Embedded Software Development:

Spottbillige Hardware + OSS =

Zum Spielen zu Schade!

Gregor Hohpe

www.eaipatterns.com
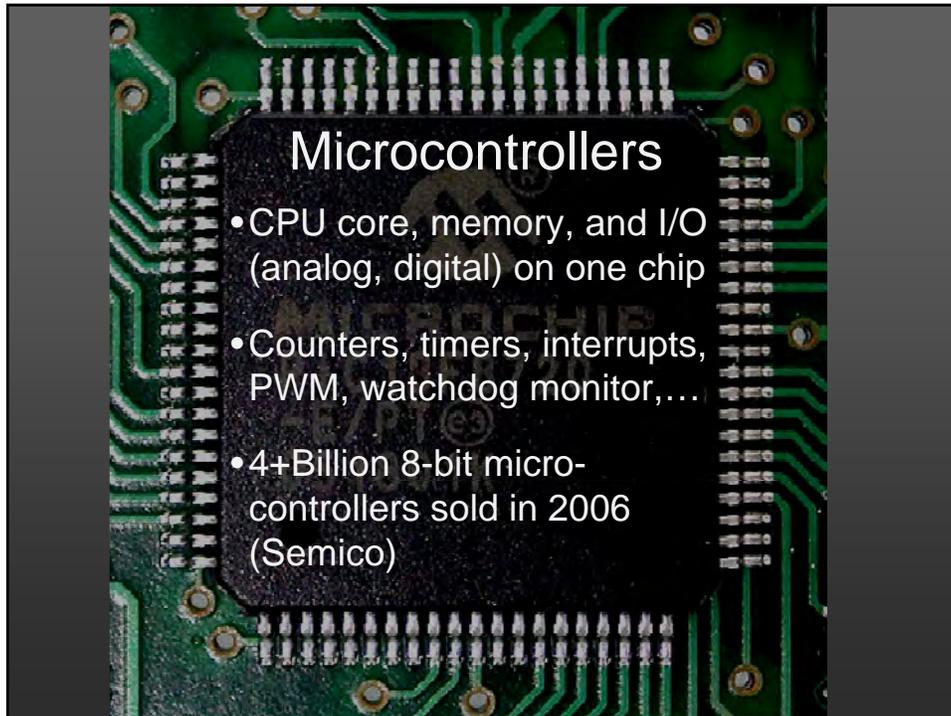
Microcontrollers
- CPU core, memory, and I/O (analog, digital) on one chip
- Counters, timers, interrupts, PWM, watchdog monitor,…
- 4+Billion 8-bit micro-controllers sold in 2006 (Semico)

This is nothing new!

We had this in the 80ies!

Yes, we did!

Intel 8048 (1977)
- 8-bit timers, 27 I/O ports, RAM (64 Bytes), EPROM
- IBM Keyboard

Intel P8051 (1980)
- 16-bit Timers, UART, I/O, RAM, register banks

NEC uPD7810 (198x)
- Timers, UART, 44 I/O, A/D, RAM
- Games, printers

What Is Different Now, Then?

- FLASH, EEPROM – iterative development
- Memory capacity – programming model
- Price – $1 gets you started
- Open Source – sharing and reuse
- USB – integrate with PC and Phone
- Mobile phones – computing power on the go
- Make Magazine – mainstream audience
- Community – particularly non-engineers

Hardware is Art and Freedom of Expression

http://www.instructables.com/id/LED-Throwies/

http://www.adafruit.com

Wearables

Do This at Home!

- 32KB Flash, 2 KB RAM, 1KB EEPROM   **$2**
- Up to 20 MIPS
- Counters, A/D converters, Parallel & Serial I/O, PWM, BOD

- Libraries, GCC targets   **$0**
- Programming and debug tools

- Turning hardware problems into software problems   **Priceless**

Chose Your Weapon - Arduino $25

- **Plug and Play – USB Bootloader**
- **Open source**
  - **Hardware: Creative Commons Attribution**
  - **IDE GPL, firmware LGPL**
- **IDE w/ C-like language**
- **Vast collection of "shields", e.g. USB, Ethernet**
- **Countless clones and variations: Uno, Mega, NetDuino, …**
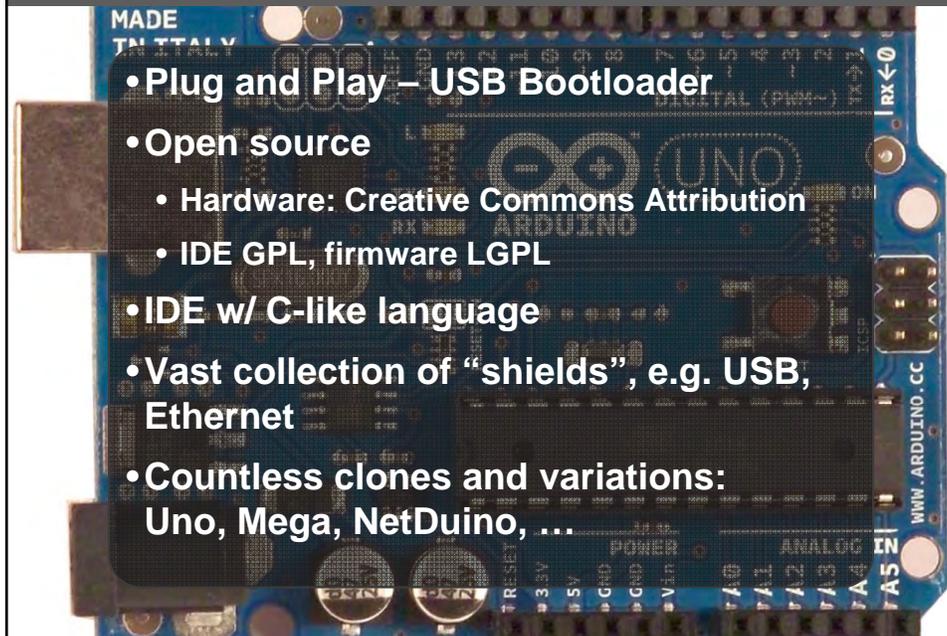
Chose Your Weapon – Bare Bones $1

Atmel AVR ATMEGA, ATTINY

- Cheap: $1-$3. Up to 20 MIPS.
- Open source tool chain: AVR-gcc, WINAVR
- Requires programmer. Can be built w/ AVR: e.g., HIDSPX
- Atmel AVR Studio live debugging
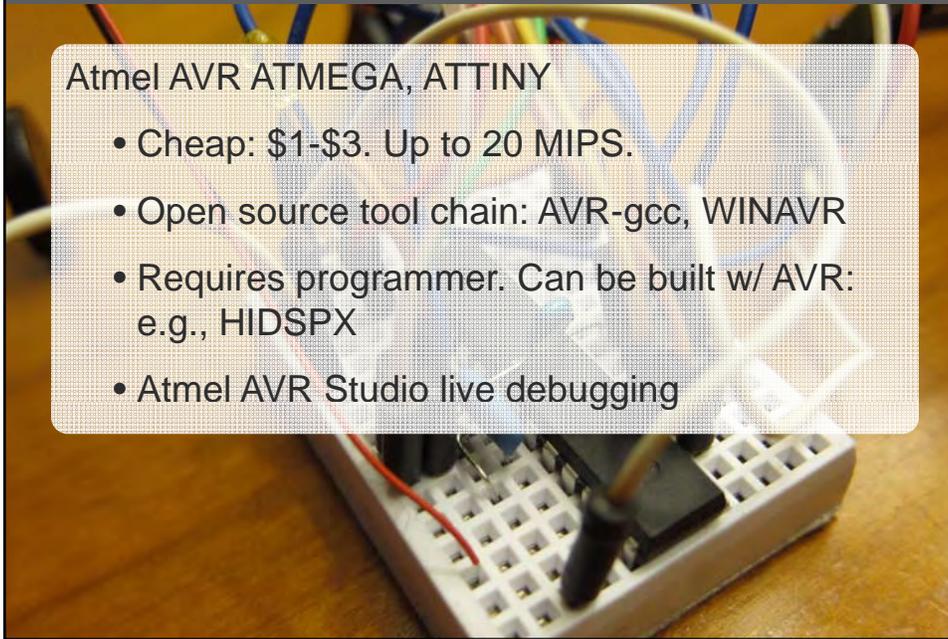
Variation – Almost Bare Bones $15

Teensy: AVR w/ Built-in USB

- Cheap: $3 for chip, $15 for board
- USB boot loader, no programmer needed
- AVR-gcc or Teensyduino sketch
- Board not open hardware
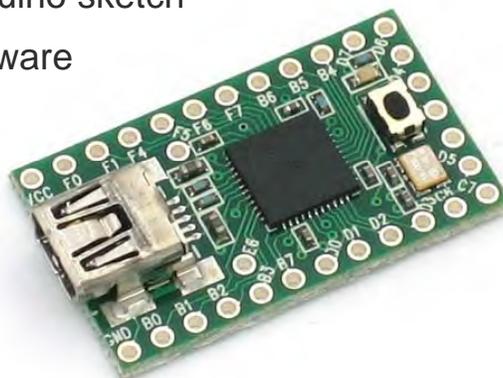
Chose Your Weapon – ARM Power $59

mbed

- mbed.org, supported by ARM

- NXP Cortex-M0 running @ 96MHz,
  512KB FLASH, 32KB RAM

- Cloud-based compiler, C/C++

- Proprietary boot loader
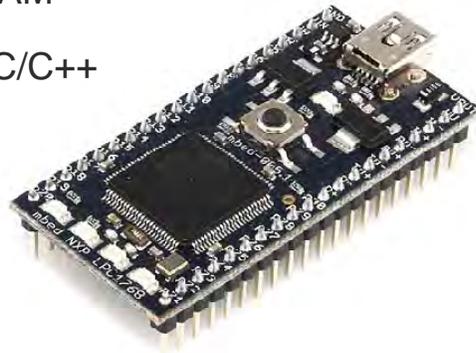
Chose Your Weapon – UNIX $89

Beagle Bone

- Texas Instruments, based on ARM

- ARM Cortex A8, 720MHz, 256MB RAM, Ethernet

- Enough power for image processing

- Angstrom Distribution w/ OpenEmbedded

- CC share-alike

- node.js
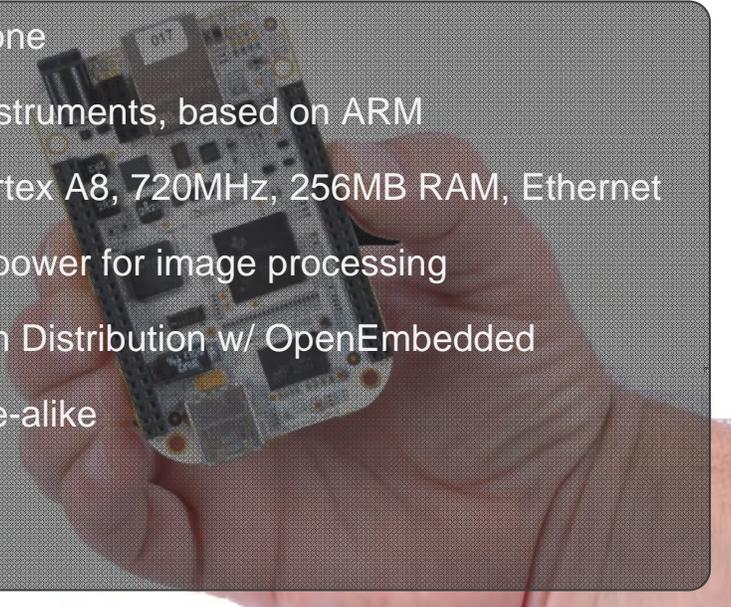
Embedded Development Cycle

- Firmware Development

- Debugging / Testing

- Circuit Design

- Prototyping

- PCB Design

- Manufacturing

Firmware Development

```
68   uint8_t i2c_receive(bool ack) {
69       if (ack)
70         TWCR = _BV(TWINT) | _BV(TWEN) | _BV(TWEA);
71       else
72         TWCR = _BV(TWINT) | _BV(TWEN);
73       i2c_wait();
74       return TWDR;
75   }
76
77   void max_write_register(uint8_t reg, uint16_t value) {
78       PINB = _BV(ACTV_LED);
79       i2c_start();
80       i2c_send(I2C_ADDR);
81       i2c_send(reg);
82       i2c_send(value >> 8);
83       i2c_send(value & 0xFF);
84       i2c_stop();
85       PINB = _BV(ACTV_LED);
```

Firmware Development

- Limited stack space – in place manipulation

- Event loops

- Short interrupts – timing constraints

- Beware of printf and floating point (on 8 bit)

- Massive manuals for I/O registers
  (550 pages for ATMEGA328)

- Power considerations
  - No busy loops
 - Peripheral usage

Libraries

- LCD Drivers (common controller chips)

- Encryption, e.g AES-128

- SD Card reader, FAT support

- I²C / TWI

- …

Debugging & Testing Techniques

- LED On / Off

- LCD (Many Drivers)

- Serial to USB+ http://www.aitendo.co.jp/product/2890

- JTAG Live Debugging (e.g., AVR Studio / Dragon)
  - Hardware breakpoints
  - View and modify registers, i.e. I/O ports

Embedded TDD

The Pragmatic Programmers

Test-Driven Development for Embedded C

James W. Grenning

Edited by Jacquelyn Carter
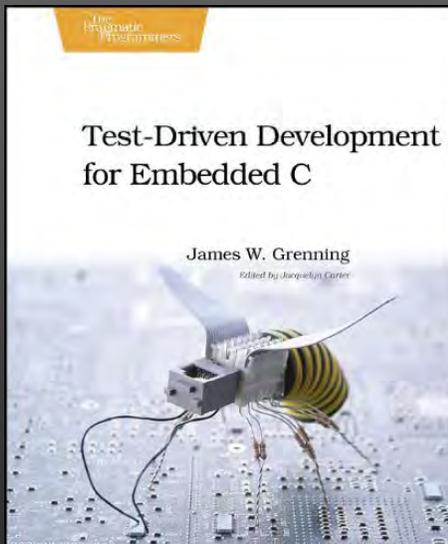
- Mock out hardware dependencies

- Compile and run on host system

On Chip Unit Testing

- Allows hardware interaction, incl. EEPROM
- Simple asserts, drive LCD
- Need to flash device for each run

Serial Debugging

Serial2USB:

SILCON LABS CP2102

FTDI FT232BL

...

Circuit Design – EAGLE CAD

- Light Edition: dual layer, 100x80mm.
  - Free for hobby (non-profit), $69 for professional use.

- Many component libraries, e.g. sparkfun.lbr

- Widely used by community
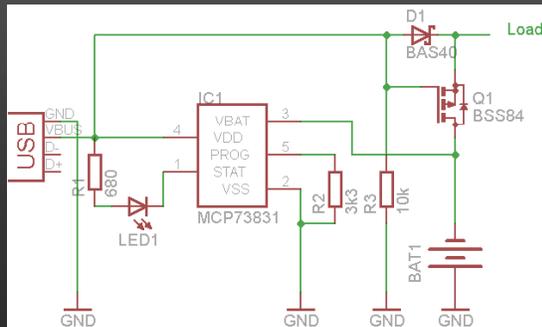
Prototyping - No Solder Solution

PCB Design - EAGLE

- Custom component layouts in libraries
- Auto router sometimes helpful, but mostly by hand
- Positioning mechanical parts / connectors
- Special parts: light pipes, threaded studs, etc
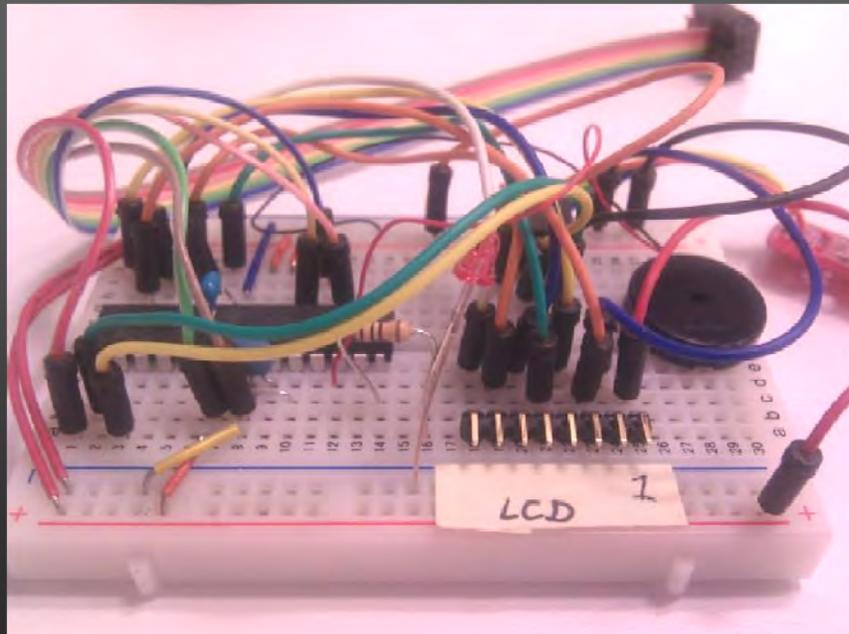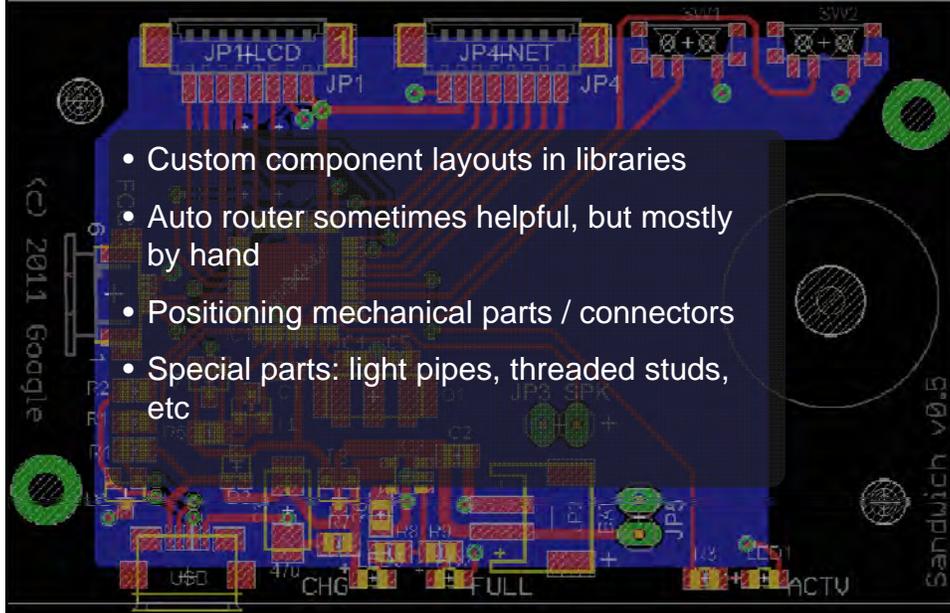
Manufacturing - Printed Circuit Boards

- Sparkfun BatchPCB
  $20 + $2.50 / sq. in.
- 4pcb.com
  $33/each (1+)
- P-ban (Japan)
  50 boards $270
- Leiton (Germany)
- PCB Pool (Germany)

1. Design schematic with EAGLE
2. Create board layout from schematic
3. Export as Gerber files
4. Upload to manufacturer   http://www.ladyada.net/library/pcb/costcalc.html

Embedded + Mobile: Android ADK

- Based on Arduino Mega 2560 + USB Host Shield (Circuits@Home)

- Connects to Android mobile device as USB Host

- Many clones, Creative Commons Attribution

Android SDK   Android Device   Arduino IDE

App

I/O

USB Host

USB Host

Firmware

Peripherals
LED, Switch, PWM, Servo, Sensor,…

Arduino ADK
(Arduino Mega 2560 + USB Host)

Android Open Accessory Development Kit
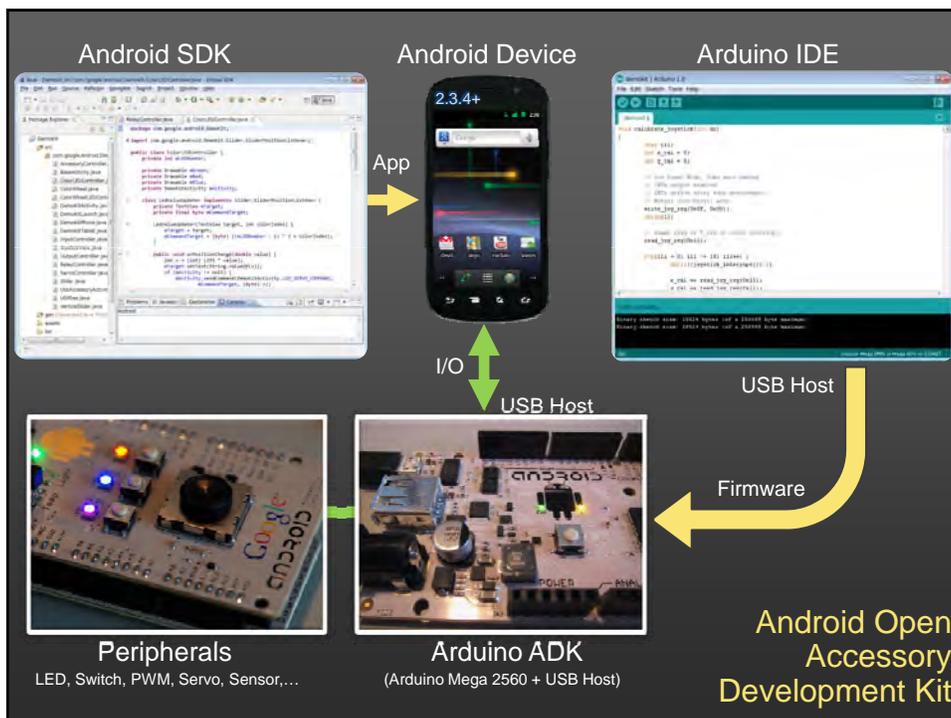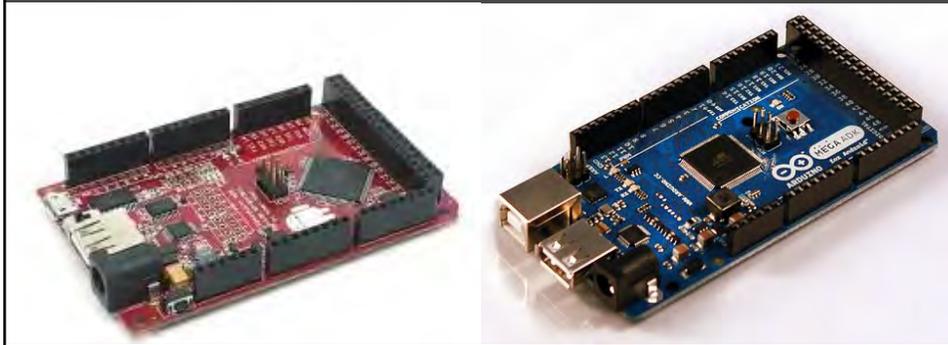
IOIO ("Yo-yo")

- Android 1.5 and up

- USB or Bluetooth to Android

- Microchip PIC Controller

- Hardware Creative Commons
  Attribution Share-Alike 3.0

- Firmware permissive with Attribution
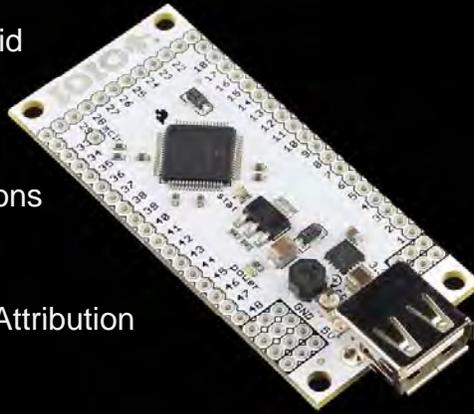
Glowing Orb
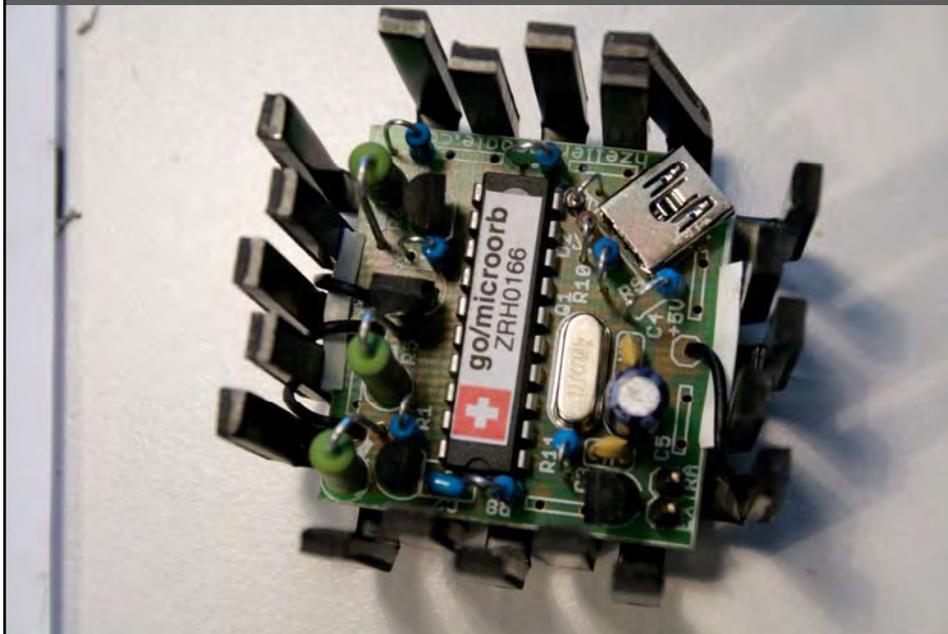
NFC Smart Tag

- AVR ATMEGA 328
- Connects to Sony NFC module via serial (USART)
- Li-Poly charger w/ power source switch
- Firmware USB emulation (V-USB)

NFC Handheld

Electronic Money Balance Reader

http://www.ask-embedded-world.de