EEL 4924 Electrical Engineering Design

(Senior Design)

Final Report

25 April 2012

Project Title:

The Ad-Flier!

Team Name:

Sky Lights

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PROJECT ABSTRACT:

What are the three most important things to remember in advertising? Location, location, location! The Ad-Flier is a solution to two of the greatest problems currently faced in the college of engineering: first, the publication of more Go Gators banners and advertisements; second, an easier solution to the take-off and landing of autonomous unmanned aerial vehicles.

Team Sky Lights has found the opportunity to take out two UM Ibis' with one stone, by developing an easier solution for a control system on a standard Quadrocopter frame and removing all the nags of common air flight, our system will allow the most novice of fliers the ability to enter a coordinate path (created using Google Maps) and takeoff! It does this by separating the flight functions into two separate chips, one processor devoted to stabilization of the craft and controlling the motors, and the second devoted to attaining coordinates and calculating the alterations of the current path. This separation will allow the stabilizer to react more quickly to changes in the environment while still ensuring it is following a stated course. The navigation unit will contain on-board memory to store its course and (time permitting) also contain a communications system to provide 2-way transmissions for course alteration and telemetry.

So what does this all mean to the average Joe? While our football team is drowning out the Crimson Tide in Alabama, we can have our Ad-Fliers circling the stadium with Go Gators! and Enjoy Pepsi! logos attached, cheering our team and fans on to victory!

TABLE OF CONTENTS

PRODUCT FEATURES/OBJECTIVES

During specification, a series of requirements were placed to ensure adequate and safe operation of the craft.

1. A Manual Switch & Emergency Software Shutdown
   a. The manual switch serves to ensure the craft will never engage when it is undesired. The manual switch is placed in-series between the battery and the main power junction to the Electronic-Speed-Controllers and the Fight Control Board
   b. The Emergency Software Shutdown is a combination of two triggers: one if the device went outside of radio communications range, and second a direct shutdown command that could be activated if the device engaged in unwanted behavior.
2. Hover / Hold-Position

   At a minimum, the device is required to engage in a mode where upon power-up, it will lift-off approximately one foot and hold its position in air. This requirement would prove the functionality of the stability controls implemented on the Flight Control Board.
3. Positional Sensing

   By combining an 3-Axis accelerometer, gyroscope, and magnetometer, the Ad-Flier obtains a highly accurate and reliable vector of its current orientation in space. Coupled with a barometer to act as an altimeter, the device possesses all of the sensory inputs required to self-sustain itself in air while supplied with power.

HARDWARE OVERVIEW

MECHANICAL OVERVIEW

FRAME

X 525 Quadcopter frame was chosen to be the frame for the Quadcopter. The frame was made with a fiberglass base and aluminum rods to support the plus configuration. The ends of the rods are attached to mounts supported by springs that allow for softer landings. The fiberglass and hollow aluminum tubes all the craft to be made lighter so smaller motors and a smaller battery can be used.

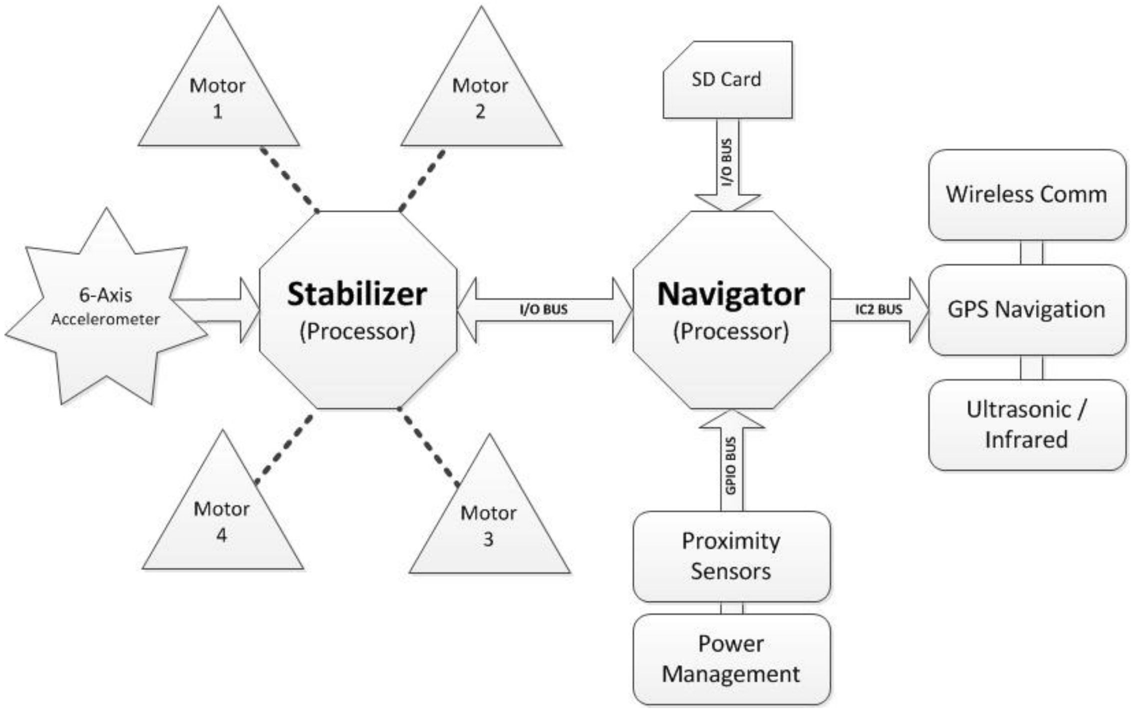
MOTORS

Four XXD 2212 KV1000 brushless motors were used. These motors take an 11.1 V power supply from the battery as well as the input signal from the ESC. The maximum efficiency of the motors was rated at 75%. They also have a no load speed of 10800 rpm and a load speed of 5880 rpm. Each motor weighs approximately 218g.

ESC

In order to control the motors, HobbyWing Skywalker 20A 2A-BEC Brushless ESCs were used. An ESC is an electronic servo controller. The ESC uses a 50 Hz PWM signal with a 1 to 2ms-pulse width to control the motor between 0 and 100% output. The ESC's had to be programmed using a programming card. This allowed control over the timing mode, the startup mode, and the cut off voltage. The cut off voltage was the most important parameter. If the battery reaches a certain low on the voltage the ESCs reduce the speed of the motor slowly so the battery does not drain below a dangerous level and so the Quadcopter doesn't instantly shut off and crash.

Flight Control Board Overview



Core Components

1. PIC32MX795F512L 32-Bit Microcontroller

   This device serves as the central math processing unit and communication hub of the craft. It interfaces all of the long and short range communication systems, GPS sensors, and on-board digital storage devices to the FPGA.

2. EP2C8T144C8N Cyclone II FPGA by Altera

   This device served by providing the logic functions necessary for implementing the PID controller and other stability control systems. It directly interfaced with the Electronic-Speed-Controllers for the motors to regulate speed.

Position Sensors

1. Accelerometer – This sensor gives us the approximate angle the device is relative to a point of gravity. This position can change due to acceleration and would thus need another array of devices to guarantee its position.
2. Gyroscope – This sensor delivers the approximate rotation of the craft in degrees per second. This measurement is taken every 1/100th of a second and reported to the stability control on the craft. Since this sensor only gives you a rate of change measurement, it is coupled with the outputs of the accelerometer and the magnetometer to provide a highly-accurate positional vector.
3. Magnetometer – Focusing in on the magnetic poles of the earth, this sensor acts as a digital compass, delivering us a reading in Gauss of the largest magnetic field in the area. Since the motors often would cause interruptions and disturbances with this sensor, the sensitivity was carefully calibrated to average out the noise of the motors and still provide an accurate heading.
4. Barometer – This sensor provides the Flight Control Board with the relative pressure of its current location. This value is incredibly useful in calculating height at large intervals and was thus used as an altimeter when the ultrasonic sensors went out of range.

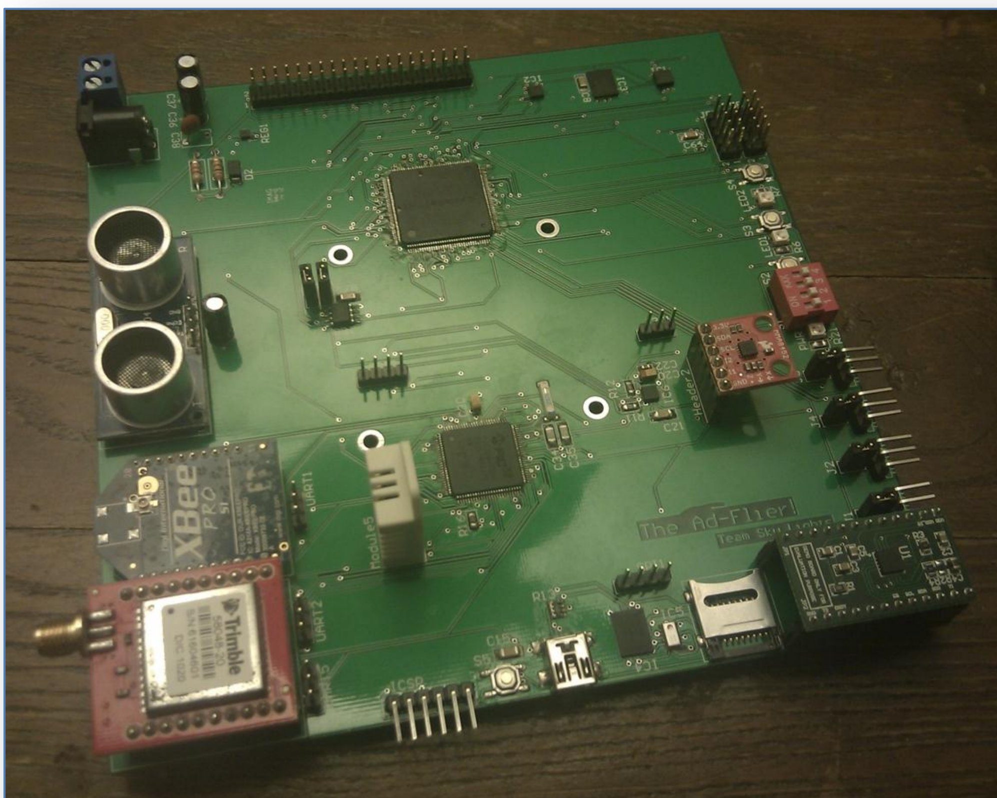
5. Humidity Sensor – The humidity sensor is a safety feature that will detect when the air surrounding the device becomes too rich with moisture to ensure safe operations of the craft. Specific concerns were related to moisture damaging operating circuits.

Communication System

1. The Flight Control Board is equipped with two means of communicating with the outside world. First, a Full-Speed USB port is provided to interface with the PIC Microcontrollers as a virtual serial port. This makes downloading information from the SD-Card or on-board Flash SRAM a snap.
2. The second, and main communication system, is the long-range XBee S1 Pro communication system. This device is capable of transmitting and receiving data at 57.6Kbps at incredible ranges. The XBee's receiving module is connected to the Base Station, which will be later discussed.

On-Board Storage

1. The primary storage medium is the MicroSD card slot connected to the PIC32 Microcontroller. It is responsible for recording flight logs, sensor data, and to store photos from the camera board.
2. The Flight Control Board is also equipped with two 128MB Serial Flash SRAM chips; one connected to the FPGA and the other connected to the PIC32. Each is capable at operating at speeds up to 104Mbps which was well within the operating clock speeds of both devices. The FLASH SRAM modules were implemented to serve as short-term storage for data intensive mathematical processes for the FPGA or PIC.



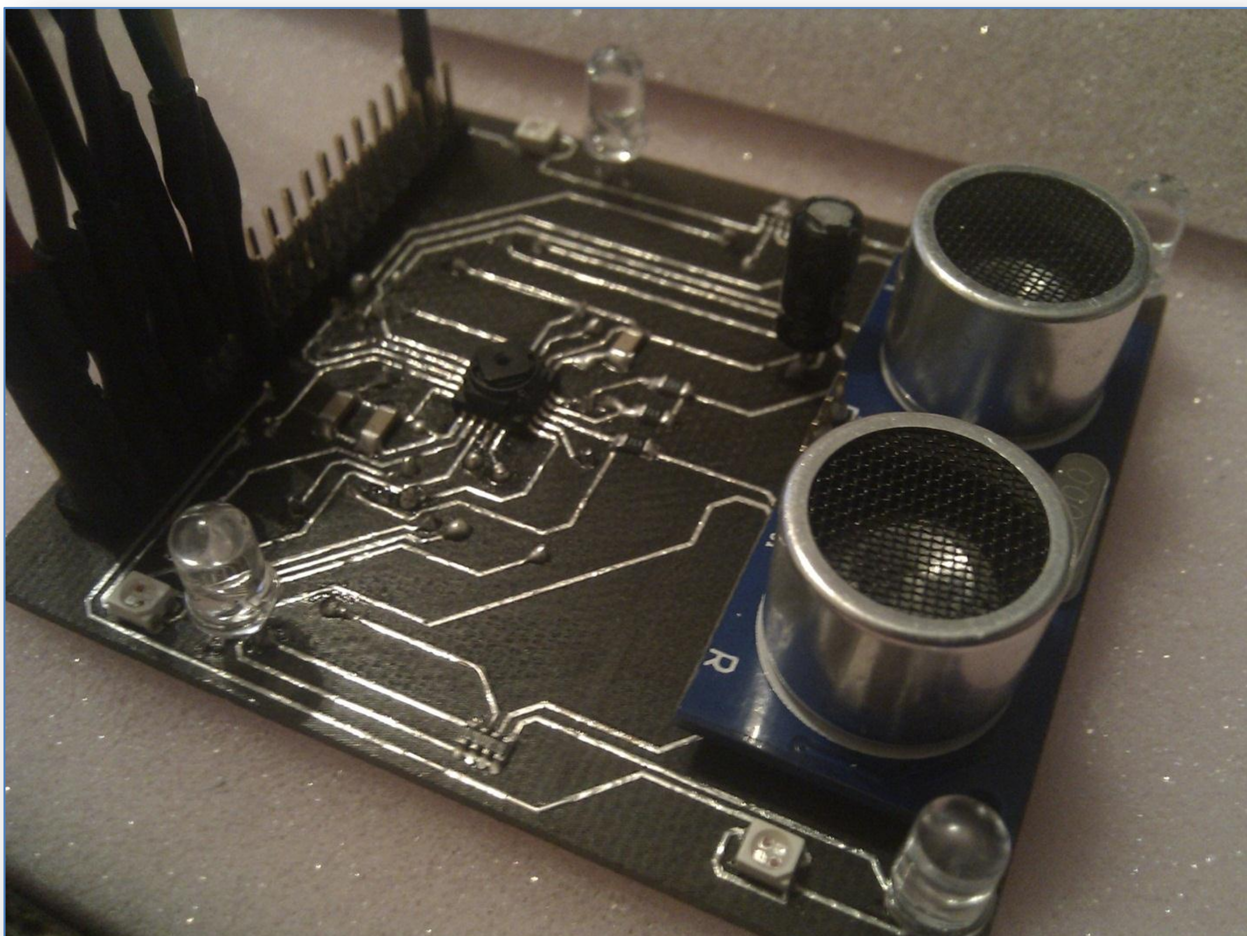
Camera Board Overview

0.3MP On-Board Camera

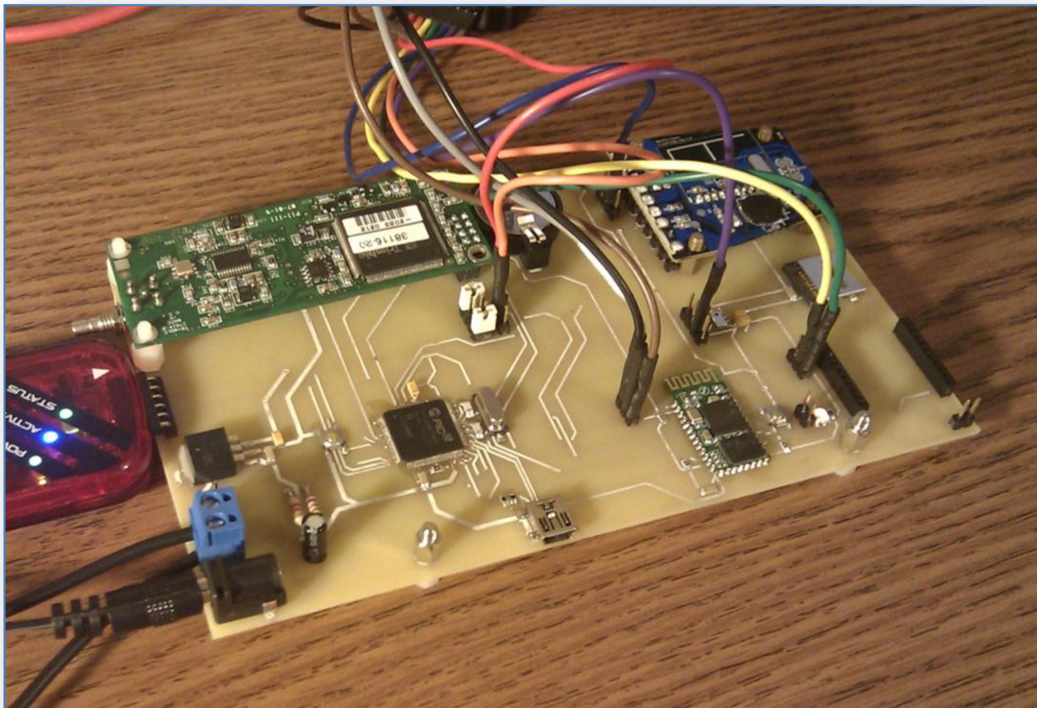
The bottom camera is capable of capturing images at up to 640x480 pixel resolution and outputs them in RGB format across a 50MHz databus. This is picked-up by the FPGA, processed, and stored as an image on the MicroSD card. The camera module serves as a future implementation of an automatic-landing mechanism, where an image will be taken and using image processing techniques, the FPGA will attempt to locate and align with a target.

Long-Range Ultrasonic Ranger

The Ad-Flier is equipped with two Ultrasonic rangefinders mounted on the top and bottom of the craft. Each has an operational range of up to 150cm (59.055 ft.) and a measuring angle of 30°.



Base Station Overview



Core Components

PIC32MX795F512L 32-Bit Microcontroller

This device serves as a hub for all ground-to-air communications. It fans-out the data stream coming from the Ad-Flier into several useable mediums and ensuring that the device is behaving safely. Should the device act out of accordance with its programming, the base station will have the ability to remotely terminate operations of the craft and either force an immediate shutdown, or allow the craft to hover down to the ground.

Communication System

1. USB Full-Speed Virtual Serial Port – This allows for quick transfers of information form the PIC to a connected PC. This also allows a future implementation of programming the PIC Microcontroller directly from the USB port instead of requiring an additional programmer.
2. XBee Long-Range S1 Wireless Module – This device allowed incredibly long-range communications with the Ad-Flier while in flight. Operating distance is reduced greatly when the craft is not in line-of-sight.
3. Bluetooth Serial Interface – This module specifically serves the role of debug output and operational commands to the craft from a connected PC. It is also designed to interface with the GUI Console to display the Ad-Flier's current position, heading, and other system information.
4. PlayStation II Wireless Remote Control – This module gives the user manual control of the craft and allows them to enjoy the full limits of what it is capable of.

Relative Sensors

1. Barometer – The relative barometric pressure sensor is used to obtain the relatve pressure of ground. This is used in the Ad-Flier's height calculations as a basis. The barometer also features a built-in thermometer.
2. Global Positioning System – The Base Station features a Trimble GPS system which provides it with its current location. This allows the Ad-Flier to have an approximate location of where HOME is located and where it should return when the battery voltage drops below the desired threshold.

On-Board Storage

1. The primary storage medium is the MicroSD card slot connected to the PIC32 Microcontroller. It hold flight logs, error reports, and other sensor data logs.

Software Overview

The Proportional Integral Derivative Controller

In order to implement stabilization of the Quadcopter, several PID controllers were used. A PID controller, short for proportional, integral, derivative, is a useful control loop feedback mechanism. The controller works by first calculating an error. The error is the difference of the desired process variable and the measured process variable. In our case, there were three PID controllers used to control the angles of the axes, pitch, roll, and yaw. There was also one controller used to control altitude.

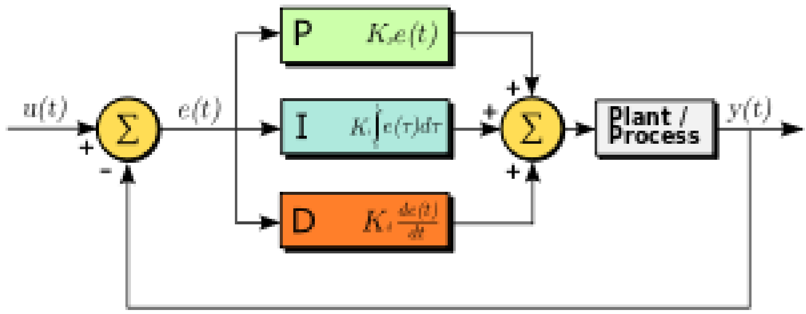
Pitch is the orientation for the machine with respect to the nose of the quad. A positive pitch degree indicates that the nose is pointed up and the device will fly backwards. A negative pitch angle indicates that the noise is pointed down and that the quad will fly forward. In our machine, positive pitch was a counterclockwise rotation in the positive y-axis. Stabilization of pitch was controlled by offsets to the front and rear motors.

Roll is the orientation of the machine with respect to the wings. A positive roll degree indicates that the right wing is higher and the quad will fly to the left. A negative roll angle indicates that the left wing is higher and the machine will drift to the right. In our machine, positive pitch indicates a counterclockwise rotation in the positive x-axis. Stabilization of pitch was controlled by offsets to the left and right motors.

Yaw is the orientation of the machine perpendicular to pitch and roll. In our machine this would be the z-axis. A positive yaw rotation would be a clockwise rotation about the positive z-axis, where the positive z-axis is the axis extending out of the top of the quad. Stabilization of yaw is controlled by increasing torque of either the front and back motor or the left and right motor with respect to the other pair of motors. This stabilization is possible in the quad because each pair of motors has either clockwise rotating props or counterclockwise rotating props. Each pair tends to make the craft rotate in a different direction.

The altitude was how high off the ground the quad was. Adding or subtracting the same amount of torque to each motor achieved stabilization of the altitude.

The inputs of the PID controllers were either angles or altitude and the outputs were all an 8 bit vector used in conjunction with the PWM module to change the speed of the motors. A typical block diagram of a PID controller, obtained from Wikipedia, can be seen in the figure below.



Block Diagram of a PID controller

In order to create the PID controller in VHDL the equations had to be discretized. The equation of the discreet PID controller is given as

$$u(t) = u(t-1) + K_c\left[e(t) - e(t-1)\right] + \frac{K_c T_s}{T_i} e(t) + \frac{K_c T_d}{T_s}\left[e(t) - 2e(t-1) + e(t-2)\right]$$

This is known as the velocity form of the PID equation. The terms with K and T were replaced with KP, KI, and KD. These are all constants that are separate for each separate controller. The constants are determined by tuning. In the process of tuning, KI, and KD are set equal to zero while KP is increased until oscillation in the desired controller output is achieved. Then KD is increased until the oscillations subside. Finally KI is increased until the steady state time is achieved in an acceptable time.

Tuning the PID controller proved to be a daunting task. First, implementing the equations in VHDL had to be done with integer math. This required a lot of changing of variables. Determining the limits for the PID controller was also challenging. For the limits, it was determined that a 30-degree error in either direction would cause the motor for the drooping side to operate at 80%. This greatly increases the speed before the quad flips over and becomes uncontrollable. Also, while tuning for pitch and roll takes place separately, when combined the angles of pitch and roll actually effect each other. This adds another level of complexity to the tuning process and makes the results less desirable. Scaling down the integer values used in the PID in order to achieve an 8 bit values that was actually proportional to the desired output was also a challenging task.

The PID controllers used can be seen in the code attachment.

Pulse Width Modulator Control System

The PWM component was also composed in VHDL for use on the FPGA. The purpose of the PWM module was to convert the output from the PID controllers to a useful signal that was capable of controlling the motors. As mention above, the motors are driven by an ESC. The ESC takes an input PWM signal to control the motor. This signal is composed of a 50 Hz frequency signal with varying pulse with for the duty cycle. The pulse width for the ESC input ranges from 1ms to 2ms. A 1ms pulse indicates 0% of the motor power. A 2ms pulse indicates 100% of the motor power.

The first step in the code was to create a 50 Hz signal from the 25.175 Mhz clock on the FPGA. Using a clock divider did this. The next step was to make an input to the module create different pulse widths for the output. The resolution of the PWM controller was 8 bits for a 1ms swing in output. This is .04% change in motor speed for each count in the input vector.

The only problem with the control of the motors is that all motors are not created the same. Each motor required a different offset value before it would actually turn on. This offset was accounted for by using the rangefinder to make sure that each motor initialized for the same input value plus offset to the PWM unit.

FPGA-Microprocessor Interface

Overview

To allow communications between the PIC and FPGA, and allow the passing of nessecary data, a simple 8-bit parallel port communications system was constructed between the two devices. Using a handshake method, the PIC Microcontroller is able to either read a specified list of registers on the FPGA or write to a list of specified registers on the FPGA.

Tested Data Rates

When a continuous read/write test was performed, the PIC was able to transfer at a rate of 2.66Mbps

Sensors

Gyroscope

The L3G4200D Gyroscope transfers 16-bit values across the SPI bus in 8-bit increments. It can achieve a maximum rate of 10MHz when in SPI Mode.

Accelerometer

Magnetometer

The HMC5883L Magnetometer communicates using the I2C line with rates up to 400KHz. The data is stored as 12-Bit ADC readings and need proper conversion back to Gauss before they can be used.

Barometer

The MPL115A1 Barometer communicates using the SPI bus at a max rate of 8 MHz Several iterations of conversions are needed before the data outputted is usable. The pressure readings are also significantly affected by the relative temperature and operating conditions.

Bill of Materials

Part	Manufacturer	Description
EP2C8T144C8N	Altera	Cyclone II FPGA
TCM8230MD	Toshiba	640x480 Camera Module
TCM8230MD	Toshiba	640x480 Camera Module
EP2C8T144C8N	Altera	Cyclone II FPGA
XBEE Pro S1	Digi International	Long-Range Wireless

PIC32MX795F512L	Microchip	32bit PIC Processor
Copernicus	Trimble	GPS Module
EPCS16SI8N	Altera	16MB FPGA Configuration SRAM
SD Card	EgoChina	SD Card
RF-2400W	Inhaos	Short Range Wireless
S25FL128P	Spansion	128MB 104MHz Flash Memory
HMC5883L	Honeywell	Magnetometer
RHT03	Maxdetect	Humidity Sensor
SST26VF032	Silicon Storage Technologies	32MB Serial Quad I/O Flash
MCP2200	Microchip	USB -> USART
HC-06	Itead Studio	SMD Bluetooth Module
MMA8452Q	Freescale Semiconductors	Accelerometer
L3G4200D	STMicroelectronics	Gyroscope
MPL115A1	Freescale Semiconductors	Pressure Sensor
DS1085	Maxim Semiconductors	Programmable Clock Synthesizer
HC-SR04	Itead Studio	Ultrasonic Ranger

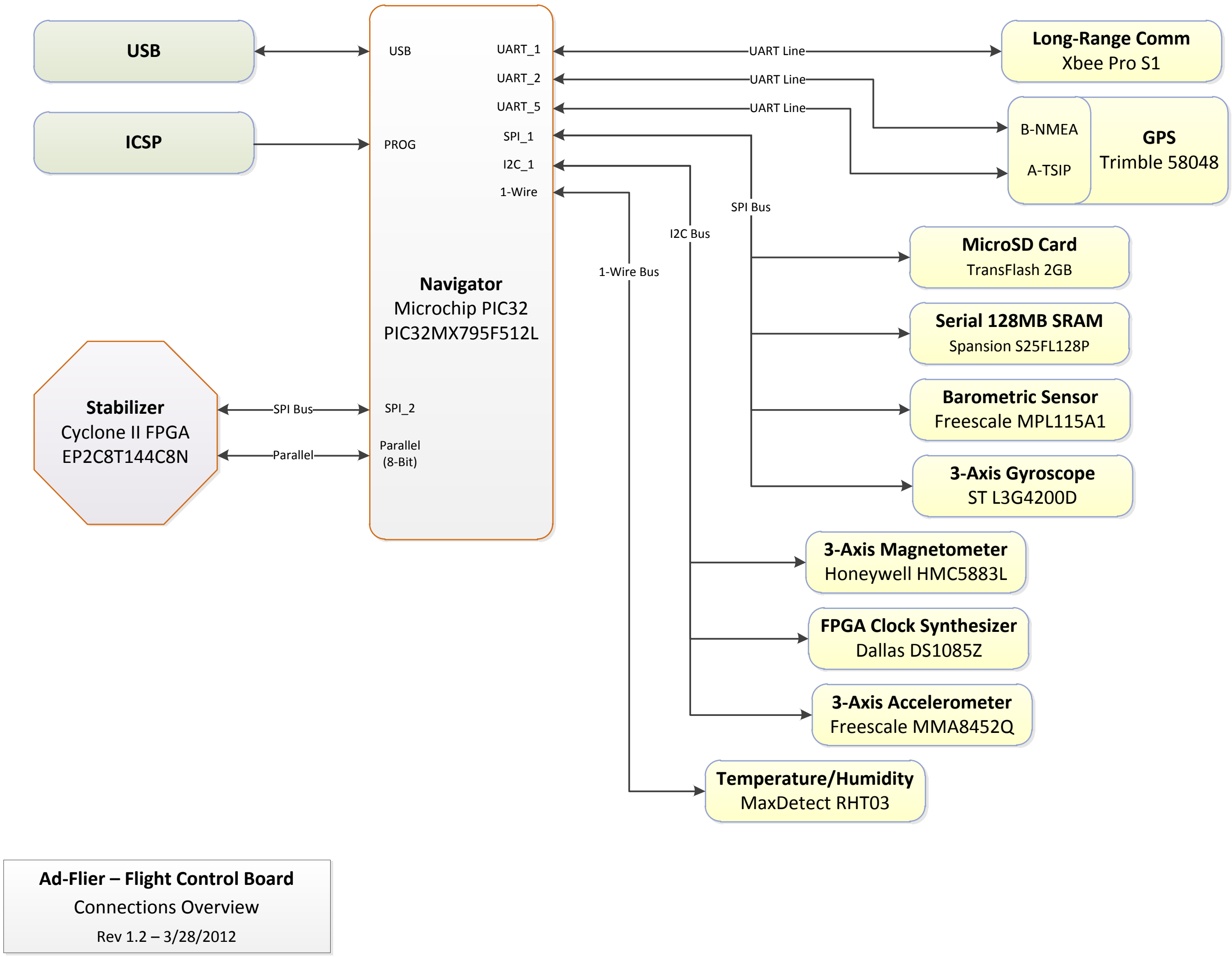
Division of Labor

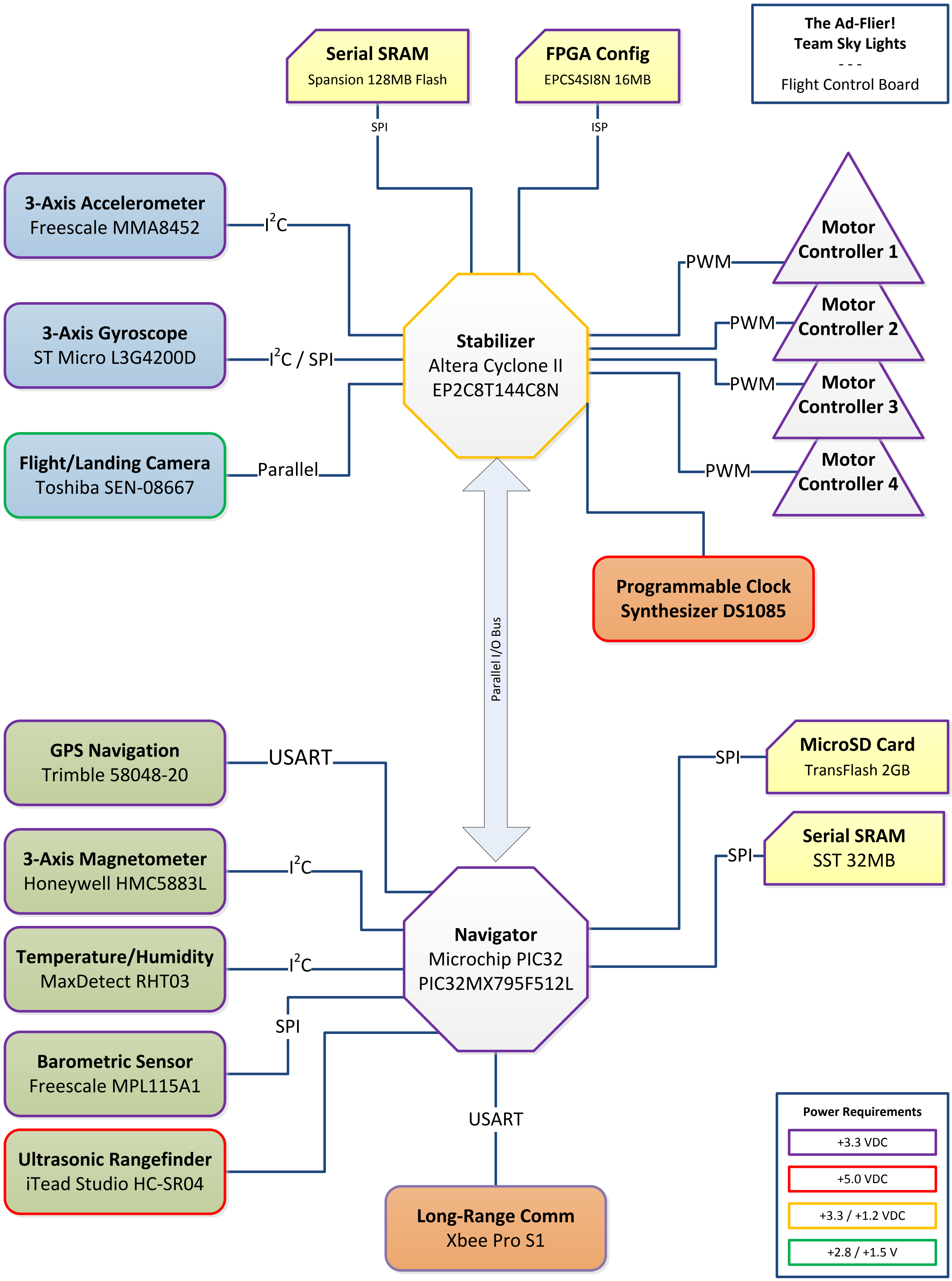
Item	Sal D'Acunto	Info	David Greene	Info
Process Flowcharts	50	FPGA Stabalization and Sensor Filter Design	50	PIC Navigation Processes
Parts Identification	50	Frame, Battery, etc...	50	PCB Hardware and Components
PCB Design	0		100	Flight Control Board and Base Station Board
FPGA Motor Control Programming	100	Creating the Pulse Width Modulation Structures and Controller in the FPGA	0	
FPGA Kalman Filter Design	100	Integration of Sensors into factoring current position	0	
FPGA PID Loop Control	100	Integration of Sensors into stabilizing based on current position	0	
FPGA Image Processing	0		100	Landing Pad Alignment and other Image Processing Tasks
PIC Programming	0		100	Navigator IC and Base Station
Frame Construction	100	Frame, Battery, PCB Mounting...	0	
Manual Controller Design (with PC Program)	0		100	For manual control of the craft with sensor outputs
Documentation	50		50	

Gantt Chart

Appendix

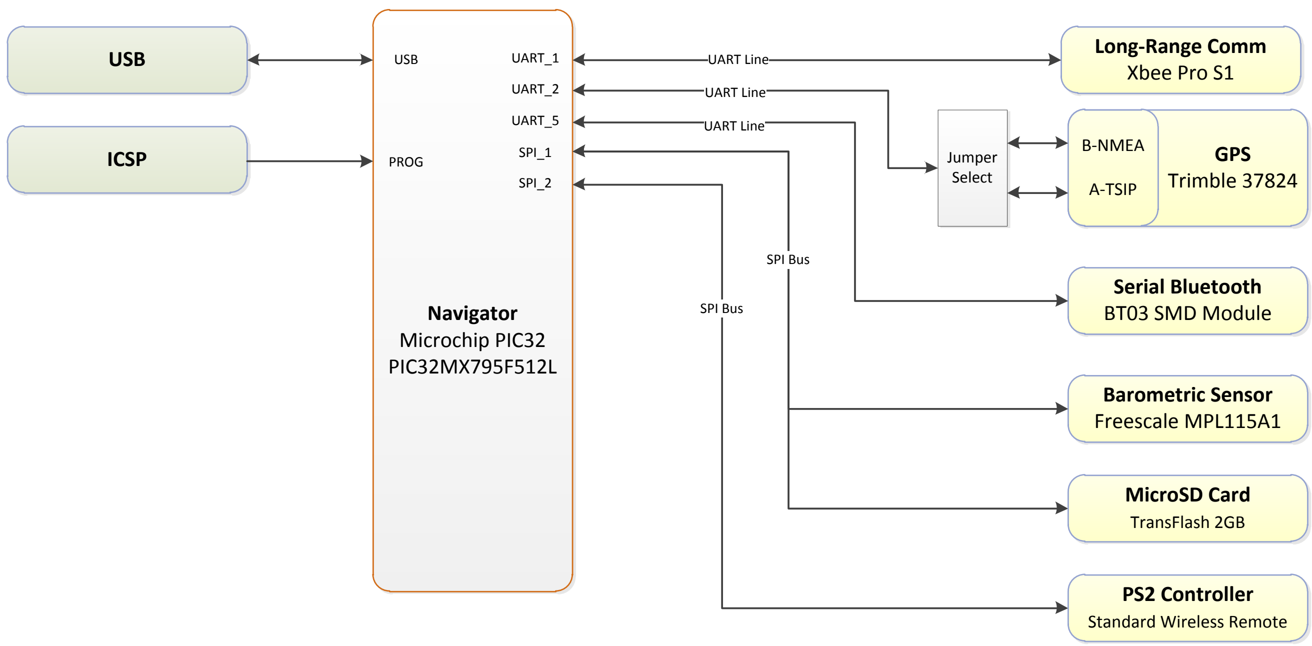
Appendix A – Overview of the Flight Control Board



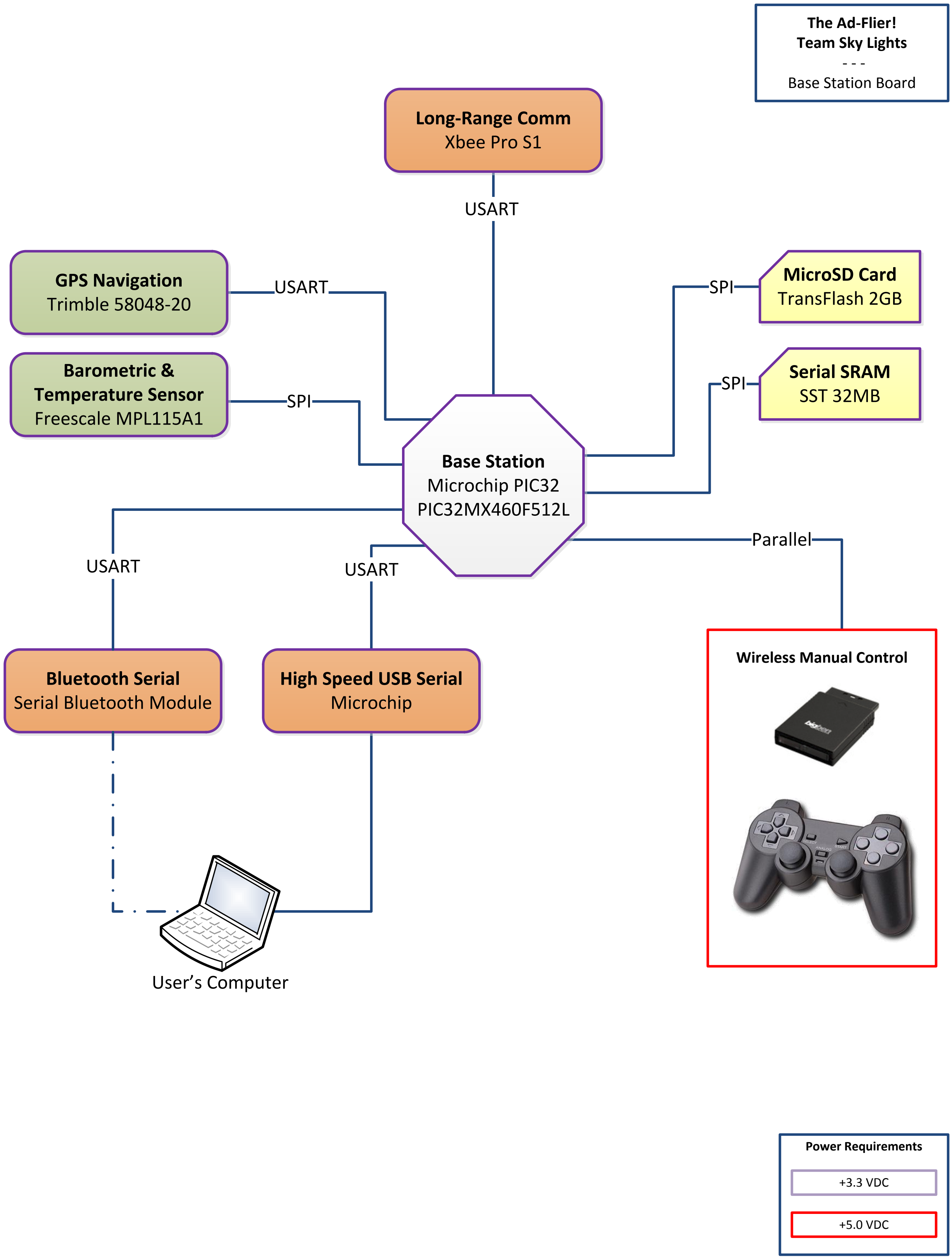


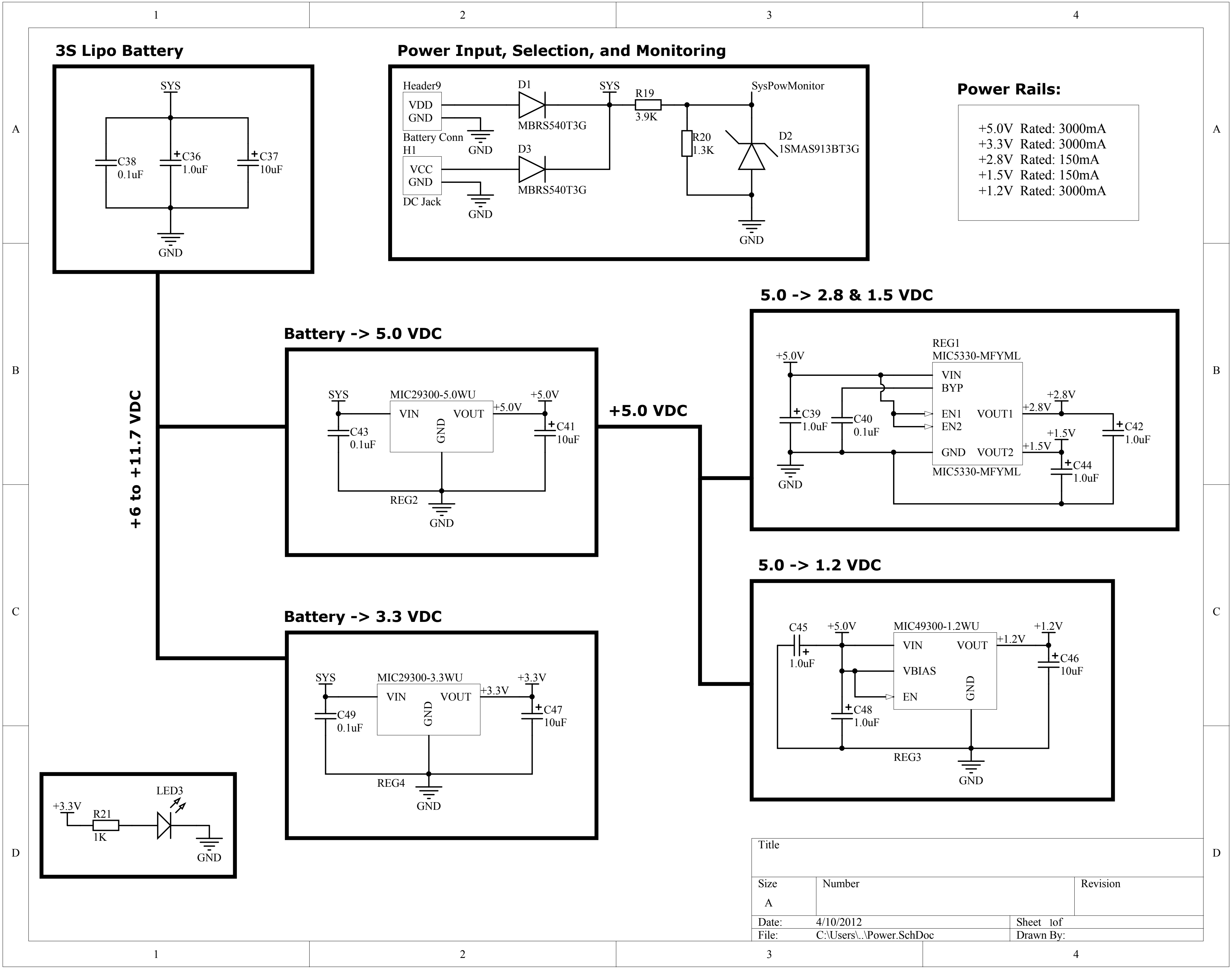
The Ad-Flier!
Team Sky Lights
- - -
Flight Control Board
Serial SRAM
Spansion 128MB Flash
SPI
FPGA Config
EPCS4SI8N 16MB
ISP
3-Axis Accelerometer
Freescale MMA8452
I2C
3-Axis Gyroscope
ST Micro L3G4200D
I2C / SPI
Flight/Landing Camera
Toshiba SEN-08667
Parallel
Stabilizer
Altera Cyclone II
EP2C8T144C8N
PWM
Motor Controller 1
PWM
Motor Controller 2
PWM
Motor Controller 3
PWM
Motor Controller 4
Programmable Clock Synthesizer DS1085
Parallel I/O Bus
GPS Navigation
Trimble 58048-20
USART
3-Axis Magnetometer
Honeywell HMC5883L
I2C
Temperature/Humidity
MaxDetect RHT03
I2C
SPI
Barometric Sensor
Freescale MPL115A1
Ultrasonic Rangefinder
iTead Studio HC-SR04
Navigator
Microchip PIC32
PIC32MX795F512L
SPI
MicroSD Card
TransFlash 2GB
SPI
Serial SRAM
SST 32MB
USART
Long-Range Comm
Xbee Pro S1
Power Requirements
+3.3 VDC
+5.0 VDC
+3.3 / +1.2 VDC
+2.8 / +1.5 V

Appendix B – Overview of the Base Station Board



Ad-Flier – BaseStation Board
Connections Overview
Rev 1.2 – 3/28/2012


The Ad-Flier!
Team Sky Lights
- - -
Base Station Board
Long-Range Comm
Xbee Pro S1
USART
GPS Navigation
Trimble 58048-20
USART
Barometric &
Temperature Sensor
Freescale MPL115A1
SPI
MicroSD Card
TransFlash 2GB
SPI
Serial SRAM
SST 32MB
SPI
Base Station
Microchip PIC32
PIC32MX460F512L
Parallel
USART
USART
Bluetooth Serial
Serial Bluetooth Module
High Speed USB Serial
Microchip
Wireless Manual Control
User's Computer
Power Requirements
+3.3 VDC
+5.0 VDC


3S Lipo Battery
SYS
C38 0.1uF
C36 1.0uF
C37 10uF
GND
Power Input, Selection, and Monitoring
Header9
VDD
GND
Battery Conn
H1
VCC
GND
DC Jack
D1
MBRS540T3G
D3
MBRS540T3G
SYS
R19 3.9K
R20 1.3K
SysPowMonitor
D2 1SMAS913BT3G
GND
Power Rails:
+5.0V Rated: 3000mA
+3.3V Rated: 3000mA
+2.8V Rated: 150mA
+1.5V Rated: 150mA
+1.2V Rated: 3000mA
+6 to +11.7 VDC
Battery -> 5.0 VDC
MIC29300-5.0WU
VIN
VOUT
GND
C43 0.1uF
C41 10uF
REG2
+5.0V
+5.0 VDC
5.0 -> 2.8 & 1.5 VDC
REG1
MIC5330-MFYML
VIN
BYP
EN1
EN2
GND
VOUT1
VOUT2
C39 1.0uF
C40 0.1uF
C42 1.0uF
C44 1.0uF
+2.8V
+1.5V
Battery -> 3.3 VDC
MIC29300-3.3WU
C49 0.1uF
C47 10uF
REG4
+3.3V
5.0 -> 1.2 VDC
MIC49300-1.2WU
VIN
VBIAS
EN
VOUT
C45 1.0uF
C48 1.0uF
C46 10uF
REG3
+1.2V
LED3
R21 1K
Title
Size A
Number
Revision
Date: 4/10/2012
Sheet 1of
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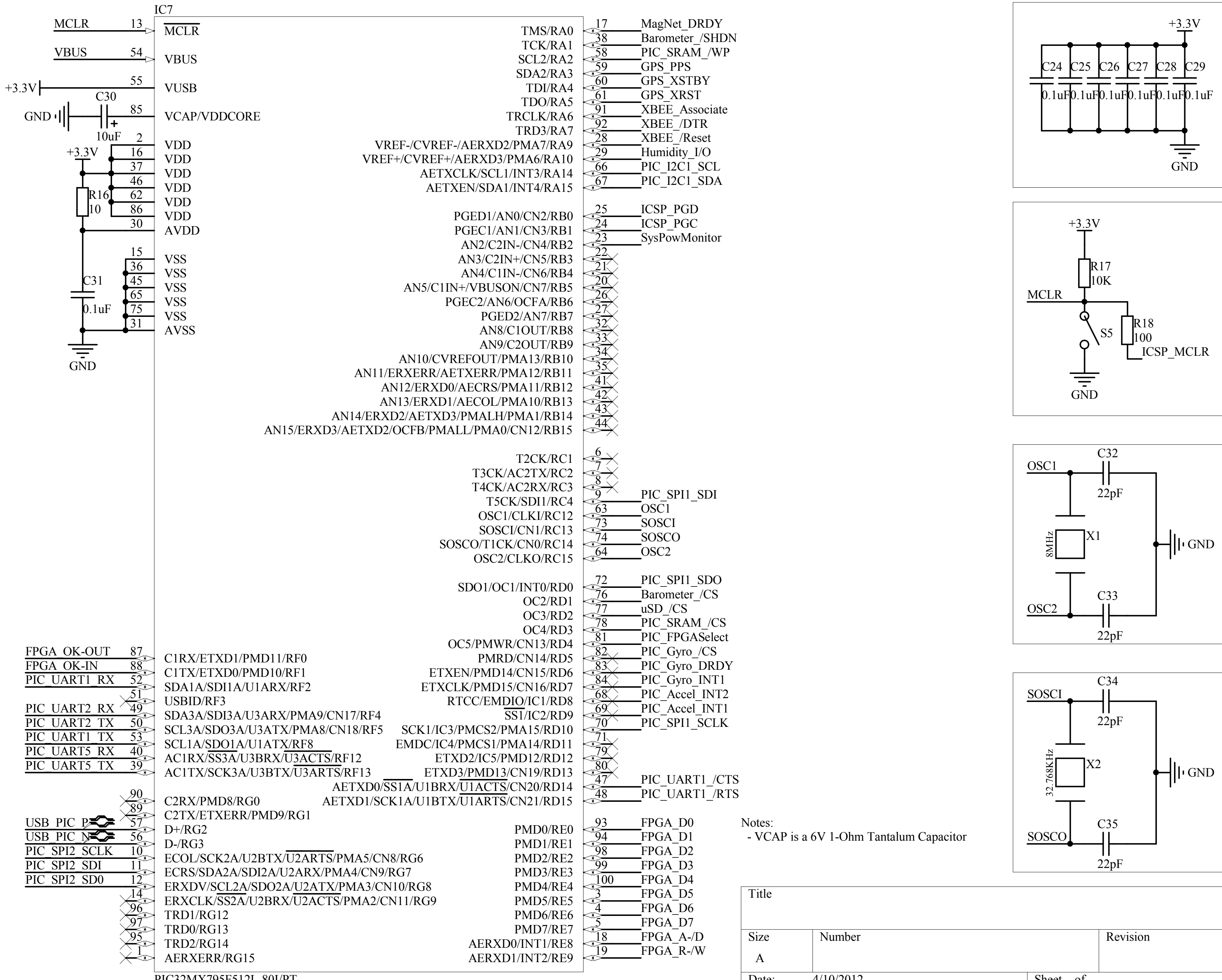
Drawn By:



Notes:
- VCAP is a 6V 1-Ohm Tantalum Capacitor

Title		
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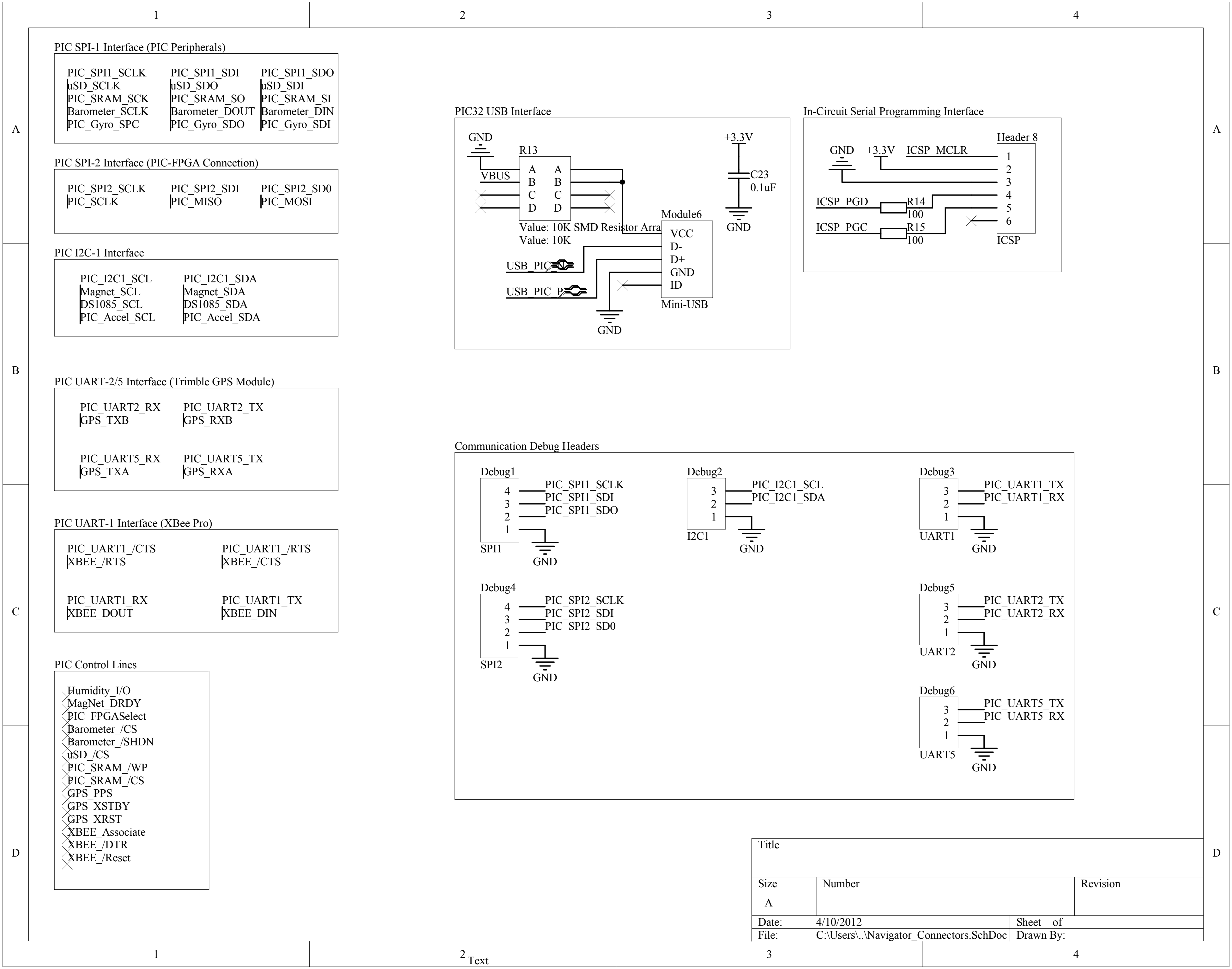
File: C:\Users\..\Navigator_Core.SchDoc		Drawn By:



PIC SPI-1 Interface (PIC Peripherals)
PIC_SPI1_SCLK
uSD_SCLK
PIC_SRAM_SCK
Barometer_SCLK
PIC_Gyro_SPC
PIC_SPI1_SDI
uSD_SDO
PIC_SRAM_SO
Barometer_DOUT
PIC_Gyro_SDO
PIC_SPI1_SDO
uSD_SDI
PIC_SRAM_SI
Barometer_DIN
PIC_Gyro_SDI
PIC SPI-2 Interface (PIC-FPGA Connection)
PIC_SPI2_SCLK
PIC_SCLK
PIC_SPI2_SDI
PIC_MISO
PIC_SPI2_SD0
PIC_MOSI
PIC I2C-1 Interface
PIC_I2C1_SCL
Magnet_SCL
DS1085_SCL
PIC_Accel_SCL
PIC_I2C1_SDA
Magnet_SDA
DS1085_SDA
PIC_Accel_SDA
PIC UART-2/5 Interface (Trimble GPS Module)
PIC_UART2_RX
GPS_TXB
PIC_UART2_TX
GPS_RXB
PIC_UART5_RX
GPS_TXA
PIC_UART5_TX
GPS_RXA
PIC UART-1 Interface (XBee Pro)
PIC_UART1_/CTS
XBEE_/RTS
PIC_UART1_/RTS
XBEE_/CTS
PIC_UART1_RX
XBEE_DOUT
PIC_UART1_TX
XBEE_DIN
PIC Control Lines
Humidity_I/O
MagNet_DRDY
PIC_FPGASelect
Barometer_/CS
Barometer_/SHDN
uSD_/CS
PIC_SRAM_/WP
PIC_SRAM_/CS
GPS_PPS
GPS_XSTBY
GPS_XRST
XBEE_Associate
XBEE_/DTR
XBEE_/Reset
PIC32 USB Interface
GND
R13
VBUS
A B C D
A B C D
Value: 10K SMD Resistor Arra
Value: 10K
+3.3V
C23
0.1uF
GND
Module6
VCC
D-
D+
GND
ID
Mini-USB
USB_PIC
USB_PIC_P
GND
In-Circuit Serial Programming Interface
GND
+3.3V
ICSP_MCLR
Header 8
1 2 3 4 5 6
ICSP_PGD
R14
100
ICSP_PGC
R15
100
ICSP
Communication Debug Headers
Debug1
4 3 2 1
PIC_SPI1_SCLK
PIC_SPI1_SDI
PIC_SPI1_SDO
SPI1
GND
Debug2
3 2 1
PIC_I2C1_SCL
PIC_I2C1_SDA
I2C1
GND
Debug3
3 2 1
PIC_UART1_TX
PIC_UART1_RX
UART1
GND
Debug4
4 3 2 1
PIC_SPI2_SCLK
PIC_SPI2_SDI
PIC_SPI2_SD0
SPI2
GND
Debug5
3 2 1
PIC_UART2_TX
PIC_UART2_RX
UART2
GND
Debug6
3 2 1
PIC_UART5_TX
PIC_UART5_RX
UART5
GND
Title
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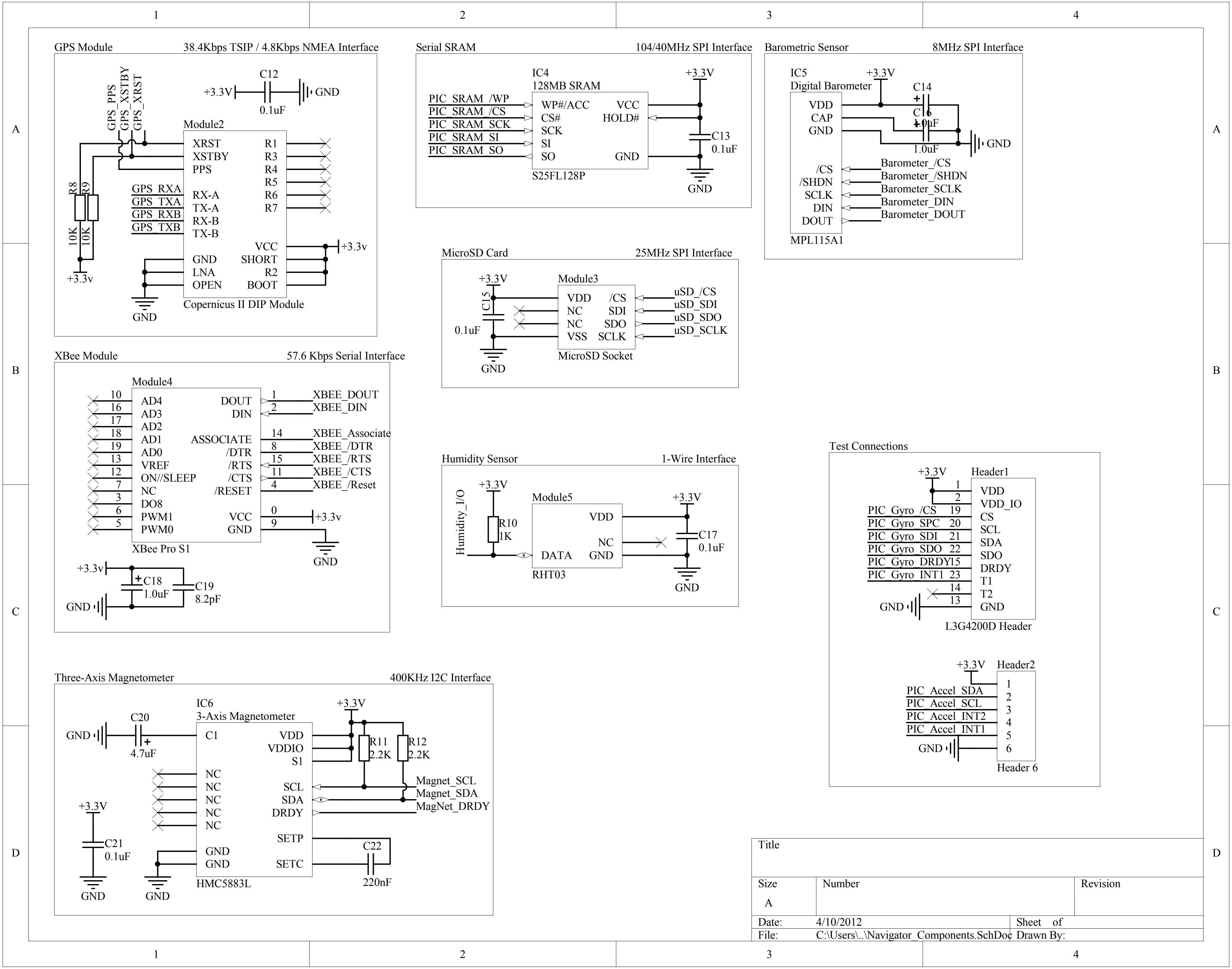

GPS Module
38.4Kbps TSIP / 4.8Kbps NMEA Interface
C12
+3.3V
0.1uF
GND
GPS_PPS
GPS_XSTBY
GPS_XRST
Module2
XRST
XSTBY
PPS
R1
R3
R4
R5
R6
R7
R8
R9
10K
10K
GPS_RXA
GPS_TXA
GPS_RXB
GPS_TXB
RX-A
TX-A
RX-B
TX-B
VCC
+3.3v
GND
SHORT
LNA
R2
OPEN
BOOT
Copernicus II DIP Module
Serial SRAM
104/40MHz SPI Interface
IC4
128MB SRAM
PIC_SRAM_/WP
PIC_SRAM_/CS
PIC_SRAM_SCK
PIC_SRAM_SI
PIC_SRAM_SO
WP#/ACC
CS#
SCK
SI
SO
VCC
HOLD#
C13
0.1uF
S25FL128P
Barometric Sensor
8MHz SPI Interface
IC5
Digital Barometer
VDD
CAP
C14
C16
1.0uF
/CS
/SHDN
SCLK
DIN
DOUT
Barometer_/CS
Barometer_/SHDN
Barometer_SCLK
Barometer_DIN
Barometer_DOUT
MPL115A1
MicroSD Card
25MHz SPI Interface
Module3
C15
NC
VSS
SDI
SDO
uSD_/CS
uSD_SDI
uSD_SDO
uSD_SCLK
MicroSD Socket
XBee Module
57.6 Kbps Serial Interface
Module4
AD4
AD3
AD2
AD1
AD0
VREF
ON//SLEEP
DO8
PWM1
PWM0
DIN
ASSOCIATE
/DTR
/RTS
/CTS
/RESET
XBEE_DOUT
XBEE_DIN
XBEE_Associate
XBEE_/DTR
XBEE_/RTS
XBEE_/CTS
XBEE_/Reset
XBee Pro S1
C18
C19
8.2pF
Humidity Sensor
1-Wire Interface
Humidity_I/O
R10
1K
Module5
DATA
C17
RHT03
Test Connections
Header1
VDD_IO
PIC_Gyro_/CS
PIC_Gyro_SPC
PIC_Gyro_SDI
PIC_Gyro_SDO
PIC_Gyro_DRDY
PIC_Gyro_INT1
CS
SCL
SDA
DRDY
T1
T2
L3G4200D Header
Header2
PIC_Accel_SDA
PIC_Accel_SCL
PIC_Accel_INT2
PIC_Accel_INT1
Header 6
Three-Axis Magnetometer
400KHz I2C Interface
IC6
3-Axis Magnetometer
C20
4.7uF
C1
VDDIO
S1
R11
R12
2.2K
Magnet_SCL
Magnet_SDA
MagNet_DRDY
SETP
SETC
C21
C22
220nF
HMC5883L
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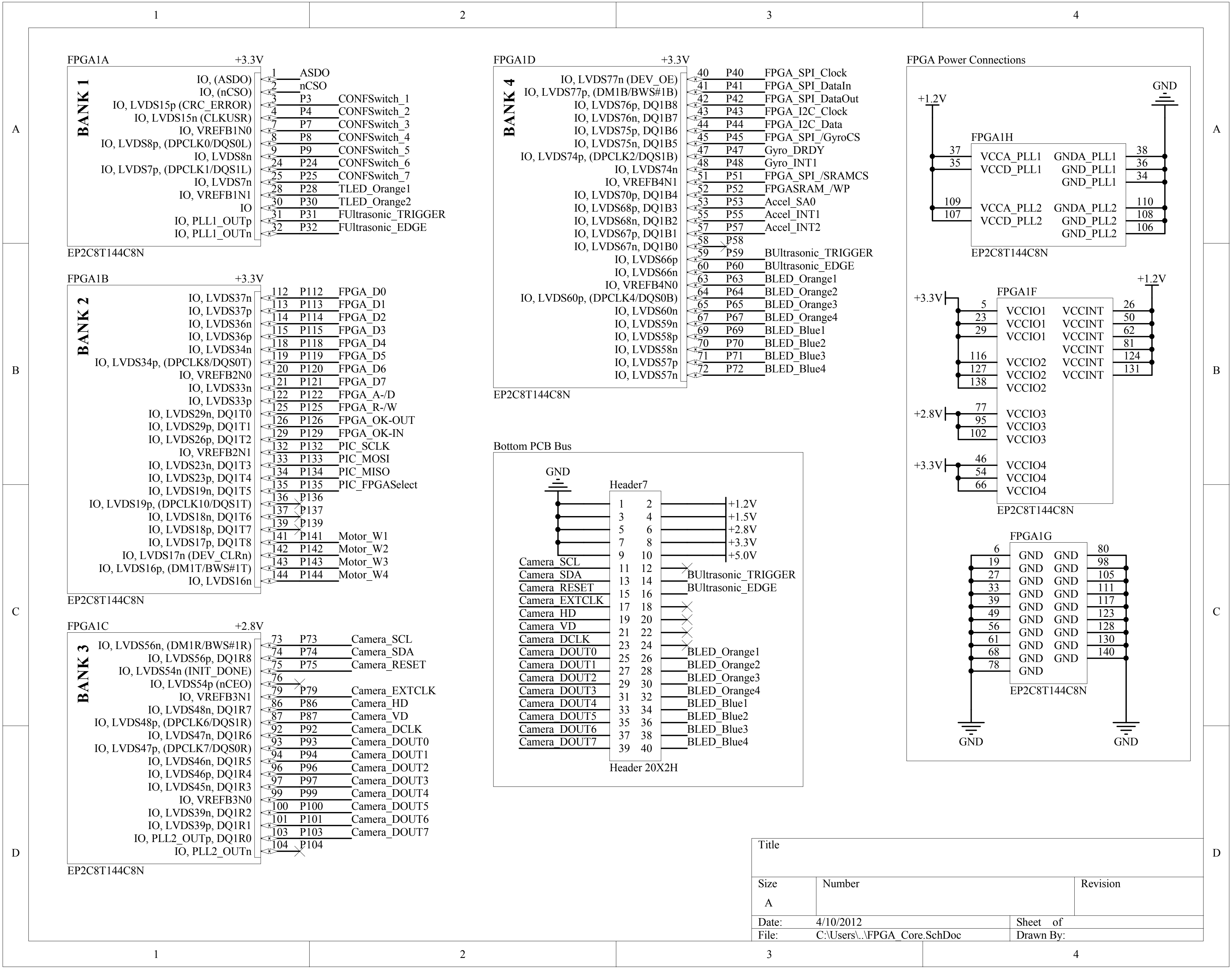
FPGA1A +3.3V
BANK 1
IO, (ASDO) 1 ASDO
IO, (nCSO) 2 nCSO
IO, LVDS15p (CRC_ERROR) 3 P3 CONFSwitch_1
IO, LVDS15n (CLKUSR) 4 P4 CONFSwitch_2
IO, VREFB1N0 7 P7 CONFSwitch_3
IO, LVDS8p, (DPCLK0/DQS0L) 8 P8 CONFSwitch_4
IO, LVDS8n 9 P9 CONFSwitch_5
IO, LVDS7p, (DPCLK1/DQS1L) 24 P24 CONFSwitch_6
IO, LVDS7n 25 P25 CONFSwitch_7
IO, VREFB1N1 28 P28 TLED_Orange1
IO 30 P30 TLED_Orange2
IO, PLL1_OUTp 31 P31 FUltrasonic_TRIGGER
IO, PLL1_OUTn 32 P32 FUltrasonic_EDGE
EP2C8T144C8N
FPGA1B +3.3V
BANK 2
IO, LVDS37n 112 P112 FPGA_D0
IO, LVDS37p 113 P113 FPGA_D1
IO, LVDS36n 114 P114 FPGA_D2
IO, LVDS36p 115 P115 FPGA_D3
IO, LVDS34n 118 P118 FPGA_D4
IO, LVDS34p, (DPCLK8/DQS0T) 119 P119 FPGA_D5
IO, VREFB2N0 120 P120 FPGA_D6
IO, LVDS33n 121 P121 FPGA_D7
IO, LVDS33p 122 P122 FPGA_A-/D
IO, LVDS29n, DQ1T0 125 P125 FPGA_R-/W
IO, LVDS29p, DQ1T1 126 P126 FPGA_OK-OUT
IO, LVDS26p, DQ1T2 129 P129 FPGA_OK-IN
IO, VREFB2N1 132 P132 PIC_SCLK
IO, LVDS23n, DQ1T3 133 P133 PIC_MOSI
IO, LVDS23p, DQ1T4 134 P134 PIC_MISO
IO, LVDS19n, DQ1T5 135 P135 PIC_FPGASelect
IO, LVDS19p, (DPCLK10/DQS1T) 136 P136
IO, LVDS18n, DQ1T6 137 P137
IO, LVDS18p, DQ1T7 139 P139
IO, LVDS17p, DQ1T8 141 P141 Motor_W1
IO, LVDS17n (DEV_CLRn) 142 P142 Motor_W2
IO, LVDS16p, (DM1T/BWS#1T) 143 P143 Motor_W3
IO, LVDS16n 144 P144 Motor_W4
EP2C8T144C8N
FPGA1C +2.8V
BANK 3
IO, LVDS56n, (DM1R/BWS#1R) 73 P73 Camera_SCL
IO, LVDS56p, DQ1R8 74 P74 Camera_SDA
IO, LVDS54n (INIT_DONE) 75 P75 Camera_RESET
IO, LVDS54p (nCEO) 76
IO, VREFB3N1 79 P79 Camera_EXTCLK
IO, LVDS48n, DQ1R7 86 P86 Camera_HD
IO, LVDS48p, (DPCLK6/DQS1R) 87 P87 Camera_VD
IO, LVDS47n, DQ1R6 92 P92 Camera_DCLK
IO, LVDS47p, (DPCLK7/DQS0R) 93 P93 Camera_DOUT0
IO, LVDS46n, DQ1R5 94 P94 Camera_DOUT1
IO, LVDS46p, DQ1R4 96 P96 Camera_DOUT2
IO, LVDS45n, DQ1R3 97 P97 Camera_DOUT3
IO, VREFB3N0 99 P99 Camera_DOUT4
IO, LVDS39n, DQ1R2 100 P100 Camera_DOUT5
IO, LVDS39p, DQ1R1 101 P101 Camera_DOUT6
IO, PLL2_OUTp, DQ1R0 103 P103 Camera_DOUT7
IO, PLL2_OUTn 104 P104
EP2C8T144C8N
FPGA1D +3.3V
BANK 4
IO, LVDS77n (DEV_OE) 40 P40 FPGA_SPI_Clock
IO, LVDS77p, (DM1B/BWS#1B) 41 P41 FPGA_SPI_DataIn
IO, LVDS76p, DQ1B8 42 P42 FPGA_SPI_DataOut
IO, LVDS76n, DQ1B7 43 P43 FPGA_I2C_Clock
IO, LVDS75p, DQ1B6 44 P44 FPGA_I2C_Data
IO, LVDS75n, DQ1B5 45 P45 FPGA_SPI_/GyroCS
IO, LVDS74p, (DPCLK2/DQS1B) 47 P47 Gyro_DRDY
IO, LVDS74n 48 P48 Gyro_INT1
IO, VREFB4N1 51 P51 FPGA_SPI_/SRAMCS
IO, LVDS70p, DQ1B4 52 P52 FPGASRAM_/WP
IO, LVDS68p, DQ1B3 53 P53 Accel_SA0
IO, LVDS68n, DQ1B2 55 P55 Accel_INT1
IO, LVDS67p, DQ1B1 57 P57 Accel_INT2
IO, LVDS67n, DQ1B0 58 P58
IO, LVDS66p 59 P59 BUltrasonic_TRIGGER
IO, LVDS66n 60 P60 BUltrasonic_EDGE
IO, VREFB4N0 63 P63 BLED_Orange1
IO, LVDS60p, (DPCLK4/DQS0B) 64 P64 BLED_Orange2
IO, LVDS60n 65 P65 BLED_Orange3
IO, LVDS59n 67 P67 BLED_Orange4
IO, LVDS58p 69 P69 BLED_Blue1
IO, LVDS58n 70 P70 BLED_Blue2
IO, LVDS57p 71 P71 BLED_Blue3
IO, LVDS57n 72 P72 BLED_Blue4
EP2C8T144C8N
Bottom PCB Bus
GND
Header7
1 2 +1.2V
3 4 +1.5V
5 6 +2.8V
7 8 +3.3V
9 10 +5.0V
Camera_SCL 11 12
Camera_SDA 13 14 BUltrasonic_TRIGGER
Camera_RESET 15 16 BUltrasonic_EDGE
Camera_EXTCLK 17 18
Camera_HD 19 20
Camera_VD 21 22
Camera_DCLK 23 24
Camera_DOUT0 25 26 BLED_Orange1
Camera_DOUT1 27 28 BLED_Orange2
Camera_DOUT2 29 30 BLED_Orange3
Camera_DOUT3 31 32 BLED_Orange4
Camera_DOUT4 33 34 BLED_Blue1
Camera_DOUT5 35 36 BLED_Blue2
Camera_DOUT6 37 38 BLED_Blue3
Camera_DOUT7 39 40 BLED_Blue4
Header 20X2H
FPGA Power Connections
+1.2V GND
FPGA1H
37 VCCA_PLL1 GNDA_PLL1 38
35 VCCD_PLL1 GND_PLL1 36
GND_PLL1 34
109 VCCA_PLL2 GNDA_PLL2 110
107 VCCD_PLL2 GND_PLL2 108
GND_PLL2 106
EP2C8T144C8N
FPGA1F +1.2V
+3.3V 5 VCCIO1 VCCINT 26
23 VCCIO1 VCCINT 50
29 VCCIO1 VCCINT 62
VCCINT 81
116 VCCIO2 VCCINT 124
127 VCCIO2 VCCINT 131
138 VCCIO2
+2.8V 77 VCCIO3
95 VCCIO3
102 VCCIO3
+3.3V 46 VCCIO4
54 VCCIO4
66 VCCIO4
EP2C8T144C8N
FPGA1G
6 GND GND 80
19 GND GND 98
27 GND GND 105
33 GND GND 111
39 GND GND 117
49 GND GND 123
56 GND GND 128
61 GND GND 130
68 GND GND 140
78 GND
EP2C8T144C8N
GND GND
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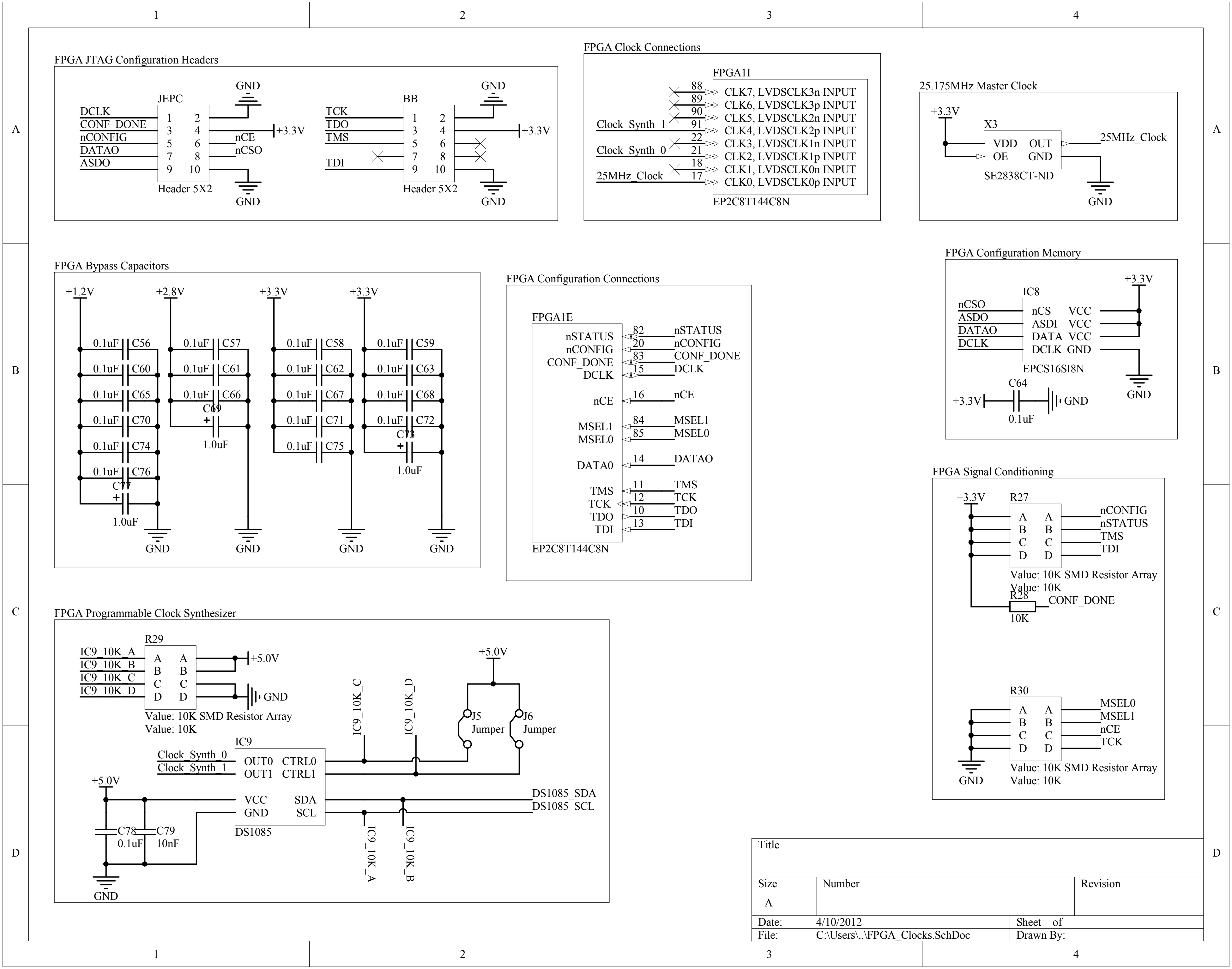

FPGA JTAG Configuration Headers
JEPC
Header 5X2
DCLK
CONF_DONE
nCONFIG
DATAO
ASDO
nCE
nCSO
+3.3V
GND
BB
Header 5X2
TCK
TDO
TMS
TDI
FPGA Clock Connections
FPGA1I
EP2C8T144C8N
CLK7, LVDSCLK3n INPUT
CLK6, LVDSCLK3p INPUT
CLK5, LVDSCLK2n INPUT
CLK4, LVDSCLK2p INPUT
CLK3, LVDSCLK1n INPUT
CLK2, LVDSCLK1p INPUT
CLK1, LVDSCLK0n INPUT
CLK0, LVDSCLK0p INPUT
Clock_Synth_1
Clock_Synth_0
25MHz_Clock
25.175MHz Master Clock
X3
VDD OUT
OE GND
SE2838CT-ND
25MHz_Clock
FPGA Bypass Capacitors
+1.2V
+2.8V
+3.3V
0.1uF C56
0.1uF C57
0.1uF C58
0.1uF C59
0.1uF C60
0.1uF C61
0.1uF C62
0.1uF C63
0.1uF C65
0.1uF C66
0.1uF C67
0.1uF C68
C69
1.0uF
0.1uF C70
0.1uF C71
0.1uF C72
C73
1.0uF
0.1uF C74
0.1uF C75
0.1uF C76
C77
1.0uF
FPGA Configuration Connections
FPGA1E
EP2C8T144C8N
nSTATUS
nCONFIG
CONF_DONE
DCLK
nCE
MSEL1
MSEL0
DATA0
DATAO
TMS
TCK
TDO
TDI
FPGA Configuration Memory
IC8
nCS VCC
ASDI VCC
DATA VCC
DCLK GND
EPCS16SI8N
nCSO
ASDO
DATAO
DCLK
C64
0.1uF
FPGA Signal Conditioning
R27
Value: 10K SMD Resistor Array
Value: 10K
R28
10K
CONF_DONE
nCONFIG
nSTATUS
TMS
TDI
R30
MSEL0
MSEL1
nCE
TCK
Value: 10K SMD Resistor Array
Value: 10K
FPGA Programmable Clock Synthesizer
R29
IC9_10K_A
IC9_10K_B
IC9_10K_C
IC9_10K_D
Value: 10K SMD Resistor Array
Value: 10K
+5.0V
IC9
OUT0 CTRL0
OUT1 CTRL1
VCC SDA
GND SCL
DS1085
Clock_Synth_0
Clock_Synth_1
J5 Jumper
J6 Jumper
DS1085_SDA
DS1085_SCL
C78 0.1uF
C79 10nF
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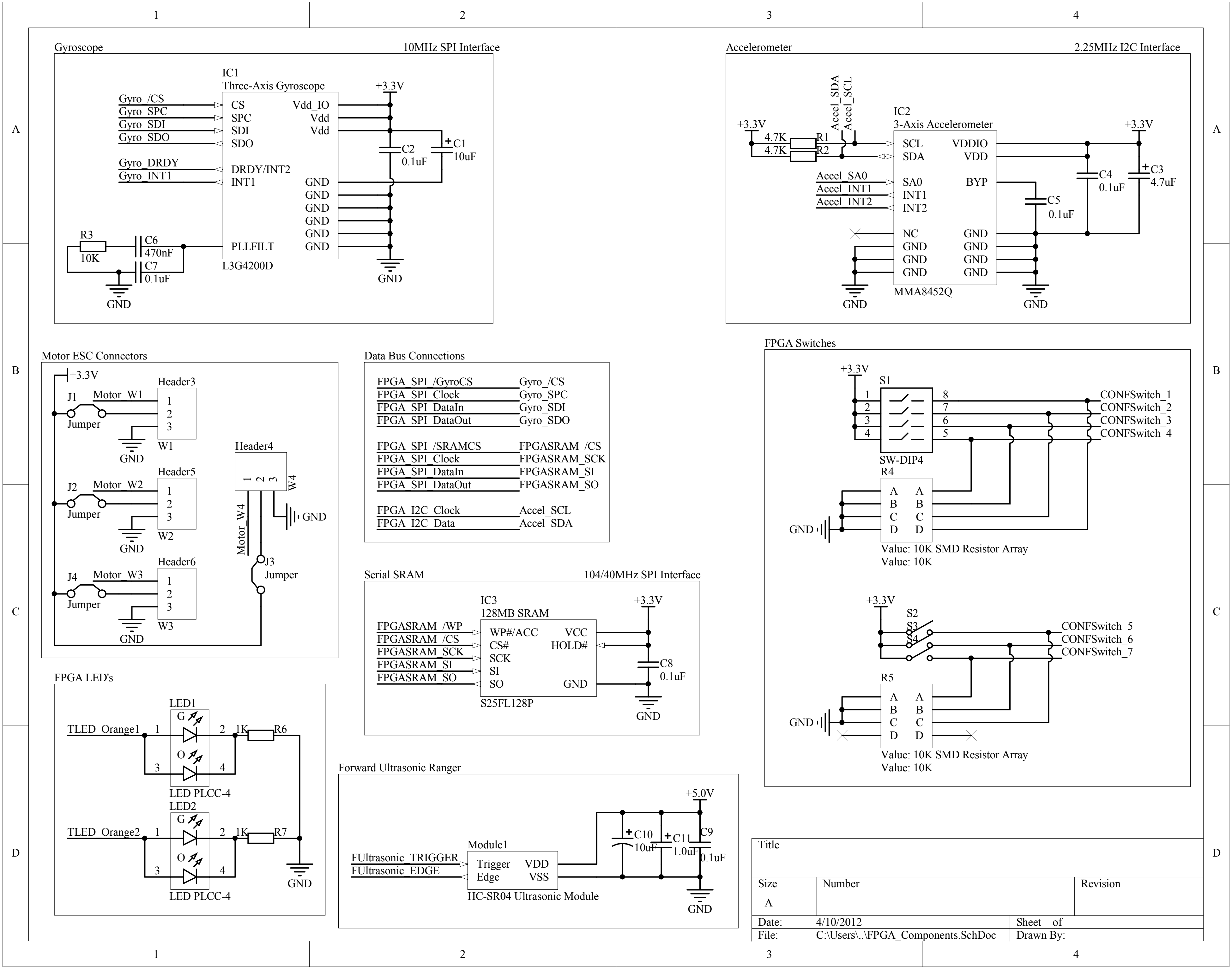
Gyroscope
10MHz SPI Interface
IC1
Three-Axis Gyroscope
+3.3V
Gyro_/CS
Gyro_SPC
Gyro_SDI
Gyro_SDO
Gyro_DRDY
Gyro_INT1
CS
SPC
SDI
SDO
DRDY/INT2
INT1
PLLFILT
Vdd_IO
Vdd
Vdd
GND
C2
0.1uF
C1
10uF
R3
10K
C6
470nF
C7
0.1uF
L3G4200D
GND
Accelerometer
2.25MHz I2C Interface
Accel_SDA
Accel_SCL
IC2
3-Axis Accelerometer
+3.3V
4.7K
R1
R2
SCL
SDA
SA0
INT1
INT2
NC
GND
VDDIO
VDD
BYP
Accel_SA0
Accel_INT1
Accel_INT2
C4
0.1uF
C3
4.7uF
C5
0.1uF
MMA8452Q
GND
Motor ESC Connectors
+3.3V
J1
Motor_W1
Jumper
Header3
W1
J2
Motor_W2
Header5
W2
J4
Motor_W3
Header6
W3
Header4
W4
Motor_W4
J3
Jumper
GND
Data Bus Connections
FPGA_SPI_/GyroCS
FPGA_SPI_Clock
FPGA_SPI_DataIn
FPGA_SPI_DataOut
Gyro_/CS
Gyro_SPC
Gyro_SDI
Gyro_SDO
FPGA_SPI_/SRAMCS
FPGA_SPI_Clock
FPGA_SPI_DataIn
FPGA_SPI_DataOut
FPGASRAM_/CS
FPGASRAM_SCK
FPGASRAM_SI
FPGASRAM_SO
FPGA_I2C_Clock
FPGA_I2C_Data
Accel_SCL
Accel_SDA
Serial SRAM
104/40MHz SPI Interface
IC3
128MB SRAM
FPGASRAM_/WP
FPGASRAM_/CS
FPGASRAM_SCK
FPGASRAM_SI
FPGASRAM_SO
WP#/ACC
CS#
SCK
SI
SO
VCC
HOLD#
GND
+3.3V
C8
0.1uF
S25FL128P
GND
FPGA Switches
+3.3V
S1
CONFSwitch_1
CONFSwitch_2
CONFSwitch_3
CONFSwitch_4
SW-DIP4
R4
Value: 10K SMD Resistor Array
Value: 10K
S2
S3
S4
CONFSwitch_5
CONFSwitch_6
CONFSwitch_7
R5
Value: 10K SMD Resistor Array
Value: 10K
GND
FPGA LED's
LED1
TLED_Orange1
1K
R6
LED PLCC-4
LED2
TLED_Orange2
1K
R7
LED PLCC-4
GND
Forward Ultrasonic Ranger
+5.0V
C10
10uF
C11
1.0uF
C9
0.1uF
Module1
FUltrasonic_TRIGGER
FUltrasonic_EDGE
Trigger
Edge
VDD
VSS
HC-SR04 Ultrasonic Module
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