

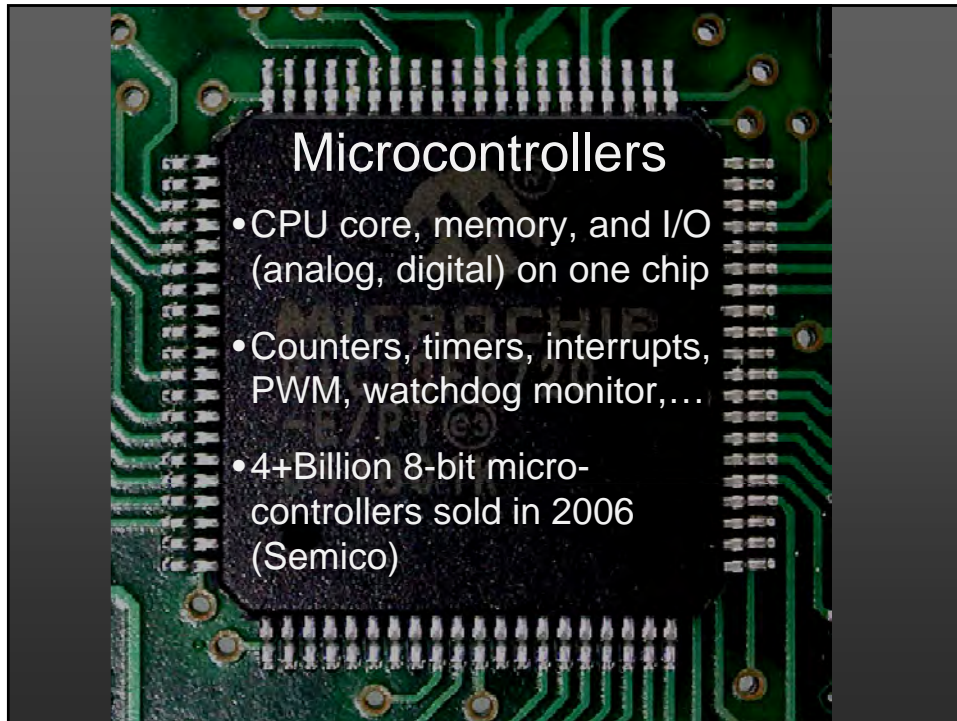
Embedded Software Development:

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



Do This at Home!

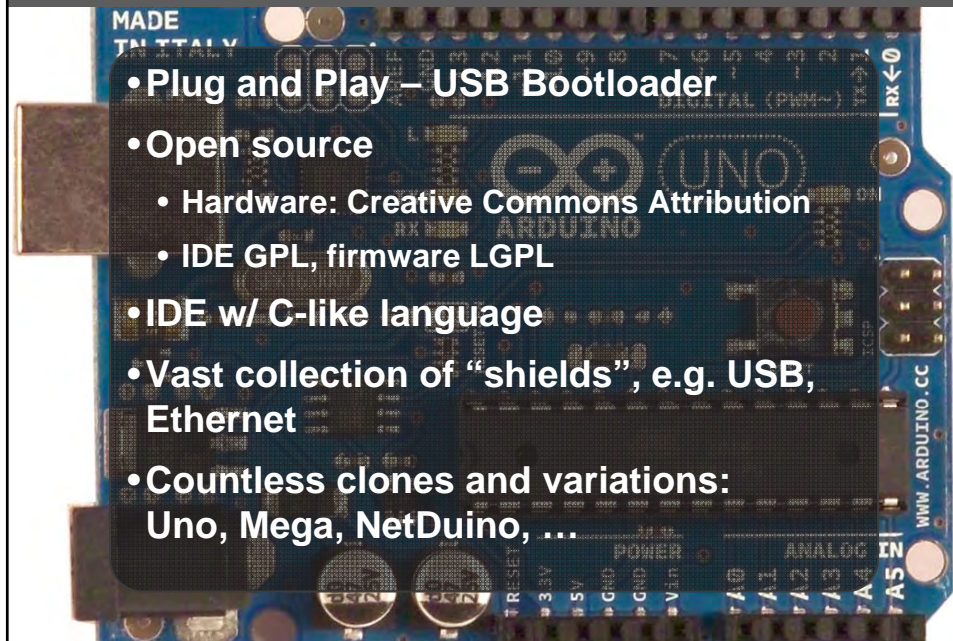
- 32KB Flash, 2 KB RAM, 1KB EEPROM **\$2**
- Up to 20 MIPS
- Counters, A/D converters, Parallel & Serial I/O, PWM, BOD

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

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

Chose Your Weapon - Arduino

\$25

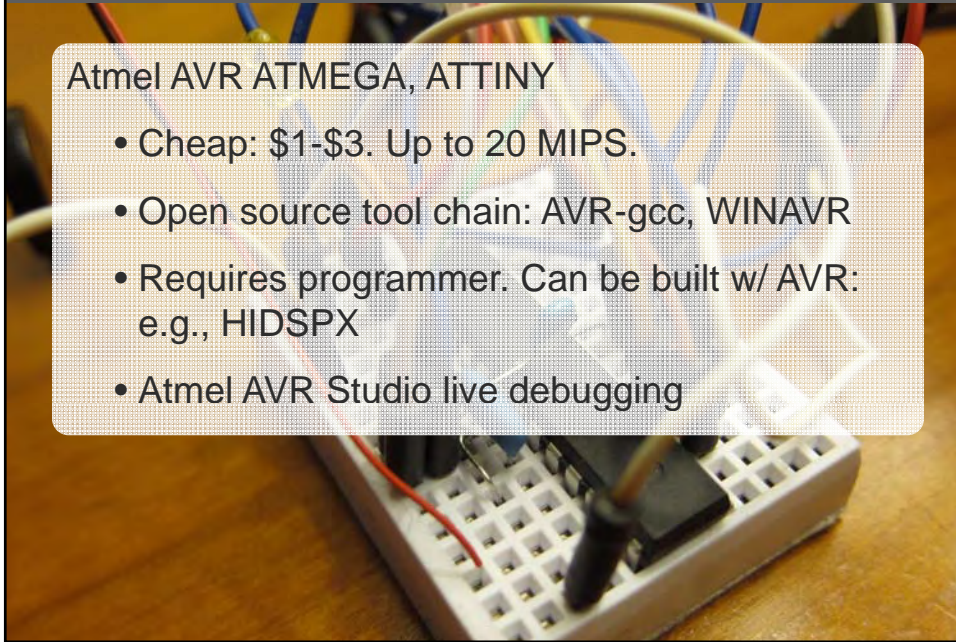


Chose Your Weapon – Bare Bones

\$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

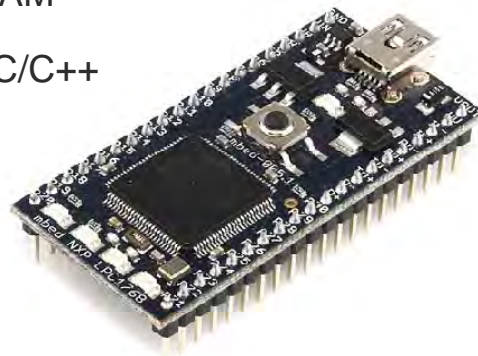


Chose Your Weapon – ARM Power

\$59

mbed

- mbed.org, supported by ARM
- NXP Cortex-M0 running @ 96MHz, 512KB FLASH, 32KB RAM
- Cloud-based compiler, C/C++
- Proprietary boot loader

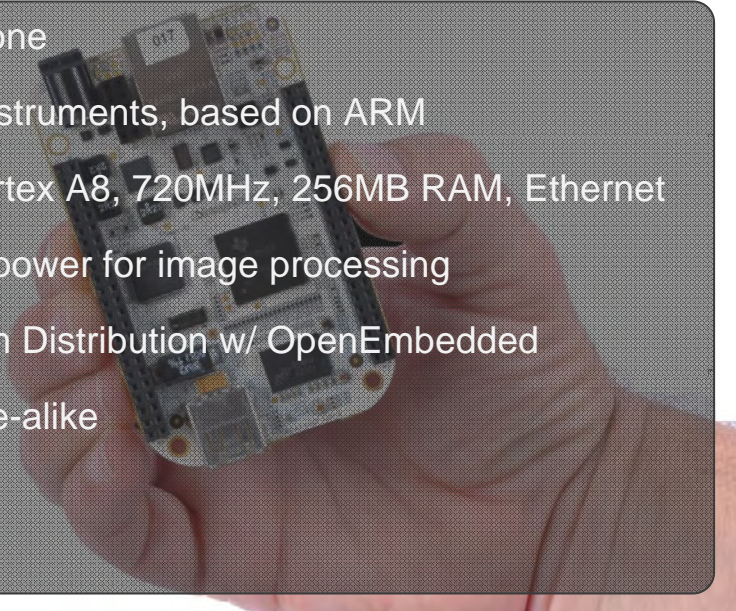


Chose Your Weapon – UNIX

\$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

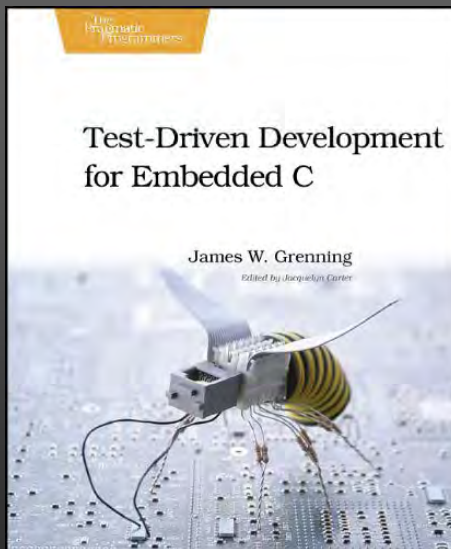
Libraries

- LCD Drivers (common controller chips)
- Encryption, e.g AES-128
- SD Card reader, FAT support
- I²C / TWI
- ...

Debugging & Testing Techniques

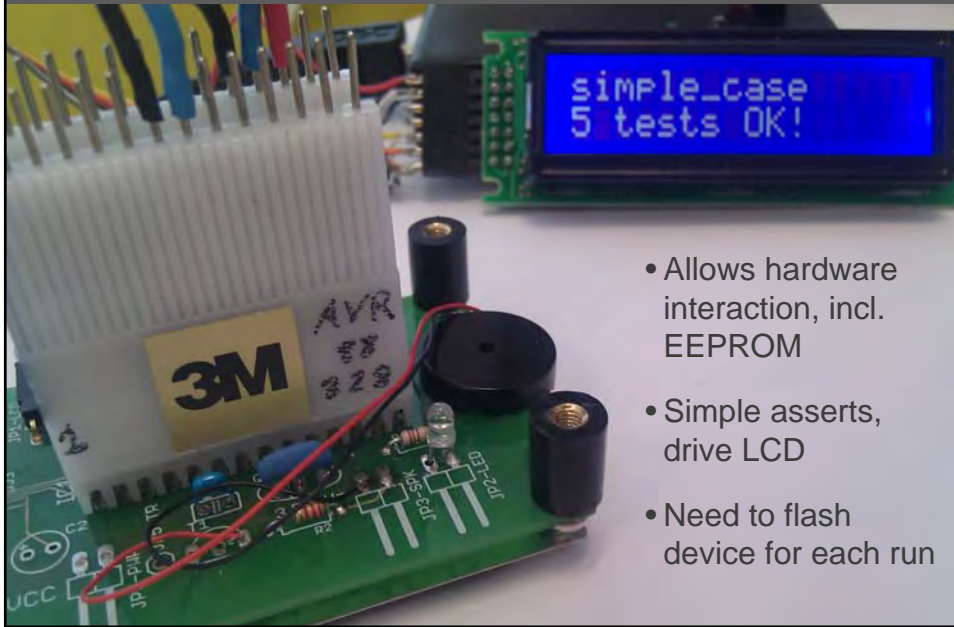
- LED On / Off
- LCD (Many Drivers)
- Serial to USB+ <http://www.aitendo.co.jp/product/2890>
- JTAG Live Debugging (e.g., AVR Studio / Dragon)
 - Hardware breakpoints
 - View and modify registers, i.e. I/O ports

Embedded TDD



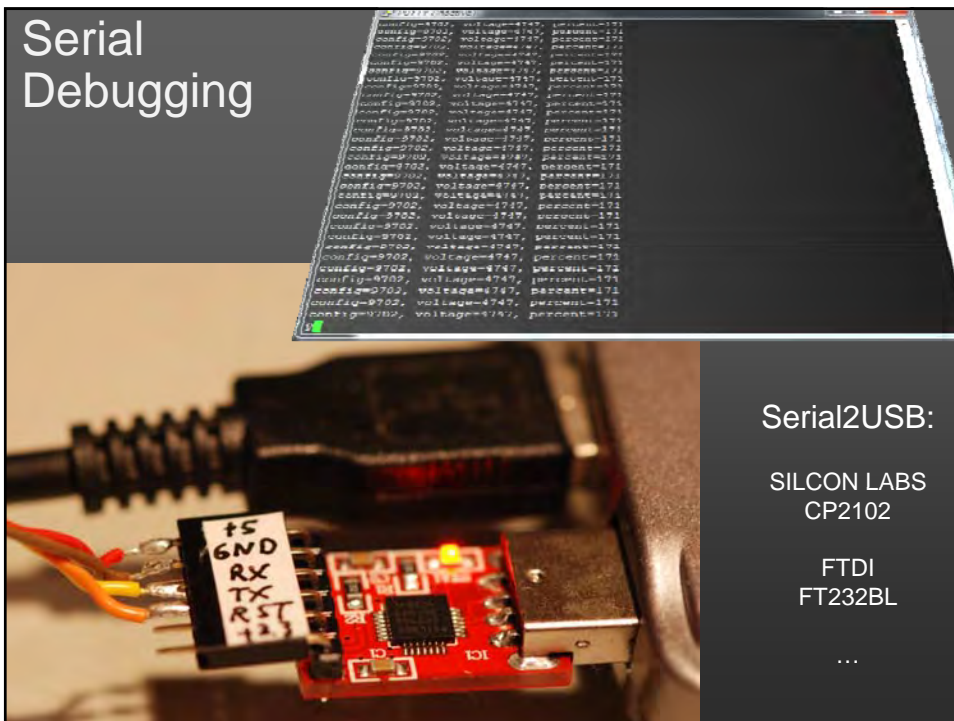
- Mock out hardware dependencies
- Compile and run on host system

On Chip Unit Testing



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

Serial Debugging



Serial2USB:

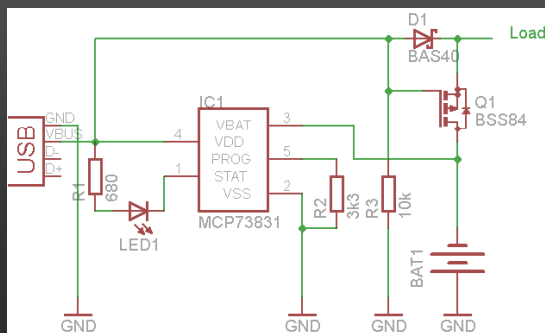
SILICON LABS
CP2102

FTDI
FT232BL

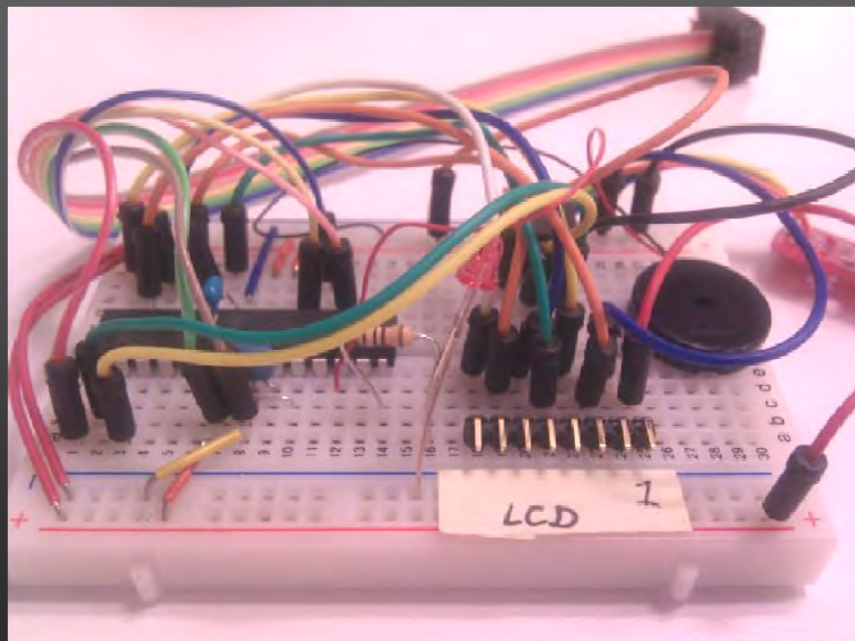
...

Circuit Design – EAGLE CAD

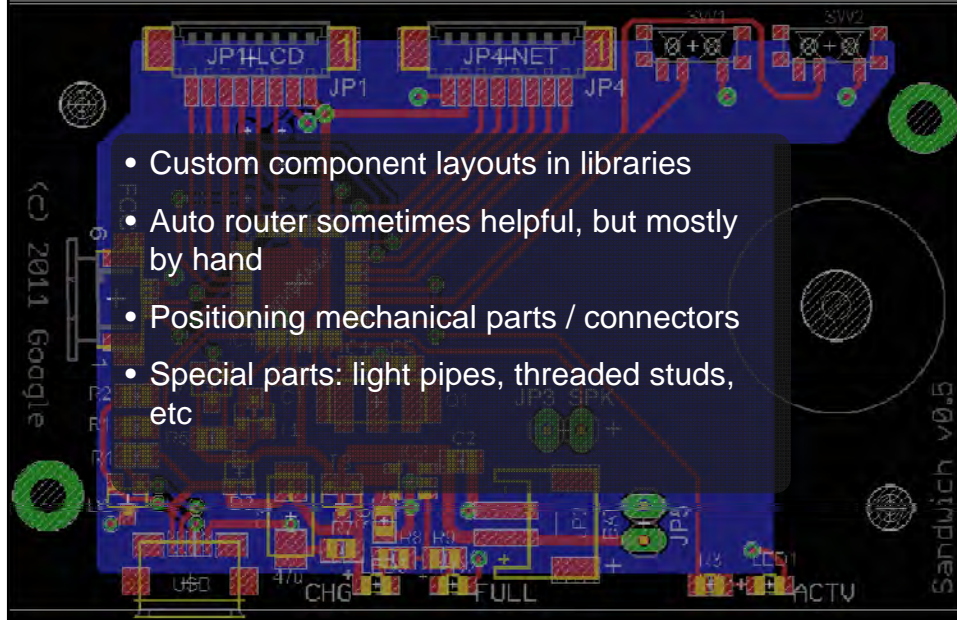
- Light Edition: dual layer, 100x80mm.
 - Free for hobby (non-profit), \$69 for professional use.
- Many component libraries, e.g. sparkfun.lbr
- Widely used by community



Prototyping - No Solder Solution



PCB Design - EAGLE



The screenshot shows a detailed PCB layout in EAGLE. The board is blue with red traces and various components. Labels include JP1HLCD, JP4NET, JP1, JP4, JP3, JP2, JP4, CHG, FULL, ACTV, and SANDWICH v0.5. A semi-transparent text box is overlaid on the center of the board.

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

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Manufacturing - Printed Circuit Boards

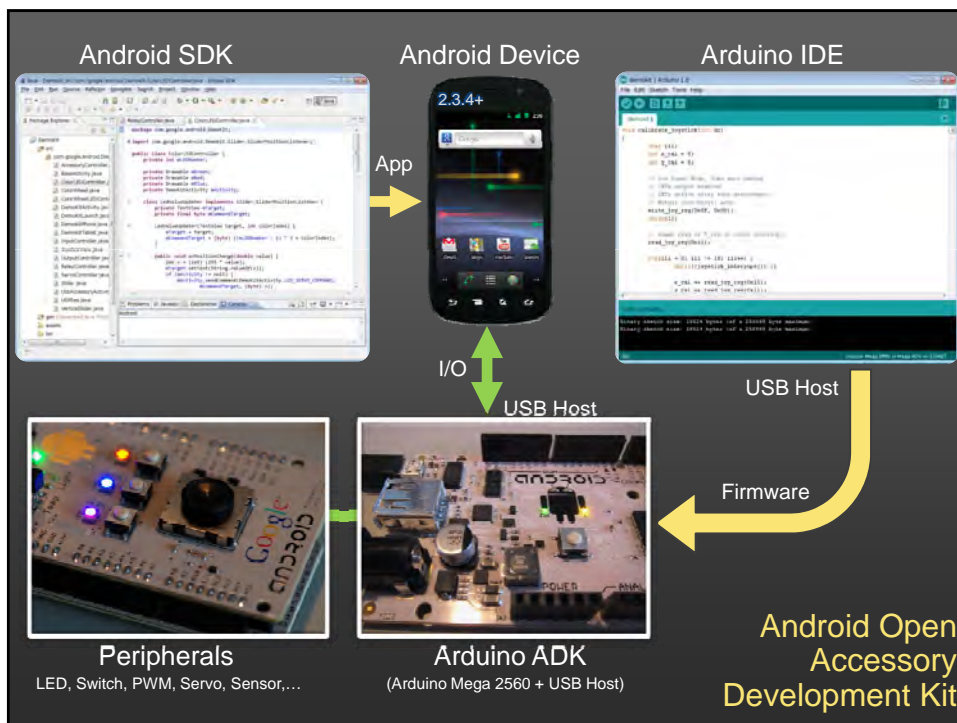
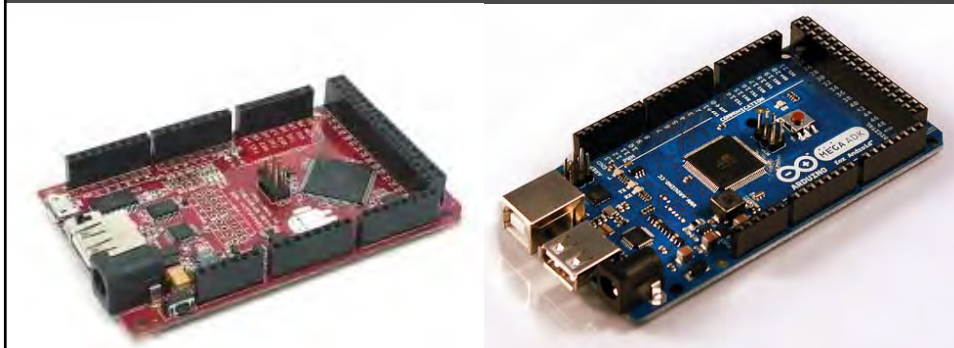


- Sparkfun BatchPCB
\$20 + \$2.50 / sq. in.
- 4pcb.com
\$33/each (1+)
- P-ban (Japan)
50 boards \$270
- Leiton (Germany)
- PCB Pool (Germany)

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>

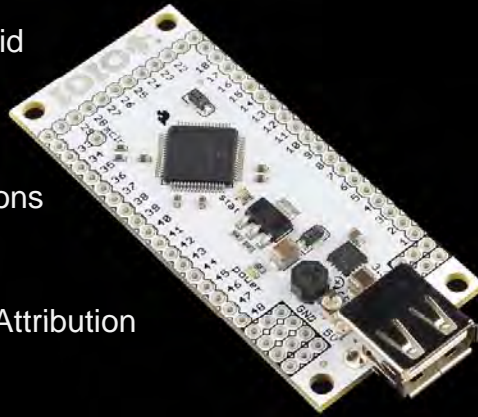
Embedded + Mobile: Android ADK

- Based on Arduino Mega 2560 + USB Host Shield (Circuits@Home)
- Connects to Android mobile device as USB Host
- Many clones, Creative Commons Attribution

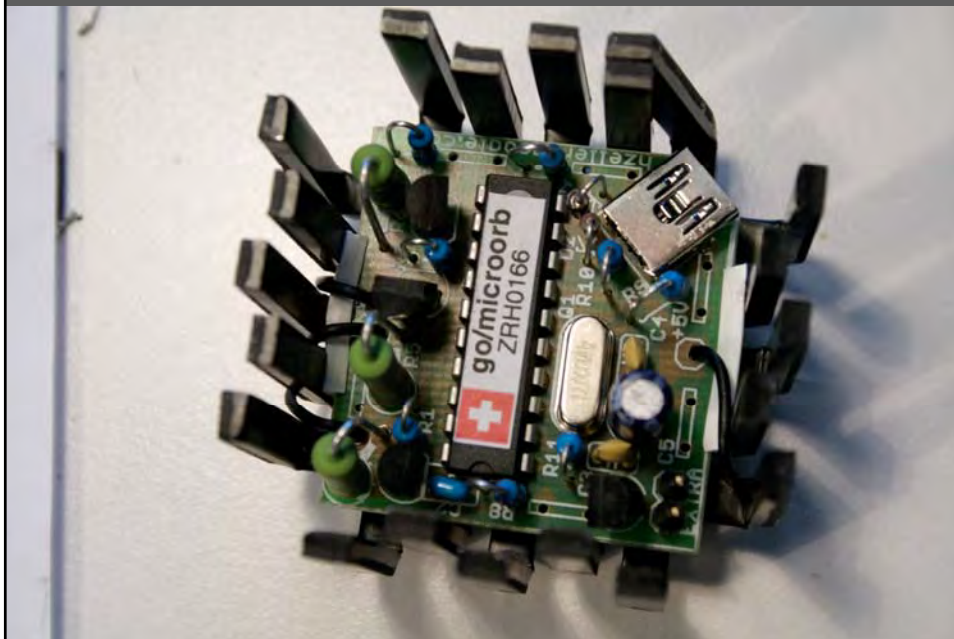


IOIO (“Yo-yo”)

- 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>