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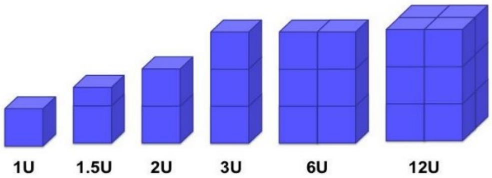
Subject: ADCS exists in CubeSat.

To: DR/ Gehan Samy

What are CubeSats?

CubeSats are a class of nanosatellites that use a standard size and form factor. The standard CubeSat size uses a "one unit" or "1U" measuring 10x10x10 cms and is extendable to larger sizes; 1.5, 2, 3, 6, and even 12U. Originally developed in 1999 by California Polytechnic State University at San Luis Obispo (Cal Poly) and Stanford University to provide a platform for education and space exploration. The development of CubeSats has advanced into its own industry with government, industry and academia collaborating for ever increasing capabilities. CubeSats now provide a cost-effective platform for science investigations, new technology demonstrations and advanced mission concepts using constellations, swarms disaggregated systems.



CubeSat to populate space with sponsored communications

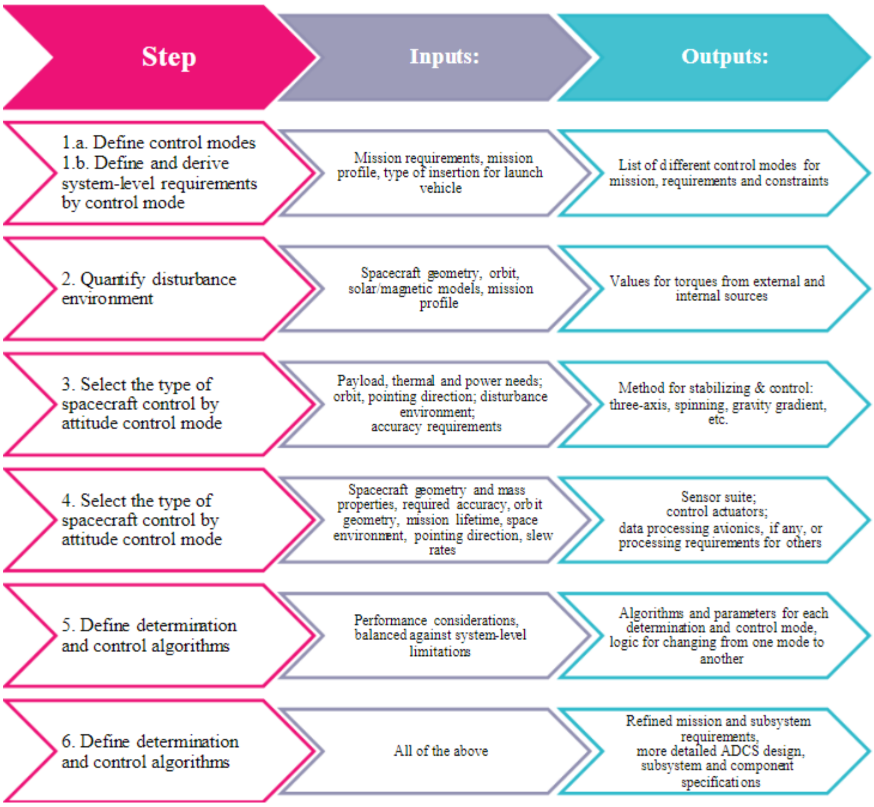
CubeSat sizes

Attitude Determination and Control System (ADCS)

The ADCS is divided into 4 modules. It is important to note that the ADCS system is currently based on a preliminary design and is subject to changes. The objectives of each module are depicted in the following list:

- The SENS is composed of a set of sensors. This set will have to harvest data in order to get information about the CubeSat position.
- The ACT are the CubeSat attitude actuators. ACT will have to adapt the CubeSat's attitude according to the mission needs.

- The ADCS controller (CTRL) objectives are to collect data from sensors and to process it to get reliable positioning information. Then the ADCS will send orders to ACT in order to correct/modify the CubeSat's attitude if OBC and EPS subsystems allow it.
- The Interface (INT) module has for objective to ensure good connection with other systems of the satellite and to send data to the other systems.



Design process of an Attitude Determination and Control System (ADCS).

Sensors System (SENS)

ADCS Sensors system will be composed of absolute sensors to get constant access to the attitude relative to an external frame. And relative sensors to get access to the current attitude relative to the previous one.

Actuators System (ACT)

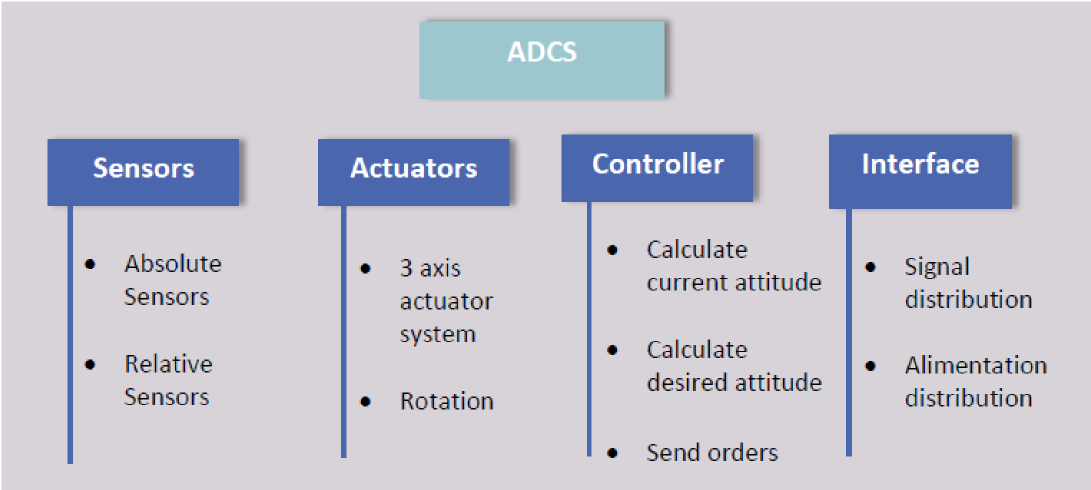
The actuators' goal is to position the CubeSat in the target attitude by rotation it around 3 axes: Yaw / Pitch / Roll. So, the Actuators System will be placed to have control over the 3 axes (X, Y, Z).

Controller (CTRL)

The ADCS Controller will calculate the attitude in which the CubeSat is thanks to the data coming from Sensors. Also, the Algorithm inside the controller will calculate the targeted attitude. And then will determine the rotations to accomplish for each axis.

Interface (INT)

The ADCS Interface is the hardware part of ADCS which transmit the signal received from Sensors to the micro-controller and it also distributes power supply coming from the EPS subsystem to the Actuators.



ADCS Subsystems

Sensors

Aim: Calculate CubeSat orientation and chose best physical input for actuators.

Needs: ● Data redundancy ● Data for both situations: eclipse and sun ● Question of sampling frequency ● Location and size/weight ● Ability to resist to environment ● Low consumption ● Low price

Estimate an angular rotation:

- Gyroscope
- Gyrometer
- Sun sensor
- Star tracker
- Horizon sensors
- Magnetometer
- Temperature sensors

Actuators

Aim: Collect useful data for attitude determination.

Needs: ● Physically act to modify attitude ● Compact design

Estimate an angular rotation:

- Reaction wheel

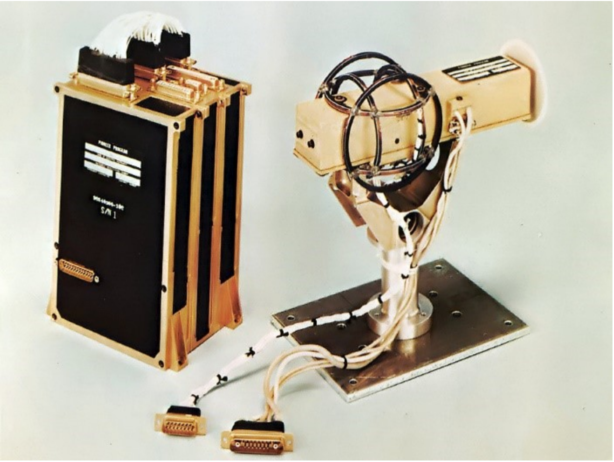
- Momentum wheel
- Control momentum gyroscope
- Magnetorquer
- Permanent magnet

Magnetometer

A magnetometer is a device that measures magnetic field or magnetic dipole moment. Different types of magnetometers measure the direction, strength, or relative change of a magnetic field at a particular location. A compass is one such device, one that measures the direction of an ambient magnetic field, in this case, the Earth's magnetic field. Other magnetometers measure the magnetic dipole moment of a magnetic material such as a ferromagnet, for example by recording the effect of this magnetic dipole on the induced current in a coil.

he first magnetometer capable of measuring the absolute magnetic intensity at a point in space was invented by Carl Friedrich Gauss in 1833 and notable developments in the 19th century included the Hall effect, which is still widely used.

In recent years, magnetometers have been miniaturized to the extent that they can be incorporated in integrated circuits at very low cost and are finding increasing use as miniaturized compasses (MEMS magnetic field sensor).



Helium vector magnetometer (HVM) of the Pioneer 10 and 11 spacecraft

magnetic torquers

A magnetorquer or magnetic torquer (also known as a torque rod) is a satellite system for attitude control, detumbling, and stabilization built from electromagnetic coils. The magnetorquer creates a magnetic dipole that interfaces with an ambient magnetic field, usually Earth's, so that the counterforces produced provide useful torque.

The magnetic dipole generated by the *magnetorquer* is expressed by the formula:

$\boldsymbol{\mu} = \mathbf{NIA}$,

where n is the number of turns of the wire, I is the current provided, and $\mathbf{A}$ is the vector area of the coil.

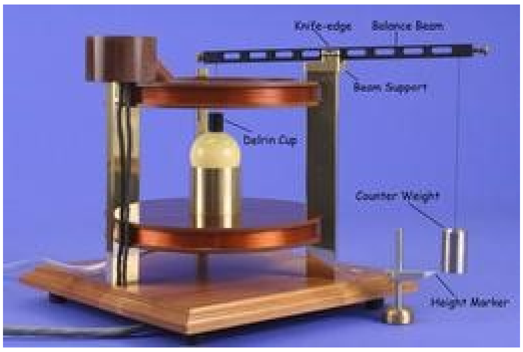
The vector A has a magnitude equal to the area of the loop and has a direction that is perpendicular to the plane of the loop, in the direction defined as follows: Curl the fingers of your right hand in a direction that traces the direction of the current around the loop, and the thumb of that hand points the direction of the vector.

The dipole interacts with the magnetic field generating a torque.

$\boldsymbol{\tau}$magnetic=$\boldsymbol{\mu}\times\mathbf{B}$,

where **m** is the magnetic dipole vector, **B** the magnetic field vector (for a spacecraft it is the Earth magnetic field vector), and **τ** is the generated torque vector.

When the loop rotates around the horizontal axis, the angle between the magnetic dipole moment and the field changes, reducing the moment arms of the forces by a factor of $\sin\theta$ – exactly the amount accounted-for in the cross-product. When the loop rotates to the point where its plane is perpendicular to the field, the magnetic moment and field are parallel, making the torque zero.

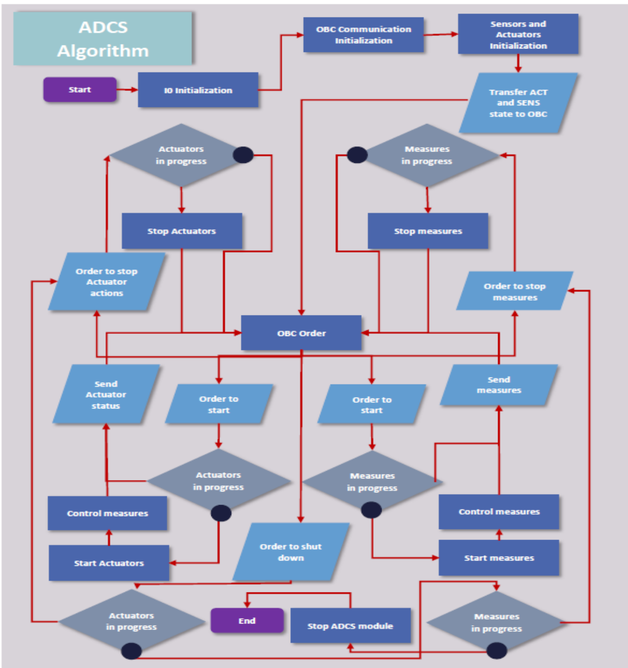


magnetic torque

The operation to determine and control position of CubeSat

The ADCS mission is to get access to sensors for attitude determination and then apply correction through actuators.

We designed our decision taking algorithm to be as it follows:

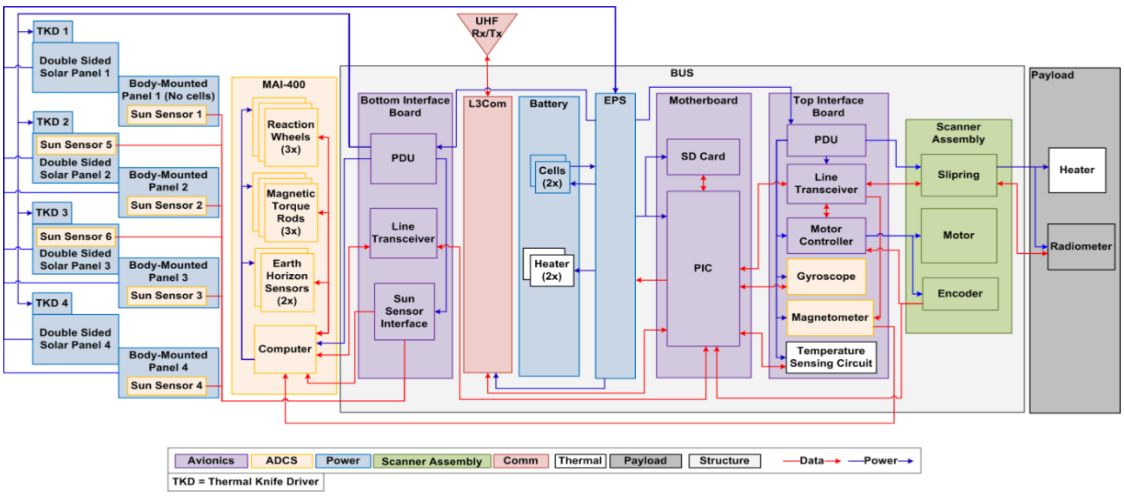


As we can see our algorithm begins with the initialization of our module (the IO, communication, sensors, and actuators). Then a confirmation of well-functioning is sent to the OBC.

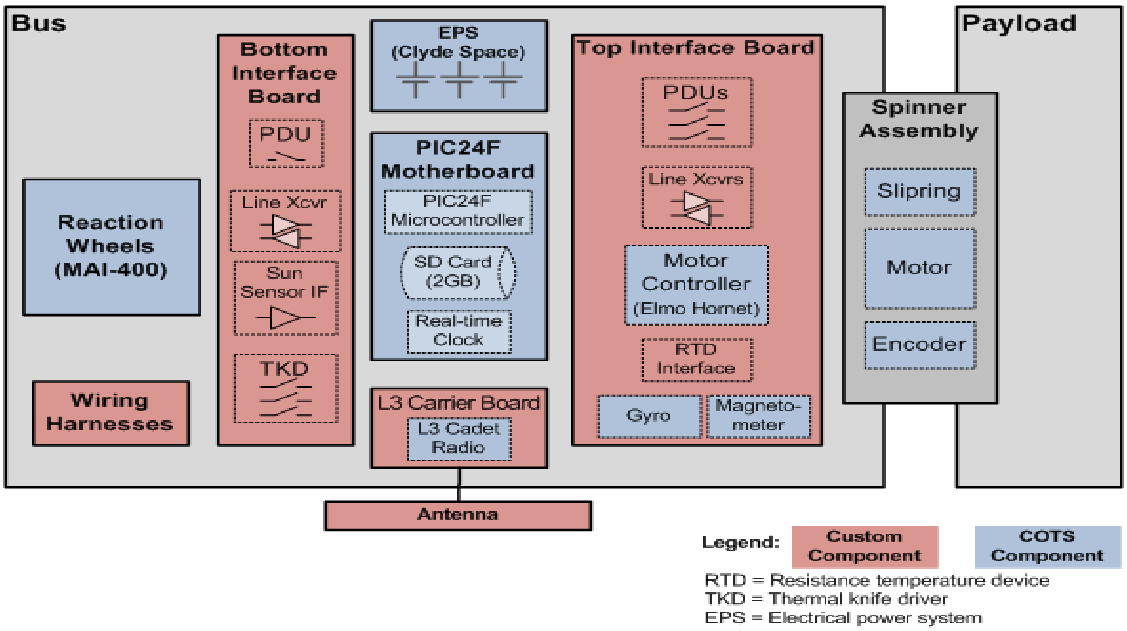
That's where we reach the central loop. The OBC can give us several order which can be classified as follow:

- If it asks us to start to take measure or to move (so to start the actuators), we check if a session in not already in progress and if it is not, we perform the task and send the data.
- If it asks us to stop measures or movement, we check if we were doing it and if it is the case, we stop doing it.
- Finally, if the OBC ask to shut down, we verify if we were performing action and then stop them. This put us to the end of our loop.

Block diagrams

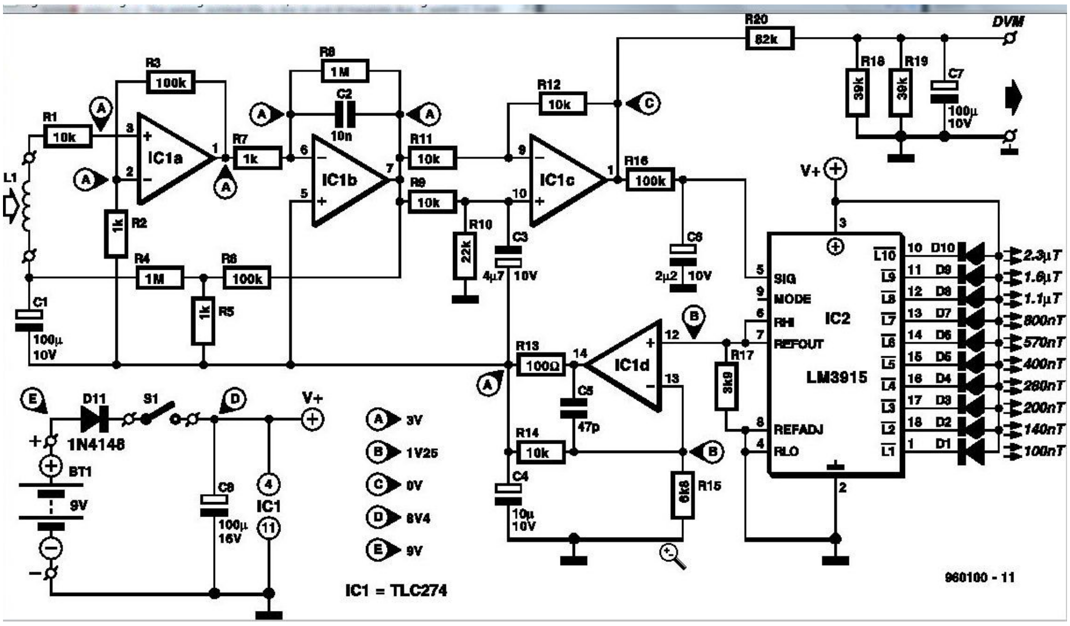


Block diagram of MicroMAS-1 showing the major components of the CubeSat's subsystems and the data and power links between them.

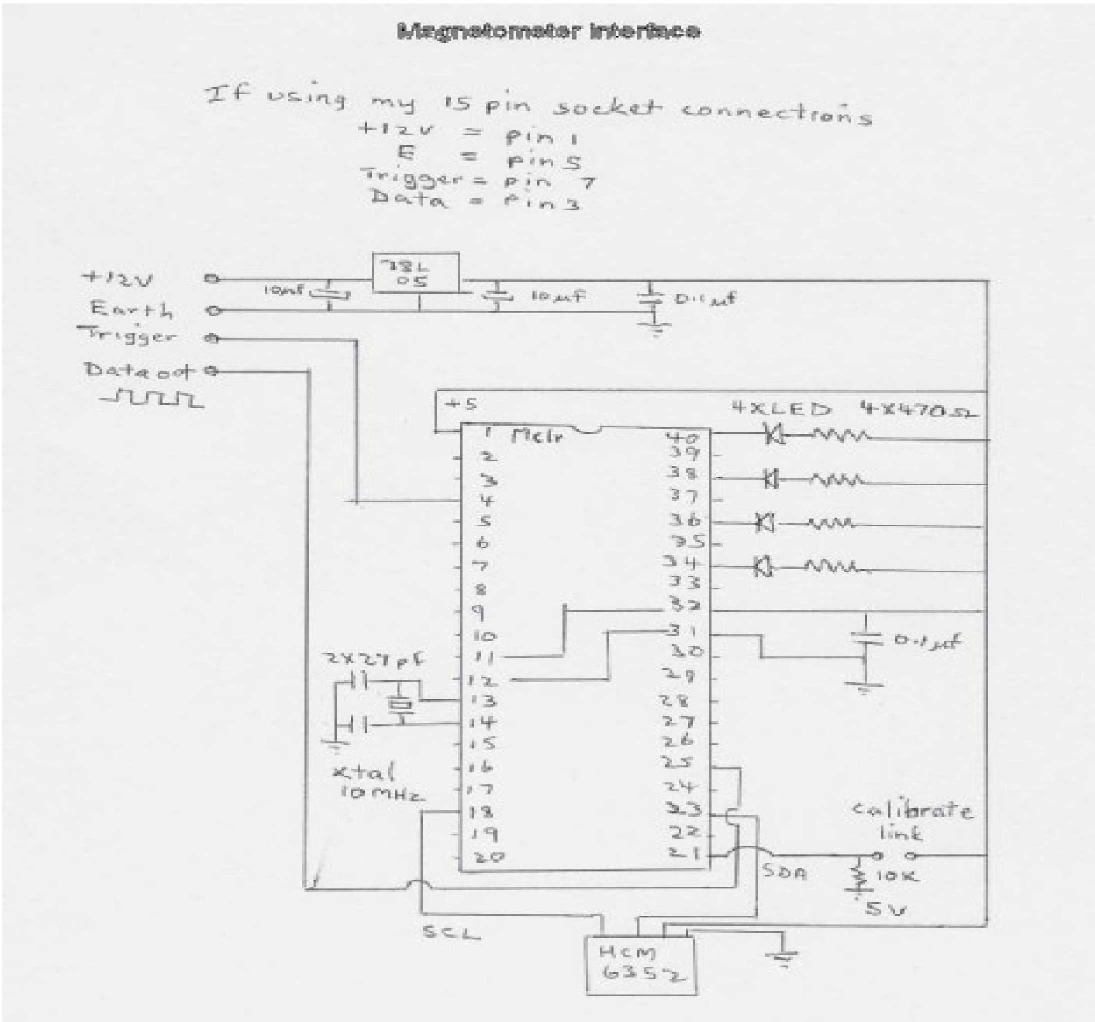


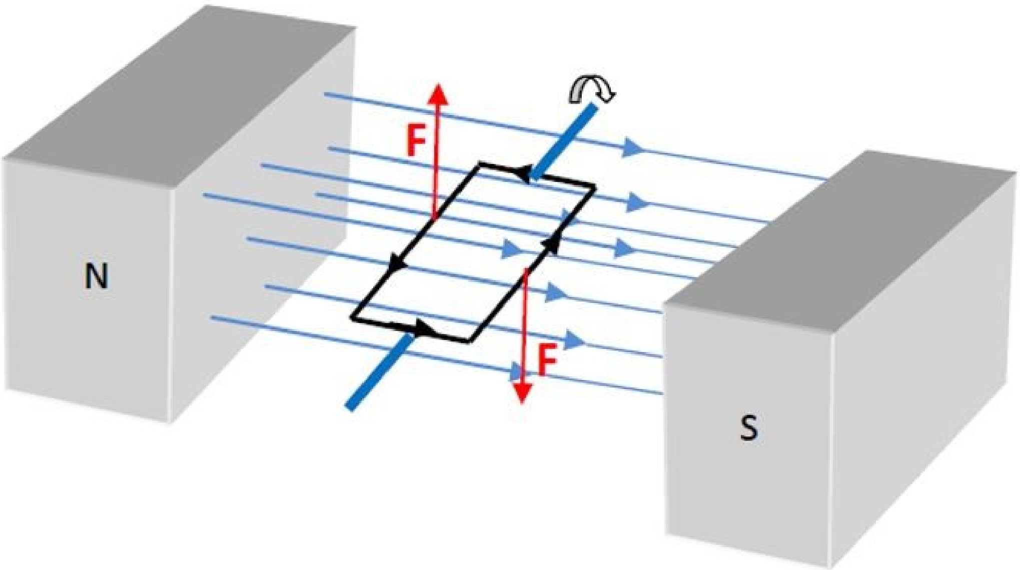
Functional block diagram of MicroMAS-1 showing commercial-off-the-shelf components (in blue) and custom-made components (in red).

Circuits used



magnetometer circuit





magnetic torque

References

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[ADCS: Attitude Determination And Control System - ECE3SAT]

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[[PDF] ADCS development for student CubeSat satellites – TalTech case study (researchgate.net)]

[Magnetometer - Wikipedia]

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[What's inside a CubeSat? | Engineering360 (globalspec.com)]