Magnetorquer Proposal

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Introduction

Objective

CubeSats often rely on magnetorquers to control attitude in space by producing a magnetic interaction. Researchers have designed a flat-coil designed printed on a PCB, however the current device's maximum output is a magnetic moment of 0.27Am^2 at 200mA which is too weak for testing purposes and its intended functionality of being able to rotate the host device at a desired rate.

The Cubesat team requires several additional features as well as a larger maximum torque induced by the coil. These new features include the ability to sense both the magnetic moment and torque produced; We will use a magnetometer and accelerometer combination. The accelerometer has been deemed by our sponsor as an extra; It is not vital to our objectives. The module will be a master/slave on the I2C BUS capable of receiving power and strength information from another master, as well as writing capabilities to the power controller and reading and writing capabilities to the magnetometer.

Background

The bus, IlliniSat-2, is intended for generality as currently five different missions are being flown with the bus. As such, when designing components for this project it is imperative to implement a common hardware design such that very little variation is required to meet the needs of multiple missions. The electrical system within the bus that we are interested in is the attitude determination and control system (ADCS), which can be viewed as the arms and legs of the satellite. It will determine the satellite's current attitude or orientation and point the satellite towards a desired position.

High-level requirements list

- The maximum magnetic moment capable must be at least twice the current value at 0.54Am^2
- The module must act as an I2C slave to receive operating status(on/off) and magnetic moment value from the master, and adjust its output correspondingly.
- The module has to provide information for its voltage, current, operating status, magnetic moment, and other relevant information via the CAN interface for debugging purposes.

Design

Block Diagram

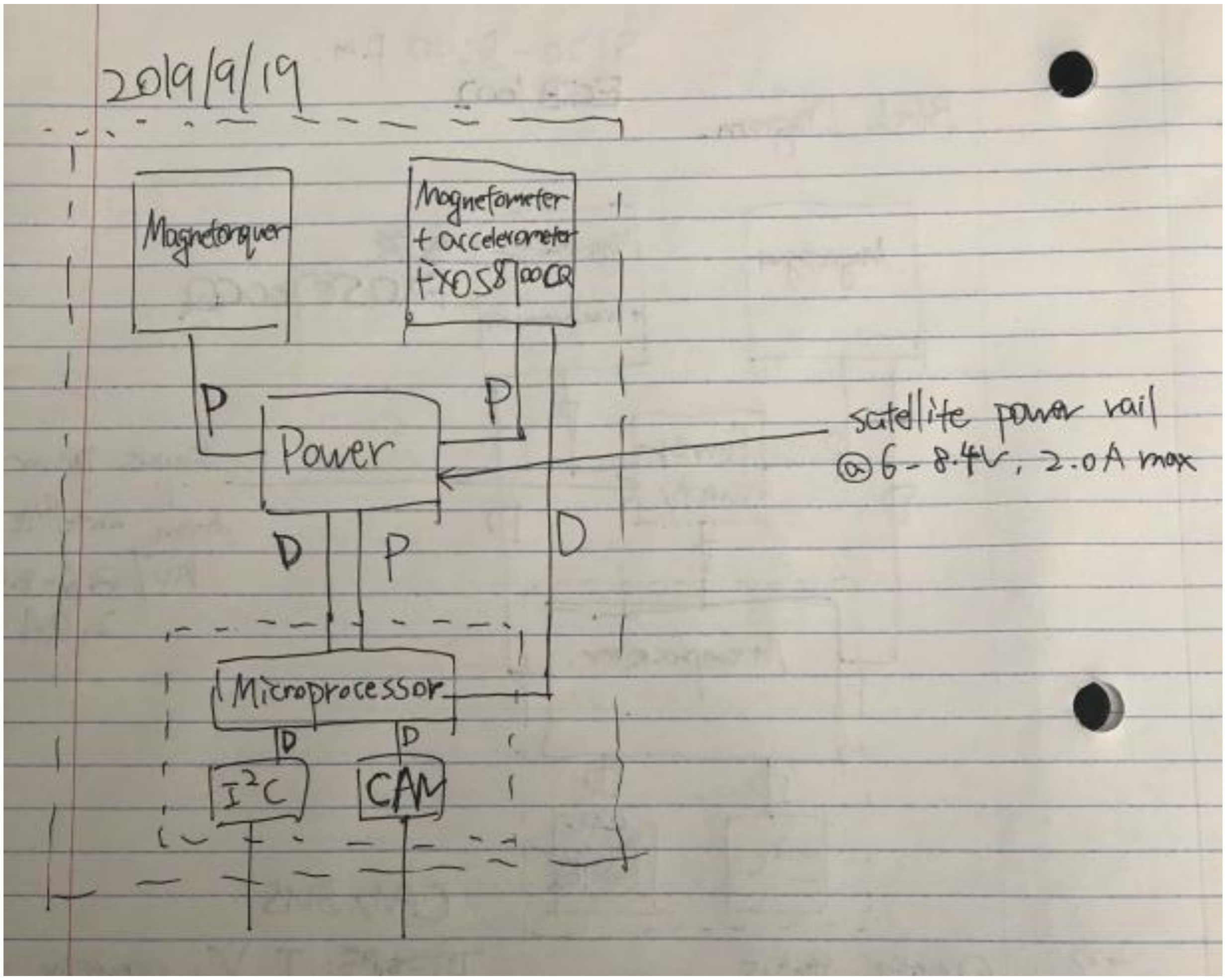

Figure 1. Block Diagram

Functional Overview and block requirement

[Magnetorquer]

Produces magnetic moment and subsequently torque. Will likely be implemented as a copper coil embedded in a PCB. It will incorporate the same design used on the current solution, i.e. a flat coil that goes through multiple layers of pcb, with modifications on design parameters like number of layers, loops, wire diameter to achieve the desired output. This is the key module that essentially completes the task of controlling flight attitude - the goal of this satellite module.

This function block takes analog power input from the power block. Because the magnetic field produced is directly related to the current, we will need to provide the corresponding current through the coil, which is controlled by the microprocessor under the instruction of the satellite and executed by the power block.

Requirement: Must produce a field with a magnetic moment that is twice that current value (.27 Am^2) at maximum.

[Magnetometer and accelerometer]

Used as a method to sense magnetic moment activity and strength, to ensure the Magnetorquer is functioning properly. This serves as a check for how the magnetorquer is functioning and can additionally provide acceleration data so that the rotation rate can be monitored.

This subsystem will use a FXOS8700CQ chip which is a 6-axis sensor with integrated linear accelerometer and magnetometer. This chip has a supply voltage of 1.95 to 3.6V, which is different from the value from satellite power rail, so we need to step down the voltage and this is achieved in the power function block.

Requirement: Must be able to communicate with the microprocessor via I^2C interface and return its sensed magnetic field and acceleration.

[Power Distribution]

This part is responsible for providing power to all other parts. It provides the microprocessor and magnetometer/accelerometer with their fixed input voltages. It also receives instructions from Data Control and then provides a tunable amount of input to the magnetorquer.

This part will be composed several dc-dc down conversion chips that takes the unregulated 6-8.4V input from satellite battery rail into the corresponding voltage values for our different subsystems.

Requirement: Must be able to accept input ranged from 6 to 8.4V and convert it to a value in the corresponding Vdd ranges of the microprocessor and magnetometer/accelerometer. Must be able to give a steady current for desired output to the magnetorquer under the instructions of the microprocessor.

[Microprocessor and external data interface]

Will be sent desired torque, calculate the required voltage and send that to the power control. Will contain a microcontroller, I2C command and data interface, and RS-485 serial debug interface. This part utilizes a ST-Microelectronics line of rad hardened ARM microcontroller. The RS-485 gives current, voltage, magnetic moment, and operating status of the magnetorquer, possibly acceleration data upon requirement of end user.

Requirement: Must be able to communicate with external devices via I^2C and CAN protocols to accept operating status(on/off) and magnetic moment; be able to return back voltage, current values, measured magnetic field and acceleration via the same interfaces; use a correct algorithm to give the power unit instructions on its output to the magnetorquer.

Risk Analysis

Producing a field with double the current magnetic moment at a maximum is a significant risk to the success of this project. The current design for the coil has it passing through a seven layer PCB with a loop at each layer. Simply adding loops to the coil poses a big challenge in manufacturing and as such will very likely call for the use of an outside vendor. It will be imperative to double check all work before sending anything to a manufacturer, as the cost and time to produce such a PCB could prove to be a detrimental risk to the project's completion. Adding more layers and loops to the design could prove to be cost inefficient and as such, finding and communicating with a manufacturer should be done as soon as possible to appropriately understand any limitations and constraints that may exist.

The magnetorquer as a whole could be redesigned however, this poses risks in itself. The current design's implementation is based upon a size constraint of the ADCS component to not exceed a depth of .16cm. A goal for this new design to keep the length and width constant, while minimizing depth. The introduction of a completely new design poses a challenge with this constraint limiting the coil to its current flat PCB implementation.

Safety and Ethics

Our project is a component of a much larger work and we are responsible for working with the team handling the entirety of the project in an ethical manner. This work relationship is an implementation of the IEEE Code of Ethics, #7: "to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others"[?]. We hope to absorb as much knowledge from the team who is much more familiar with the scope of the project than we are. At the same time, it is important that we credit the appropriate people for their ideas and help. It will be necessary to challenge the information and ideas being given to us in order to properly iterate the current design to a superior one. We will be challenging our main source of information on the project which may prove to be difficult, but it is crucial to still do so to achieve meaningful innovation.

Sources:

Wang Z.P. DESIGN OF A SCALABLE NANO UNIVERSITY SATELLITE BUS (ILLINISAT-2 BUS) COMMAND AND DATA HANDLING SYSTEM AND POWER SYSTEM(2018)

[?] Ieee.org, "IEEE IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 29- Feb- 2016].