Onboard Computer for DTUsat

Participants

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Purpose / role in satellite

The onboard computer is necessary in the satellite in order to provide services needed by the other parts of the satellite. It is the plan to have all software loaded in the onboard computer memory and use the processor I/O ports to give commands/retrieve information from all other parts. The computer will be constructed on a single board that will constitute one layer of the internal of the satellite.

Interface

Our idea is to make a socket on each layer that connects all layers in the satellite. This socket could contain all I/O ports from the processor, different power lines etc. Then each group/layer would have specific ports assigned depending on their needs. We believe this way of doing it will be easier than designing the system with a bus. A bus would complexify the design and if one part should hang there would be danger of this part blocking the entire system.

Requirements / design options

- First of all we have been looking for (ultra) low power components. It seems that such components can be found. Consult later section for further details.
- The components must be able to cope with a wide temperature range in space. The best commercial component we have found have a temperature range from – 40 C to 85 C. Components with this range will probably be our choice, because we believe this will meet the requirements in space.
- All pins of the components have to be placed along the edges of the chips (or they will break because of the vibrations).
- We have had a request from the software group, who asked if we could find a 32-bit processor in order to ease their programming. This should not be a problem.
- The software group has recently presented us with another request regarding a processor with a memory protection feature.

Our first choice of processor was an Atmel based on the ARM architecture. This processor has numerous advantages:

- It meets the above requirements
- It is fully scaleable regarding frequency allowing us to minimize the power consumption. (~3 mW / MHz)
- “Only” 100 pins (the more pins – the harder it will be to solder it).
- It is available now – so are development boards

This Atmel chip cannot meet the request of memory protection. It has been found that a MIPS processor can meet all requirements including the memory protection request. The problem with MIPS so far has been that we have only been able to find MIPS processor cores that were build in larger chips with a great number of features, which are not necessary in our satellite. These features resulted in large power consumption.
However, MIPS have been contacted, and it is possible that they have other chips available that do not have these unnecessary features. Further more such a MIPS processor might have even lower power consumption than the Atmel, and maybe we could work out a deal with MIPS supplying us both processor and development board….
We are trying to arrange a meeting in this week (week 40).
We are working with a design, which includes three types of memory:

- ROM for the bootstrap software. This ROM has to be resistant to all impacts in space, so that the computer always can restart from this memory and receive data from earth (new system software). ~8 Kbytes.
- Flash memory for the operating system and other software. ~128 Kbytes.
- RAM for working storage plus payload data. 1 Mbytes

We find that it will be necessary to implement some kind of latch-up protection in the computer. This is only possible in some degree. Because in case of latch-up we could design something that would immediately shut down the processor via the reset pin. The problem is that other parts of the satellite might be forcing a value on some pins and thereby maintaining the latch-up – which in the end could fry the processor. This phenomenon is known as back sourcing.
A solution to this problem could be to move the latch-up protection to the power supply group. From here all parts could be shut down simultaneous and instead of more groups designing latch-up protection only one would be necessary.
If all subsystems are reset/shut down simultaneously from the power supply it would prevent that a subsystem could hang because of e.g. the computer restarting in the middle of some operation performed by the subsystem.

We are not sure if the components we plan to use are able to cope with influences from space (radiation etc.) – this we will have to test later on. So for now we have to take some reservations to the above description of our design plans so far.

Criteria for success

The final goal is of course to have a functioning computer that all other groups can use. It is pretty hard to say which parts of the computer have to work in order call our project a success. Because if one part does not work – nothing will work.
On the other hand our primary goal is to learn a lot about construction of computers. As this is probably inevitable we are most likely to be partly successful ☺

Make or buy?

If we want to buy the On Board Computer there is only one commercially available product that fits in a CubeSat as far that we know. OSSS has a “CubeSat Central Processing Unit” which is built

around the MC68HC705-processor available from Motorola. This processor is an 8-bit MCU with embedded EEPROM. Its maximum frequency is 2.1 MHz. The unit also includes 1Mb of RAM memory, and has some other nice features including A/D-converters (for temperature and voltage measurements) and UART (for serial data communication). The unit consumes about 150 mW of power.
The main problem with this unit is that it doesn't fulfill the preliminary requirements that the software group has set up. Since the program memory is embedded in the processor, it's limited in size (15K bytes EPROM, 256 bytes EEPROM) and thereby it will be quite difficult to fit all the data that the software group has mentioned. Another problem is that the processor uses an 8-bit architecture that will make it harder to write the software.

We believe that it will be possible for us to build a computer that fulfills the requirements concerning memory and architecture. Our design will include A/D converters and UARTS, and is thereby functionality equivalent to the one from OSSS. The advantages of our unit will be that it is faster and has more memory. If for example we use the processor from Atmel mentioned earlier, 1MB of RAM, 8KB of ROM, and 128 KB of flash it will be possible to build a unit that uses almost the same amount of power as the unit from OSSS, but will be able to run faster.

The main advantage with the OSSS unit is that it has been in space before, and that it is a fully tested system. The components we have looked at have not been properly tested concerning radiation, and there is a probability that such a test will show, that these components are not space qualified. We believe however that it will be possible to find other equivalent components that are, and that this will not be a problem.
When we know that the components we chose are space qualified, we will be able to build and test an on board computer for the CubeSat. Our recommendation is therefore that we build the computer ourselves.

Resources needed

When we have decided which components to use, the main problem will be to make a PCB (printed circuit board) that connects the different semiconductors in the right way. In order to do this we need a software package that allows us to do this, and which can export the final layout in a standard format, so that a manufacturer can build the physical board. At the Department of Automation we have access to such a program 'Protel', so there will be no need to buy this.

The components we are looking at have not been properly tested, so we do not know if they are able to operate in a space environment. This implies that we need to carry out these tests ourselves. We do not currently know where, how, or how much it will cost to make these tests. Other groups in this project e.g. the radio hardware group will properly need to make the same tests.

In order to build a working computer it will be necessary to buy an evaluation board where we can do measurements on a properly working computer. Such a board will also make it possible for the software group to make software tests on the target processor. A board for the Atmel processor mentioned earlier can be bought for a price of about 2000 kr.
The measurements can be carried out with equipment already available at the Department of Automation.

To sum up what we need to buy is the following:

- Components including processor, memory and A/D converters. We would like to buy about 20 pieces of each in order to make the radiation tests, and to make sure, that we have some extra components from the same production batch, that can be used in future DTU CubeSat missions. The prices range from 100 kr for each processor, RAM-block and A/D converter, 500 kr for the flash.
- Evaluation board. The price is about 2000 kr
- The final PCB (4-6 layers). We don't know how much this will cost, but prices as high as 15.000 kr have been mentioned.
- It might be desirable to have the final board soldered by a professional. The price is about 1500 kr.

Risk factors

It will be possible to carry out test at the ground that shows that every part of the On Board Computer is working properly. Every subsystem can be tested, so that we know that access to RAM, ROM, flash, and A/D-converters works.
The components we choose will have been tested according to radiation and therefore it should not be a problem either.

The following can however be problems:

- During the launch some of the components may loosen if they are not soldered properly. This may cause subsystems or the entire OBC to fail.
- The components only work in a specified temperature range. If the satellite is not kept within this temperature range the computer will fail and may even be destroyed permanently.
- Too high supply voltage (spikes) may destroy the OBC.

Due to the radiation the components will properly stop to work at some time. The components should be selected so that they at least will work during the entire mission.