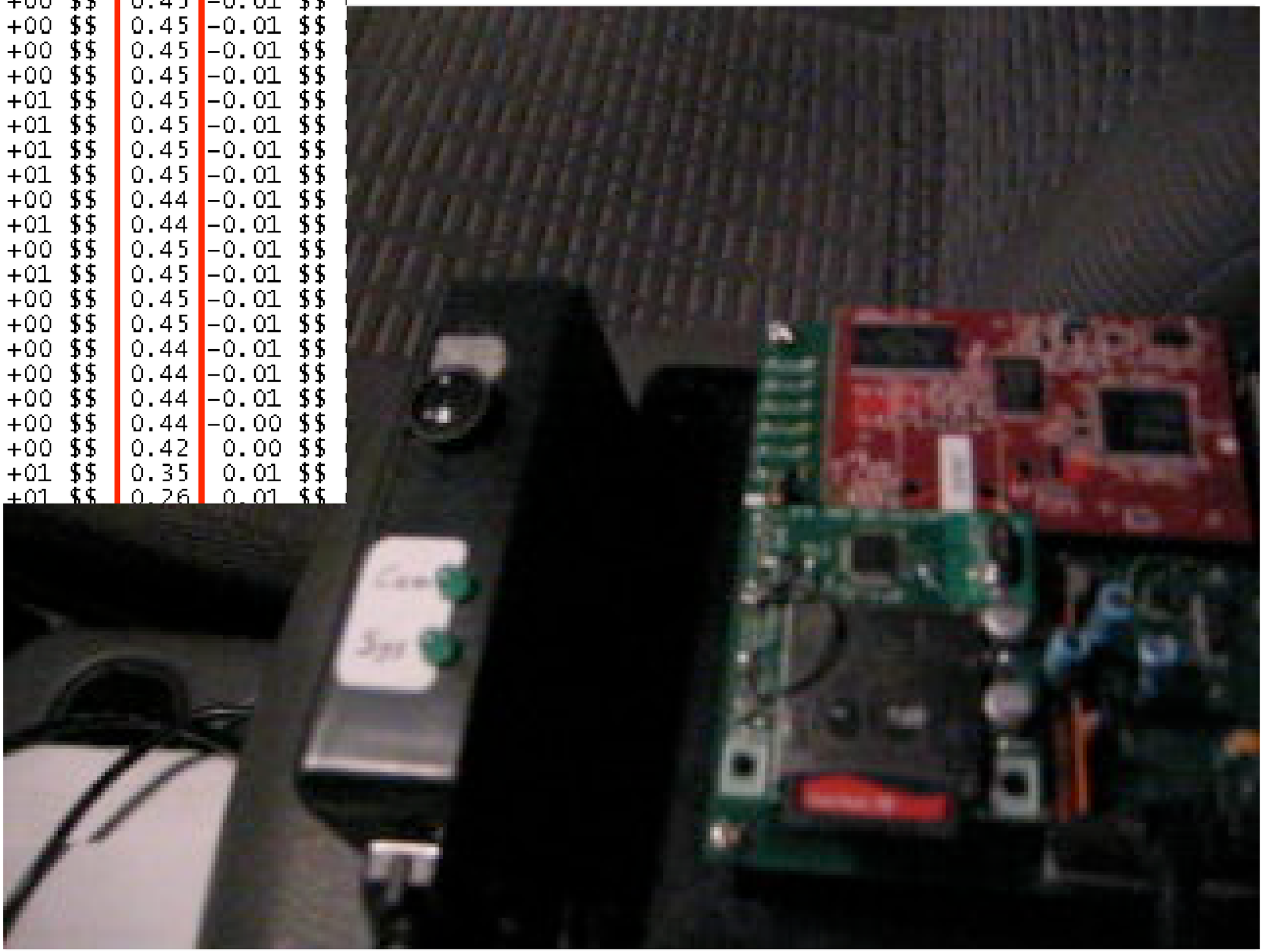
Demo!

Demonstration

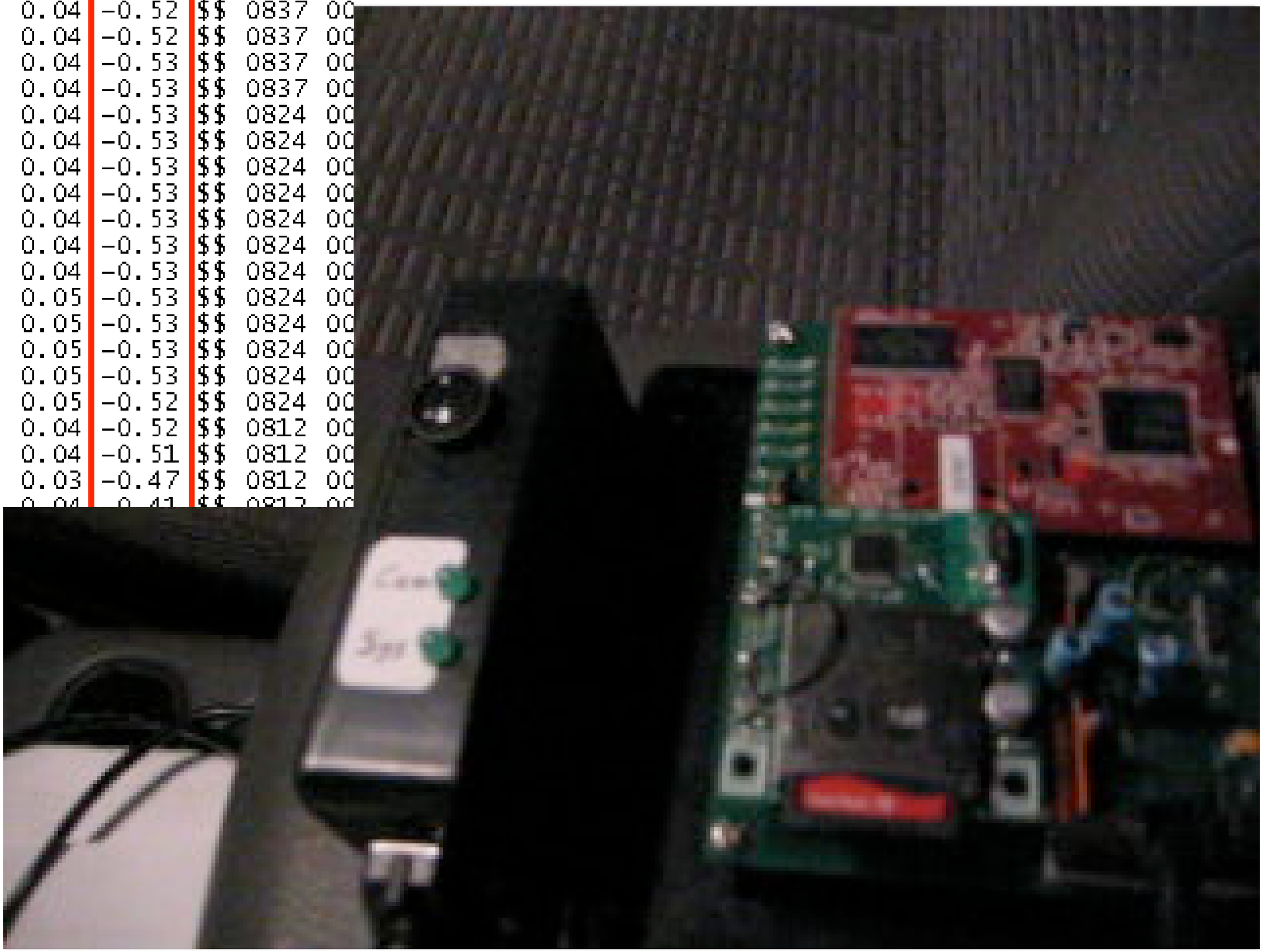
Demonstration



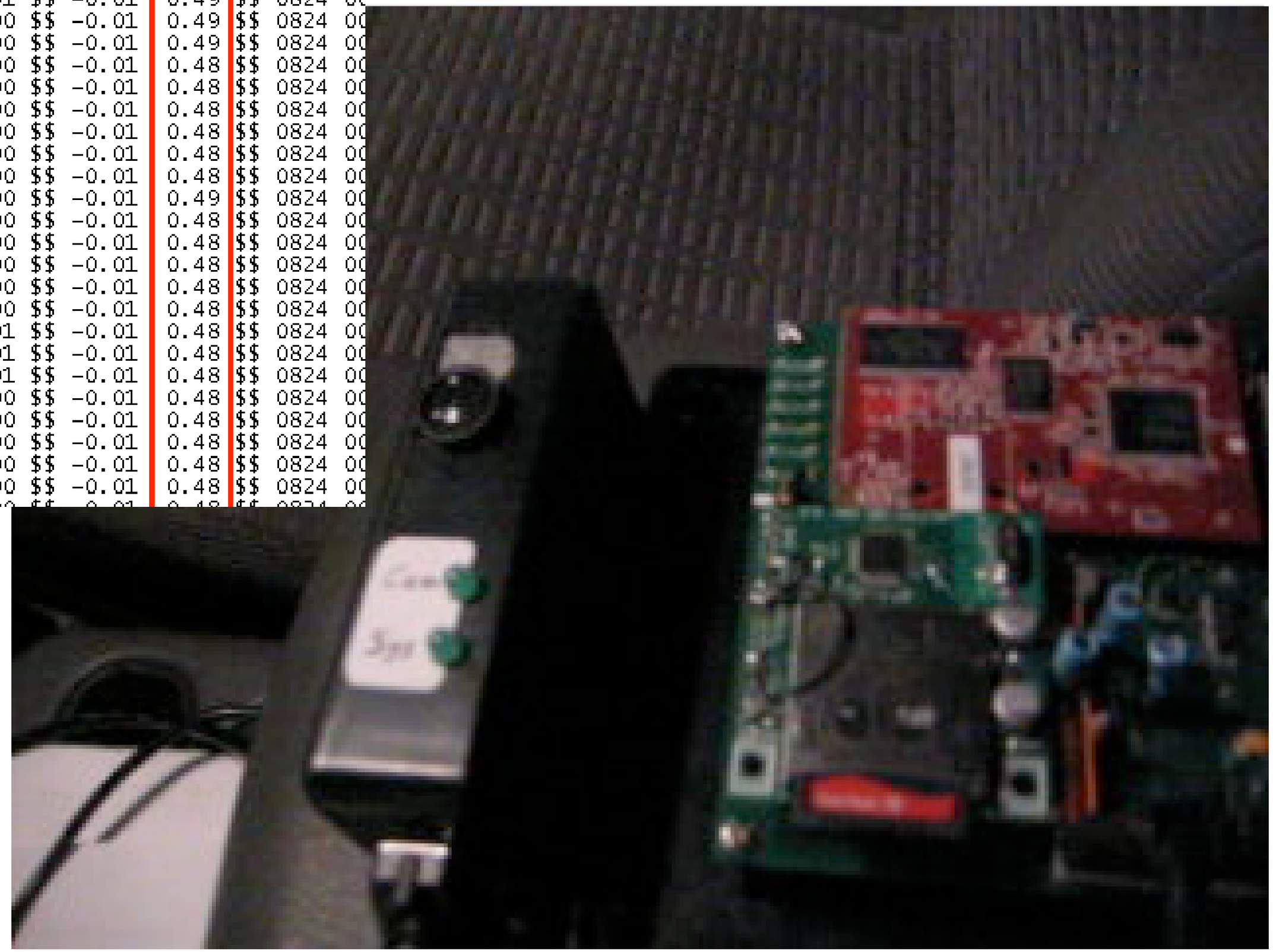
Demonstration



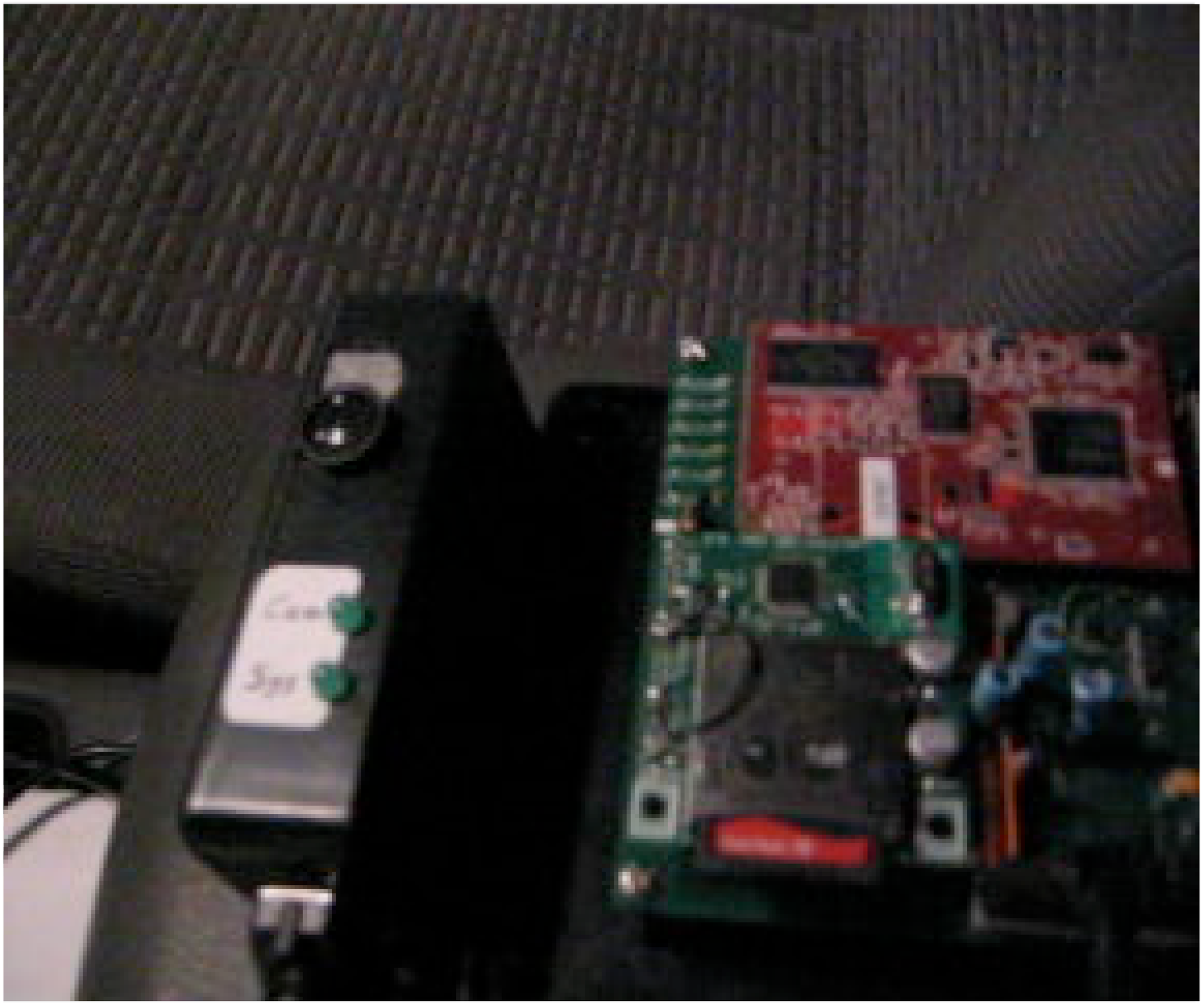
Demonstration



Demonstration

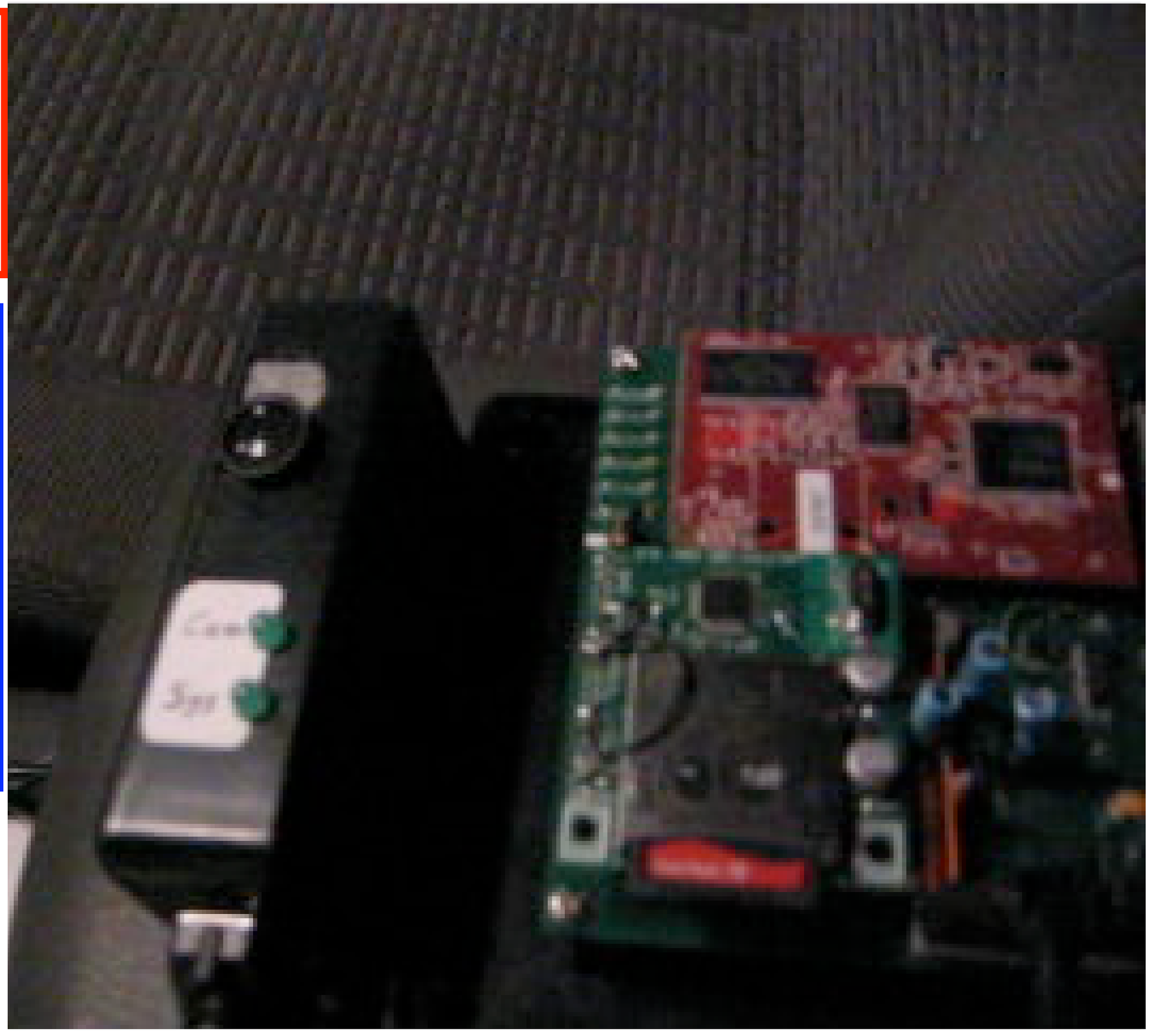


Demonstration



Demonstration

```
$ 0812 000 009
$ 0812 000 009
$ 0812 000 009
$ 0812 000 009
$ 0812 000 009
$ 0812 000 009
$ 0812 000 009
$ 3737 000 009
$ 3737 000 005
$ 3737 000 005
$ 3737 000 005
$ 2949 000 005
$ 2949 000 005
$ 2949 000 006
$ 2949 000 006
$ 2949 000 006
$ 2949 000 006
$ 2749 000 006
$ 2749 000 006
$ 2749 000 006
$ 2749 000 006
$ 2749 000 000
$ 2749 000 000
$ 2749 000 000
$ 2749 000 000
$ 2749 000 000
$ 2749 000 000
$ 2749 000 000
$ 1462 000 000
$ 1462 000 000
```



Demonstration

Data Output

Yaw Rate $$ X Y $$ RPM $$ Speed $$ Throttle Pos.

```
$$ +30 $$ -0.12 -0.35 $$ 1162 012 000
$$ +31 $$ -0.12 -0.36 $$ 1162 012 000
$$ +31 $$ -0.12 -0.37 $$ 1162 012 000
$$ +31 $$ -0.13 -0.38 $$ 1162 012 000
$$ +32 $$ -0.13 -0.38 $$ 1149 012 000
$$ +32 $$ -0.13 -0.39 $$ 1149 012 000
$$ +33 $$ -0.13 -0.39 $$ 1149 012 000
$$ +32 $$ -0.14 -0.41 $$ 1149 012 000
$$ +33 $$ -0.14 -0.40
$$ +33 $$ -0.14 -0.40 $$ 1149 012 0
$$ +34 $$ -0.14 -0.39 $$ 1062 012 0
$$ +35 $$ -0.14 -0.39 $$ 1062 012 000
$$ +35 $$ -0.14 -0.38 $$ 1062 012 000
$$ +36 $$ -0.14 -0.37 $$ 1062 011 000
$$ +36 $$ -0.14 -0.37 $$ 1062 011 000
$$ +36 $$ -0.15 -0.37 $$ 1062 011 000
$$ +36 $$ -0.15 -0.37 $$ 1062 011 000
$$ +36 $$ -0.15 -0.36 $$ 0999 011 000
```

Note harder acceleration

Tightening Turn

Data Log File

DL190732.TXT

```
UTC Time            $$ UTC Position(Lat,Lon)          $$ Yaw $$ Accel(x,y)
$$ OBD(RPM,Speed,Throttle)
-------------------------------------------------------------------------------------------------
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +01 $$  0.63 -0.55
$$ 0812 000 000
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +01 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +01 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +01 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +00 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +00 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:36 $$ 28 25.463701 N 081 15.402101 W $$ +01 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:48 $$ 28 25.463301 N 081 15.399800 W $$ +01 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:48 $$ 28 25.463301 N 081 15.399800 W $$ +01 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:48 $$ 28 25.463301 N 081 15.399800 W $$ +00 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:48 $$ 28 25.463301 N 081 15.399800 W $$ +00 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:48 $$ 28 25.463301 N 081 15.399800 W $$ +00 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:48 $$ 28 25.463301 N 081 15.399800 W $$ +01 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:48 $$ 28 25.463301 N 081 15.399800 W $$ +01 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:48 $$ 28 25.463301 N 081 15.399800 W $$ +01 $$  0.02  0.03
$$ 0812 000 000
04-19-2007 07:32:49 $$ 28 25.463499 N 081 15.399600 W $$ +01 $$  0.02  0.03
$$ 0774 000 000
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Picture Log File

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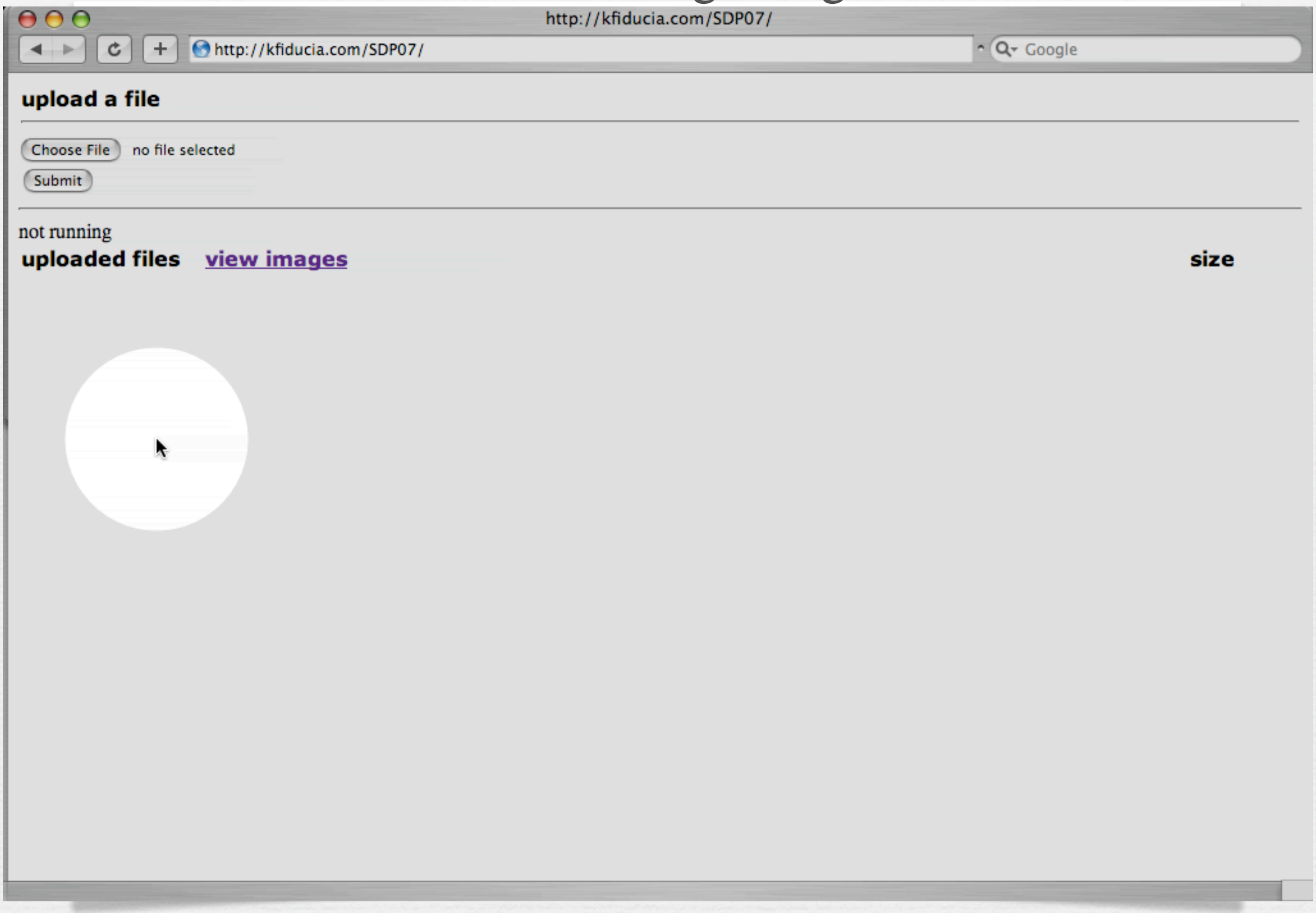
Post Processing Images



Thank you.