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 microcontrollers 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/

Wearables

http://www.adafruit.com
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

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

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.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

- 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

```c
uint8_t i2c_receive(bool ack) {
    if (ack) {
        TWCR = _BV(TWINT) | _BV(TWEN) | _BV(TWEA);
    } else {
        TWCR = _BV(TWINT) | _BV(TWEN);
    }
    i2c_wait();
    return TWDR;
}

void max_write_register(uint8_t reg, uint16_t value) {
    PINB = _BV(Activ LED);
    i2c_start();
    i2c_send(I2C_ADDR);
    i2c_send(reg);
    i2c_send(value >> 8);
    i2c_send(value & 0xFF);
    i2c_stop();
    PINB = _BV(Activ 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](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

• 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:
- SILICON 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
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
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