# Arbeitskreis Hardware

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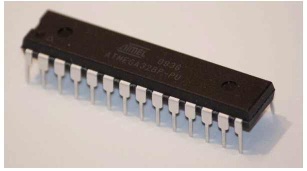
# Organization

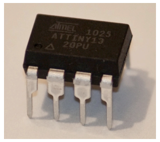
- **Objective:** Learn about embedded interactive systems
  - Just for fun, **no ECTS credits!**
- **Date:** Mondays 18-20+
  - 18-19 presentation and discussion of new topic
  - 19-20+ work on topic / project
- Schedule overview
  - 11 sessions
  - No class May 9th (CHI) and June 13th (Pfingsten)
- Hardware components provided
  - Buy AVR programmer (15 EUR) and power supply (7 EUR)

# Schedule (preliminary)

| Date | Topic (preliminary) |
|---|---|
| 2.5. | Introduction to embedded interaction, microcontrollers, hardware & software tools |
| 9.5. | *keine Veranstaltung (CHI)* |
| 16.5. | AVR architecture, AVR assembler, LED multiplexing/charlieplexing |
| 23.5. | Sensors: light, force, temperature, humidity, capacity, inductivity, distance, acceleration |
| 30.5. | Electronics basics, soldering, PCB design & fabrication, EAGLE, 3D printing |
| 6.6. | Displays (character LCDs, graphics LCDs), audio (speakers, amplification, op-amps) |
| 13.6. | *keine Veranstaltung (Pfingsten)* |
| 20.6. | I2C: interfacing to other chips (EEPROM, real-time clock, digital sensors) |
| 27.6. | Actuation: stepper motors, servo motors |
| 4.7. | Communication: fixed-frequency RF, ZigBee, Bluetooth |
| 11.7. | Project |
| 18.7. | Project |
| 25.7. | Project |

# Technologies and Tools

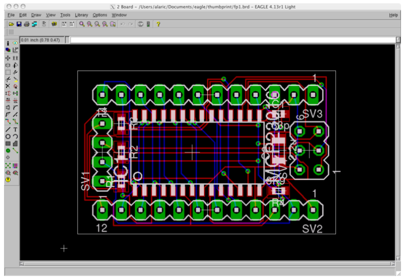




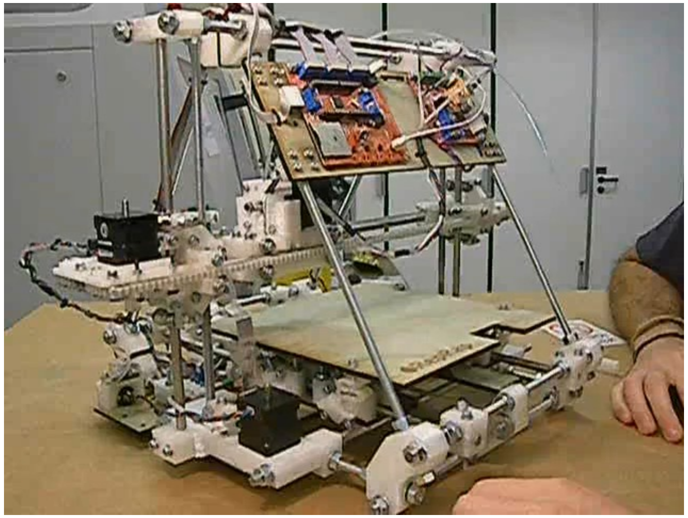
ATtiny, Atmega microcontroller

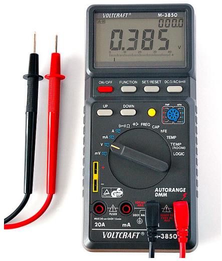

**Milling, drilling, cutting PCB:** Roland Modela

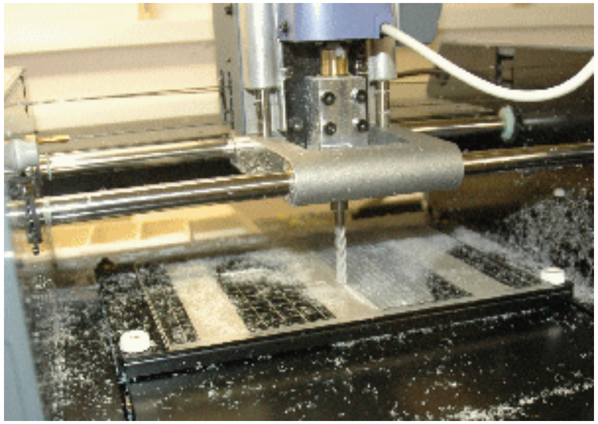
**PCB Design:** EAGLE



**Printing casings:** RepRap 3D printer







www.rolanddg.com/product/3d/3d/mdx-20_15/mdx-20_15.html

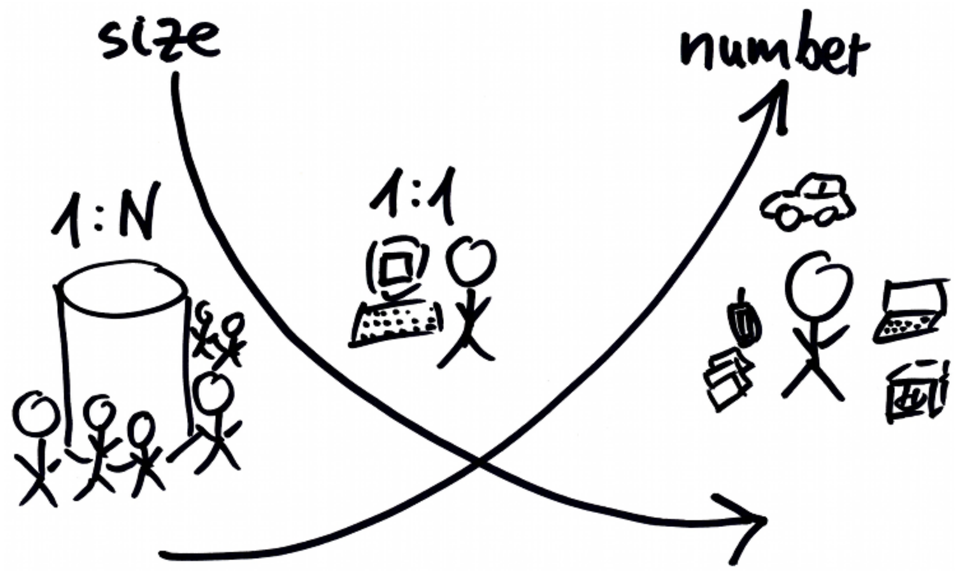
en.wikipedia.org/wiki/RepRap
www.reprap.org/wiki/Mendel

# Embedded Systems

- Computer systems with dedicated functionality
  - Cf. general-purpose computer (PC)
  - Microcontrollers, digital signal processors, sensors, actuators
- Often not perceived as a “computer”
  - Users may not know that a computer system is inside
- Examples
  - Wrist watches, mp3 players, digital cameras, GPS receivers, bike computers, heart rate monitors, cars (motor, ABS, ESP), traffic lights, microwave ovens, dishwashers, washing machines, door openers, weather stations, TV sets, remote controls, DVD players, factory automation systems, telephone switches, networked thermostats, implantable medical devices, toys

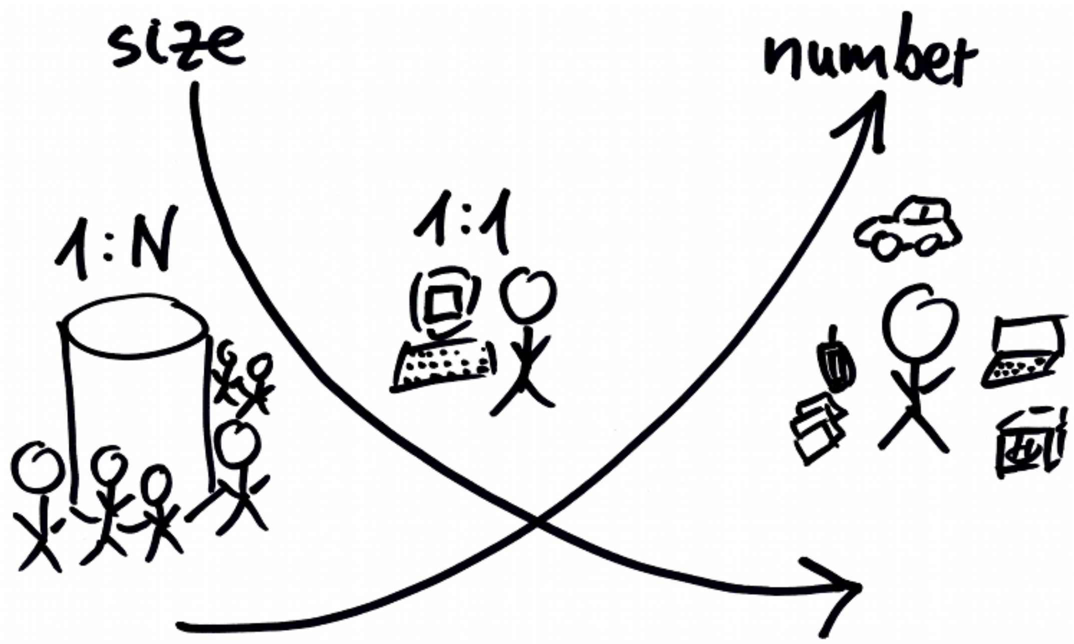
# Technological Enablers

- Processing & storage
  - Cheap, fast, reliable, small, large capacity, energy efficient
  - Moore's Law
- Networking
  - Cheap, fast, reliable, global, local, wireless, ad-hoc, low power
- Displays
  - Cheap, small, high quality, energy efficient, integrated
- Sensors & actuators
  - Cheap, small, accurate, invisible, many types



# Computing Paradigms

*"Ubiquitous computing names the third wave in computing, just now beginning. First were mainframes, each shared by lots of people. Now we are in the personal computing era, person and machine staring uneasily at each other across the desktop. Next comes ubiquitous computing, or the age of calm technology, when technology recedes into the background of our lives."* Mark Weiser



# Vision of Ubiquitous Computing

Mark Weiser

- *"The most profound technologies are those that disappear. They weave themselves into the fabric of every day life, until they are indistinguishable from it."* (Mark Weiser)
- Vision
  - Computers embedded in everyday things
  - Seamless integration into our environment
  - All components are connected and exchange information
- Ubiquitous computing vs. virtual environments
  - Computers in the world, instead of world in the computer
- Calm Technology
  - Technology moves into the background

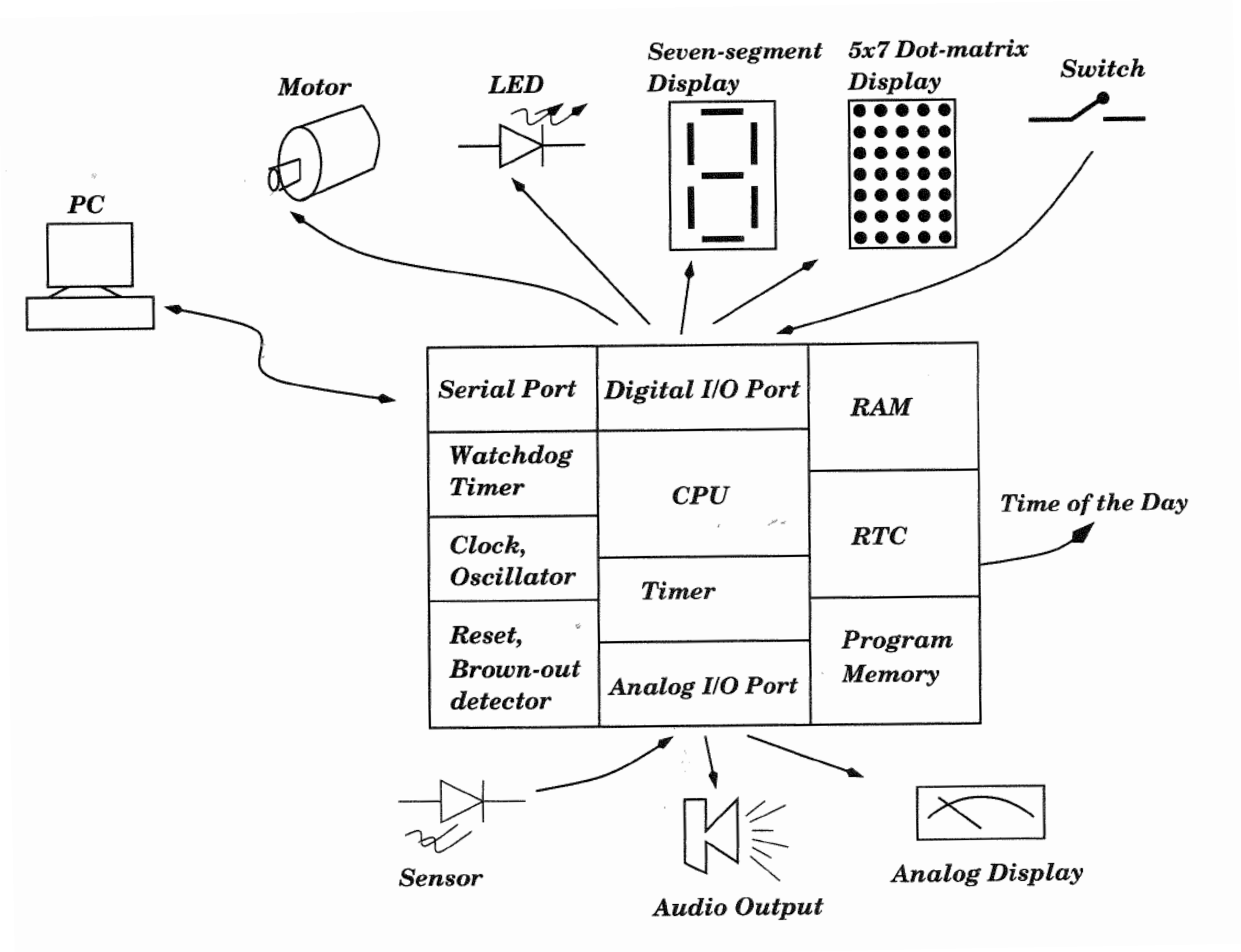
# Embedded & Tangible Interaction

- Challenges for human-computer interaction
  - How to interact with so many systems?
  - How to keep users from constant interruptions and distractions?
  - Device interaction happens in an everyday situation. How to take that into account?
  - What are novel forms of interaction?
  - Design opportunities?
- Interaction themes
  - Natural interfaces
  - Context-aware applications
  - Automatic capture and access
  - Continuous interaction

# Microcontrollers

- Integrates processor, memory, I/O peripherals, and sensors on a single chip
  - Replaces many traditional hardware components in a single chip
  - Lower cost, fewer additional components, smaller circuit board
  - Very memory efficient (sleep modes)
  - Software flexibility through software
- Memory types
  - Flash: program
  - RAM: working memory (stack, heap)
  - EEPROM: non-volatile memory
- Interrupt-driven I/O
  - Sources: signal changes, timer overflow, ADC conversion done
  - Interrupts can wake microcontroller from low-power sleep state

# Microcontrollers



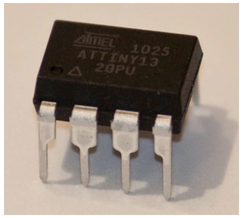

Source: Gadre, Malhotra: tinyAVR projects

# Microcontrollers

- I/O Pins
  - Used as input or output (controlled by software)
  - Serial communications (UART, $I^2C$, SPI)
  - Signal generation (PWM, timers)
  - Analog input (ADC conversion)
- Development
  - In-circuit programming and debugging, field update of firmware
  - Programming in assembly language or C
- Selectable clock frequencies
  - Lower clock rate → less energy
- No floating point unit (typically)

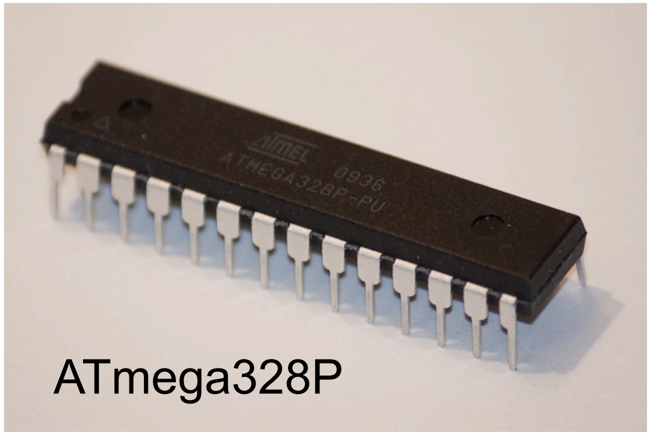
# Atmel AVR: ATtiny, ATmega

- 8-bit RISC chip, Harvard architecture
- ATtiny
  - 1–8 kB program memory
  - 6–32-pin package
  - www.atmel.com/dyn/products/param_table.asp?category_id=163&family_id=607&subfamily_id=791




ATtiny13

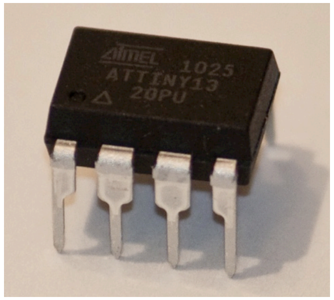
- ATmega
  - 4–256 kB program memory
  - 28–100-pin package
  - Extended instruction set
    - Multiply instructions
    - Handling larger program memories
  - www.atmel.com/dyn/products/param_table.asp?category_id=163&family_id=607&subfamily_id=760




ATmega328P

- Large family of devices, specific features

# Many types of AVRs: Choose depending on required features



ATtiny13

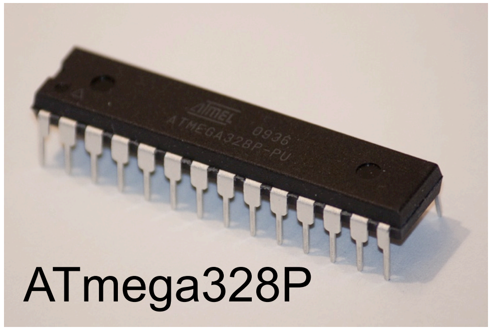
### ATtiny13

- 6 I/O pins, 1.8-5.5V operation
- 20 MPIS @ 20 MHz (clock rate selectable), internal oscillator
- 64B RAM, 64B EEPROM, 1kB Flash program memory
- 8-bit timer, 2 PWM channels, 10-bit ADC, analog comparator
- Price: €1.15

### ATtiny45

- 6 I/O pins, 1.8-5.5V operation
- 20 MPIS @ 20 MHz (clock rate selectable), internal oscillator
- 256B RAM, 256B EEPROM, 4kB Flash program memory
- 2 8-bit timers, 4 PWM channels, 10-bit ADC, analog comparator, SPI, TWI, temperature sensor
- Price: €2.05

# Many types of AVRs: Choose depending on required features



ATmega328P

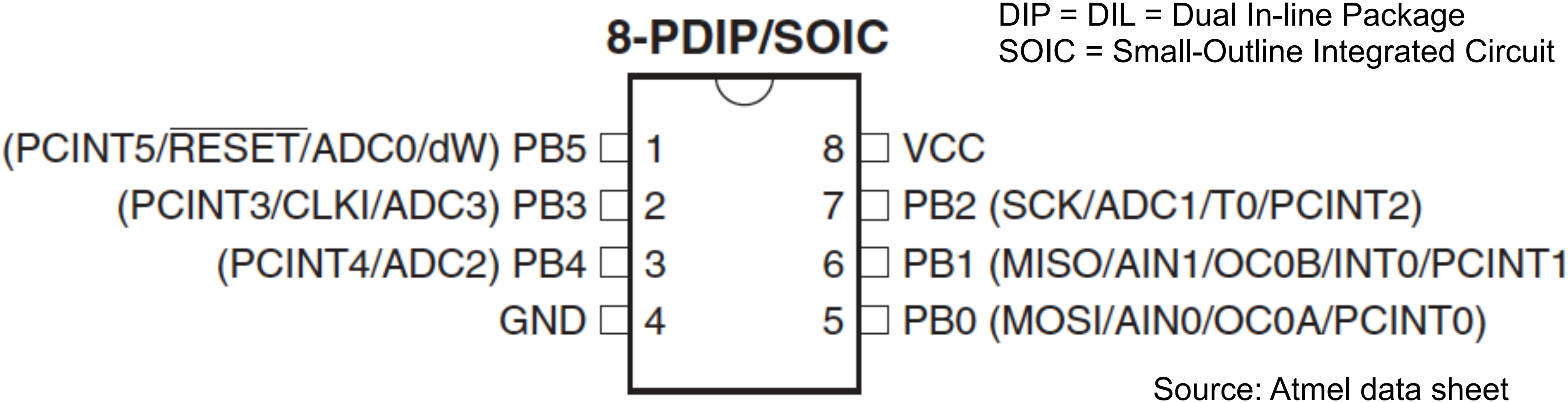
## ATmega8

- 23 I/O pins, 2.7-5.5V operation
- 16 MPIS @ 16 MHz (clock rate selectable), internal oscillator
- 1kB RAM, 512B EEPROM, 8kB Flash program memory
- 2 8-bit timers, 1 16-bit timer, 3 PWM channels, 10-bit ADC, analog cmp., SPI, TWI, USART
- Price: €2.60

## ATmega328P

- 23 I/O pins, 1.8-5.5V operation
- 20 MPIS @ 20 MHz (clock rate selectable), internal oscillator
- 2kB RAM, 1kB EEPROM, 4kB Flash program memory
- 2 8-bit timers, 1 16-bit timer, 6 PWM channels, 10-bit ADC, analog cmp., SPI, TWI, USART, temperature sensor
- Price: €3.30

# Pinout ATtiny13

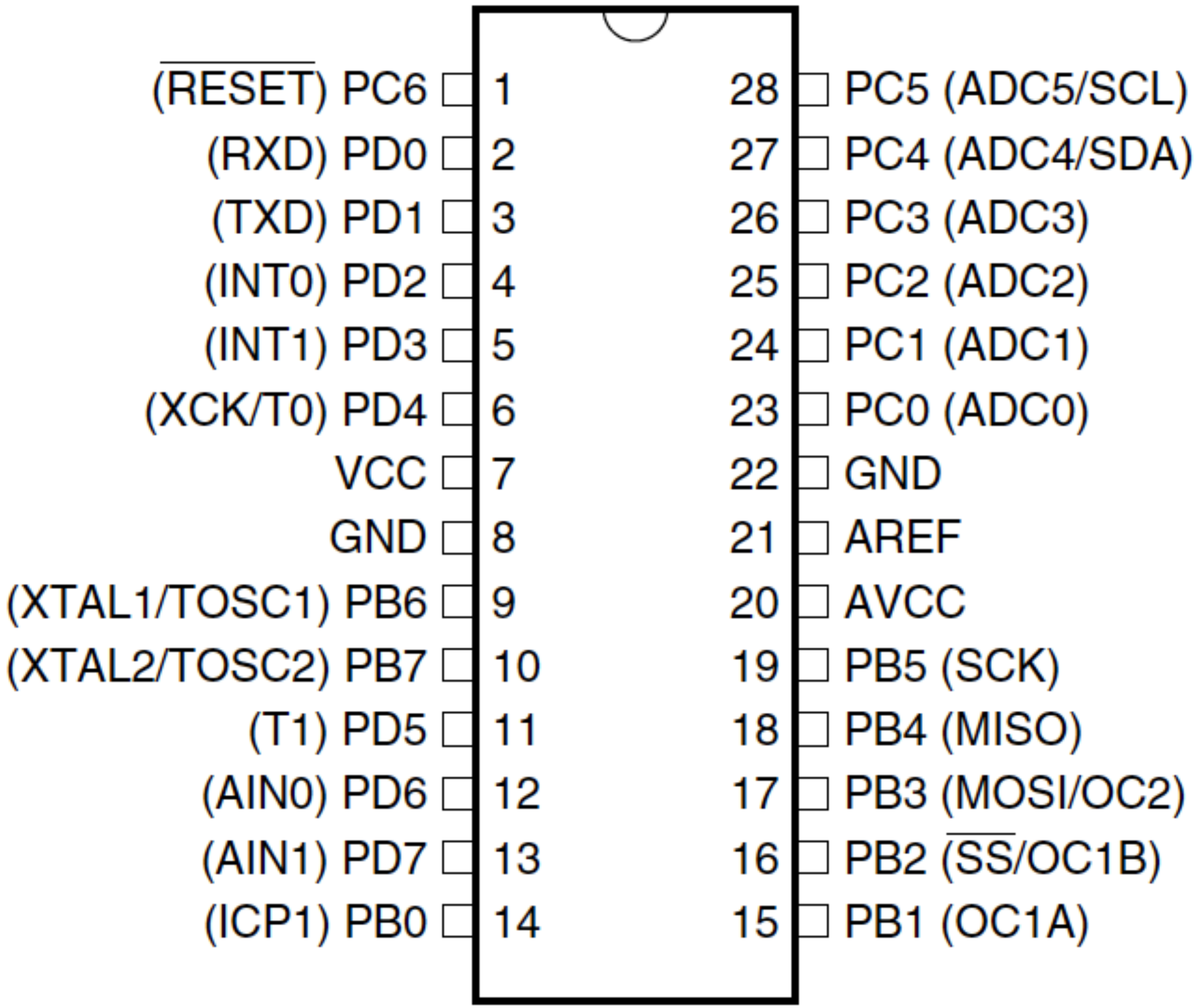



DIP = DIL = Dual In-line Package
SOIC = Small-Outline Integrated Circuit

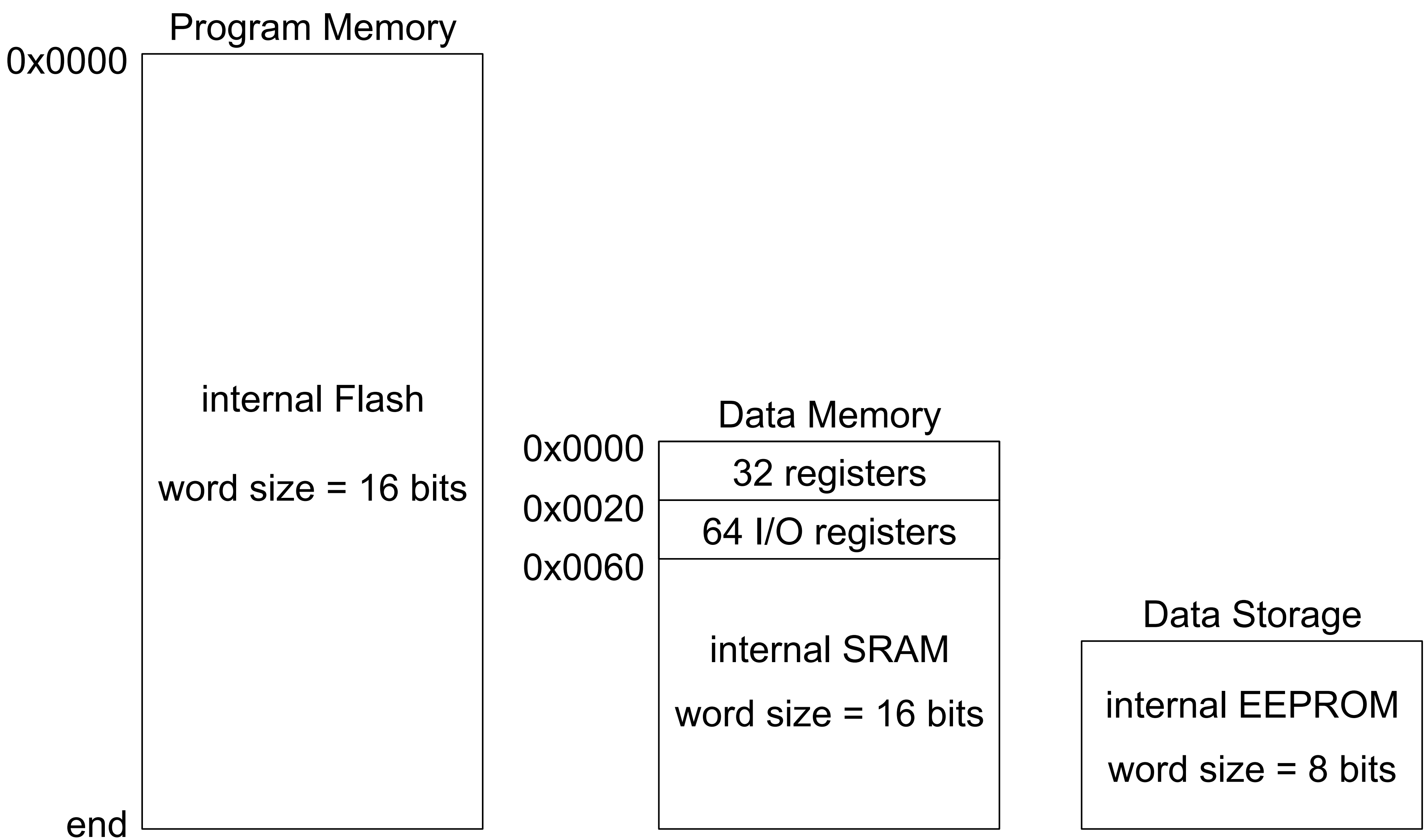
Source: Atmel data sheet

- Multiplexed pin functions, software configurable
  - Example: Flash/EEPROM programming via SPI:
    MOSI = master out, slave in (from programmer to ATtiny)
    MISO = master in, slave out (from ATtiny to programmer)
    SCK = serial clock
  - Example: ADC1 = ADC input channel 1
  - Example: PCINT3 = pin change interrupt 3

# Pinout ATmega8

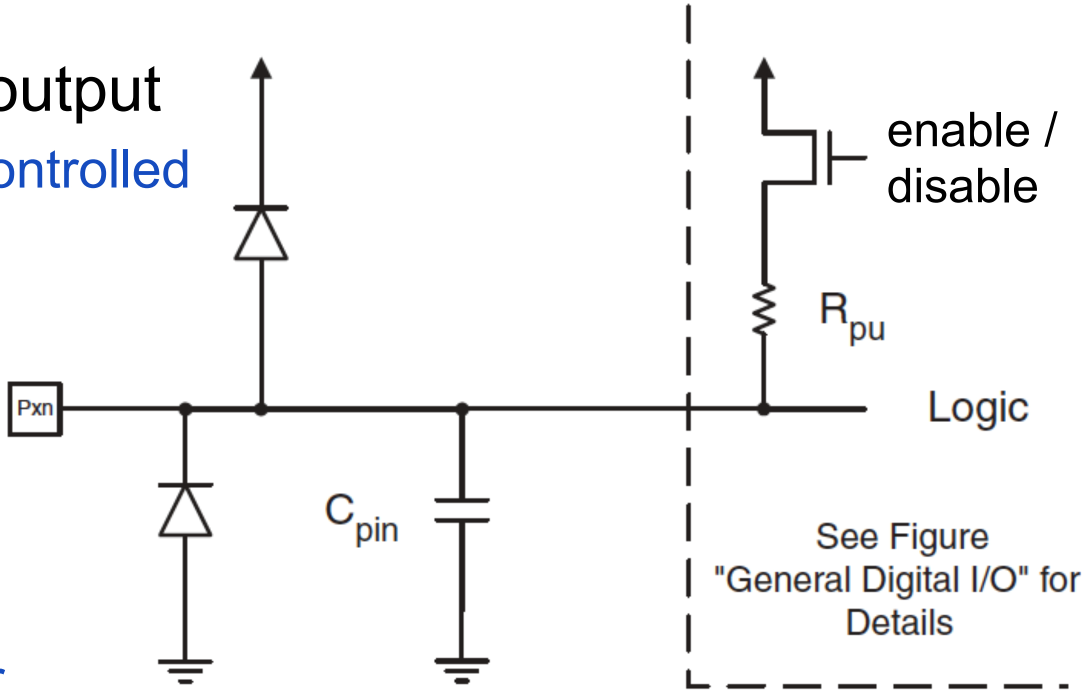


# AVR Memory Layout



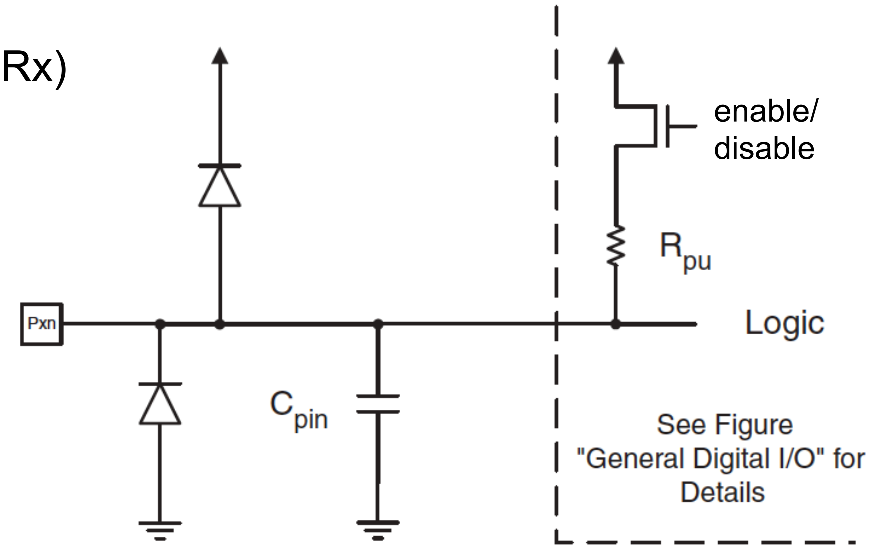
# AVR I/O Ports

- I/O pin either input or output
  - Individually software-controlled
- Pin as output
  - States: low, high
  - Can drive 40mA (→ LED)
- Pin as input
  - Internal pull-up resistor (enabled/disabled in software)
  - high resistance state (high-Z) if pull-up disabled



# Accessing the I/O Ports

- Three memory addresses for each I/O port
  - Data Direction Register: DDRx
    - 1 = output
    - 0 = input
  - Data Register: PORTx
    - if input: 1 = pull-up enabled, 0 = pull-up disabled
    - if output: 1 = PIN driven high, 0 = PIN driven low
  - Port Input Pins: PINx
    - read: PIN state (independent of DDRx)
    - write 1: toggles PORTx



# AVR I/O Ports: Pin Control Example

| **PIN** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
|---|---|---|---|---|---|---|---|---|
| **in/out** | out | out | out | out | in | in | in | in |
| **value** | 1 | 1 | 0 | 0 | pullup | hi-z | hi-z | hi-z |

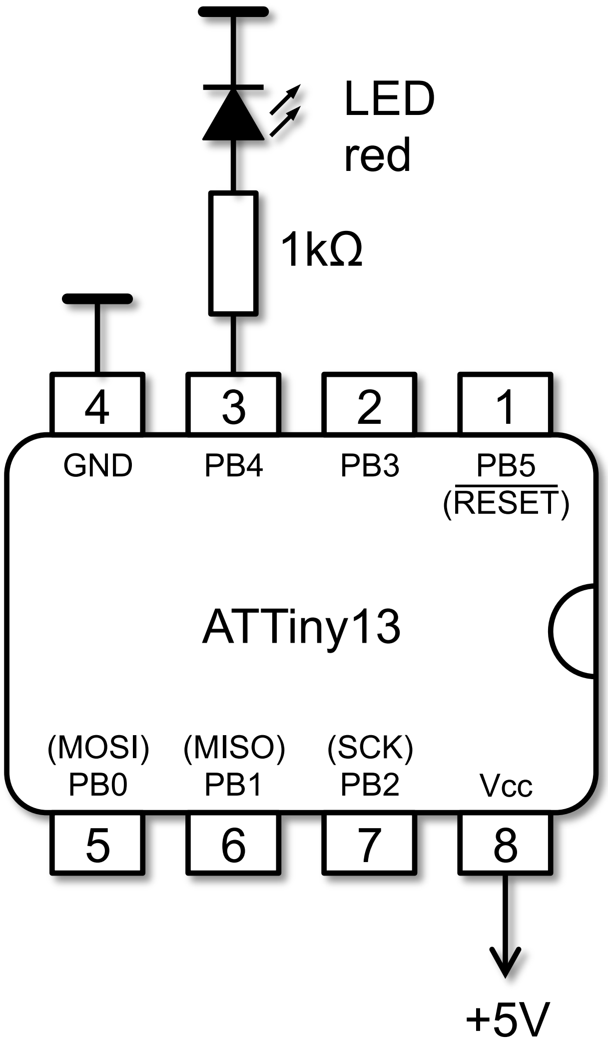
## Assembly

```
ldi r16, (1<<PB4) | (1<<PB1) | (1<<PB0)
ldi r17, (1<<DDB3) | (1<<DDB2) |
         (1<<DDB1) | (1<<DDB0)
out PORTB,r16
out DDRB,r17
nop      // synchronization
in r16,PINB
```

## C

```
unsigned char i;
PORTB = (1<<PB4) | (1<<PB1) | (1<<PB0);
DDRB = (1<<DDB3) | (1<<DDB2) |
       (1<<DDB1) | (1<<DDB0);

__no_operation(); // synchronization
i = PINB;
```

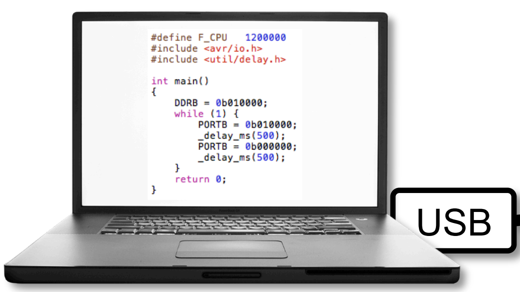
# "µC Hello World": Blinking an LED

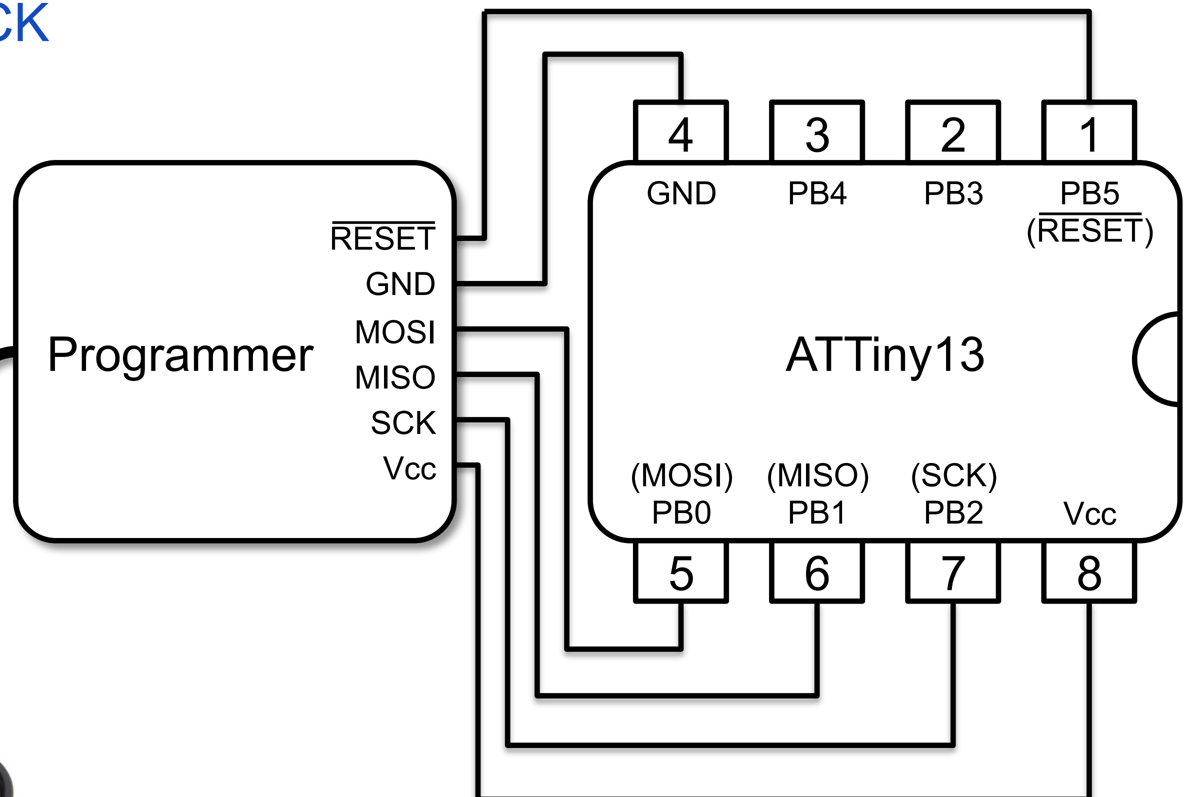


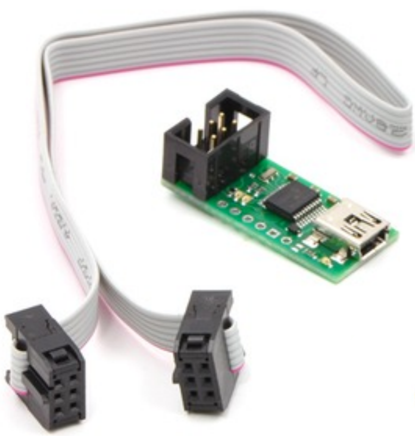

```
#define F_CPU 1200000
#include <avr/io.h>
#include <util/delay.h>

int main()
{
    DDRB = 0b010000;
    while (1) {
        PORTB = 0b010000;
        _delay_ms(500);
        PORTB = 0b000000;
        _delay_ms(500);
    }
    return 0;
}
```

# Downloading the Program to the µC

- Serial programming via Serial Peripheral Interface (SPI)
  - MISO, MOSI, SCK



# Memory Programming

- Tasks
  - Download/upload program code to/from Flash memory
  - Download/upload data to/from internal EEPROM
  - Configuring the microcontroller (“fuse bits”)
- Programming options
  - Serial programming
    - In-system programming (ISP)
    - High-voltage serial programming (HVSP, only 8-pin controllers)
  - High-voltage parallel programming
    - If RESET pin used as I/O pin: high-voltage programming
  - debugWire on-chip debug system
    - Uses RESET pin for debugging and Flash/EEPROM programming

# How to set the Fuses?

- AVRFuses tool
  - http://www.vonnieda.org/software/avrfuses
- Online fuse calculator
  - http://www.engbedded.com/fusecalc/
- ATtiny13 datasheet, 17.2 Fuse Bytes
  - ATtiny13 has two fuse bytes
  - Default: high byte = 0b11111111, low byte = 0b01101010

**Table 17-3.** Fuse High Byte

| Fuse Bit | Bit No | Description | Default Value |
|---|---|---|---|
| – | 7 | – | 1 (unprogrammed) |
| – | 6 | – | 1 (unprogrammed) |
| – | 5 | – | 1 (unprogrammed) |
| SELFPRGEN[(1)] | 4 | Self Programming Enable | 1 (unprogrammed) |
| DWEN[(2)] | 3 | debugWire Enable | 1 (unprogrammed) |
| BODLEVEL1[(3)] | 2 | Brown-out Detector trigger level | 1 (unprogrammed) |
| BODLEVEL0[(3)] | 1 | Brown-out Detector trigger level | 1 (unprogrammed) |
| RSTDISBL[(4)] | 0 | External Reset disable | 1 (unprogrammed) |

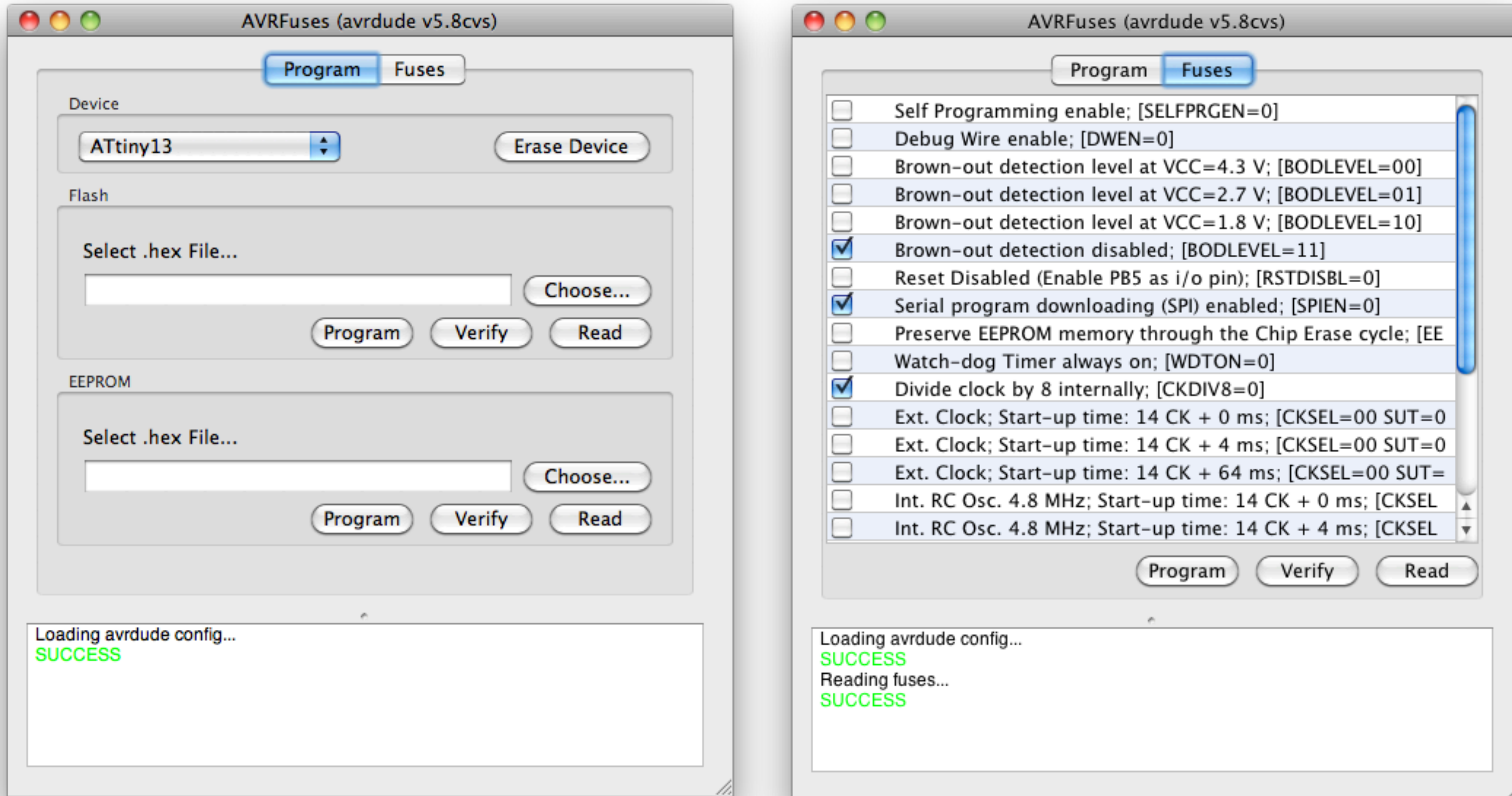
**Table 17-4.** Fuse Low Byte

| Fuse Bit | Bit No | Description | Default Value |
|---|---|---|---|
| SPIEN[(1)] | 7 | Enable Serial Programming and Data Downloading | 0 (programmed) (SPI prog. enabled) |
| EESAVE | 6 | Preserve EEPROM memory through Chip Erase | 1 (unprogrammed) (memory not preserved) |
| WDTON[(2)] | 5 | Watchdog Timer always on | 1 (unprogrammed) |
| CKDIV8[(3)] | 4 | Divide clock by 8 | 0 (programmed) |
| SUT1[(4)] | 3 | Select start-up time | 1 (unprogrammed) |
| SUT0[(4)] | 2 | Select start-up time | 0 (programmed) |
| CKSEL1[(5)] | 1 | Select Clock source | 1 (unprogrammed) |
| CKSEL0[(5)] | 0 | Select Clock source | 0 (programmed) |

# AVR Configuration via "Fuse Bits"

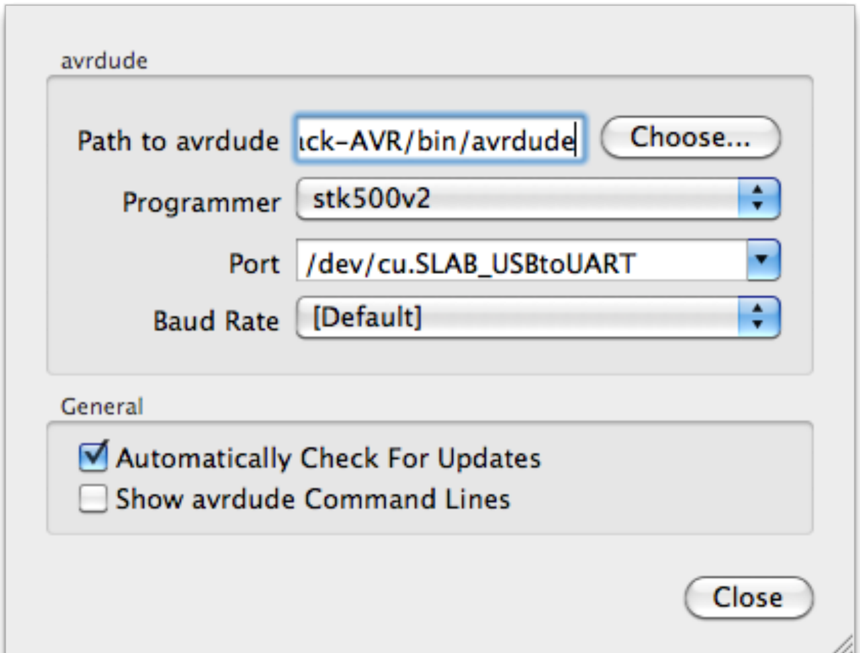
Caution: Wrong fuse bit settings may render chip unusable!

Tool: AVRFuses (www.vonnieda.org/AVRFuses/)



# Configuring AVRFuses for the Programmer and USB Port

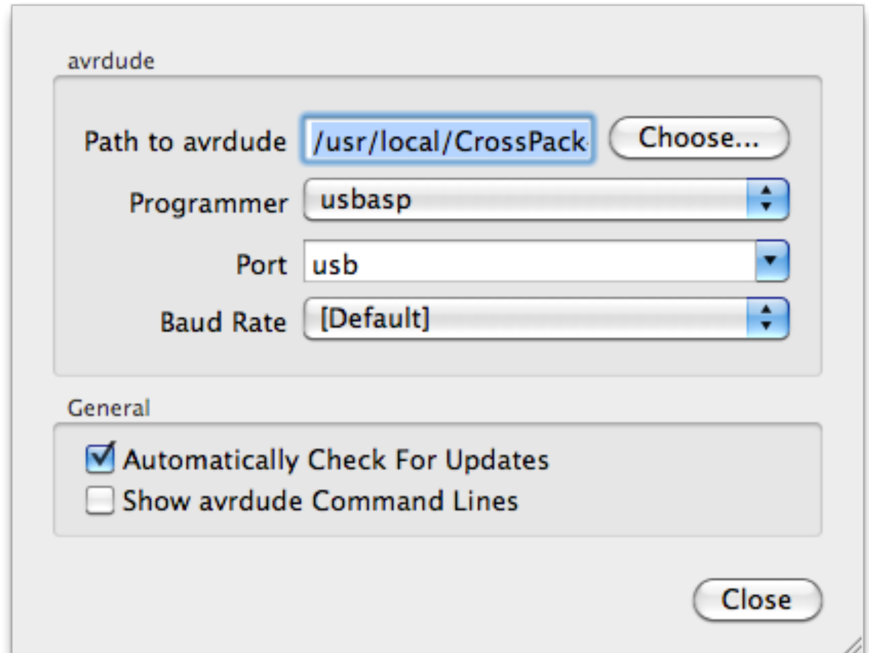
## mySmartUSB light:




/dev/cu.SLAB_USBtoUART

http://shop.myavr.ch/index.php?sp=article.sp.php&artID=200006


## USBasp:

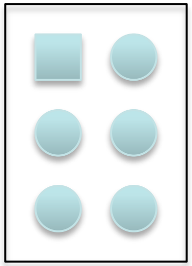



http://www.fischl.de/usbasp/

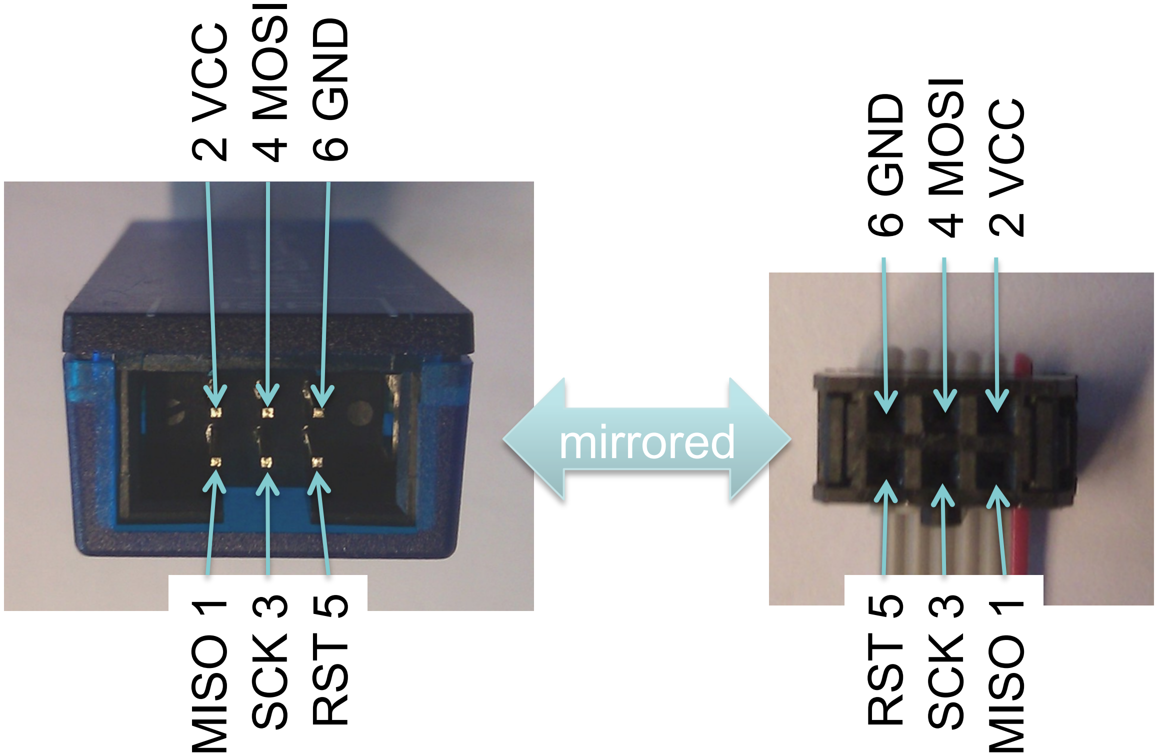
# USB Drivers for “mySmartUSB light”

- USB chip CP2102 from Silicon Laboratories
- Windows
  http://shop.myavr.ch/index.php?sp=article.sp.php&artID=200006
- Mac OS X, Linux
  http://www.silabs.com/products/mcu/pages/usbtouartbridgevcpdrivers.aspx

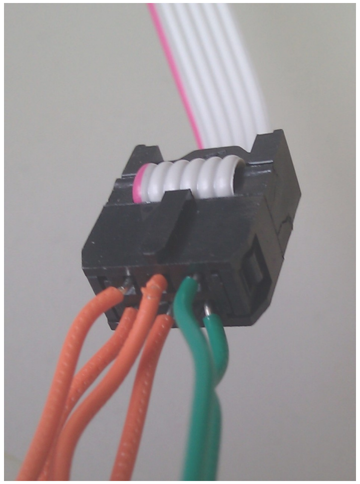
# AVR ISP Connector



- Image of small PCB with one row of connecotrs
- http://itp.nyu.edu/physcomp/Tutorials/AVRCProgramming-Programmer

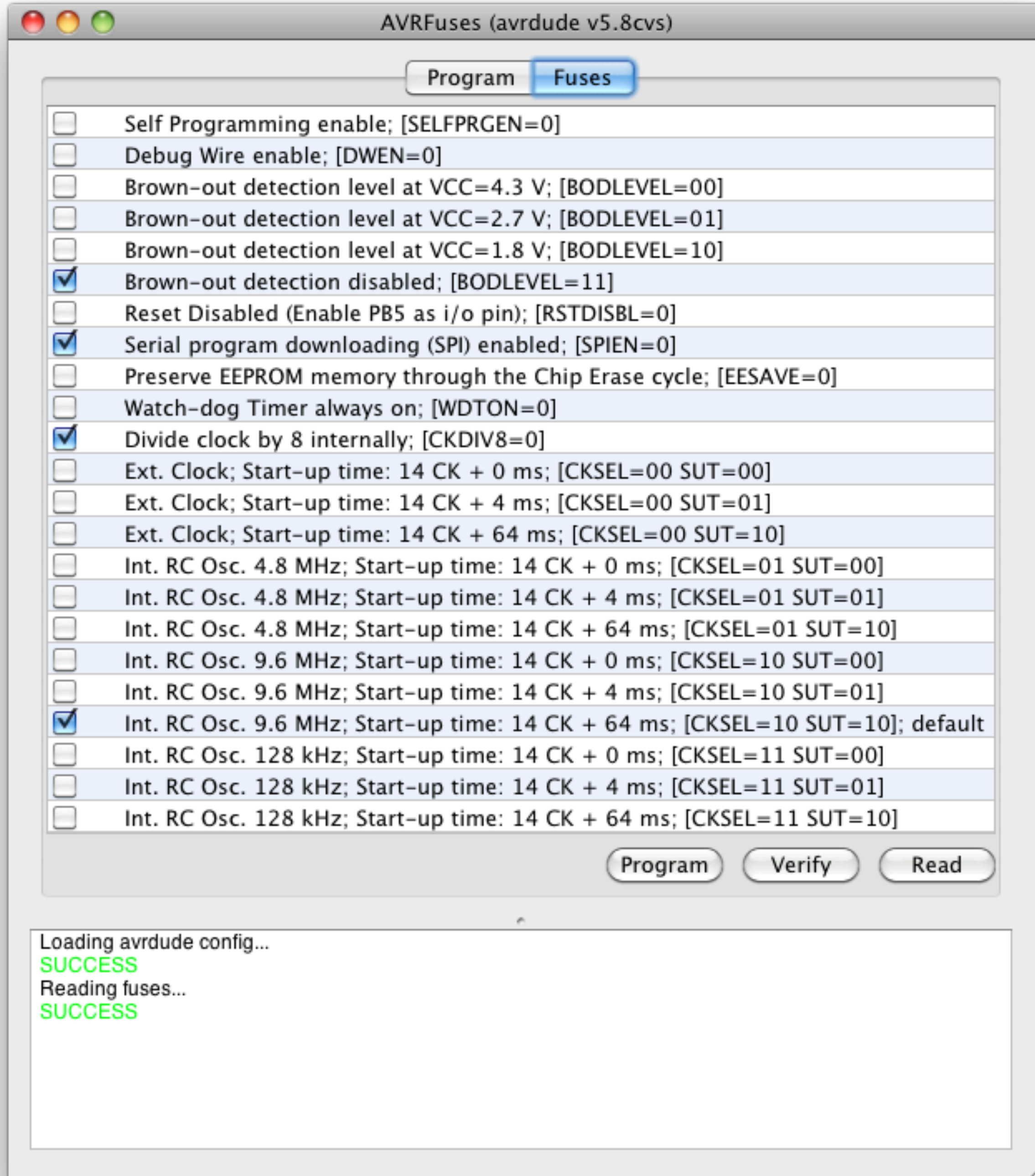



not recommended:



better solution:
solder small PCB
with 6x1 pins

- Fuses show factory configuration of ATtiny13
- Brown-out detection
  - reset when Vcc below level
- Reset disabled
  - use reset pin as I/O pin: dangerous!
- Start-up time
  - delay until conditions are stable



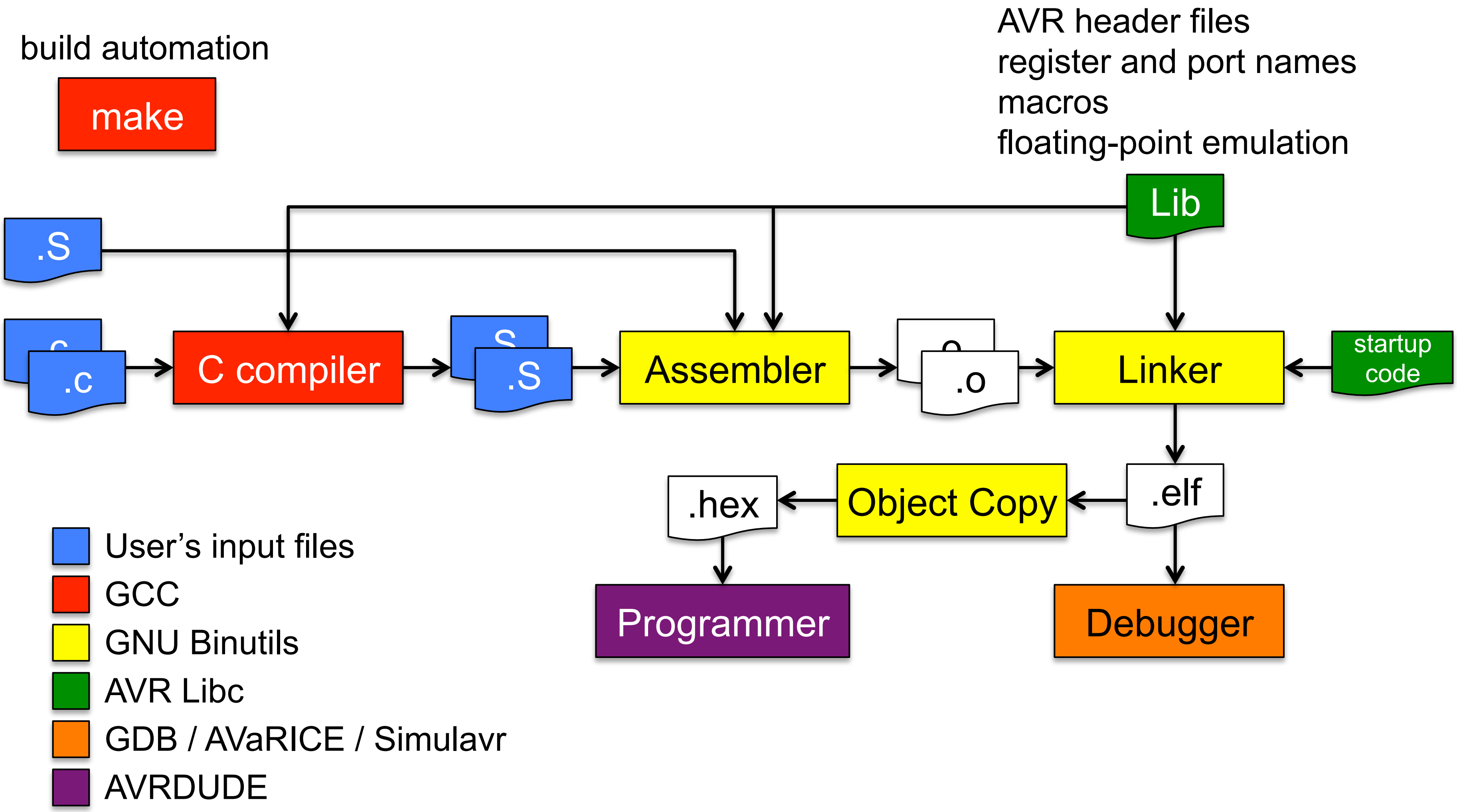
# AVR Clock Options

- Clock frequency can be chosen
  - Application requirements, power consumption
  - Clock prescaler register (divide clock by factor)
  - Component clocks can be disabled to reduce power consumption
- Clock source can be chosen
  - Internal resistor capacitor (RC) oscillator
    - Convenient, but not precise (temperature, operating voltage)
    - ATtiny13: 4.8MHz, 9.6MHz (at 3V and 25°C), 128kHz (low power)
  - External crystal oscillator
    - Highly precise, requires external quartz
- Clock source distributed to modules
  - $CLK_{CPU}$, $CLK_{I/O}$, $CLK_{flash}$, $CLK_{ADC}$
  - $CLK_{ADC}$ allows switching off other clocks during ADC conversion

# AVR Development Toolchain & IDEs

- Free AVR toolchain
  - GNU C compiler: avr-gcc (gcc.gnu.org)
  - C library: avr-libc
  - Down-/Uploader: avrdude (www.nongnu.org/avr-libc/)
- CrossPack for Mac OS X
  - avr-gcc on Mac OS X, Xcode can be used (but not required)
  - http://www.obdev.at/products/crosspack/index.html
  - oder: “sudo port install avr-gcc” (mit MacPorts)
- WinAVR for Windows
  - IDE for avr-gcc on Windows
  - http://winavr.sourceforge.net
- Atmel AVR Studio
  - http://www.atmel.com

# AVR-GCC Toolchain Overview




Source: http://www.avrfreaks.net/wiki/index.php/Documentation:AVR_GCC/AVR_GCC_Tool_Collection

# AVR Libc

- AVR Libc Home Page
  - http://www.nongnu.org/avr-libc/
- up to date?
  - http://users.rcn.com/rneswold/avr/index.html

# CrossPack: Creating a Project (Mac OS X)

**bash$** **avr-gcc-select 3**

Current default compiler: gcc 3

**bash$** **avr-project BlinkLED**

Using template: /usr/local/CrossPack-AVR-20100115/etc/templates/TemplateProject

**bash$** **cd BlinkLED/**

**bash$** **ls -l**

total 0

drwxr-xr-x  4 michaelrohs  staff  136 Apr  2 22:44 BlinkLED.xcodeproj

drwxr-xr-x  4 michaelrohs  staff  136 Apr  2 22:44 firmware

double-click to open Xcode project

**bash$** **cd firmware/**

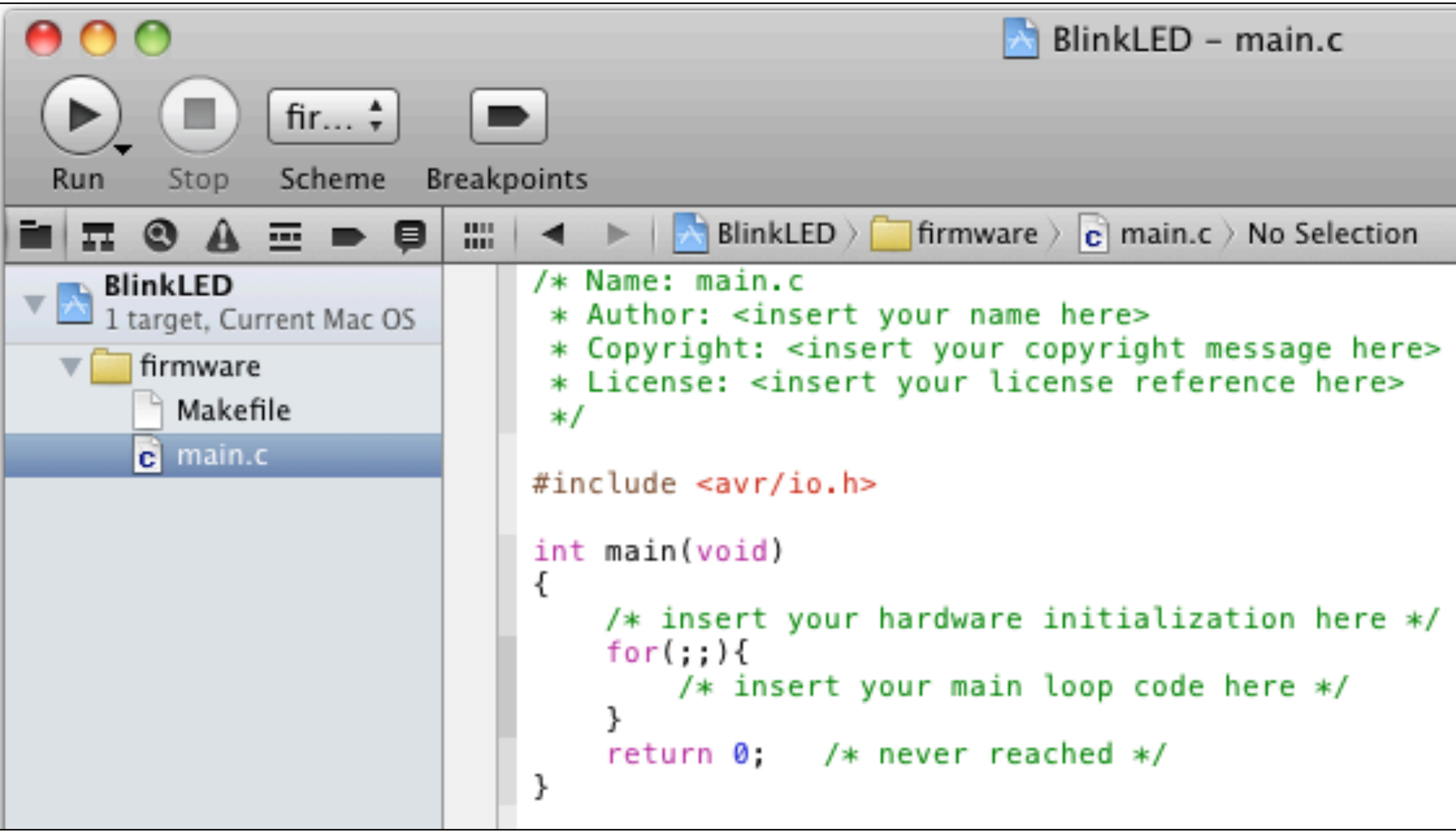
**bash$** **ls -l**

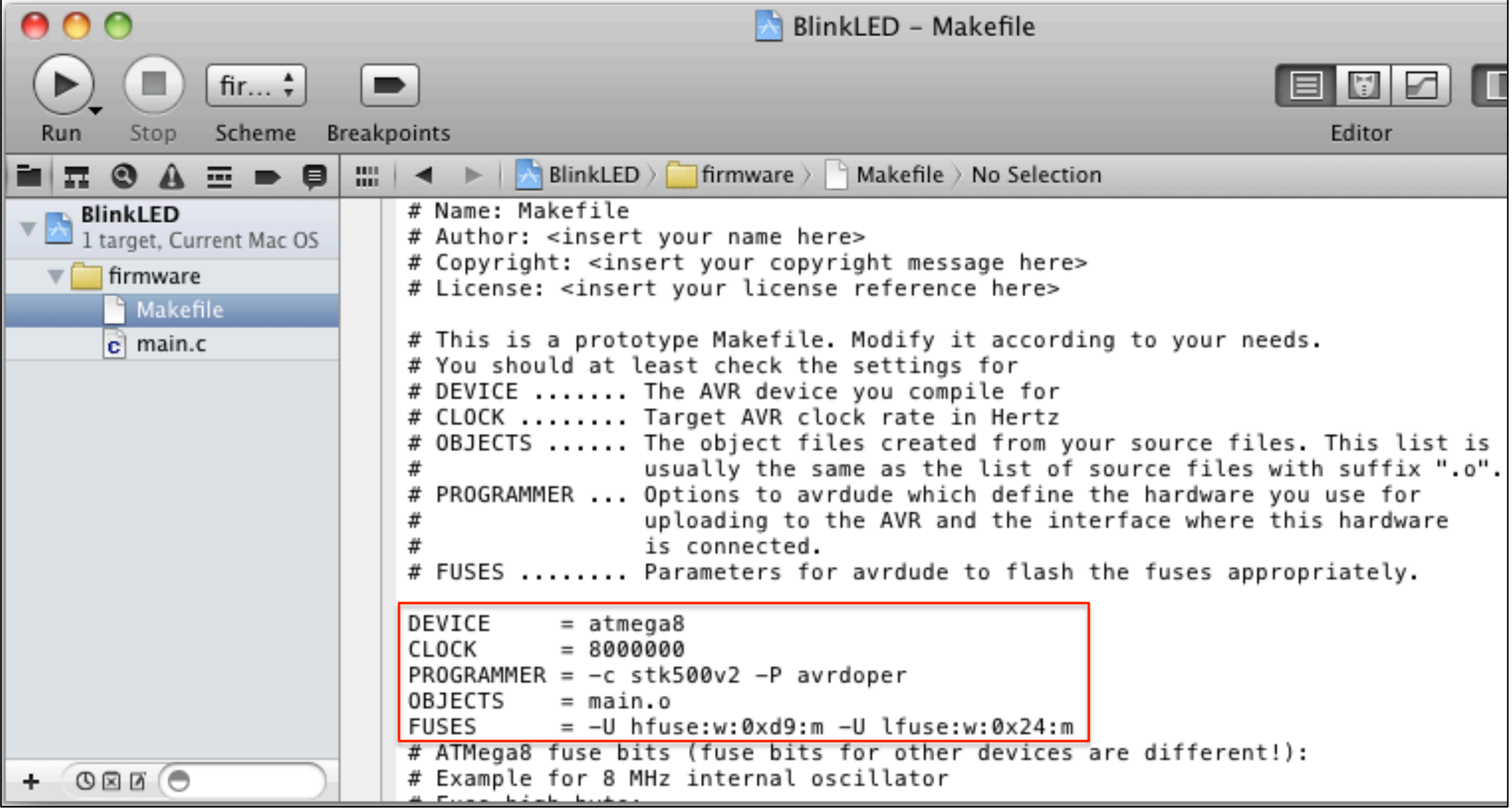
total 24

-rw-r--r--  1 michaelrohs  staff  4139 Apr  2 22:44 Makefile

-rw-r--r--  1 michaelrohs  staff   348 Apr  2 22:44 main.c

# Generated Project in XCode



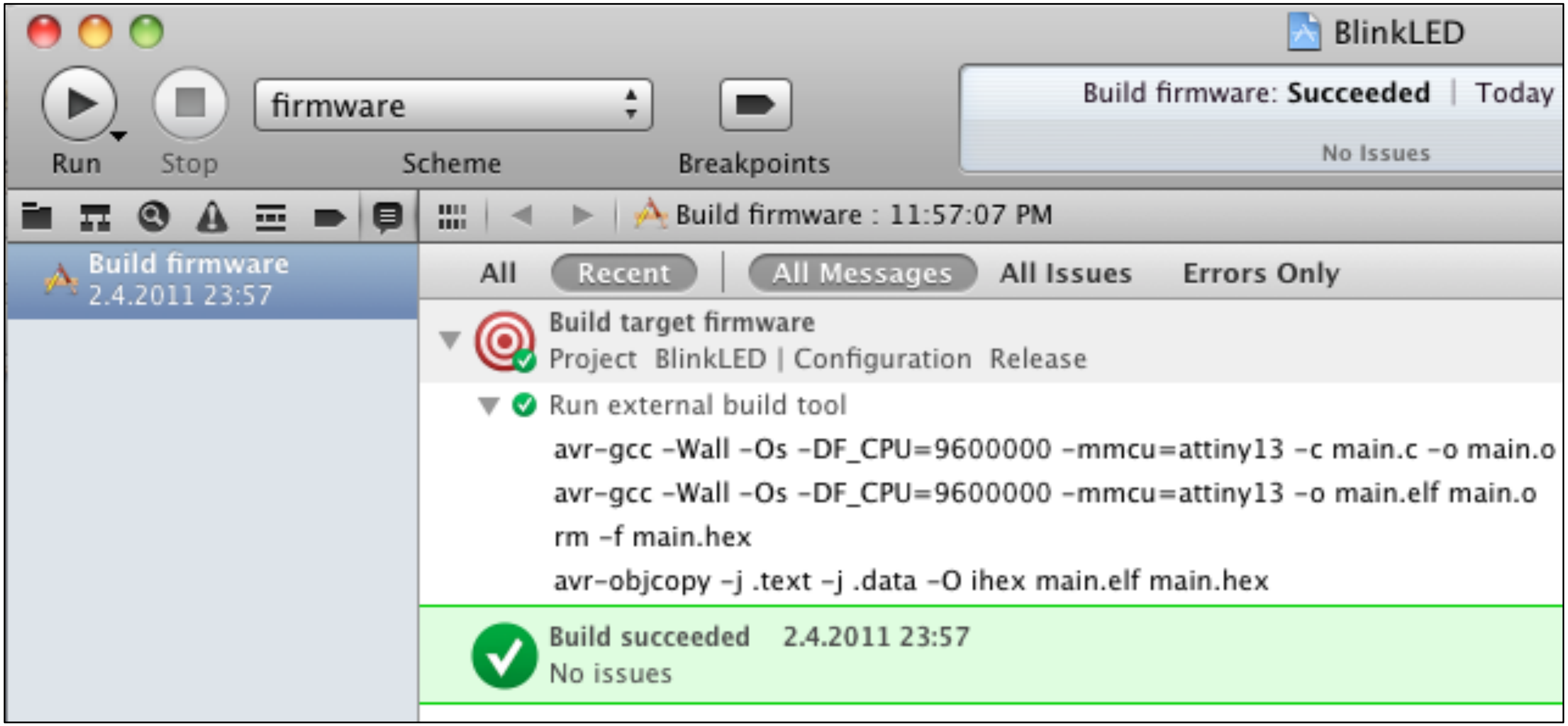



```
# Name: Makefile
# Author: <insert your name here>
# Copyright: <insert your copyright message here>
# License: <insert your license reference here>

# This is a prototype Makefile. Modify it according to your needs.
# You should at least check the settings for
# DEVICE ....... The AVR device you compile for
# CLOCK ........ Target AVR clock rate in Hertz
# OBJECTS ...... The object files created from your source files. This list is
#                usually the same as the list of source files with suffix ".o".
# PROGRAMMER ... Options to avrdude which define the hardware you use for
#                uploading to the AVR and the interface where this hardware
#                is connected.
# FUSES ........ Parameters for avrdude to flash the fuses appropriately.

DEVICE     = atmega8
CLOCK      = 8000000
PROGRAMMER = -c stk500v2 -P avrdoper
OBJECTS    = main.o
FUSES      = -U hfuse:w:0xd9:m -U lfuse:w:0x24:m
# ATMega8 fuse bits (fuse bits for other devices are different!):
# Example for 8 MHz internal oscillator
```

- Adapt Makefile as required
  - DEVICE, CLOCK, FUSES
  - PROGRAMMER
  - OBJECTS

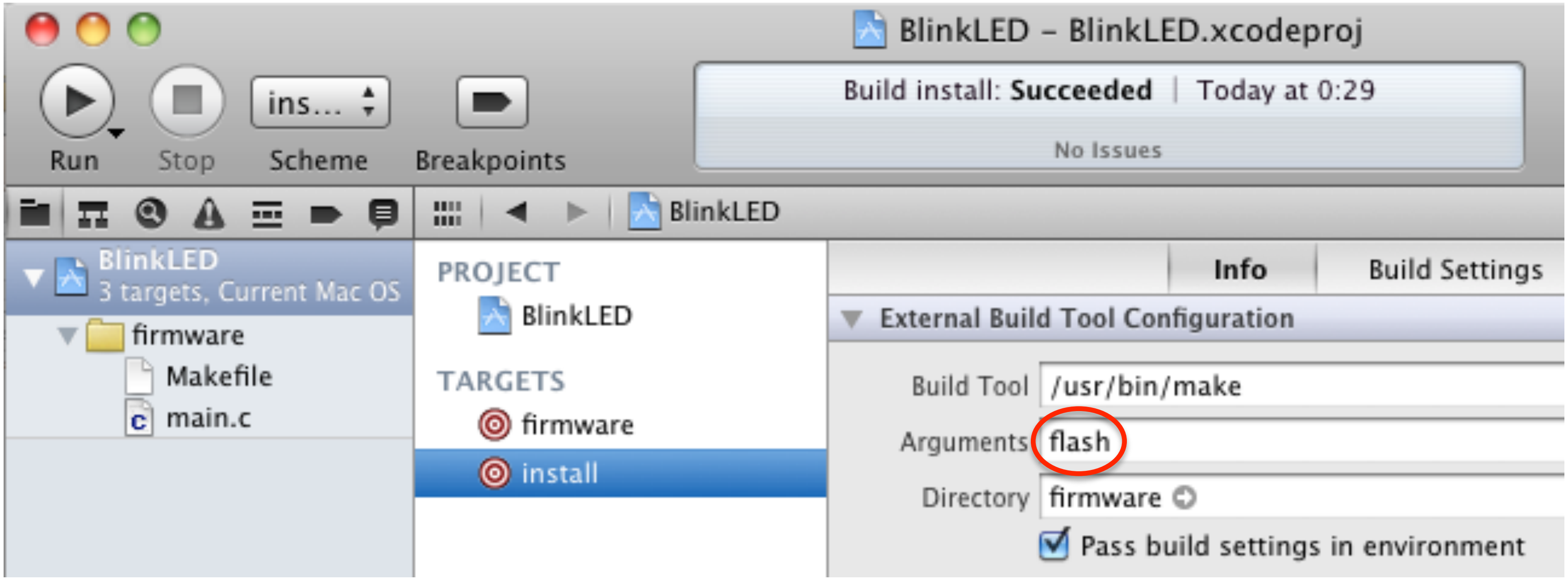
```
DEVICE     = attiny13
CLOCK      = 9600000
PROGRAMMER = -c USBasp
OBJECTS    = main.o
FUSES      = -U lfuse:w:0x7a:m -U hfuse:w:0xff:m
```

# Building within XCode

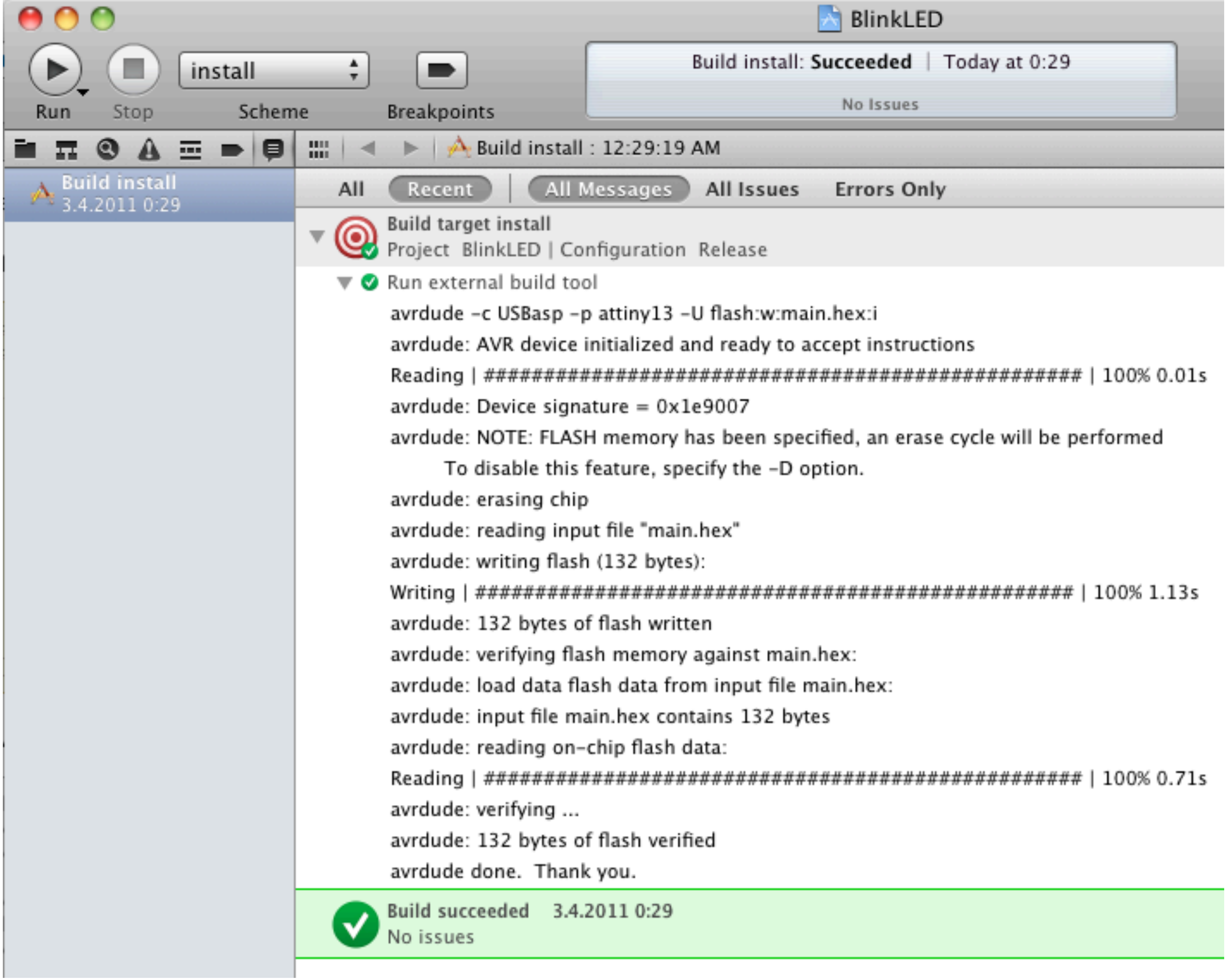


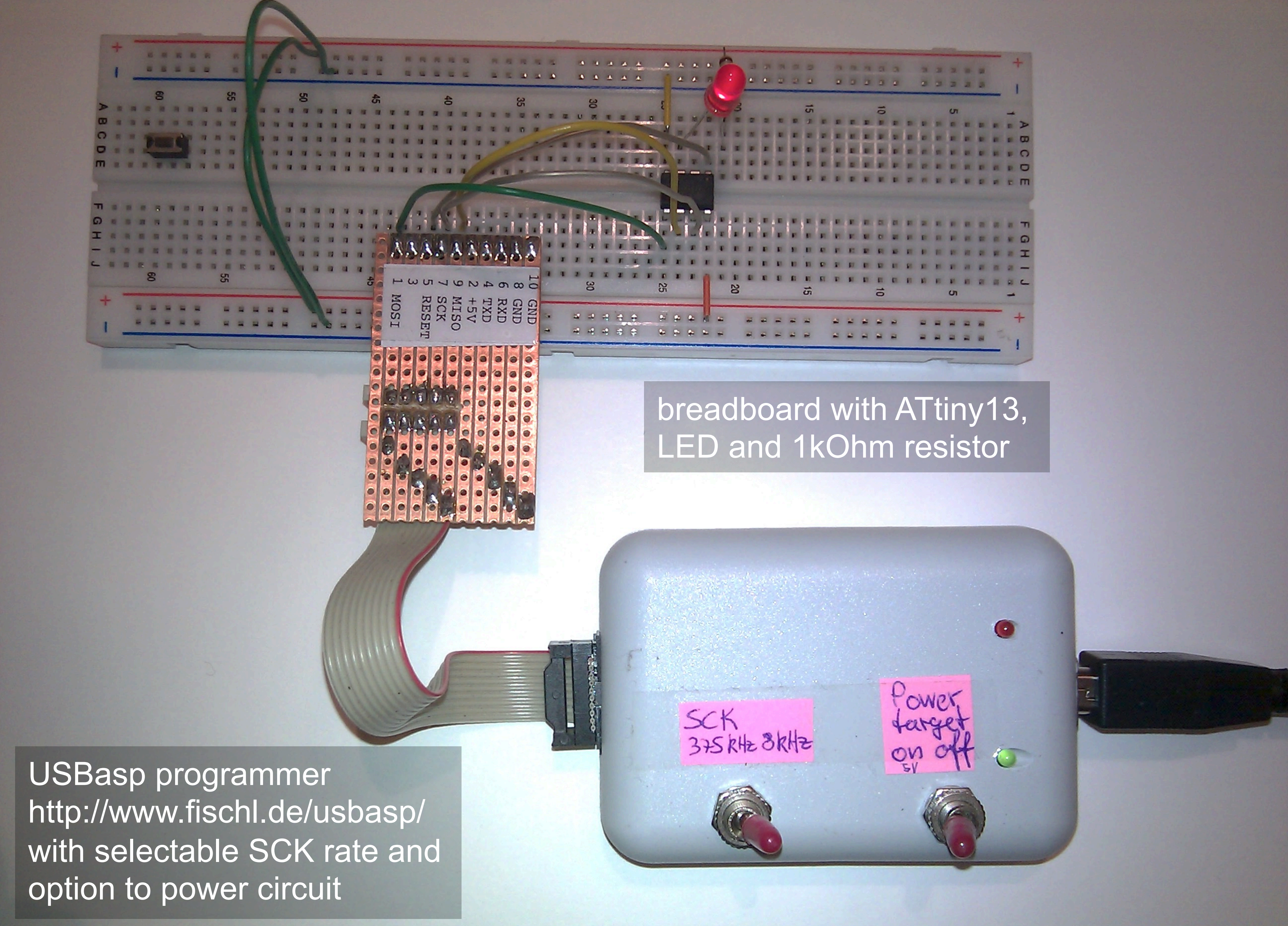
# Flashing AVR from within XCode

- Duplicate existing "firmware" target
- Rename to "install"
- Change Info | Arguments to "flash"




→ store custom template in
~/.CrossPack-AVR/templates/TemplateProject


BlinkLED
Run
Stop
install
Scheme
Breakpoints
Build install: Succeeded | Today at 0:29
No Issues
Build install : 12:29:19 AM
Build install
3.4.2011 0:29
All
Recent
All Messages
All Issues
Errors Only
Build target install
Project BlinkLED | Configuration Release
Run external build tool
avrdude -c USBasp -p attiny13 -U flash:w:main.hex:i
avrdude: AVR device initialized and ready to accept instructions
Reading | ################################################## | 100% 0.01s
avrdude: Device signature = 0x1e9007
avrdude: NOTE: FLASH memory has been specified, an erase cycle will be performed
To disable this feature, specify the -D option.
avrdude: erasing chip
avrdude: reading input file "main.hex"
avrdude: writing flash (132 bytes):
Writing | ################################################## | 100% 1.13s
avrdude: 132 bytes of flash written
avrdude: verifying flash memory against main.hex:
avrdude: load data flash data from input file main.hex:
avrdude: input file main.hex contains 132 bytes
avrdude: reading on-chip flash data:
Reading | ################################################## | 100% 0.71s
avrdude: verifying ...
avrdude: 132 bytes of flash verified
avrdude done. Thank you.
Build succeeded 3.4.2011 0:29
No issues

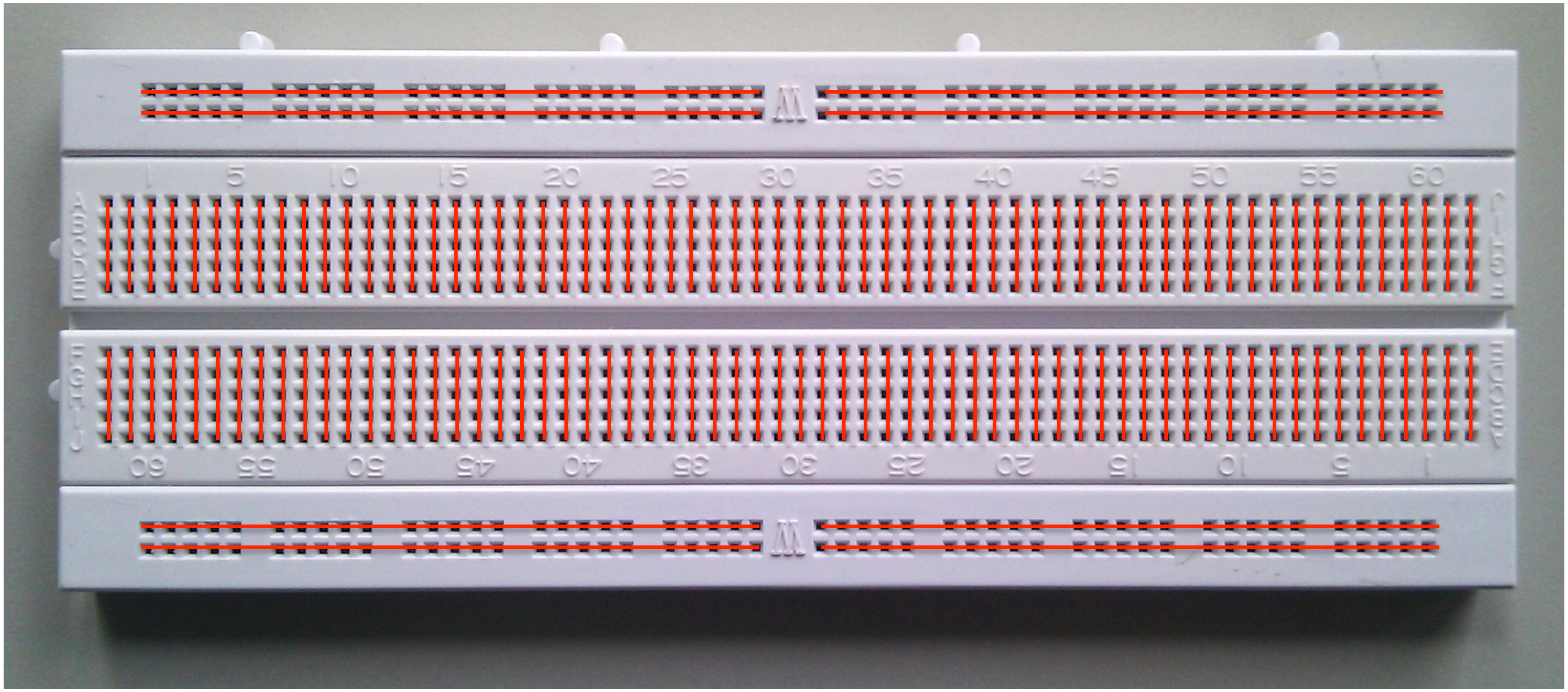



breadboard with ATtiny13, LED and 1kOhm resistor

USBasp programmer
http://www.fischl.de/usbasp/
with selectable SCK rate and option to power circuit

# Breadboard

- Quick prototyping
  - Changing/adding components is easy
- Can get confusing soon (“spaghetti wires”)



# Using the command line (not Xcode)

**bash$ ls**

Makefile      main.c

**bash$ make**

avr-gcc -Wall -Os -DF_CPU=9600000 -mmcu=attiny13 -c main.c -o main.o

avr-gcc -Wall -Os -DF_CPU=9600000 -mmcu=attiny13 -o main.elf main.o

rm -f main.hex

avr-objcopy -j .text -j .data -O ihex main.elf main.hex

**bash$ make flash**

avrdude -c USBasp -p attiny13 -U flash:w:main.hex:i

> **with mySmartUSB:**
> avrdude -p attiny13 -c stk500v2
>     -P /dev/cu.SLAB_USBtoUART
>     -U flash:w:main.hex:i

avrdude: AVR device initialized and ready to accept instructions

…

avrdude: writing flash (132 bytes):

Writing | ################################################## | 100% 1.13s

…

avrdude: 132 bytes of flash verified

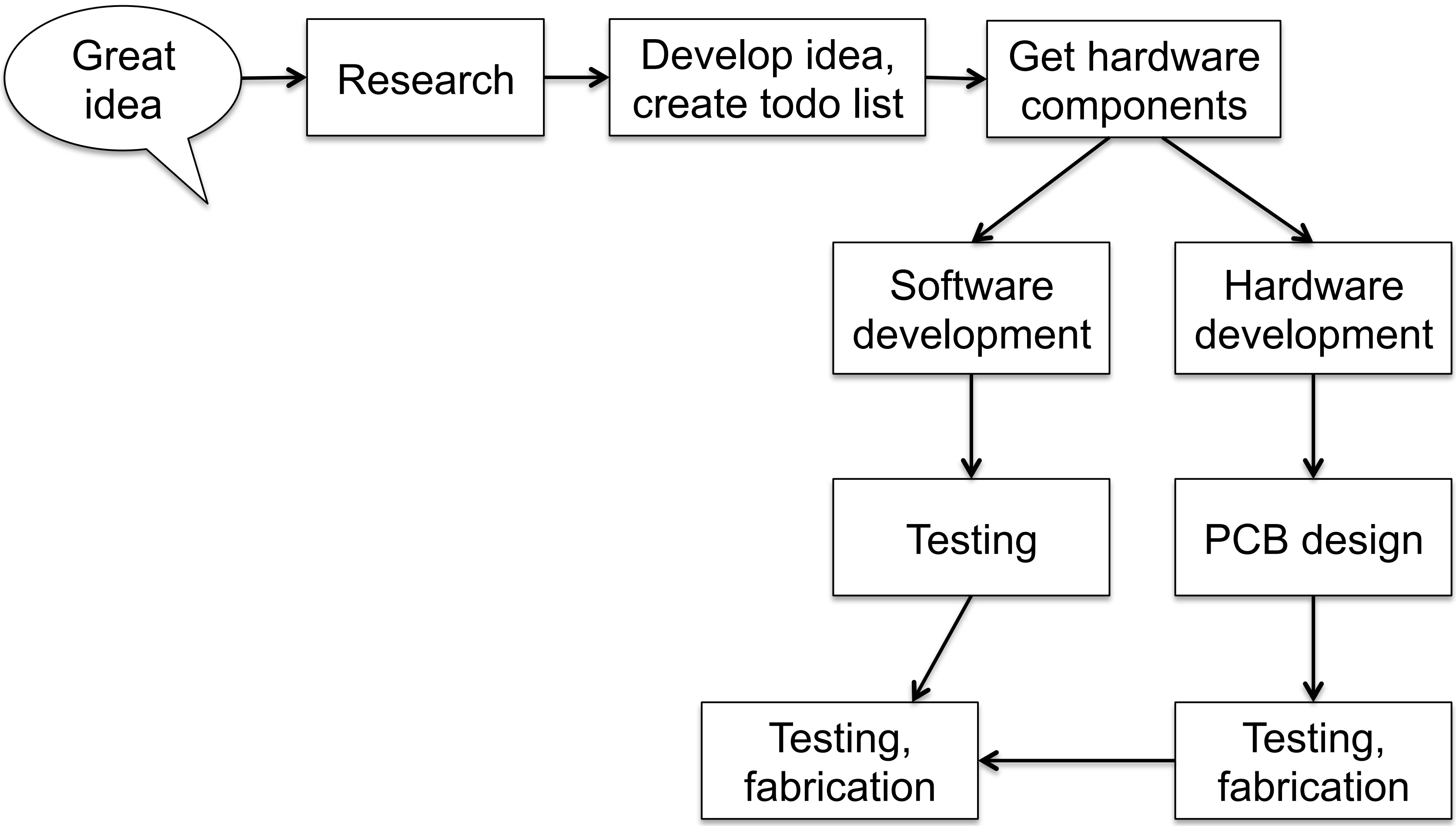
avrdude: safemode: Fuses OK

avrdude done.  Thank you.

# Assembly Language

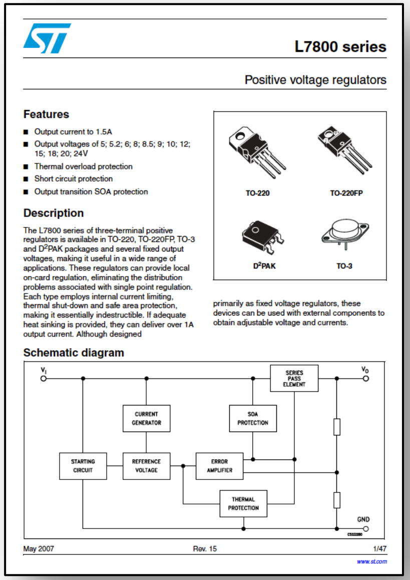
- ATtiny have relatively simple instruction sets and are reasonably simple to program
  - ATtiny13: 120 instructions
- http://avra.sourceforge.net/index.html
- make
  - http://www.gnu.org/software/make/manual/make.html
  - http://www.makelinux.net/make3/make3-CHP-2-SECT-4.html
- V-USB
  - http://www.obdev.at/products/vusb/index.html

# Development Process




Source: Gadre, Malhotra: tinyAVR projects

# Reading Data Sheets


L7800 series

Positive voltage regulators

**Features**

- Output current to 1.5A
- Output voltages of 5; 5.2; 6; 8; 8.5; 9; 10; 12; 15; 18; 20; 24V
- Thermal overload protection
- Short circuit protection
- Output transition SOA protection

**Description**

The L7800 series of three-terminal positive regulators is available in TO-220, TO-220FP, TO-3 and D²PAK packages and several fixed output voltages, making it useful in a wide range of applications. These regulators can provide local on-card regulation, eliminating the distribution problems associated with single point regulation. Each type employs internal current limiting, thermal shut-down and safe area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltage and currents.

TO-220 TO-220FP D²PAK TO-3

**Schematic diagram**

May 2007 Rev. 15 1/47

www.st.com

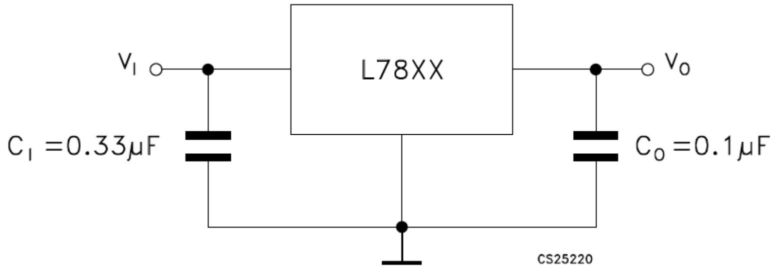
- Extremely important to read carefully
  - Easy to find online
- Example: 7805 +5V voltage regulator
  - Operate according to "electrical characteristics"

## 4 Electrical characteristics

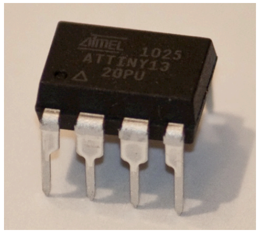
**Table 3. Electrical characteristics of L7805** (refer to the test circuits, $T_J$ = -55 to 150°C, $V_I$ = 10V, $I_O$ = 500 mA, $C_I$ = 0.33 µF, $C_O$ = 0.1 µF unless otherwise specified)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_O$ | Output voltage | $T_J$ = 25°C | 4.8 | 5 | 5.2 | V |
| $V_O$ | Output voltage | $I_O$ = 5mA to 1A, $P_O$ ≤15W<br>$V_I$ = 8 to 20V | 4.65 | 5 | 5.35 | V |

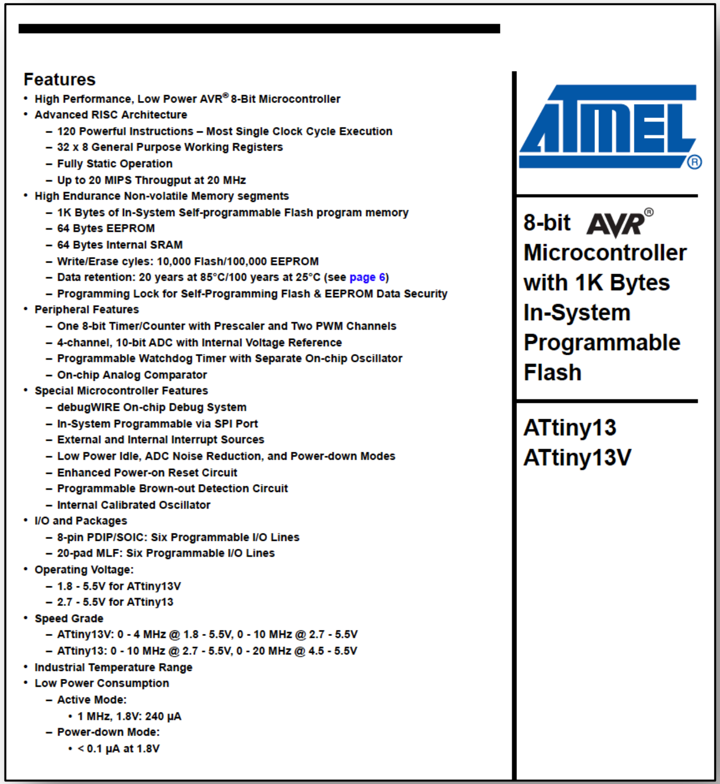
  - "Application Circuits" show typical usage



# ATtiny13 Data Sheet




- 176 pages! (22 pages per pin!)
  - for next time: have a look at the data sheet



**Features**

- High Performance, Low Power AVR® 8-Bit Microcontroller
- Advanced RISC Architecture
  - 120 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 20 MIPS Througput at 20 MHz
- High Endurance Non-volatile Memory segments
  - 1K Bytes of In-System Self-programmable Flash program memory
  - 64 Bytes EEPROM
  - 64 Bytes Internal SRAM
  - Write/Erase cyles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C (see page 6)
  - Programming Lock for Self-Programming Flash & EEPROM Data Security
- Peripheral Features
  - One 8-bit Timer/Counter with Prescaler and Two PWM Channels
  - 4-channel, 10-bit ADC with Internal Voltage Reference
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
- Special Microcontroller Features
  - debugWIRE On-chip Debug System
  - In-System Programmable via SPI Port
  - External and Internal Interrupt Sources
  - Low Power Idle, ADC Noise Reduction, and Power-down Modes
  - Enhanced Power-on Reset Circuit
  - Programmable Brown-out Detection Circuit
  - Internal Calibrated Oscillator
- I/O and Packages
  - 8-pin PDIP/SOIC: Six Programmable I/O Lines
  - 20-pad MLF: Six Programmable I/O Lines
- Operating Voltage:
  - 1.8 - 5.5V for ATtiny13V
  - 2.7 - 5.5V for ATtiny13
- Speed Grade
  - ATtiny13V: 0 - 4 MHz @ 1.8 - 5.5V, 0 - 10 MHz @ 2.7 - 5.5V
  - ATtiny13: 0 - 10 MHz @ 2.7 - 5.5V, 0 - 20 MHz @ 4.5 - 5.5V
- Industrial Temperature Range
- Low Power Consumption
  - Active Mode:
    - 1 MHz, 1.8V: 240 µA
  - Power-down Mode:
    - < 0.1 µA at 1.8V

ATMEL®

8-bit AVR® Microcontroller with 1K Bytes In-System Programmable Flash

ATtiny13
ATtiny13V

# Hands-On

- Install AVR GCC

- Create stable 5V power supply on breadboard
- Program "µC Hello World" (blinking an LED) onto a ATtiny13

- Store your components into a sealed bag

- For next time: have a look into ATtiny13 datasheet