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Real-Time Systems

Exercise #1

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Laboratory assignment

Organization:

The schedule
- The laboratory sessions run weekly, starting in study week 2
- Each project group is guaranteed one session per week
- Deadline to register for a project group is Monday @ 09:00

The parts
- The assignment consists of Part 0, Part 1 and Part 2
- The parts normally take a total of 6 sessions to complete
- Part 0 typically takes 1 session to complete
- Part 1 typically takes 1−2 sessions to complete
- Part 2 typically takes 3−4 sessions to complete

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Laboratory assignment

Basic prerequisites for approval:

Respecting the Rules of Conduct (link on 'Assignment' page)
- Show respect for others in the laboratory room
- Refrain from cheating

Sufficient lab session attendance
- Since the assignment involves significant interaction with laboratory assistants as well as other groups each student is expected to attend at least three laboratory sessions, the first attendance being no later than study week 3.

Project report of sufficient quality
- Should contain description of solutions to selected design challenges in the lab-PM (see 'Assignment' page for details)

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Laboratory assignment

The grade will be based on your performance in:

Implementation
- How many of the coding challenges in Part 2 that you can successfully implement and demonstrate.

Design
- How well you know the design and behavior of your code.

Debugging
- How well you identify, and solve, problems with your code.

Paradigm
- How well you understand, and can make use of, the reactive, concurrent and timing-aware programming paradigm.

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Laboratory assignment – Part 0

Getting started:
- Compile the template code using the cross compiler
- Upload the machine code to the target computer

Interacting with the target computer:
- Take input from the workstation's keyboard
- Generate output to the workstation's console window

Preparatory work for Part 1 and Part 2:
- Pre-compute periods for all tones that will be played
- Prepare data structures to allow a melody to be transposed to different keys

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Laboratory assignment – Part 1

Tone generator:
- Generate a 1 kHz tone (square wave signal) and output it to the audio jack on the target computer

Background load:
- Add a background task with a scalable load
- Experiment: disturb tone generator by increasing the load
- Repeat the experiment with deadline scheduling enabled

Worst-case execution times:
- Measure the execution times of the program code in the tone generator task and the background load task

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Laboratory assignment – Part 2

Single instrument: [each group individually]
- Capable to play tones in a 12-tone scale in different keys
- Capable to play the melody "Brother John", and be able to change key and/or tempo while playing

Basic orchestra: [collectively, with two or more computers]
- Capable to play "Brother John" in chorus form (unison), with one target computer being the orchestra leader (conductor)
- Conductor should be able to set initial key and tempo

Advanced orchestra: [collectively]
- Play in canon form, with conductor role as above
- Conductor should be able to change tempo dynamically

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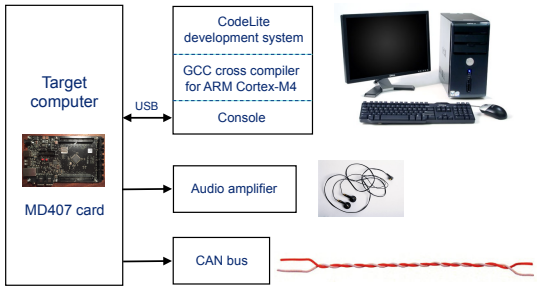
Laboratory assignment – Setup



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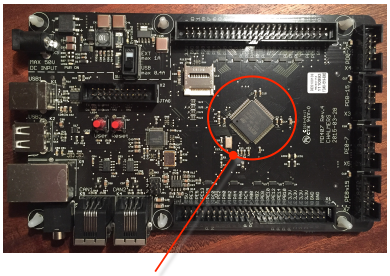
The MD407 computer card



STMicroelectronics' STM32F407 microcontroller /w ARM Cortex-M4 core

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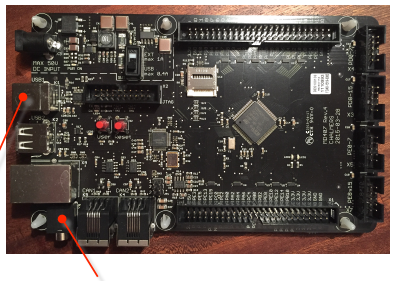
The MD407 computer card



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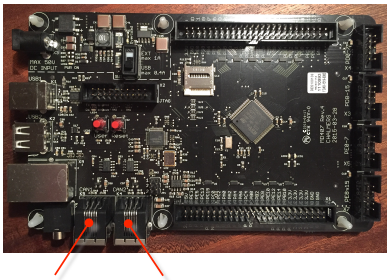

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The MD407 computer card

The STM32F407 microcontroller:

Based on the ARM Cortex-M4 processor core

- 168 MHz processor clock
- 32-bit registers (data and address)
- 16-bit instructions (Thumb)
- 1 MB of Flash memory (for resident monitor/debugger)
- 128 kB of RAM (for user programs)
- On-chip floating-point unit
- On-chip CAN modules, serial communications interfaces, parallel ports, digital-to-analog converters, high-resolution timers, ...

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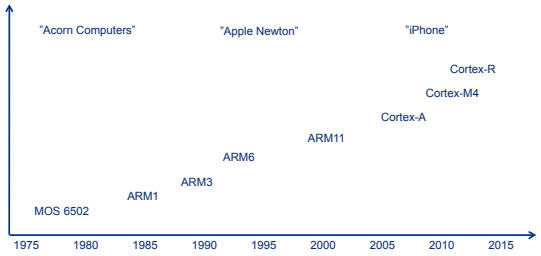
The MD407 computer card

The ARM processor family tree:



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STM32F407 block diagram:

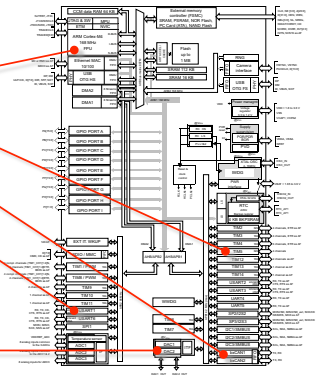
CPU – Cortex-M4 core

TIM5 – used by TinyTimber for high-resolution clock

bxCAN1 – available for your connection to other cards

USART1– connects to console via USB debug port

DAC2 – available for your sound generation



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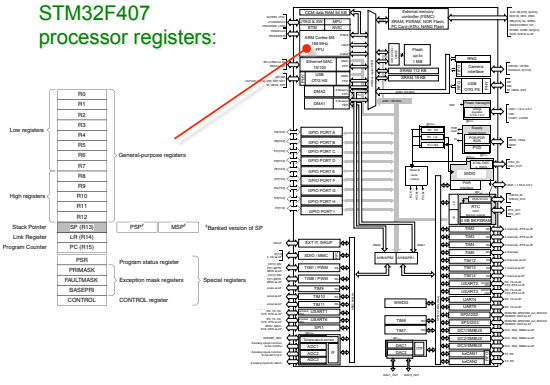
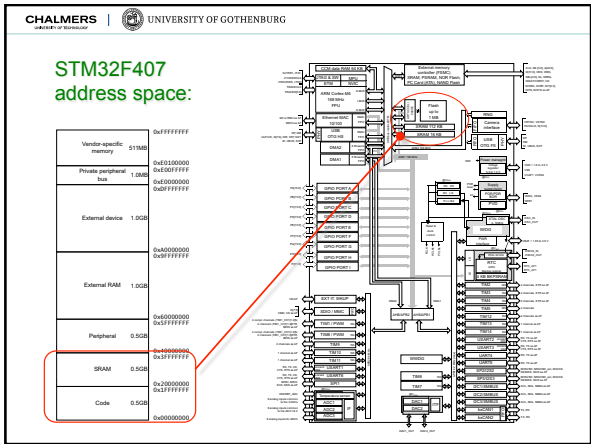
STM32F407 processor registers:

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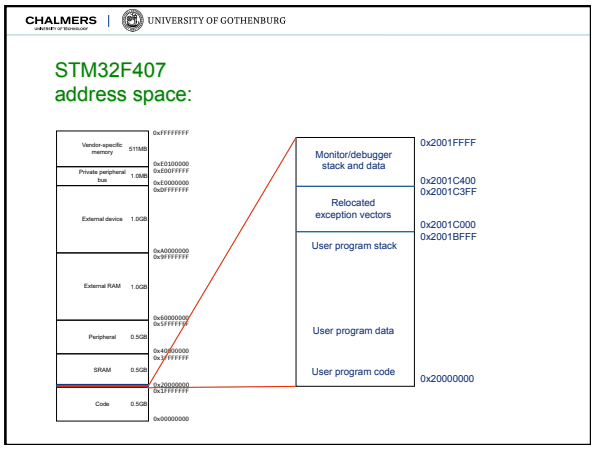
STM32F407
address space:
Vendor-specific memory
511MB
Private peripheral bus
1.0MB
External device
1.0GB
External RAM
1.0GB
Peripheral
0.5GB
SRAM
0.5GB
Code
0.5GB
0xFFFFFFFF
0xE0100000
0xE00FFFFF
0xE0000000
0xDFFFFFFF
0xA0000000
0x9FFFFFFF
0x60000000
0x5FFFFFFF
0x40000000
0x3FFFFFFF
0x20000000
0x1FFFFFFF
0x00000000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0xE0000000
0xDFFFFFFF
0xA0000000
0x9FFFFFFF
0x60000000
0x5FFFFFFF
0x40000000
0x3FFFFFFF
0x20000000
0x1FFFFFFF
0x00000000
Monitor/debugger stack and data
Relocated exception vectors
User program stack
User program data
User program code
0x2001FFFF
0x2001C400
0x2001C3FF
0x2001C000
0x2001BFFF
0x20000000