0: Introduction to Embedded Systems

Organizational Meeting

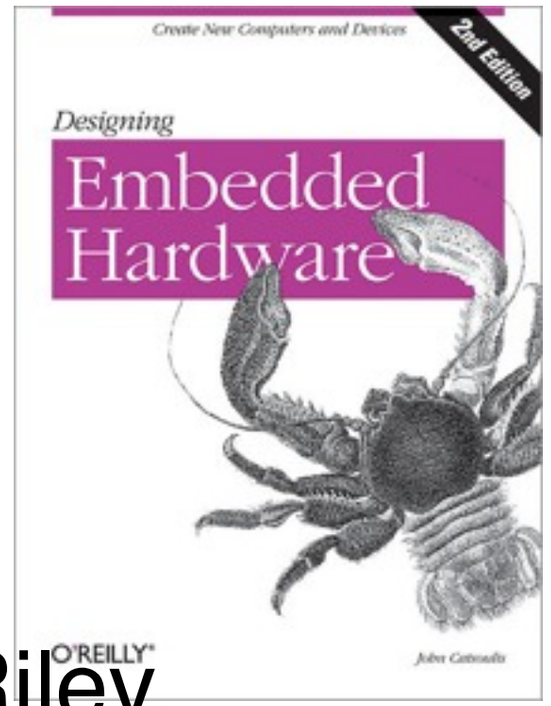
Lecture 1: Overview

- Introduction
  - Course overview
- Setting up your environment
  - Download Simulator, Compiler
  - GIT repository
- Preview of
  - EcoBT board
- Project Ideas

Course Web Page

- LMS page at NTHU
  - http://lms.nthu.edu.tw/course/17136
  - Syllabus: content, schedule, policy, contact
  - Homework assignments, announcements
  - Discussion forums
- GIT repository
  - Create account on gitlab.com

Textbook

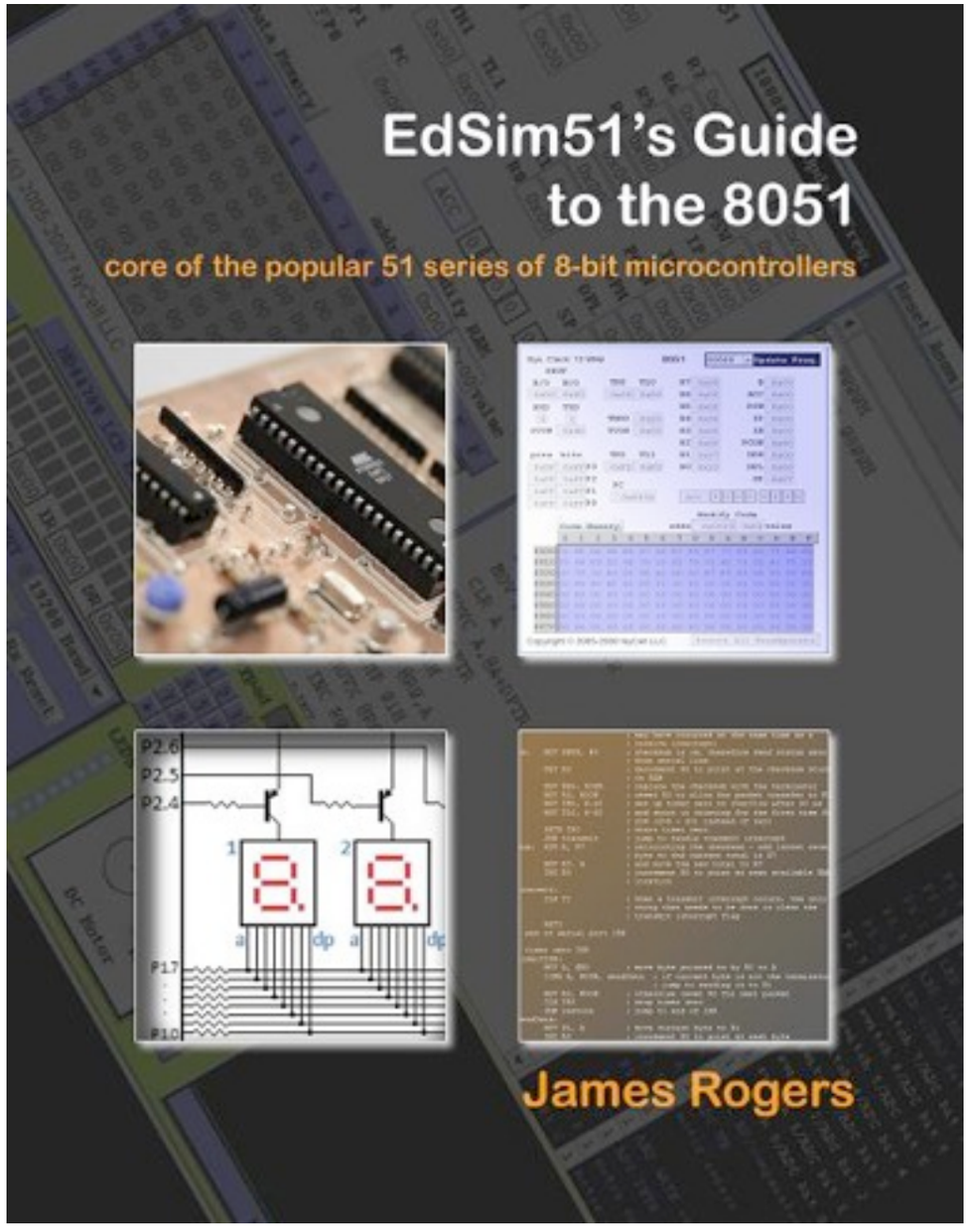


- John Catsoulis,
  Designing Embedded Hardware, O'Riley,
  ISBN 0-596-00755-8, May 2005. 400 pages.
- Comment:
  good coverage, basic topics quite in-depth;
  USB and later sections somewhat
  superficial.
- http://proquest.safaribooksonline.com/0596007558

Reference: EdSim51

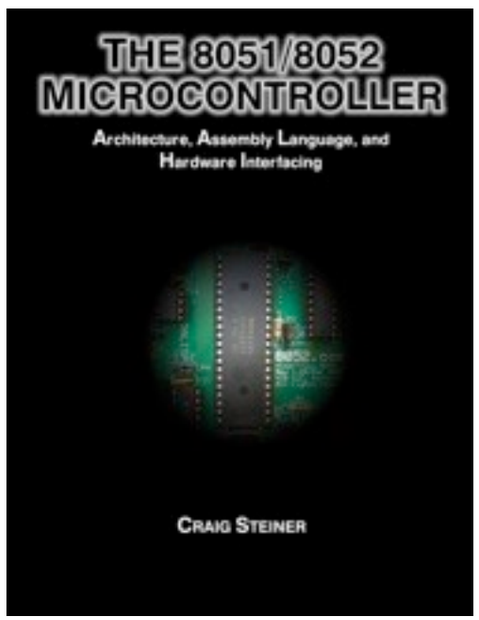
- Optional but useful
- Free simulator download
  - simulates 8051 MCU + I/O
  - Used for class assignments!

http://www.edsim51.com/



Reference: 8051/8051 MCU

- The 8051/8052 Microcontroller: Architecture, Assembly Language, and Hardware Interfacing
  - Many same topics as this course
  - by the author of 8052.com
- Optional but can also be helpful See also the 8052.com website for tutorials



Supplemental Material

- To be posted
- Data sheets
  - CC2540/2541 microcontroller
  - BLE stack and OSAL
- IAR Compiler documentation

Catalog Description

- Concepts and techniques for using microprocessor-based systems to gather data and control peripheral devices.
- Relationship between microprocessor hardware and software, including input/output operations.
- Experience with a microprocessor system is provided.
- Functional requirements are realized through software and I/O hardware design.

Course Objectives

- the design of microprocessor peripherals,
- parallel and serial interfaces,
- memory and different busses
- Hardware and software problems related to peripherals

Course Outcomes

- Analyze and understand bus/interface.
- Characterize the timing/performance behavior of interfaces.
- Develop system software in C or assembly language.
- Program and debug microprocessor devices.
- Control/use peripherals, devices, and buses.

Hands-on component

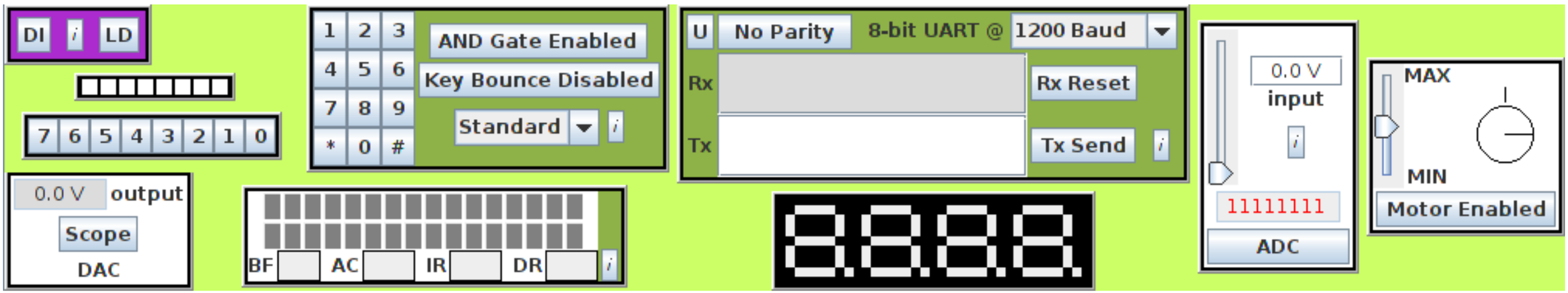
- First-part: Simulation
  - Hardware/Software interfacing
  - Low-level coding
- Second part: real MCU board
  - using Bluetooth 4.0 Low Energy
  - in conjunction with smartphone
  - peripheral device interfacing

Getting Started

- Download EdSim51
  - from http://edsim51.com/
  - Runs as a Java app
- Two versions
  - Edsim DI - standard, with everything
  - Edsim SH - customizable

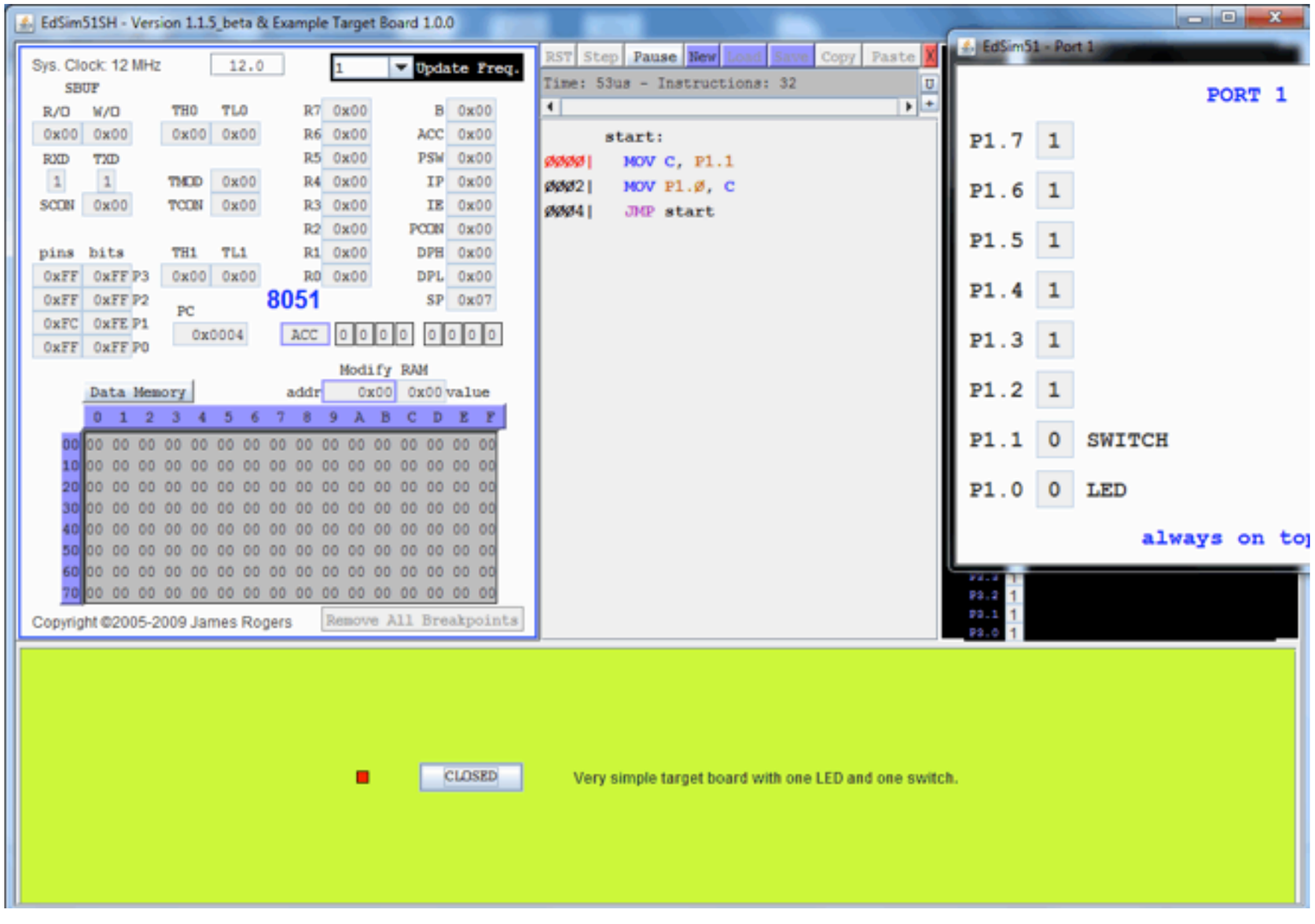
EdSim51 DI
(Dynamic Interface)

- Simulates a complete embedded system
- LED, LCD, keypad, buttons, ADC, DAC,
- Accurate to the cycle



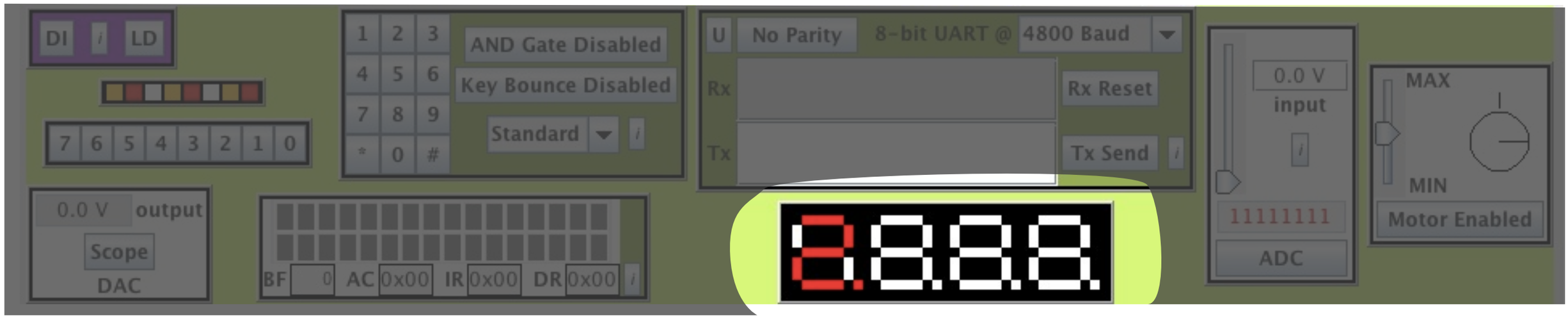
Edsim51 SH

- Customize the devices to use



First program

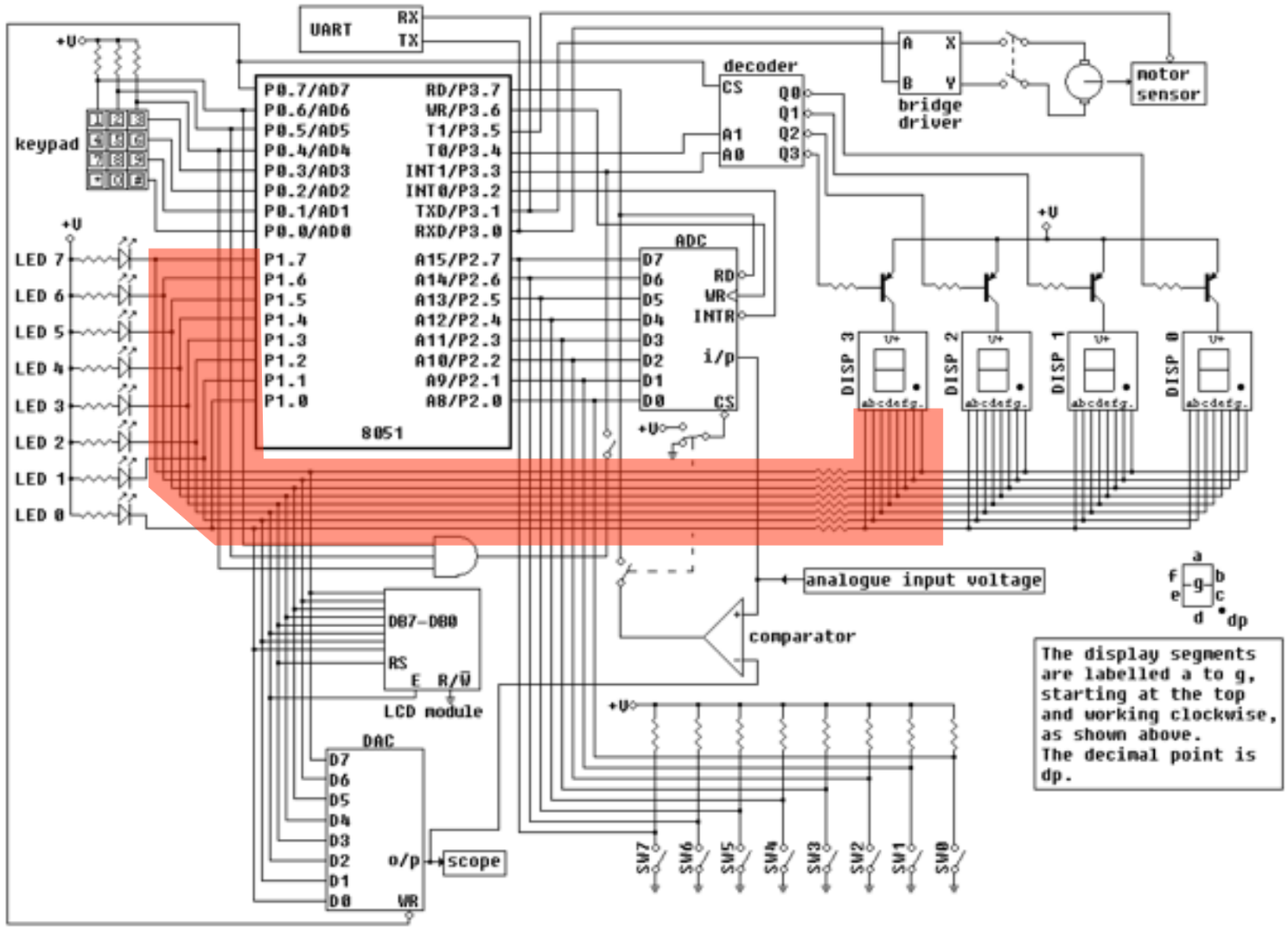
- Open EdSim51, type the code
  ORG 0000H
  MOV 90H, #24H
  END
- Click Assm, and Run. You'll see



How it works

- Schematic
- 0 = on,
  1 = off
- 0x24 is

a=0
f=1 b=0
g=0
e=0 c=1
d=0 h=0



What's an embedded system?

- Controller
  - Microcontroller, programmable
  - could be FPGA, hardwired control etc
- Peripherals
  - input and output devices
  - sensors and actuators, storage, communication
- Power and energy subsystem

How to develop for embedded systems

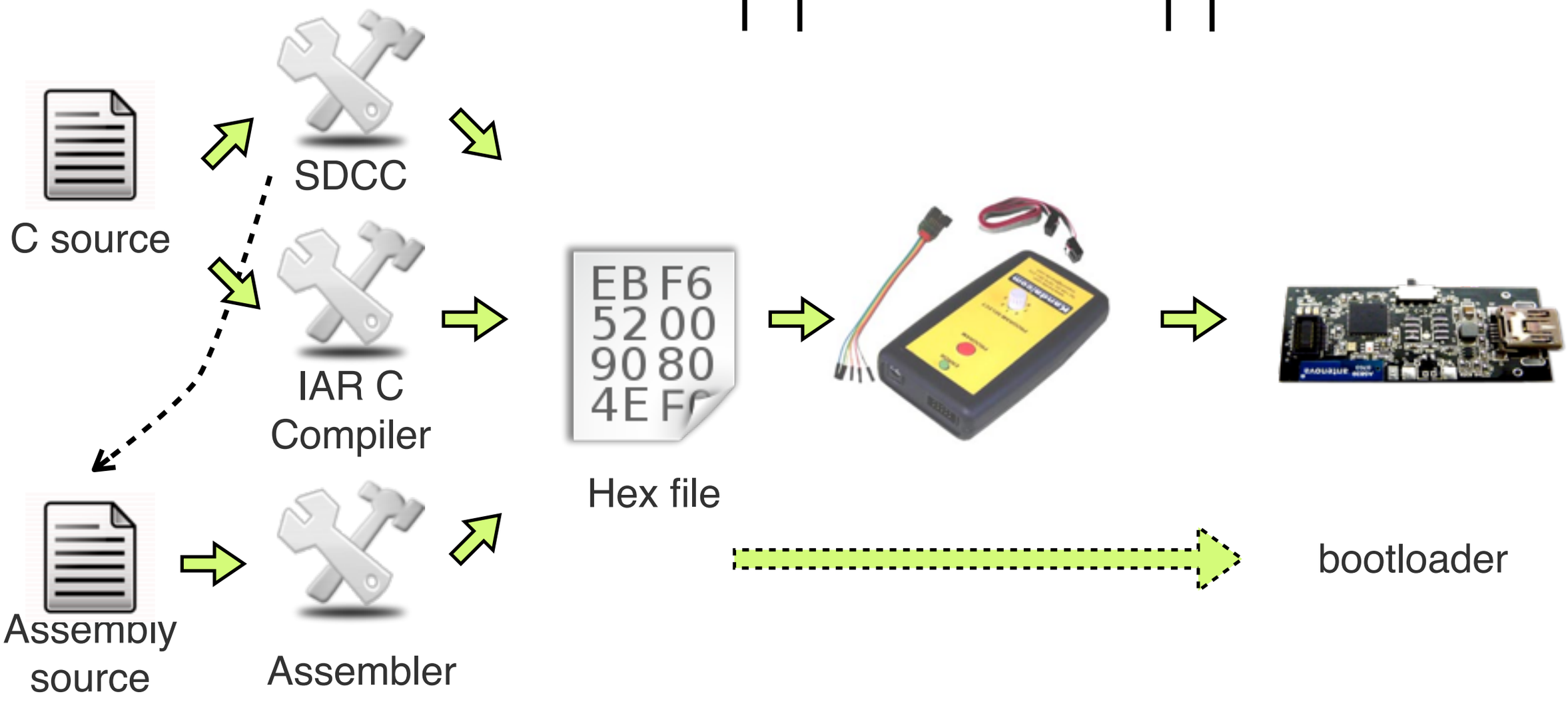
- Hardware
  - Make your own board! - somewhat difficult
  - Use existing board ("platform") - easier
- Software (firmware)
  - Cross compilation (compile on PC)
  - Program (write code into memory) using either programmer or bootloader

Cross Development

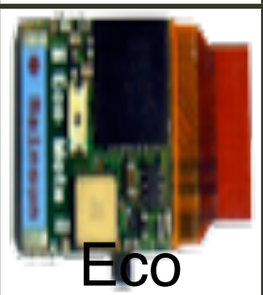
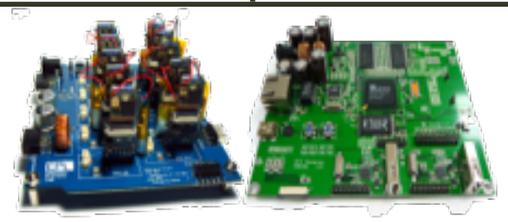
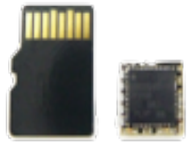
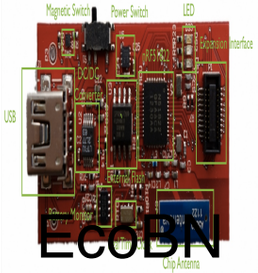
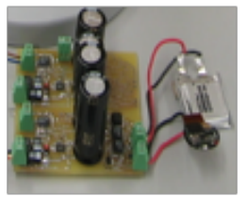
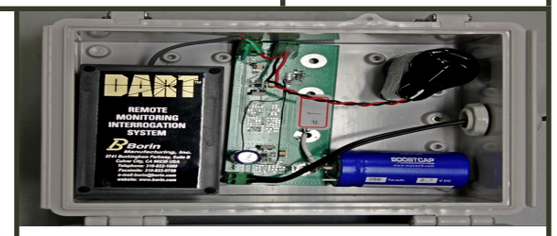
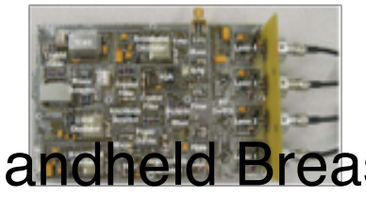
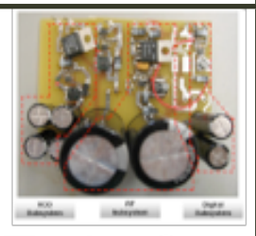
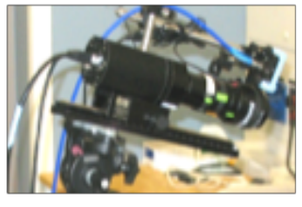
PC side

Programmer

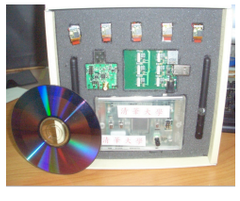
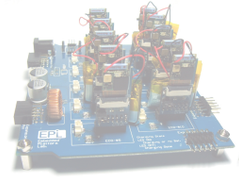
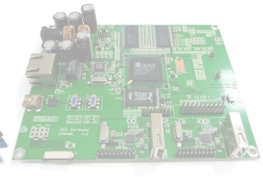
Board

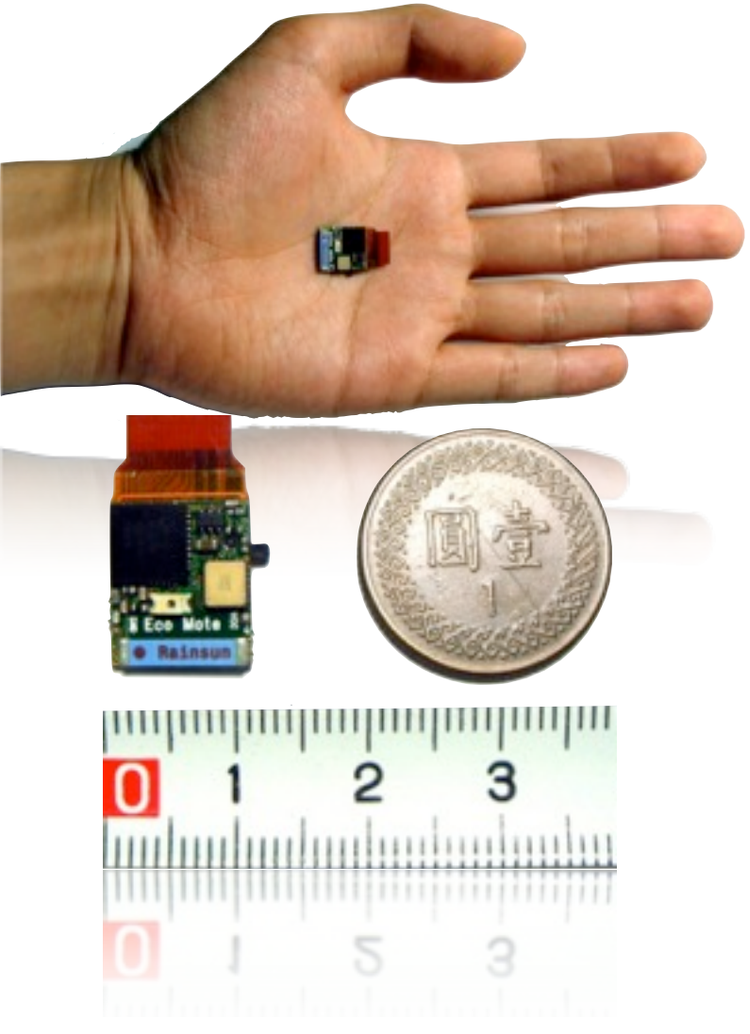


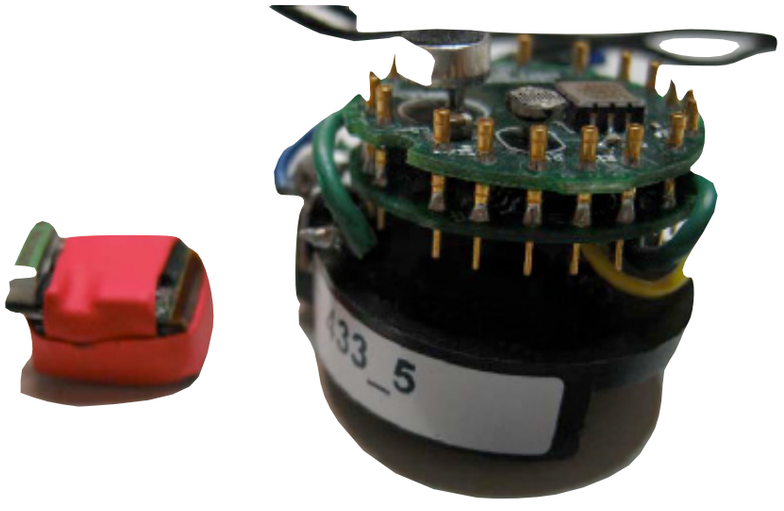
Embedded Platforms from EPL

Year	2003-06	2007	2008	2009	2010	2011	2012	2013
Mini WSN	 Eco	 EcoKit	 EcoSpire	 Charger, Gateway		 EcoSD	 EcoBT	 EcoBN
Structural Health & Logistics	 DuraNode	 DuraNode v.2		PipeTECT v.1 		PipeTECT v.2 aka DuraMote 		 Smart Container
Energy harvester	 Ambimax	 Everlast		DuraCap Energy Harvester 		 EscaCap	 HysCap	
Medical Device	 Handheld Breast Scanner	 TurboCap		 Laser Speckle Imager		 ECG, EEG modules		 SIDS Monitor

Eco Node

Year	2006	2007	2008	2009	2010	2011	2012	2013
Mini WSN								
Eco	EcoKit	EcoSpire	Charger, Gateway			EcoSD	EcoBT	EcoBN

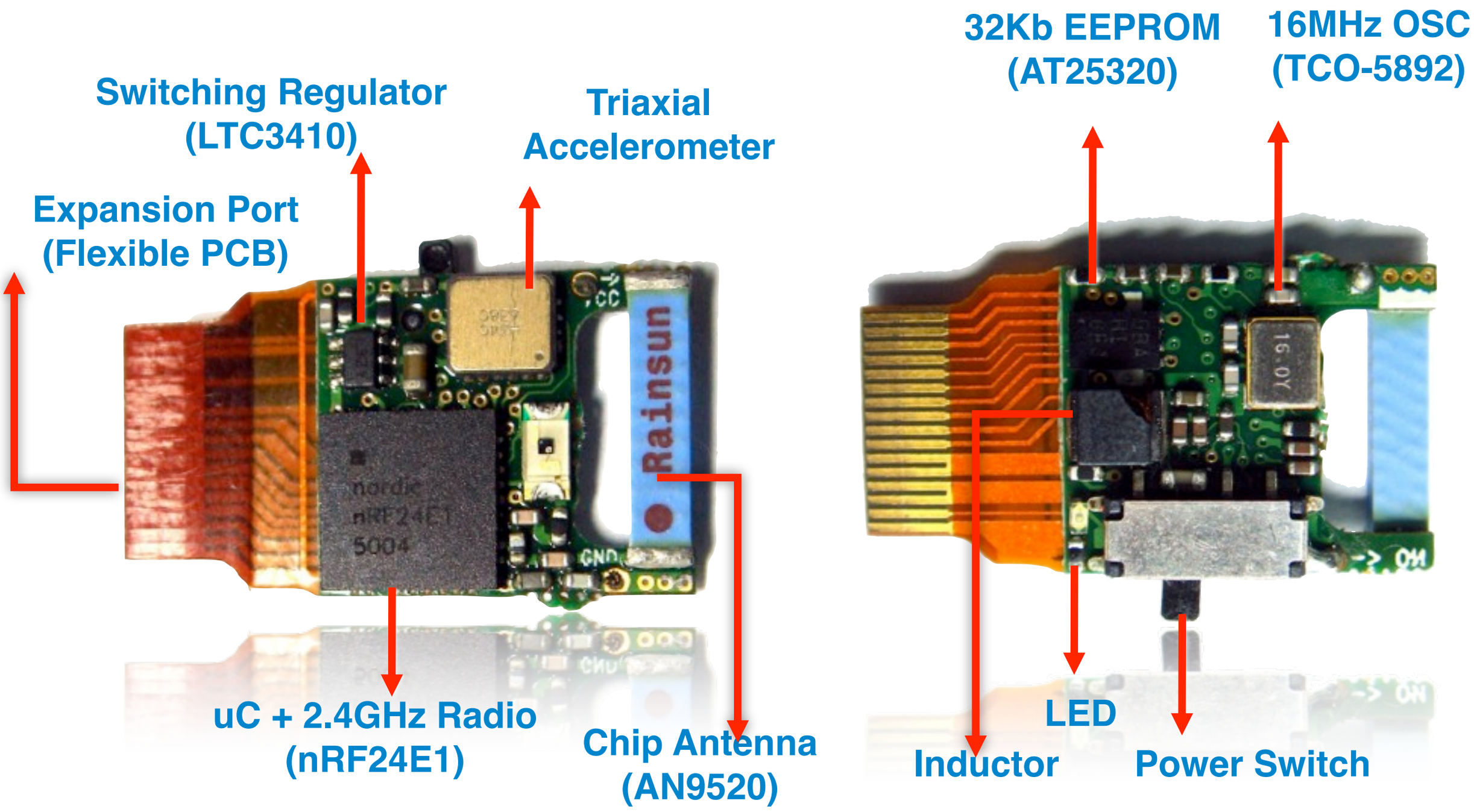




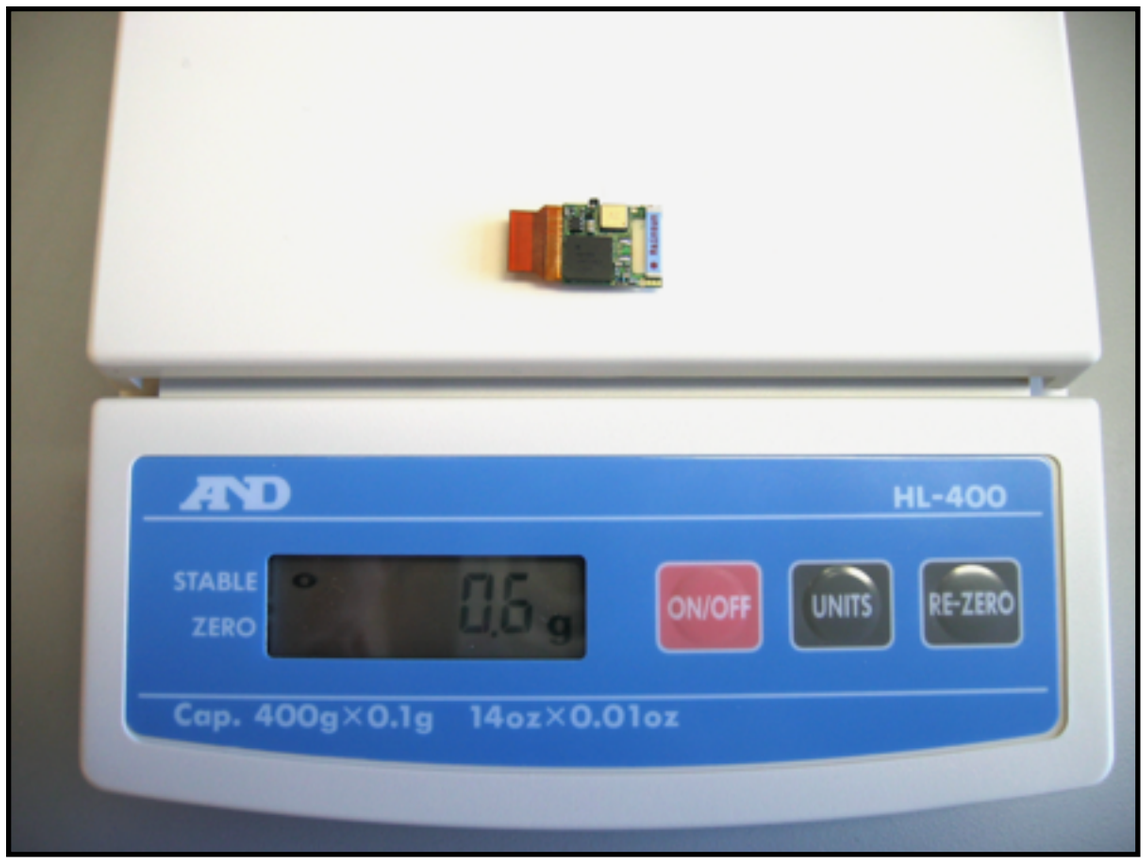
Eco vs. Mica2DOT

- 1cm³, 2 grams include battery & antenna!
- 11% of Mica2DOT, 11 x 13 x 7 = 1001mm³
- RF: 1Mbps, 10 m range
- Battery life: 4 Hrs (40mAh)

Eco Node


Switching Regulator
(LTC3410)
Triaxial
Accelerometer
32Kb EEPROM
(AT25320)
16MHz OSC
(TCO-5892)
Expansion Port
(Flexible PCB)
nordic
nRF24E1
5004
Rains
uC + 2.4GHz Radio
(nRF24E1)
Chip Antenna
(AN9520)
LED
Inductor
Power Switch

Weight – Eco Board

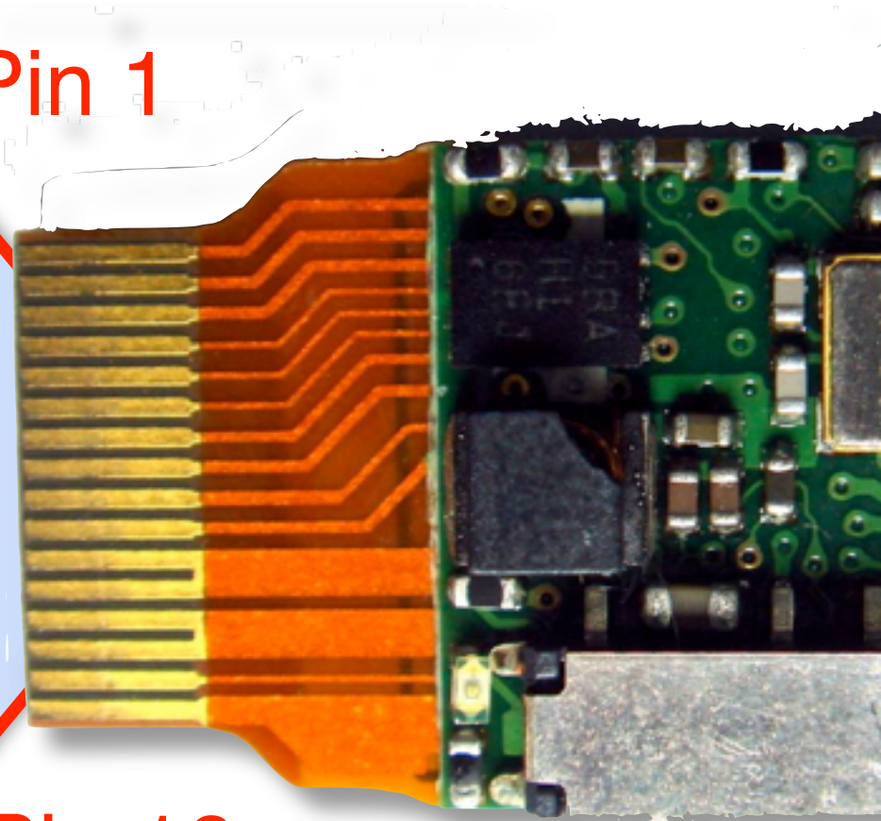


Eco: 0.6 grams

Battery: 1.2 grams

Expansion Port

#	Description
1	GND
2	Digital I/O5 & INT0
3	TXD (UART)
4	CS (SPI)
5	RXD (UART)
6	SCLK (SPI)
7	SI (SPI)
8	Analog Input 0
9	SO (SPI)
10	Analog Input 1
11	VCC (Min.3V, Max5V)
12	VCC (Min.3V, Max5V)
13	Battery(+), Charger Input
14	Battery(+), Charger Input
15	Regulator Shut Down (Active Low)
16	GND

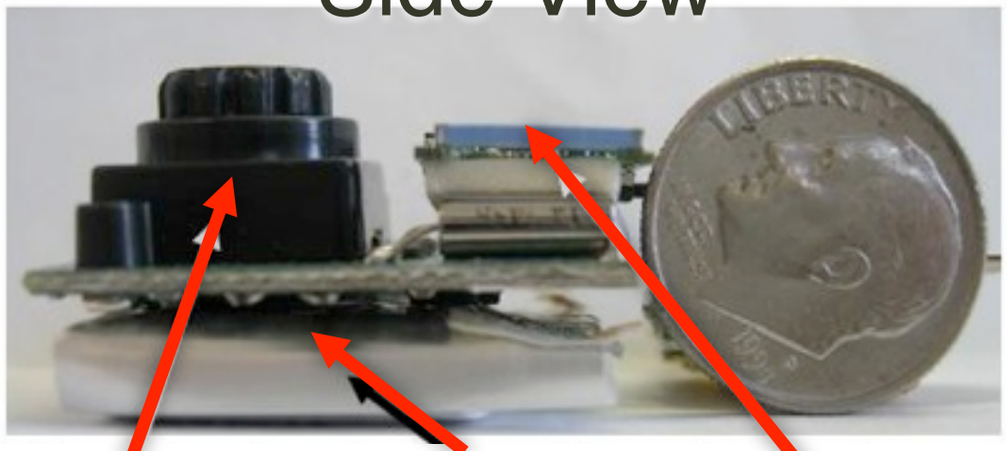


Expandability

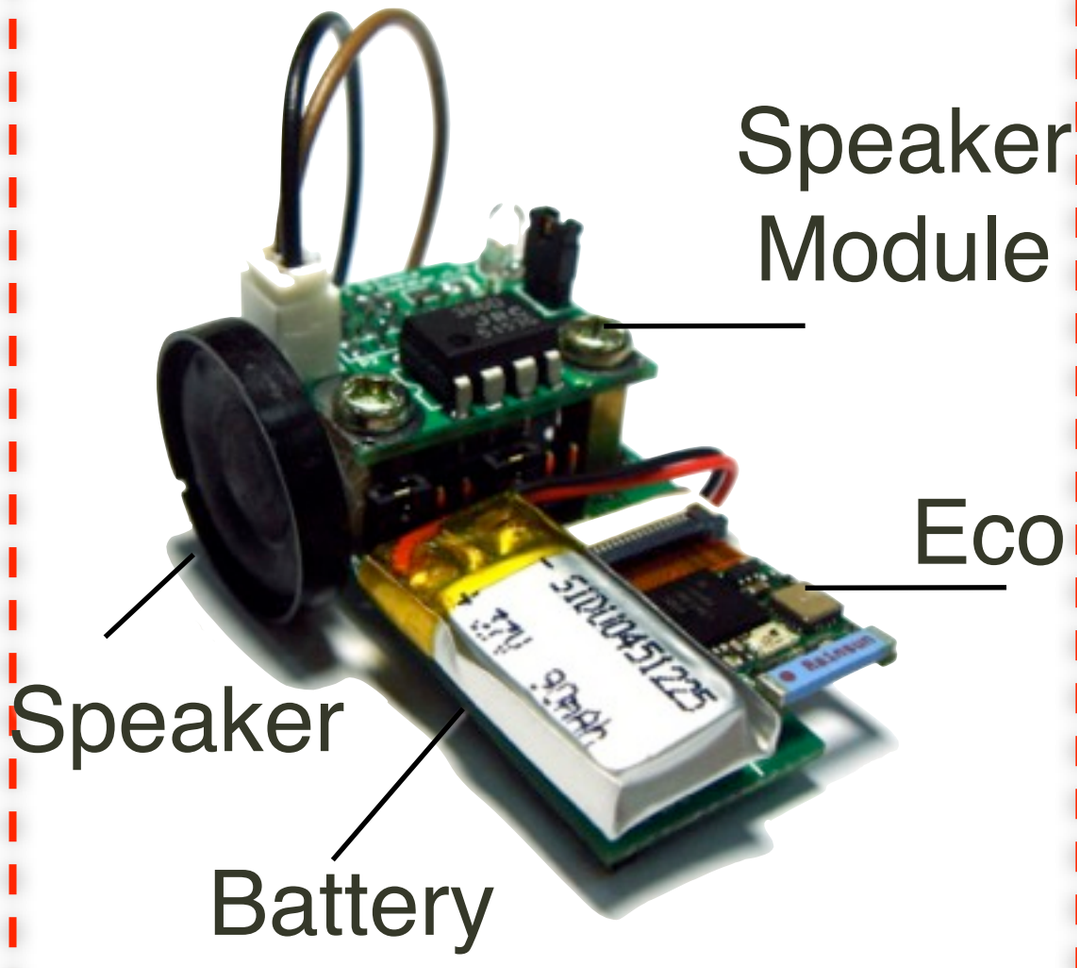
Eco VGA Camera

Top View

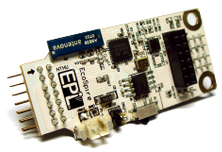
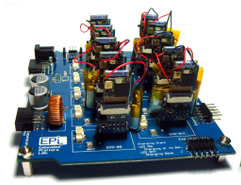
Side View



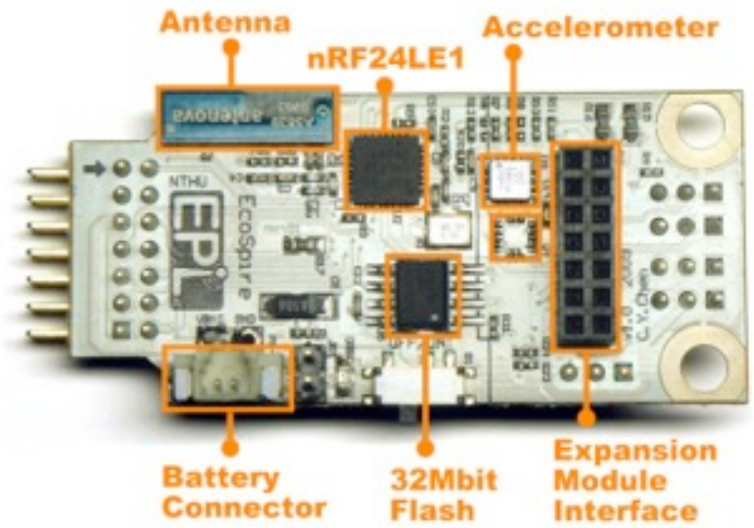
Eco Module Board



EcoSpire (2nd Gen)

Year	2006	2007	2008	2009	2010	2011	2012	2013
Mini WSN	Eco	EcoKit	 EcoSpire	 Charger, Gateway		EcoSD	EcoBT	EcoBN

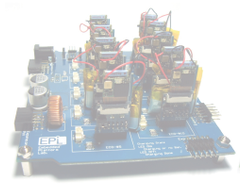
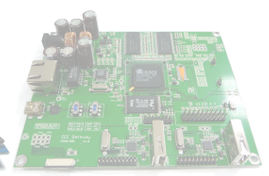
Super Node (w/ MicroSD)



Simple Node (no SD card)

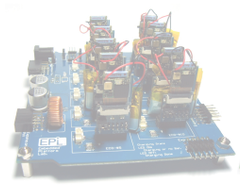
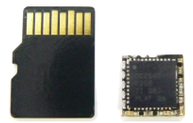
- Improvements over Eco:
  - 16K on-chip flash (vs. 4K off-chip EEPROM)
  - 2 Mbps RF, autoack/autoReTx (vs. 1 Mbps)
  - Digital accelerometer (vs. analog)

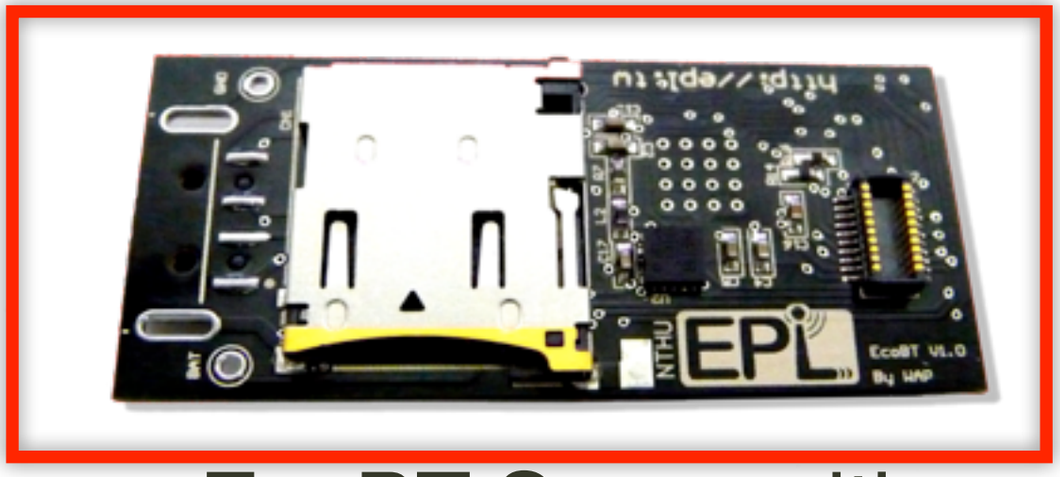
EcoSD (2.5th Gen, 2011)

Year	2006	2007	2008	2009	2010	2011	2012	2013
Mini WSN	Eco	EcoKit	EcoSpire	 Charger,	 Gateway	 EcoSD	EcoBT	EcoBN

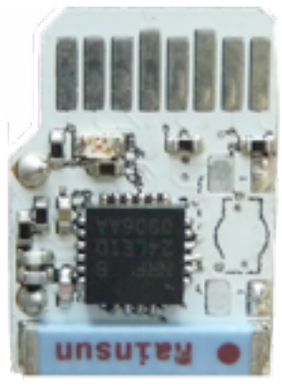
- Size & shape of MicroSD
  - Allows use of robust connector
  - Not electrically compatible with MicroSD
- Option of magnetic switch
- Same MCU as EcoSpire

EcoBT (3rd Gen., 2012)

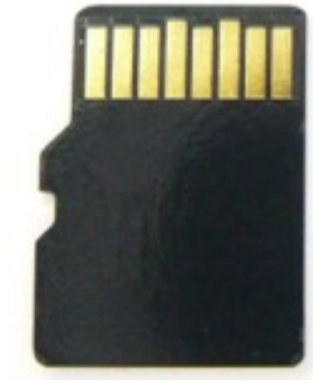
Year	2006	2007	2008	2009	2010	2011	2012	2013
Mini WSN	Eco	EcoKit	EcoSpire	 Charger, Gateway		EcoSD	 EcoBT	EcoBN



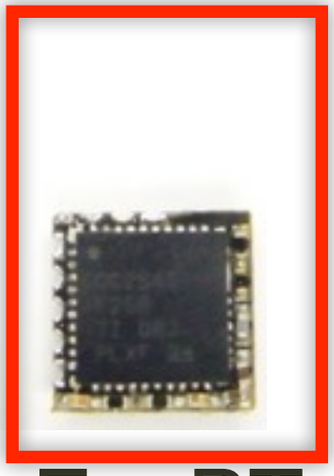
EcoBT Super with MicroSD slot



EcoSD



MicroSD

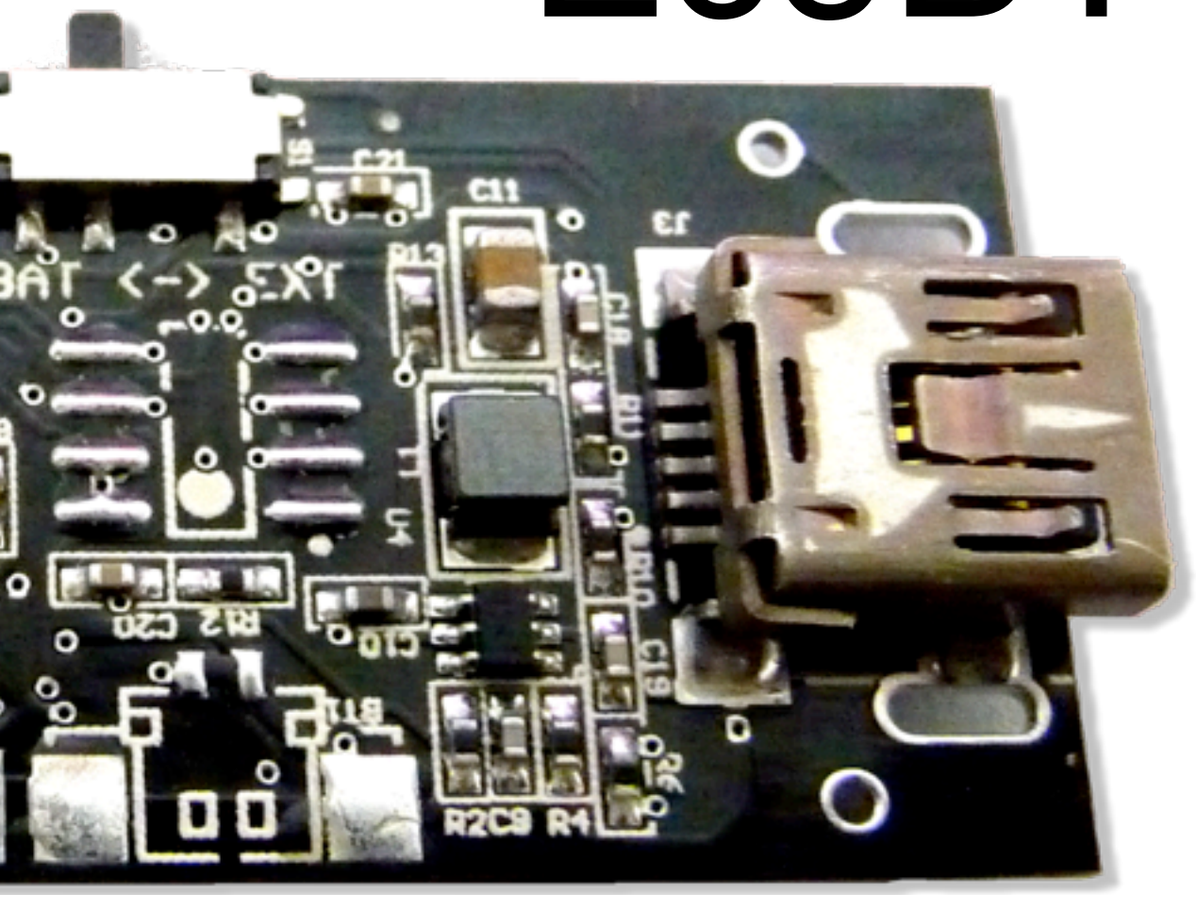


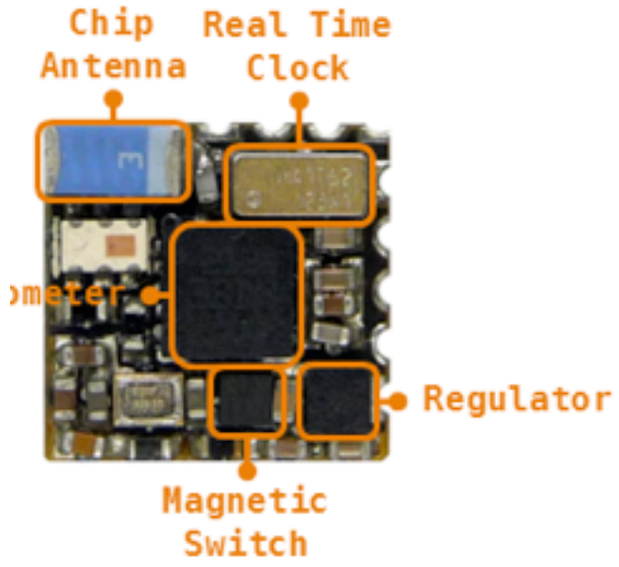
EcoBT Mini

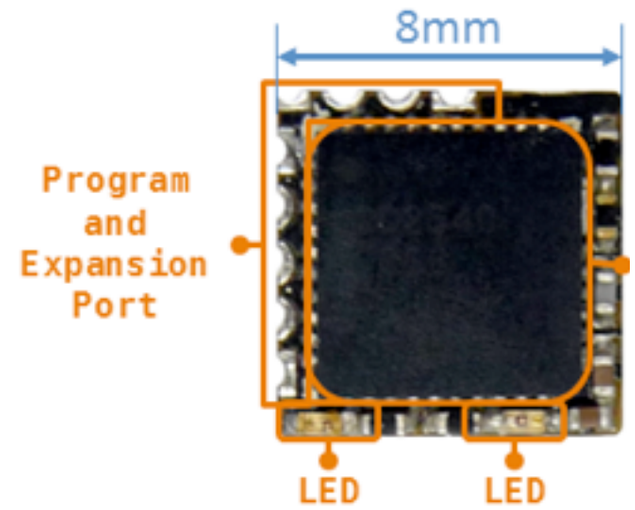
4.0 Bluetooth®

8mm x 8mm

EcoBT Features







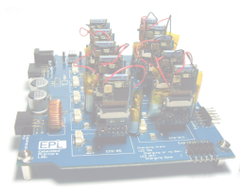
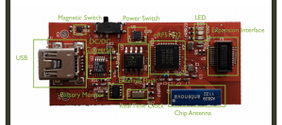
Feature	Super	Mini
Dimensions	42mm x 20mm	8mm x 8mm
Memory	2 MB serial flash	n/a
Expansion Ports	MicroSD, Molex, USB	PCB Edge Connector
On-board peripherals	LIS331DLH (accelerometer) RTC, light, magnetic	LIS331DLH (accelerometer), RTC,
MCU features	8051 core w/BLE MAC/PHY/stack, on-chip 12-bit ADC, on-chip voltage comparator, DMA, on-chip regulator	

Uplink Options for EcoBT

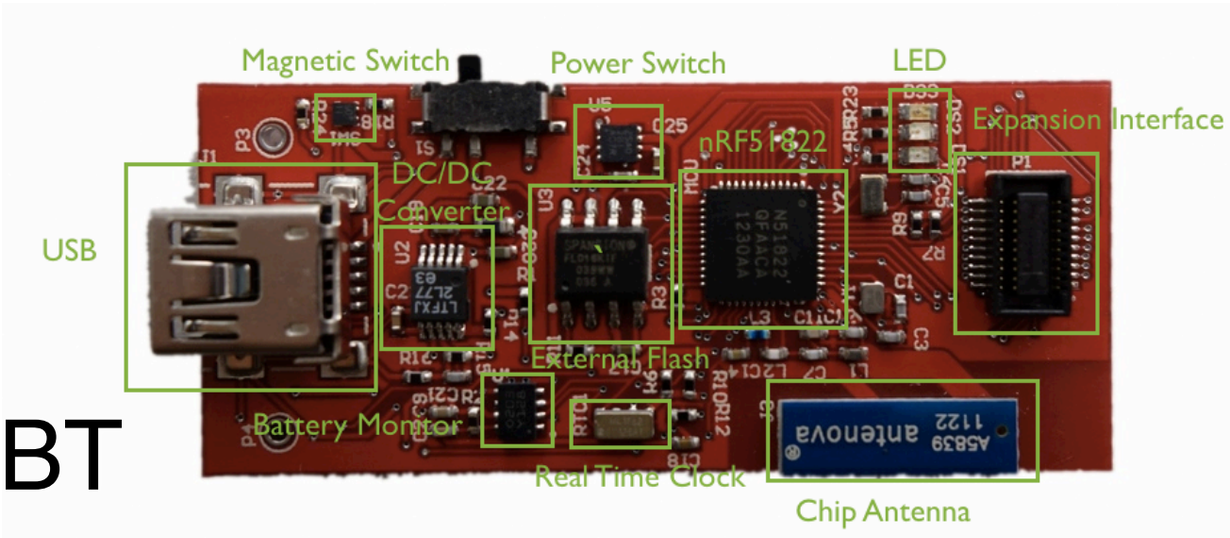
- New Gateway
  - PandaBoard (Dual-core ARM/Linu
  - Ethernet, Wi-Fi, BTLE, USB
  - Stand-alone operation

- Smart Phones with BLE support
  - E.g., iPhone 4S, iPhone 5,
    also iPad3, iPad4, iPad Mini, Mac
  - No dongle needed!

EcoBN

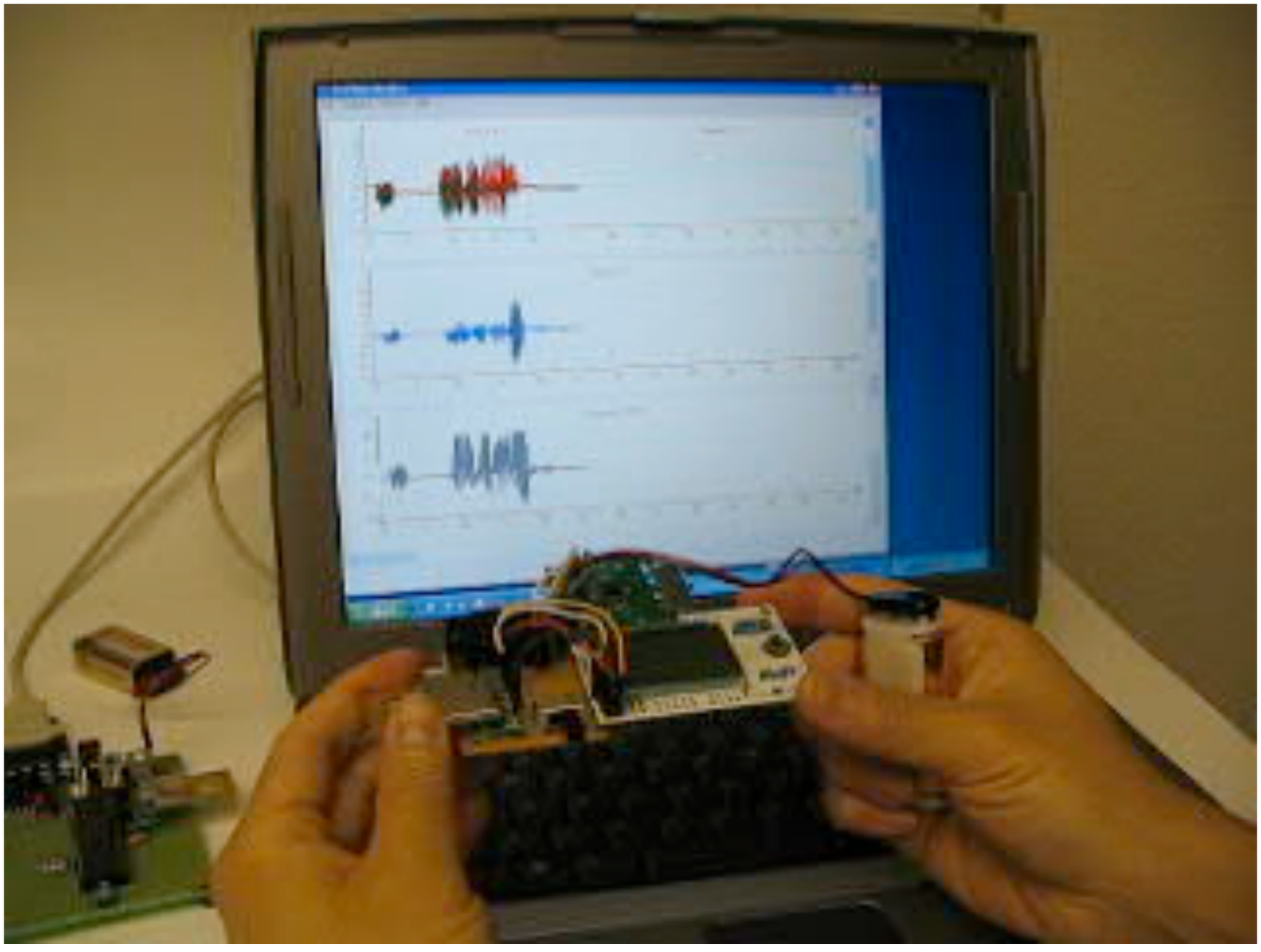
Year	2006	2007	2008	2009	2010	2011	2012	2013
Mini WSN	Eco	EcoKit	EcoSpire	 Charger, Gateway		EcoSD	EcoBT	 EcoBN

- Nordic nRF51822
- ARM Cortex M0 core
- BLE slave stack
- same features as EcoBT



Demo

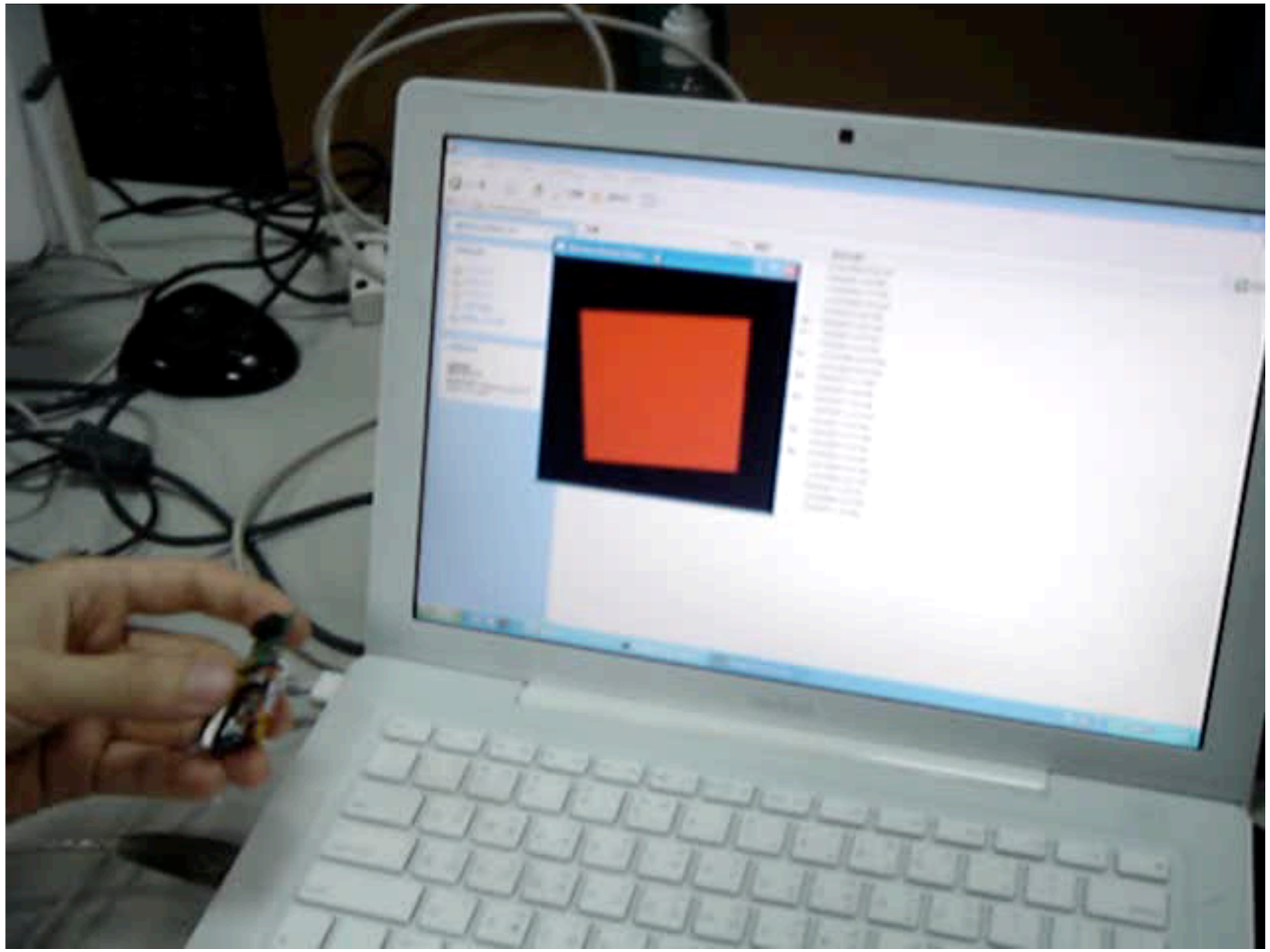
Accelerometer - time history (2005)



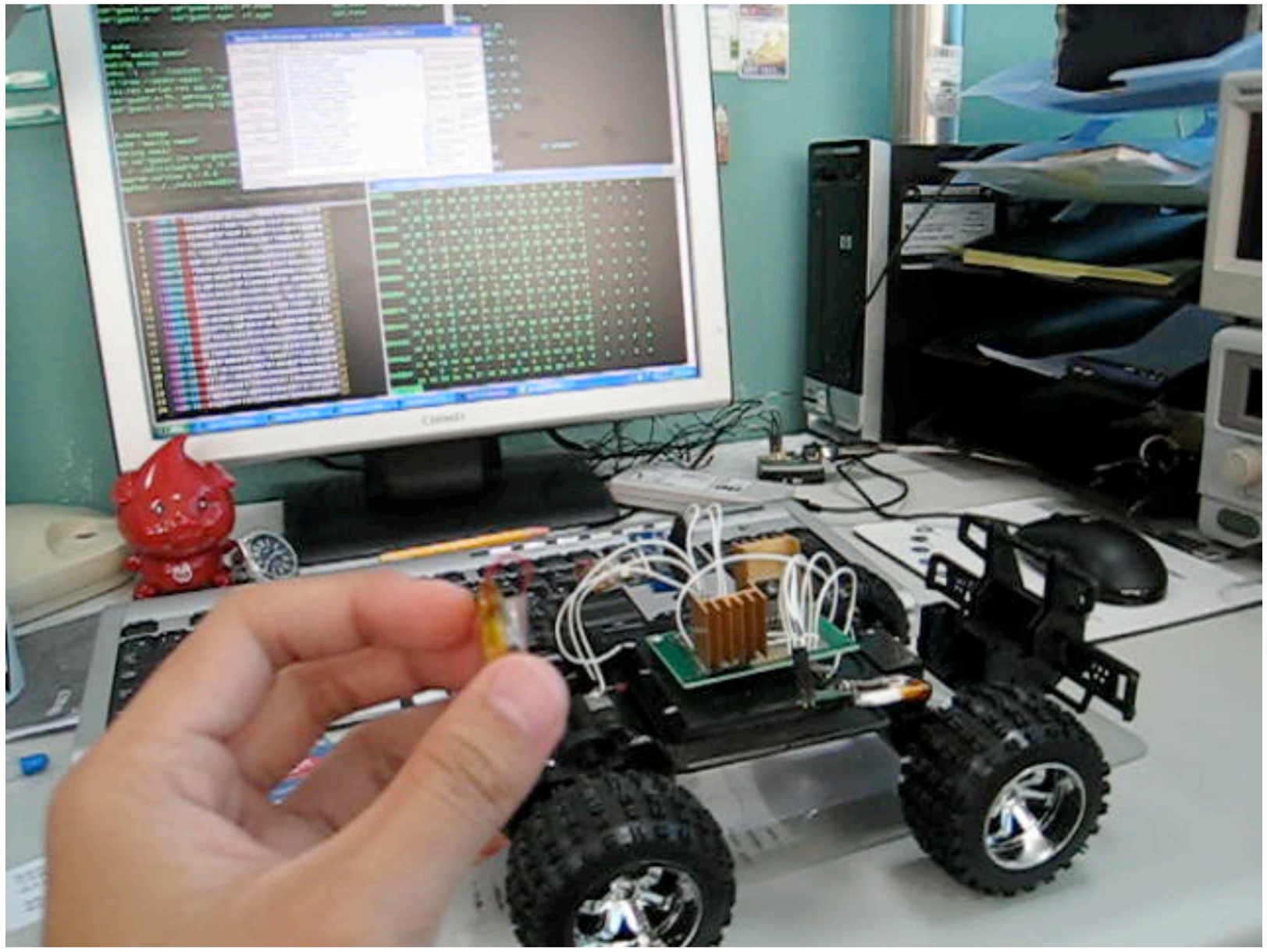
Infant Monitoring (2010)

http://infantmovementdiagnostics.com/

Accelerometer as Tilt Sensor

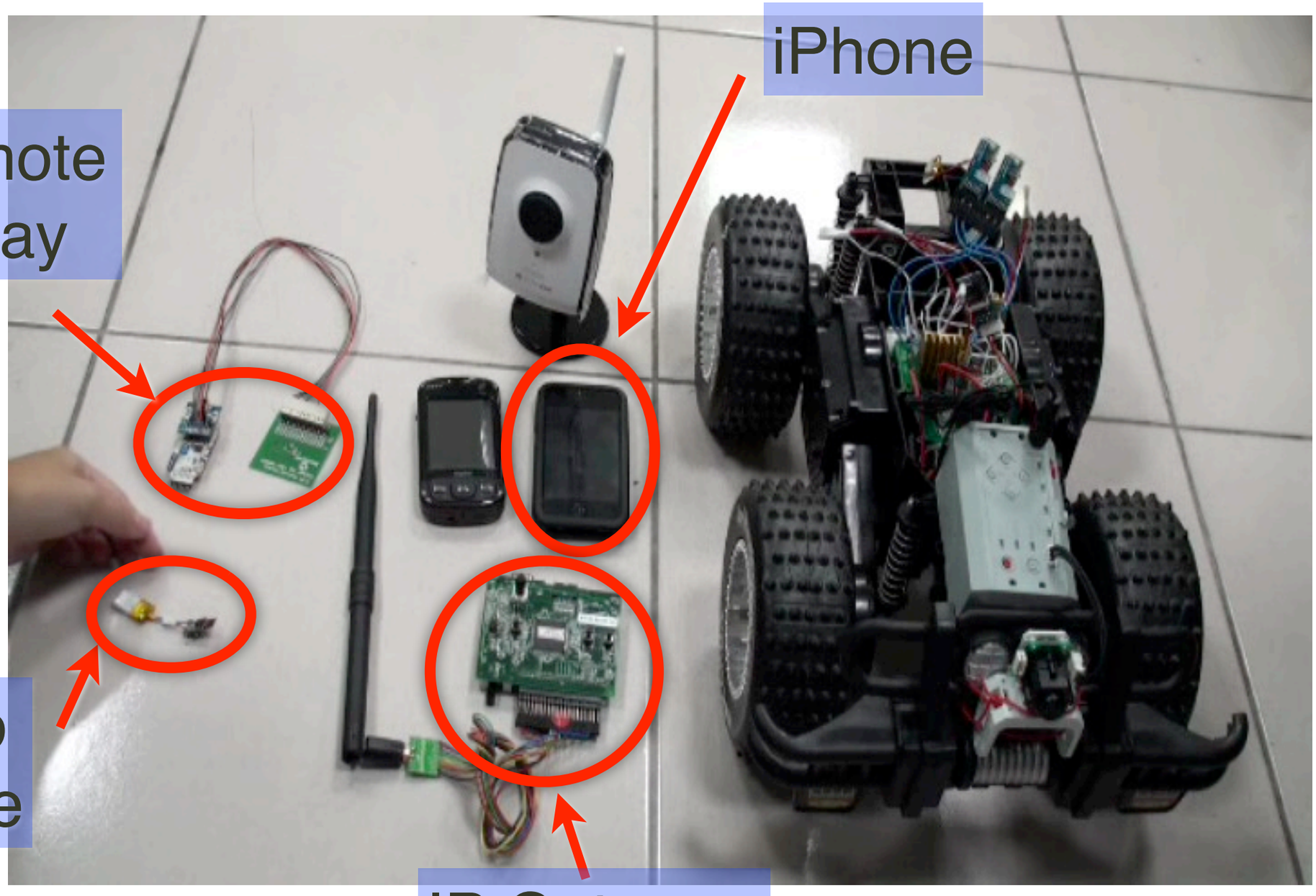


Tilt sensing for remote control

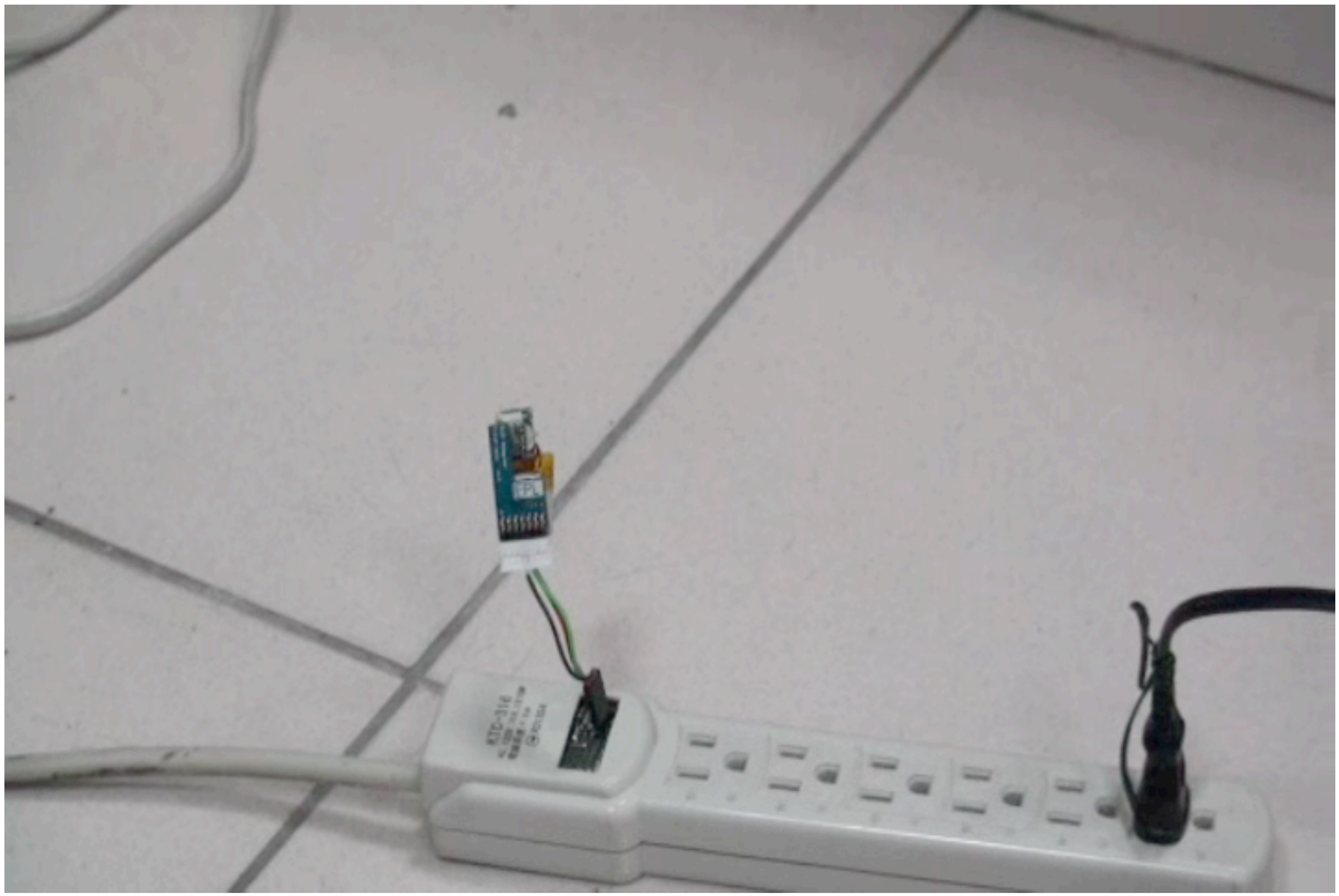


Flick-based Input

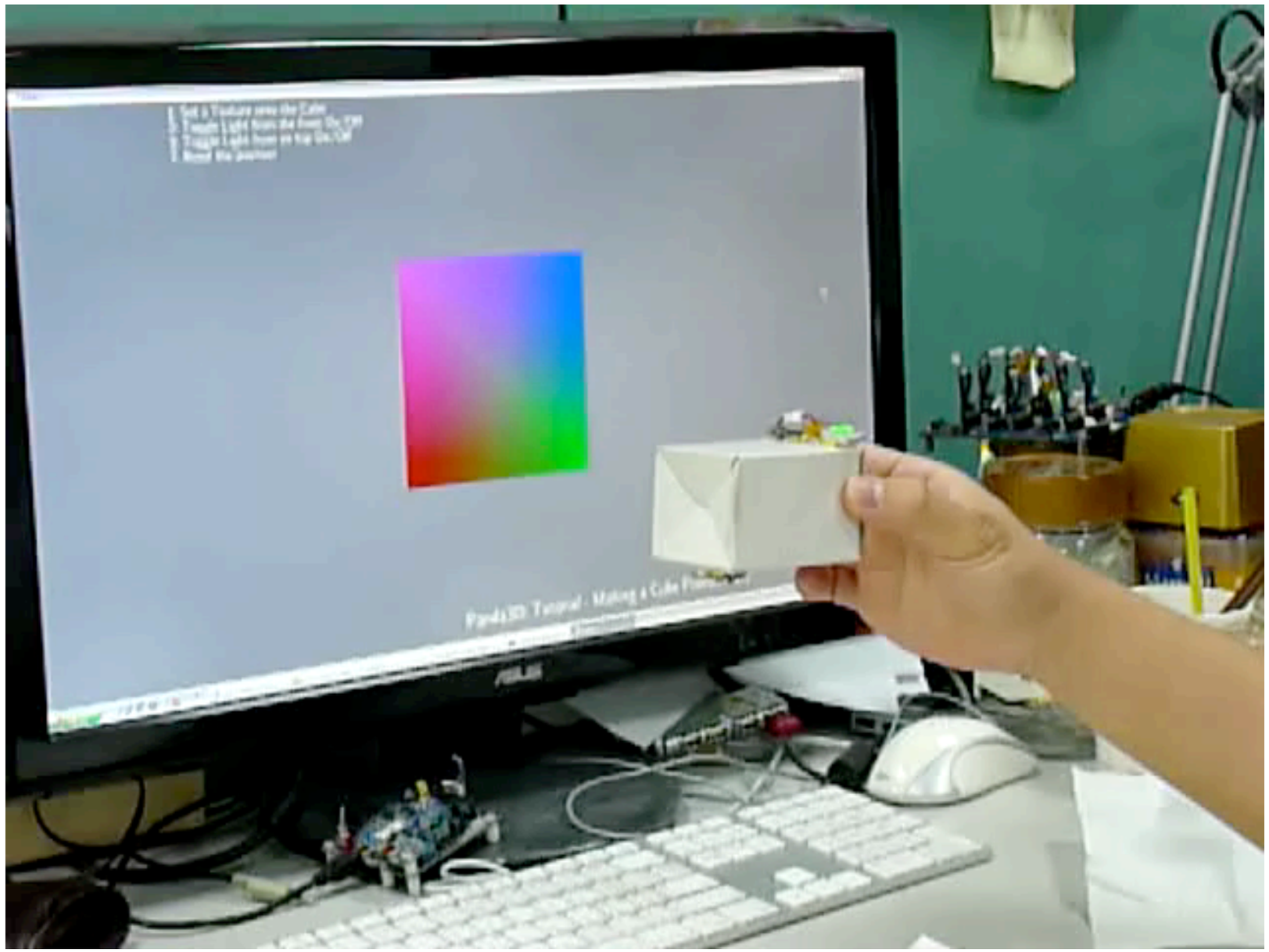
Functional Prototype



Home control on smart phone



Eco-IMU: rotation & displacement

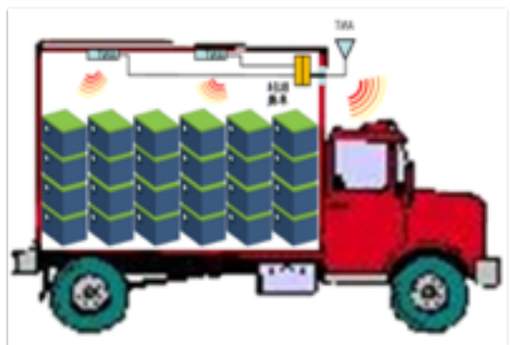


"Data Grabber"

Other projects by our lab

- Smart container
  - Monitors internal temperature of insulating shipping container
  - Alerts driver on smartphone in case of abnormal temperature
- Smart medicine cabinet
  - Scans barcode
  - lights up grid of selected medicine
- Smart Lighting Control
- EcoCast interactive execution system

Smart Container



- Thermally insulating shipping contain
  - Target market: cold-chain logistics
    - Cold pack to maintain temperature (saves fuel)
- Monitors interior temperature of container
  - Notifies deliverer in case of abnormal temperature
  - RF via BLE to user smartmobile

Course Format

- May post lecture recording online
  - View recordings before coming to class
  - View as many times as needed, at your own convenience
- Class attendance is required
  - Class time for two-way interactions
  - Demo, Q&A, discussion, ...
- Online discussion forums

Assignments

- Coding and interfacing exercises
  - C and assembly, about one per week
  - Done by individuals
- Project at the end of the quarter
  - Starts mid-semester
  - Done in small groups
  - Most likely BLE devices

Action item

- Download EdSim
- Download and install SDCC
- Start thinking about project ideas
- Get Textbook and start reading