Design Document for the ADCS Subsystem

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1. Introduction

Controller design

A set of controller candidates has been developed and are shown in table 1. The rate detumbling controller is very simple, and require only measurements from the magnetometer. The other controllers require estimates of angular velocities and attitude from an observer.

Table 1 Controller candidates

Mode	Controller law	Comment
Rate/Angle detumbling	$\mathbf{m}^b = -k\dot{\mathbf{B}}^b - \mathbf{m}_c$	$\mathbf{m}^b$ - Magnetic torque $\dot{\mathbf{B}}^b$ - Mag.field rate of change.
Stabilization	$\mathbf{m}^b = h\boldsymbol{\omega}_{ob}^b \times \mathbf{B}^b - \alpha\,\boldsymbol{\varepsilon} \times \mathbf{B}^b$	
Spin	$\mathbf{m}^b = h\boldsymbol{\omega}_{ib}^b \times \mathbf{B}^b$	

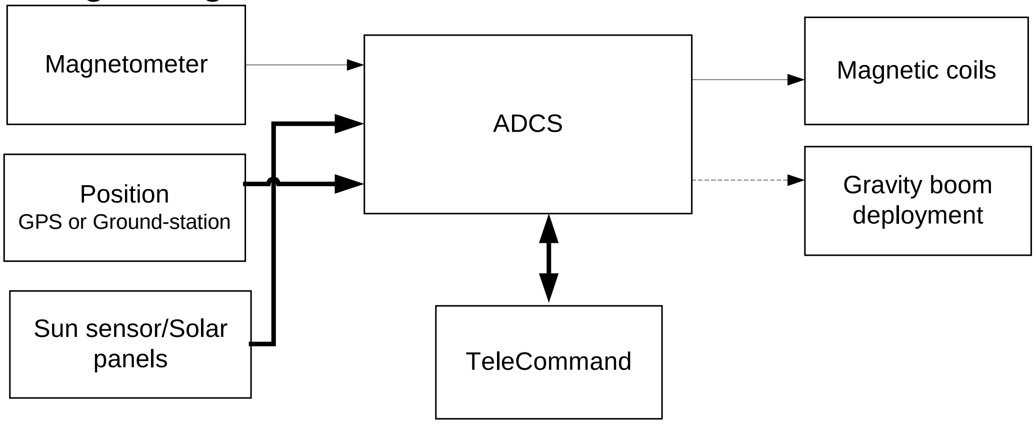
2. System Description

2.1 Functional Description

The primary objective of the ADCS system is to demonstrate that it is possible to estimate the attitude and both actively and passively control the orientation of NCUBE. The control system must stabilize the satellite within 20° about nadir.

The most important subsystem functions are
1. Detumble the satellite.
2. Estimate attitude,angular velocities and position.
3. Deploy a gravity gradient boom.
4. Stabilize the satellite.

2.2 Block Diagram /figure



2.3 Operational Modes

Operation mode	Description
Tumbling (default)	ADCS turned off.
Detumbling	Spin is slowed down until the gravity boom can be safely deployed.
Attitude acquisition	Only sensors are used.
Attitude estimation	No sensors, only filters
Stabilization	Point the satellite within 20° about nadir.
Spin	Slowly spin the satellite about the z-axis
Boom upside-down recovery	Turn the satellite if it is detected to point upside down.

Modes where the actuators are used are the detumbling, stabilization, spin and ’boom upside-down revocery modes. The detumbling mode requires very little initialization, while the other modes requires estimates of attitude and angular velocities. Before attitude acquisition starts, an estimate of the satellite position is required.

3. Electrical Interfaces

3.1 Input Specifications

Telecommands	Operation	Comment
Start ADCS	Starts the active control.	The ADSC will determine itself which mode it shall be in.
Power save I	No active control, measurements and estimation still enabled.	
Power save II	No active control, no measurement from magnetometer. Estimation enabled.	
Stopp ADCS	Stops the entire ADCS.	

Deploy boom	Burns off the nylon holding the boom if Bdot is small enough.	Whether the ADCS shall deploy the boom or give the order for the boom to be deployed is yet TBD
Log data	Starts data logging.	
Send data	Sends the stored data to ground.	
Reset	Restart Kalman filters.	
Request mode	The ADCS enters requested mode if possible.	The ADCS will try to make it possible to enter requested mode.

Physical inputs:	Description/ Comment
Magnetometer	There are so far two alternative magnetometers under consideration. One analog and one digital. The analog requires three analog inputs and three analog outputs. For the measurement and for the offset. The digital magnetometer has a 9600 baud nine-pin conector. See datasheets for the magnetometers for detailed connector configuration.
Solar Panel data	One measurement for each solar panel.
Satellite position	Update to the orbit model. The orbit model will either be analytical or a Kalman filter.
IGRF data	The magnetic field model for the current orbit is stored in a table and used for comparison in the magnetometer attitude estimation.
Boom sensor	A sensor which indicates whether the boom is successfully deployed or not.

The digital magnetometer is considerably bigger than the analogue one.

3.2 Output Specifications

Currents for the coils	The torque in the coils is controlled by the current.
Deploy boom	One bit signal
State and measurement information	Data to ground. ASCII floating point. Approximately 40byte stored for every second. ≈3.5MB/hour

3.3 Power Supply

Unit	Voltage	Maximum Current
Magnetometer	6-15V	20mA
Magnetic coils	TBD(3.3)	TBD
Magnetometer set/reset circuit	20	3000mA
GPS	TBD	TBD
Boom release	12	500mA
Micro Controller		

Set/reset circuit is not needed with the digital magnetometer.

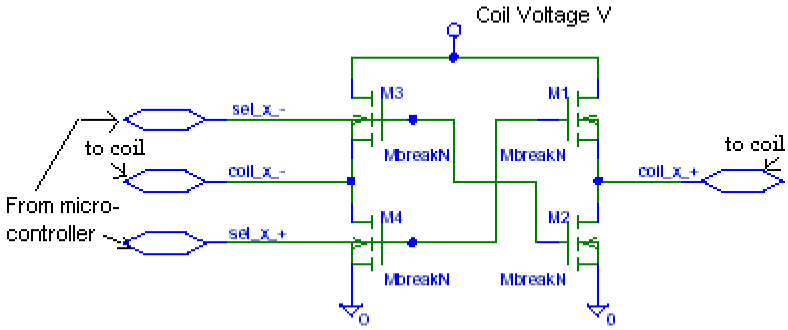


Figure 1 Possible drive circuit for the coils.

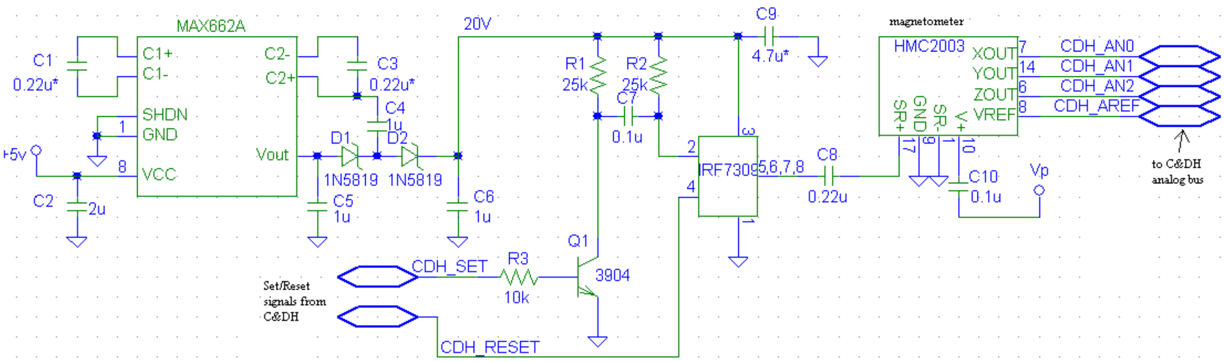


Figure 2 Magnetometer schematics, including a set/reset circuit.

3.4 Grounding and EMC

4. Software

The software used in the control-algorithms and the Kalman-filter will be C(?)

5. Hardware Components

Quantity	Type	Description	Supplier	Unit price	Delivery time
1	HMC2003 HMR2300	3-axis magnetometer	Honywell	1500(?) 5250(?)	TBD
1	31.3207	Measuring tape	Clas Ohlson	39	1h
3		Magnetic Coils	NTNU	TBD(Cost prize)	TBD
1	TBD	Microcontroller	Atmel(?)	TBD	TBD
1	TBD	GPS	TBD	TBD	TBD
1	TBD	Set-Reset circuit	NTNU	TBD	TBD

6. Mechanical Interfaces

6.1 Mechanical Layout

Component	**Size (mm x mm x mm)**	**Location**
ADCS Micro Controller	TBD	TBD
Magnetic Coils (3)	(99 x 99 x 1)x3	4.8 cm from the centre of the satellite on all axis
Boom and deployment device	(30 x 30 x 13)	At the bottom of the satellite (z-axis)
Magnetometer	(19,1 x 25,4 x 8,0)/(75 x 25,4 x 8)	TBD
GPS	TBD	TBD
Set-Reset circuit	TBD	TBD

6.2 Mass Properties

Component	**Weight**	**Center of Gravity**	**Moment of inertia**
ADCS Micro Controller	TBD		
Magnetic Coils (3)	<20 (60)		
Boom and deployment device	85		
Magnetometer	4/28		
GPS	<30		
Set-Reset circuit	TBD		

6.3 Mounting

Yet to be determined. Please indicate the preferred way of mounting the hardware to the satellite.

6.4 Thermal Interfaces

The resistance of the magnetic coils is temperature-dependent. This means that current regulation may be necessary.

7. Environmental

All system components should have (as far as possible) the following environmental specifications:

- Temperature range: - 40 - + 85 degrees Celcius
- Storage temperature: - 55 - + 125 degrees Celcius
- Radiation: (TBD)
- Vibrations: (TBD)

8. Test Plan

It is important to establish a test plan for the subsystems onboard. This plan should be worked out during the winter 2003, but already now there might be tests that should be performed to evaluate different components (such as vacuum test of different kinds of batterys, temperature tests of potential radio modems etc)

Please indicate if there are any tests that needs to be done at this stage.
- Electrical
- Mechanical
- Thermal test
- Vibration test
- Thermal vacuum test

9. Technical Challenges

One of the greatest challenges is the design and deployment of a gravity boom. Accurate control is possible without the gravity boom, but only for short periods of time. When the ADCS system is switched off the satellite will start to tumble and we have to start from scratch when the ADCS system is switched on again.

Another challenge is the computational requirements. Attitude determination requires a complex model of the magnetic field, which may require some memory and CPU time. Some of the controller candidates require state information from a Kalman filter, which can be CPU intensive. Ideally the Kalman filter should run all the time, even when the magnetic coils are not used. When

10. References

http://www.mae.cornell.edu/cubesat/cube2002.html Recommended!
http://www.nspo.gov.tw/meweb/chinese/yamsat.htm
http://www.cubesat.auc.dk/doc.html

Appendix

Attach data sheets of the selected system components.