

Embedded System Development for Autonomous Underwater Chemical Sensors

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Outline

- Introduction
- Sampling Problem in the Ocean.
- Sensors.
- Embedded system development
 - Hardware design
 - Software design

Introduction

- A new Embedded system platform is developed to replace an aging Embedded system for the Autonomous underwater sensor system **SeapHOx**.
- An ARM Cortex M4 microcontroller from Texas Instruments(LM4F232H5QD)
- Replacement of 24 bit ADC and 16 bit with faster sampling rate chips.
- Microcontroller hardware/software
- ADC hardware/software development



What is the SeapHOx?

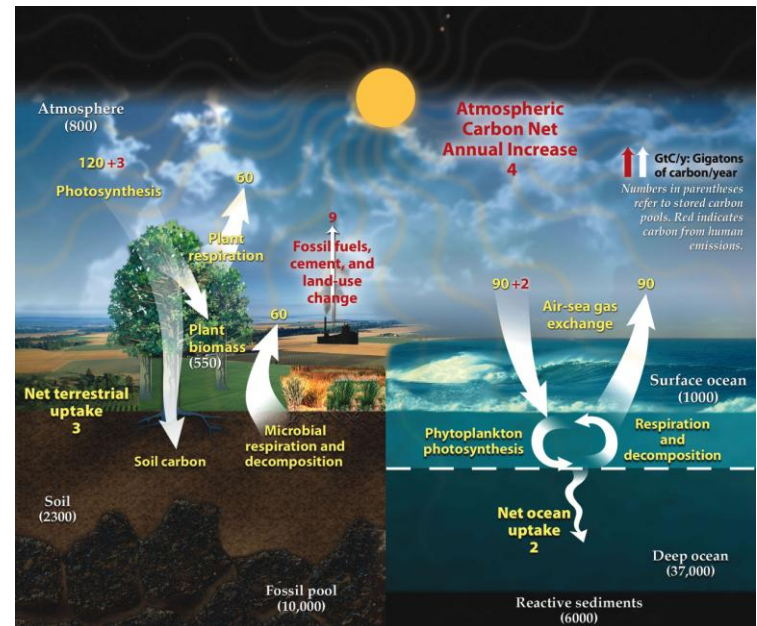
- A autonomous Sensing system for the marine carbon cycle developed at Martz Lab at Scripps Institution of Oceanography:
 - pH
 - Oxygen
 - Temperature
 - Salinity
 - Pressure



FUTURE DATA

Carbon dioxide and pH sensors were deployed on buoys in the Pacific Ocean in December 2009 by the Scripps Institution of Oceanography, which provides data to California Current Ecosystem research projects. Such information will improve forecasts of ocean acidification trends.

72 SCIENTIFIC AMERICAN

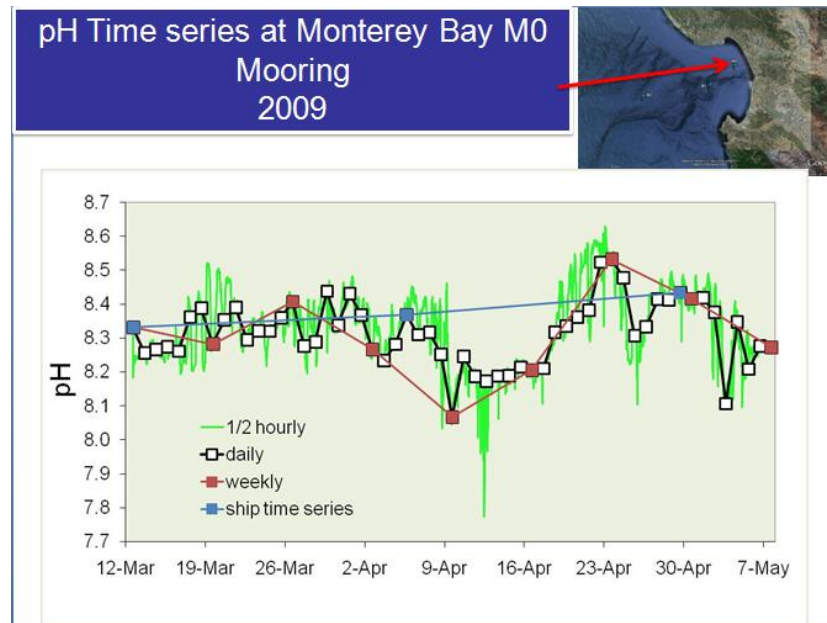


Carbon cycle

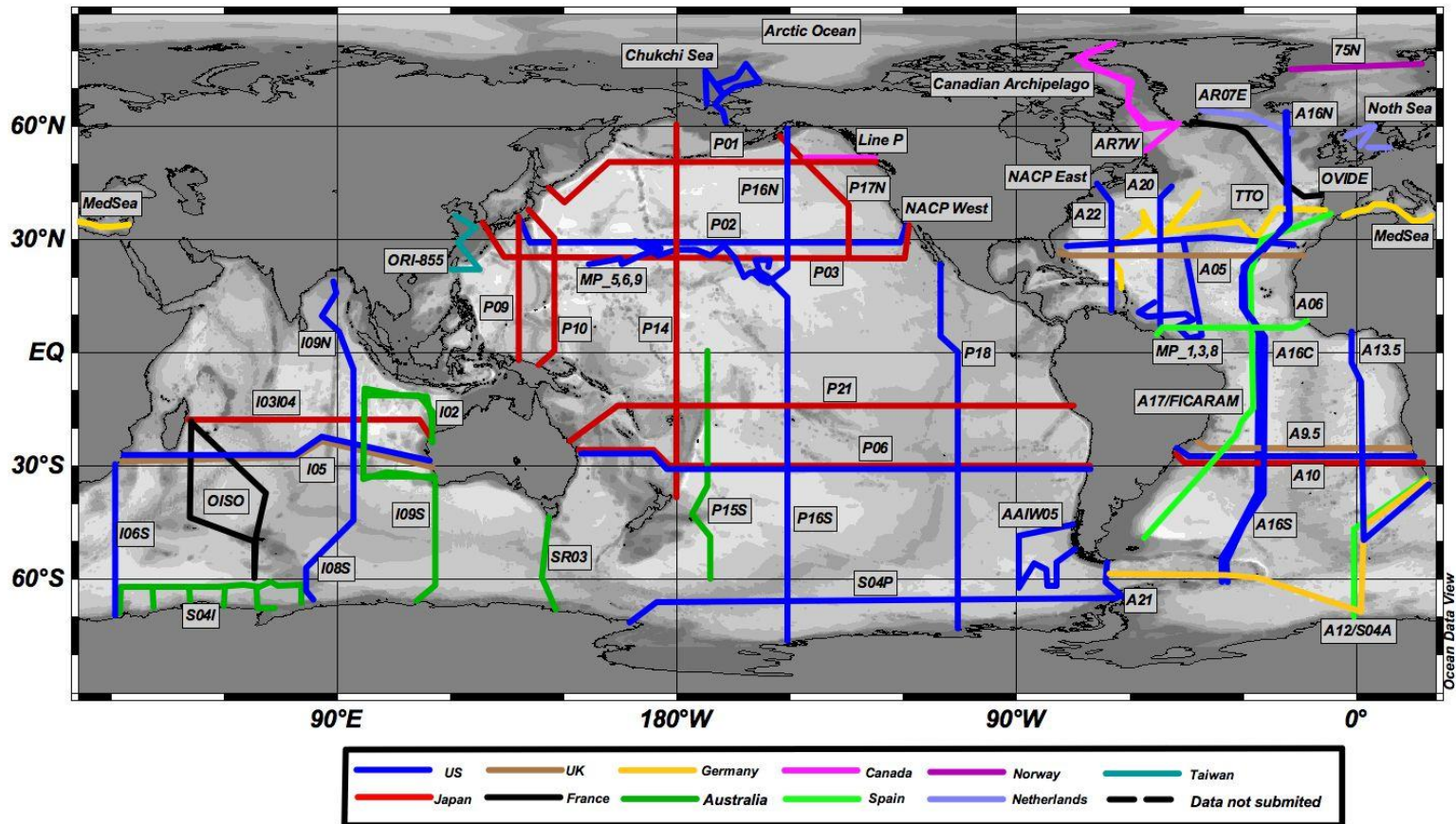
The sampling problem

“Much of the ocean is sampled only a few times in a decade because of the long (weeks in some cases) transit times from seaports to mid-ocean regions. Even in the coastal ocean, or lakes, and rivers, samples for chemical analysis are generally collected only at monthly intervals if at all...”

Johnson K, et al “Chemical Sensors Networks for the Aquatic Environment”

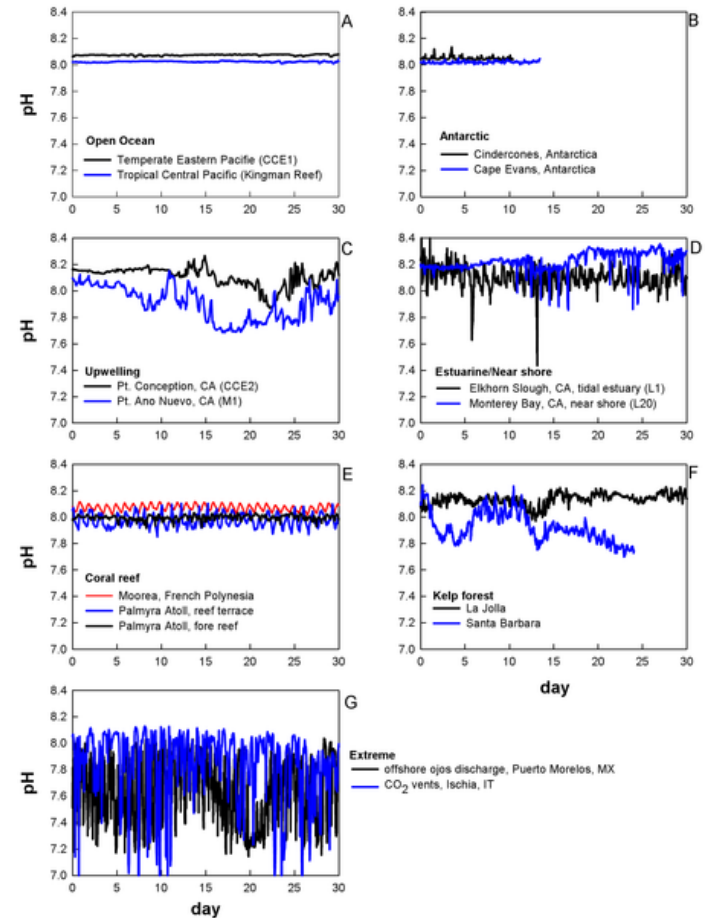


The sampling Problem



The Ocean is chronically under-sampled.

Sensing with the SeapHOx

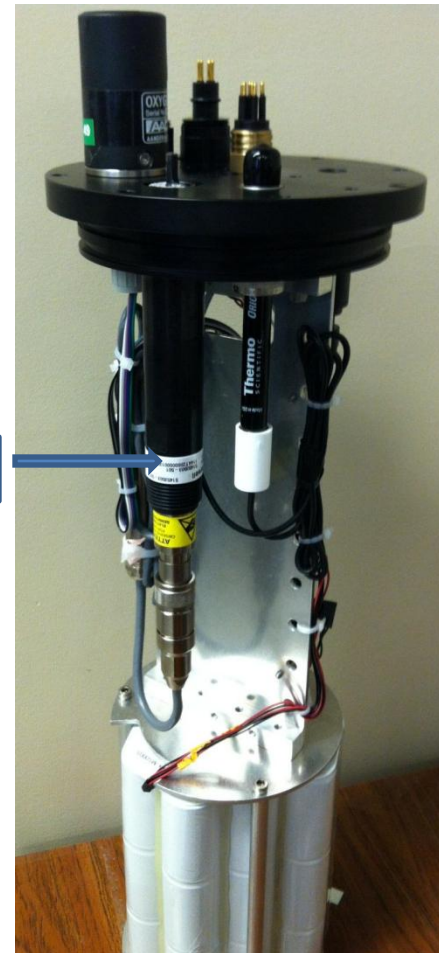


Hofmann GE, Smith JE, Johnson KS, Send U, et al. (2011) High-Frequency Dynamics of Ocean pH: A Multi-Ecosystem Comparison. PLoS ONE 6(12): e28983. doi:10.1371/journal.pone.0028983
<http://www.plosone.org/article/info:doi/10.1371/journal.pone.0028983>

Measuring CO2

- Commercial available Honeywell Durafet ion sensitive field effect transistor (ISFET)
- ISFET is a metal oxide semiconductor Field effect Transistor (MOSFET) without a metal gate electrode over the conduction channel.
- A conventional reference electrode is used in lieu the removed gate.
- A pH signal is proportional to the reference electrode to Voltage source

DURAFET



Sensing Oxygen

Dissolved Oxygen concentration is an indicator of primary production of fixed organic material and respiration of organic carbon.

- Andeera Optode T3830 –Optical sensor
 - Measuring Range: 0-500 μ M(micro Molar)
- RS232 communication



Conductivity, Temperature and Pressure

- CTD Sea-bird Microcat
 - Conductivity to measure salinity.
 - Thermistor based Temperature
 - UART communication
- MLH series Pressure sensor by Honeywell
 - ADC voltage measurement.



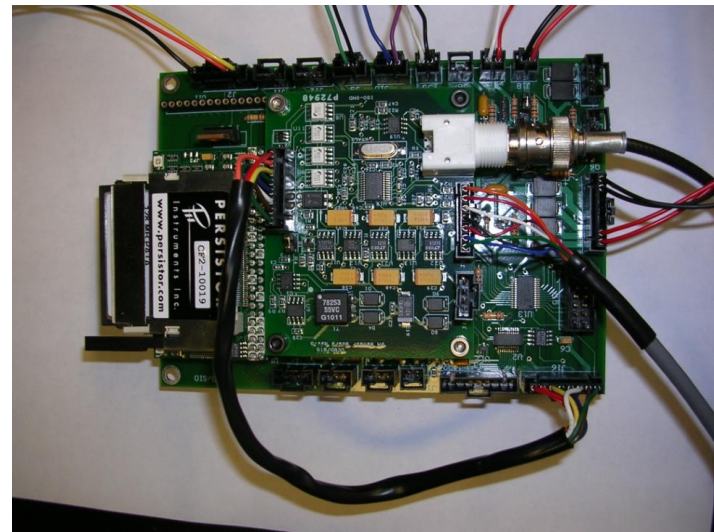
Sea-Bird Microcat



MLH series Pressure sensor

Embedded system to replace: CF2

- Persistor CF2 introduced in 2002
- Widespread use in the Oceanographic community.
- CF2 uses a Motorola 68332 (32-Bit MCU) as a main controller and a Texas Instruments MSP430 (16-Bit) as a slave.
- Cons:
 - Price (~\$400)
 - Relies in port extender to get more peripherals (not enough of them)
 - Performance compared to newest MCU's.
- Pros:
 - Low-Power thanks to MSP430
 - Relatively easy to use (Palm OS libraries)



Selecting a new Microcontroller

Decision Table

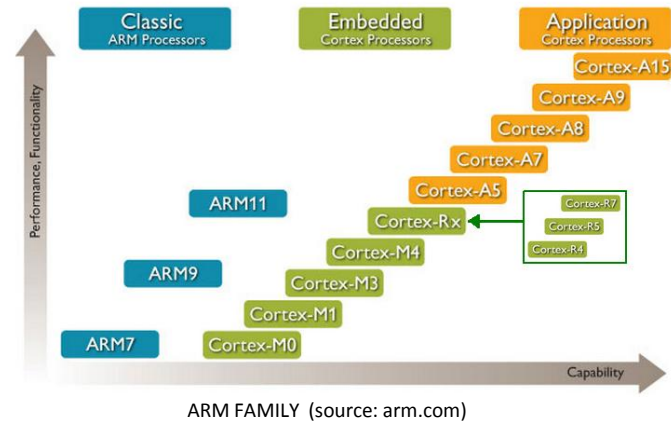


MCU	Price (low is better)	Performance	Peripherals	Software Support
LM4F232 (32-Bit ARM Cortex M4F)	Low	Excellent	Excellent	Excellent
PIC32 (32-Bit MIPS)	Low	Good	Good	Medium
LPC1700 (32-Bit ARM Cortex M3)	Low	Good	Excellent	Good

- All the MCU were tested at evaluation board.

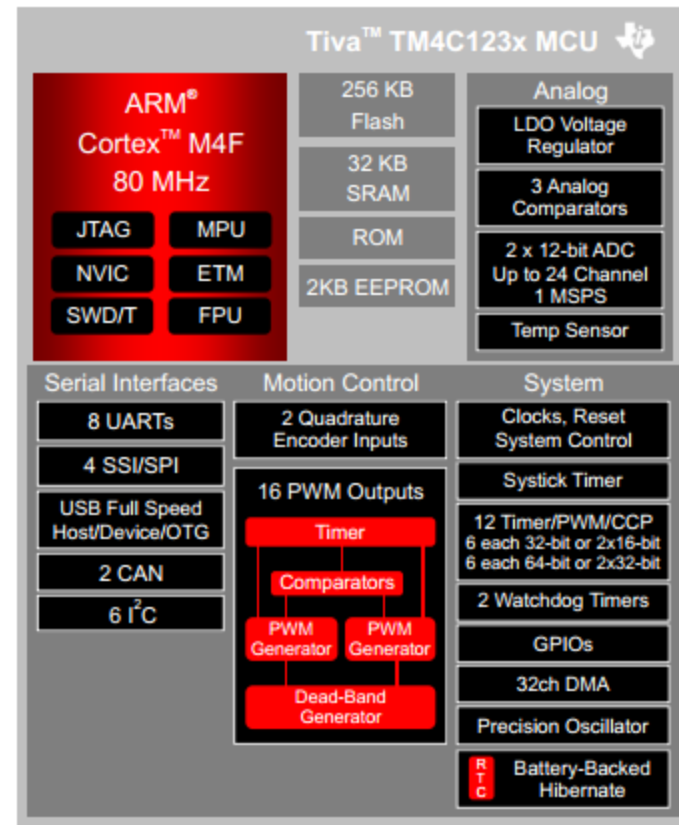
ARM Architecture

- 32-Bit architecture
- Multiple vendor support
- Wide range of parts
- 95% smarthphone market.
- Power efficient



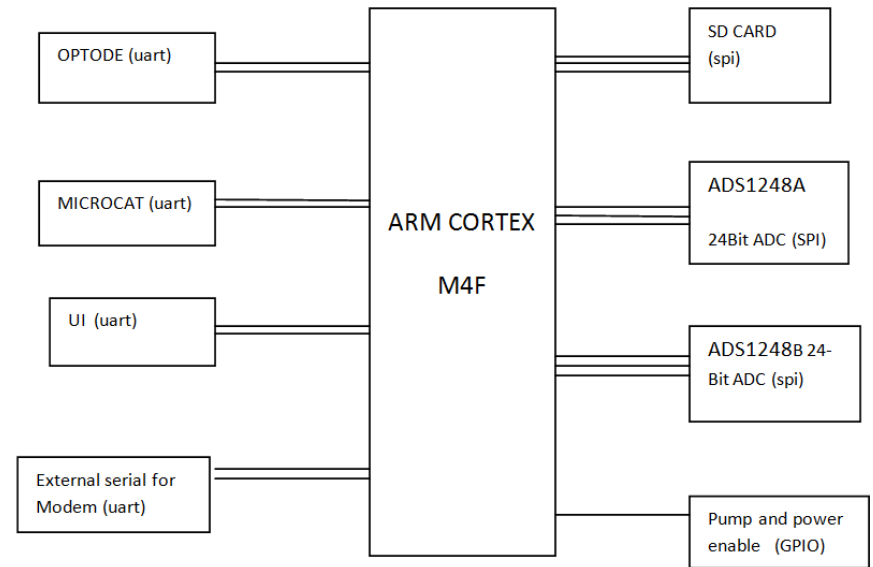
ARM CORTEX M4F

- 32-Bit Architecture
- 80 Mhz max clock frequency.
- 256 KB flash memory.
- 32 KB SRAM
- 2 KB EEPROM
- Operating range -40 to 85 C
- Floating Point Unit (FPU)
- Memory Protection Unit (MPU)



Cortex M4F peripherals

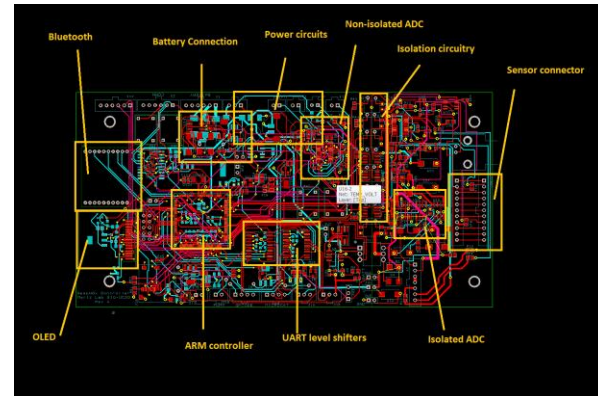
- 8 UART (5 used)
- 4 SPI (3 used)
- 1 USB
- 24 Channels 12-Bit ADC @1 mSPS
- 104 GPIO (62 free)
- 2 CAN



Block Diagram

Embedded Hardware

- Basically the same electronics of the original SeapHOx.
- Added Higher frequency ADC.
- New Microcontroller ARM Cortex M4F
- Some power electronics added.



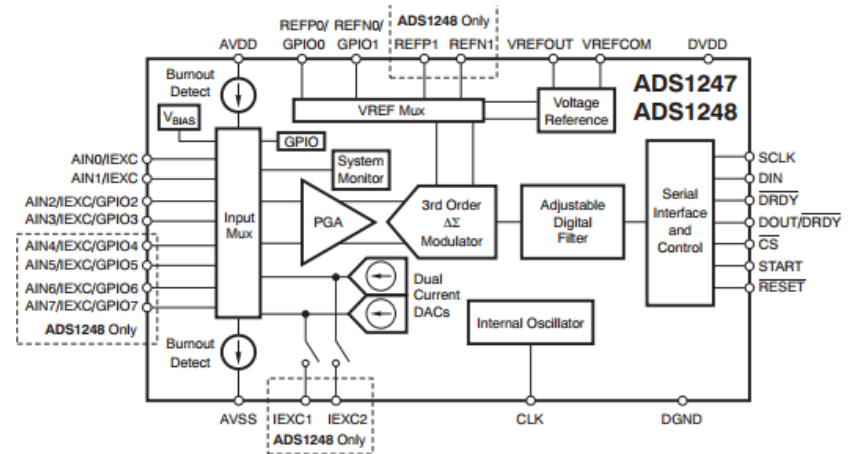
PCB Design



Testing new board

24 bit ADC

- 2x24-Bit Delta-Sigma ADC
- 2 kSPS Sampling rate
- 7 Channels
- Internal V. Reference
- Serial SPI communication
- Measure:
 - Temperature, Battery Voltage, Pressure, pH int, pH ext,



Embedded Software

- C programming, GCC compiler.
- Stellaris (TI) API for peripherals.
- Eclipse based Code Composer Studio IDE
- Microelektronika's Mikro-E Programmer/debugger.

	LM4F232HQ5D	Resources used
12C	6	0
CPU	ARM Cortex-M4	NA
Pin/Package	144LQFP	NA
Max Speed (Mhz)	80	48
Operating temperature	-40 to 85 °C	NA
Memory Protection Unit	Yes	NA
Watchdog timers	2	1
SSI (SPI)	4	3
ADC units	2	1
ADC resolution	12-bit	NA
UART	8	4
GPIO's	105	61(FREE)
SRAM (KB)	32	NA
Flash (KB)	256	NA

Questions?

Acknowledgement

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