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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
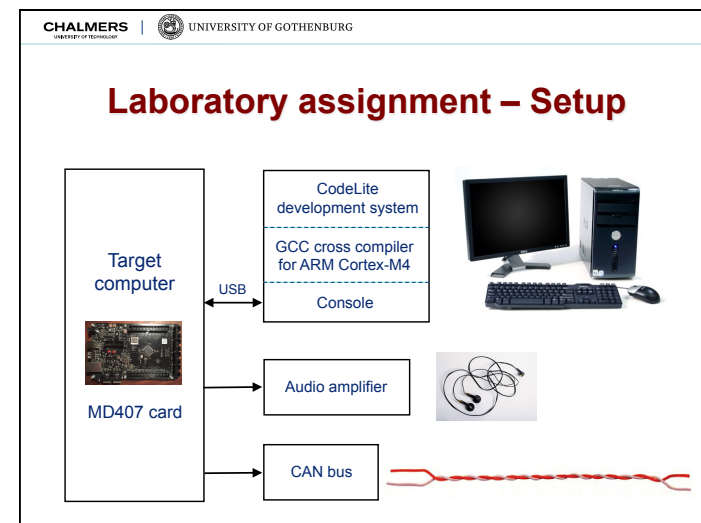
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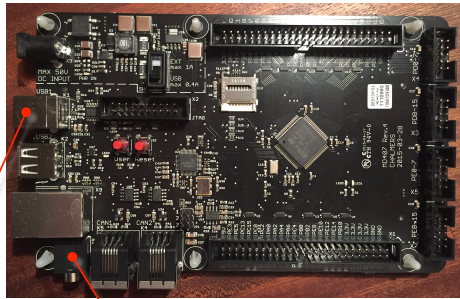
## The MD407 computer card

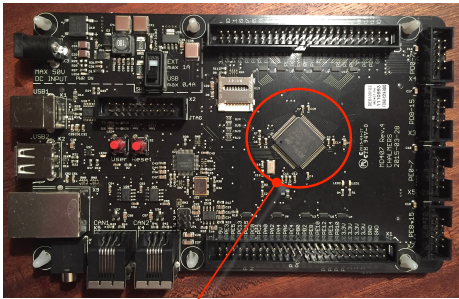STMicroelectronics' STM32F407 microcontroller /w ARM Cortex-M4 core

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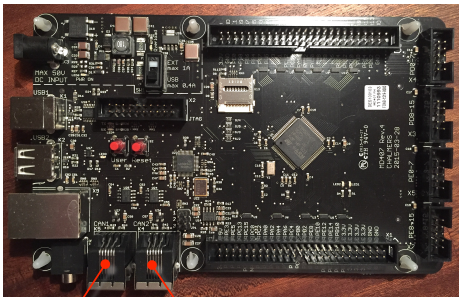
## The MD407 computer card

USB debug port        Audio output jack

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## The MD407 computer card

Main CAN bus        Loopback CAN bus

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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, ...

## Slide 1

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# The MD407 computer card

### The ARM processor family tree:

"Acorn Computers"    "Apple Newton"    "iPhone"

Cortex-R
Cortex-M4
Cortex-A
ARM11
ARM6
ARM3
ARM1
MOS 6502

1975  1980  1985  1990  1995  2000  2005  2010  2015

## Slide 2

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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

## Slide 3

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STM32F407
processor registers:

| | |
|---|---|
| R0 | |
| R1 | |
| R2 | |
| R3 | |
| R4 | |
| R5 | |
| R6 | |
| R7 | |
| R8 | |
| R9 | |
| R10 | |
| R11 | |
| R12 | |

Low registers

High registers

General-purpose registers

Stack Pointer   SP (R13)   PSP[a]   MSP[a]   [a]Banked version of SP
Link Register   LR (R14)
Program Counter PC (R15)

PSR
PRIMASK        Program status register
FAULTMASK      Exception mask registers   Special registers
BASEPRI
CONTROL        CONTROL register

## Slide 4

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STM32F407
address space:

| | | |
|---|---|---|
| Vendor-specific memory | 511MB | 0xFFFFFFFF |
| Private peripheral bus | 1.0MB | 0xE0100000 / 0xE00FFFFF |
| | | 0xE0000000 / 0xDFFFFFFF |
| External device | 1.0GB | |
| | | 0xA0000000 / 0x9FFFFFFF |
| External RAM | 1.0GB | |
| | | 0x60000000 / 0x5FFFFFFF |
| Peripheral | 0.5GB | |
| | | 0x40000000 / 0x3FFFFFFF |
| SRAM | 0.5GB | |
| | | 0x20000000 / 0x1FFFFFFF |
| Code | 0.5GB | |
| | | 0x00000000 |