The Electrical Subsystem Design for a REMUS-Derived AUV
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December 17th, 2012

Overview

During the Fall semester of the previous year, a group of seniors set out to provide a streamlined mechanical system for the a small autonomous underwater vehicle as a part of ENGR 3390, Design For Manufacture. Their target, the REMUS submarine sold by Hydroid, has the largest user base and deployment quantities of any AUV. It is, however, a design whose age is beginning to show. With a mechanical redesign completed, the main missing piece is a robust electrical subsystem capable of driving the modified mechatronic systems in the tail section, capable of meeting size, power, and communication constraints imposed by coexisting with both the original electrical system and the redesigned mechanical system, without artificially limiting future development efforts.

The proposed design is a square PCB with a corner-to-corner diagonal length of 4.493 inches, featuring the XMEGA32A4U usb-enabled microcontroller as the primary communication device, capable of accepting a variety of digital IO signals and communicating with several varieties of external computers including the REMUS primary drive computer, the Lego NXT, and any additional device with USB support such as a FIT2 PC, Raspberry Pi, etc.

Functional Specification

The revised design allocates a 4.493 inch diameter cylinder, 2.968 inches deep, for the sum total of the electrical hardware. This is a nontrivial amount of space, but poses notable limitations with regards to the use of commercial, off-the-shelf, electrical hardware. The electronics package should be capable of meshing well with the existing REMUS electrical systems, which is to say make use of the 28V high-current power backbone, and communicate via the mainline RS232 bus. The electronics package should be capable of executing closed-loop control of the three directional vanes and open loop speed control of the primary drive BLDC thruster. The revised design selected the US Digital MAE3-P12-125-220-7-1 PWM-OUT encoder and the Faulhaber 2622-012B brushless gearmotor with hall effect sensors. The revised design makes use of a custom-assembled brushless motor and a hobby COTS speed controller with integrated back-EMF commutation logic.

Digital IO

The previously stated requirements mandates support for a nontrivial number of digital communication and input/output schemes. The primary autonomy computer, motors, encoders, and any/all external controllers each require their own set of digital communication resources.

I2C / Lego NXT

The Lego NXT control brick is a robust microcontroller with solid abstractions and excellent LabVIEW support. While even with hardware modifications, it is too large to fit in the space allocated in the tail section, it is the path of least resistance to allow someone without embedded development skills to interface with the several electrical subsystems on the current design. The NXT communicates via I2C at 9600 bps, nominally at 5v. The purposed board includes level shifting logic to allow this piece of hardware to interface with standard 3v3 microcontrollers. The NXT requires all additional devices on the bus to operate as I2C slave mode devices, in which configuration the ATXMEGA32A4U on the design would make the encoder value and RS232 buffer available via I2C. The XMEGA's PC0 and PC1 are used for I2C communication.

PWM Input - Encoders

The selected encoders report absolute position with twelve bits of precision at a 250Hz update rate. The position is encoded as pulse width, with a full range of 1.00uS at zero degrees to 4097uS at 359.91 degrees. The encoders require a 5V and output 5V PWM signals, requiring level shifters (resistive voltage dividers) to interface with the 3v3 microcontroller. The XMEGA's PD0..2 are used for PWM input. The XMEGA's PD0..2 and TCD0 are used for PWM input via timer/counter compare functionality to measure pulse width.

PWM Output - Motors

Preliminary design efforts were based off the assumption that commercial off-the-shelf hobby two-quadrant brushless DC motor controllers could used for the control of the directional vanes on the redesign. After further research, brushless motor drivers with current-aware control loops may be required, but this assertion remains not yet entirely verified[1]. As such, the proposed design supports the output of four channels of hobby-compatible (50Hz / 1-2mS) PWM, one for each of the directional control motors, and one for the primary drive motor. These PWM signals are 3v3 output, protected by a 100KO surface mount resistor array. The XMEGA's PE0..3 and TCE0 peripheral are used for PWM output.

RS232 Communication

As per documentation provided by Hydroid (R100 Tail Wiring.pdf,) included in appendices, the REMUS submarine uses a standard RS232-compliant signalling backbone. This physical protocol is compatible with the XMEGA's universal sync/async receiver and transmitter (USART,) but requires level shifting logic to peacably coexist with 3v3 logic. This level shifting functionality is provided by the dual channel MAX232-compatible chip, Texas Instrument's SN75C3232. Both channels of this chip are used, as RS232 may provide an attractive interface solution for external brushless motor controllers such as Faulhaber's MCBL5004, Nonolith's PWMSMU, or the Open BLDC project, should full four-quadrant control prove necessary. The XMEGA's PC2/3 and PC6/7 are used for serial communications.

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[1] These motors have been successfully controlled via a Castle brand 10A COTS BLDC driver, but the minimum drive speed may be insufficient

Analog Design Concerns

This board, functioning as both a logic board and a motor control / interface board, offers several analog design concerns centered around both DC supplies and transient signals.

This board must take a 28V unregulated supply and offer several low-noise voltage supplies with different current parameters and efficiency mandates. The below power budget provides insight into the information that shaped the design of this board.

3V3 supply

- XMEGA has a maximum current draw directly related to peripheral usage, not to exceed 100mA
- SN75C3232 has a maximum current draw of approximately 1mA
- PCA9306 has a maximum current draw of no more than 60mA

5V0 supply

- magnetic encoders have a maximum draw of 20mA ea, or 60mA total
- integrated hall effect sensors have an unspecified maximum current draw, estimated at 20mA ea, or 60mA total

12V0 supply

- Faulhaber motors have a stall current of 0.4224A / ea, or 1.2672A total

A high efficiency, highly integrated switch-mode regulator with 12V output was selected to provide for the Faulhaber motors, part number PT78ST112V. It is capable of directly accepting line spikes of up to 38VDC and supplying a regulated 12V supply with a short circuit output of 3.5A.

A chained LDO design was adopted for the 5v0 and 3v3 supplies. The IFX27001TF is a 5V / 1A SMD linear regulator in a surface mount TO252-3 package, capable of directly accepting input voltages of up to 40VDC. Low profile tantalum capacitors decouple the output of this chip. The 3v3 supply is generated by the AP1117E33GDICT-ND, with a maximum current output of 1A, and available in a surface mount SOT-223 package. Low profile tantalum and ceramic capacitors decouple this supply.

Noise resistance is provided primarily via decoupling capacitors as well as electrical isolation of drive components. The motor drive circuitry is not integrated with this board, but is instead provided by external Turnigy TrackStar 1/18th scale 18amp car ESCs and a Castle 60A ICE ESC. The supply for the TrackStar ESCs is heavily decoupled with high value, low ESR tantalum capacitors. The primary thrust ESC is supplied directly from the 28V power backbone of the submarine.