Building Interactive Devices and Objects

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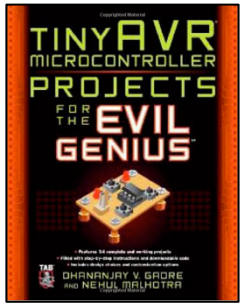
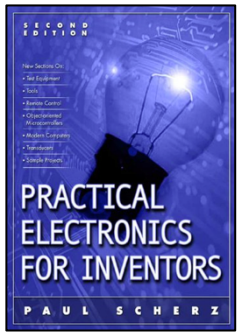
Books

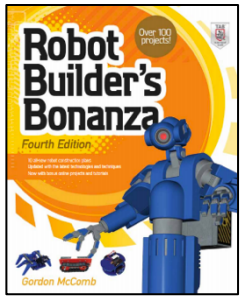
- Dhananjay Gadre, Nehul Malhotra: tinyAVR Microcontroller Projects for the Evil Genius, McGraw-Hill, 2011



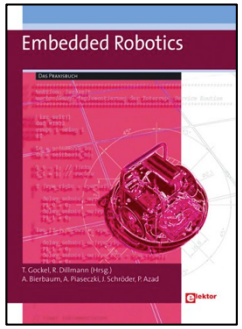
- Paul Scherz: Practical Electronics for Inventors, 2. Auflage, McGraw-Hill, 2006



- Gordon McComb: Robot Builder's Bonanza, 4. Auflage, McGraw-Hill, 2011



- Alexander Bierbaum, Alexander Piaseczki, Joachim Schröder, Pedram Azad, Tilo Gockel, Rüdiger Dillmann: Embedded Robotics - Das Praxisbuch, Elektor-Verlag, 2005

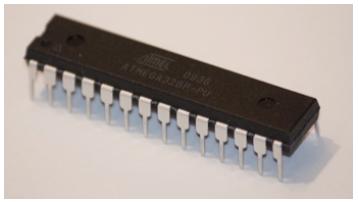


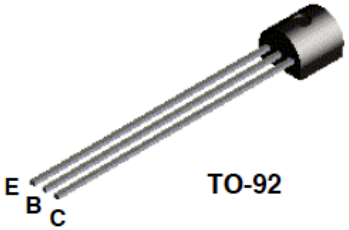
Schedule

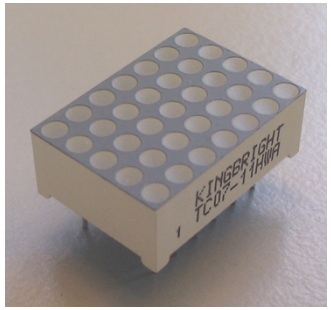
#	Date	Topic	Group Activity
1	19.4.2012	Session 1: Introduction	Team building
2	26.4.2012	Session 2: Microcontrollers & Electronics	
3	3.5.2012	Session 3: Sensors	Concept development
4	10.5.2012	CHI	Concept development
5	17.5.2012	Christi Himmelfahrt	Concept development
6	24.5.2012	Session 4: Actuators	Concept presentation, Hardware requ.
7	31.5.2012	Session 5: Physical Objects (Sven)	
8	7.6.2012	Frohnleichnam	Project
9	14.6.2012		Project
10	21.6.2012		Project
11	28.6.2012		Project
12	5.7.2012		Project
13	12.7.2012		Evaluation
14	19.7.2012		Evaluation, Presentation

Sessions 2: Microcontrollers & Electronics

- AVR microcontrollers, LEDs, buttons, transistors
- Exercises
  1. Hello world (LED blinking)
  2. Button debouncing, switching LED
  3. Controlling multiple LEDs







Today

- AVR Eclipse Plugin
- Configuring and uploading
- Microcontrollers
- LEDs and buttons
- Exercise 2

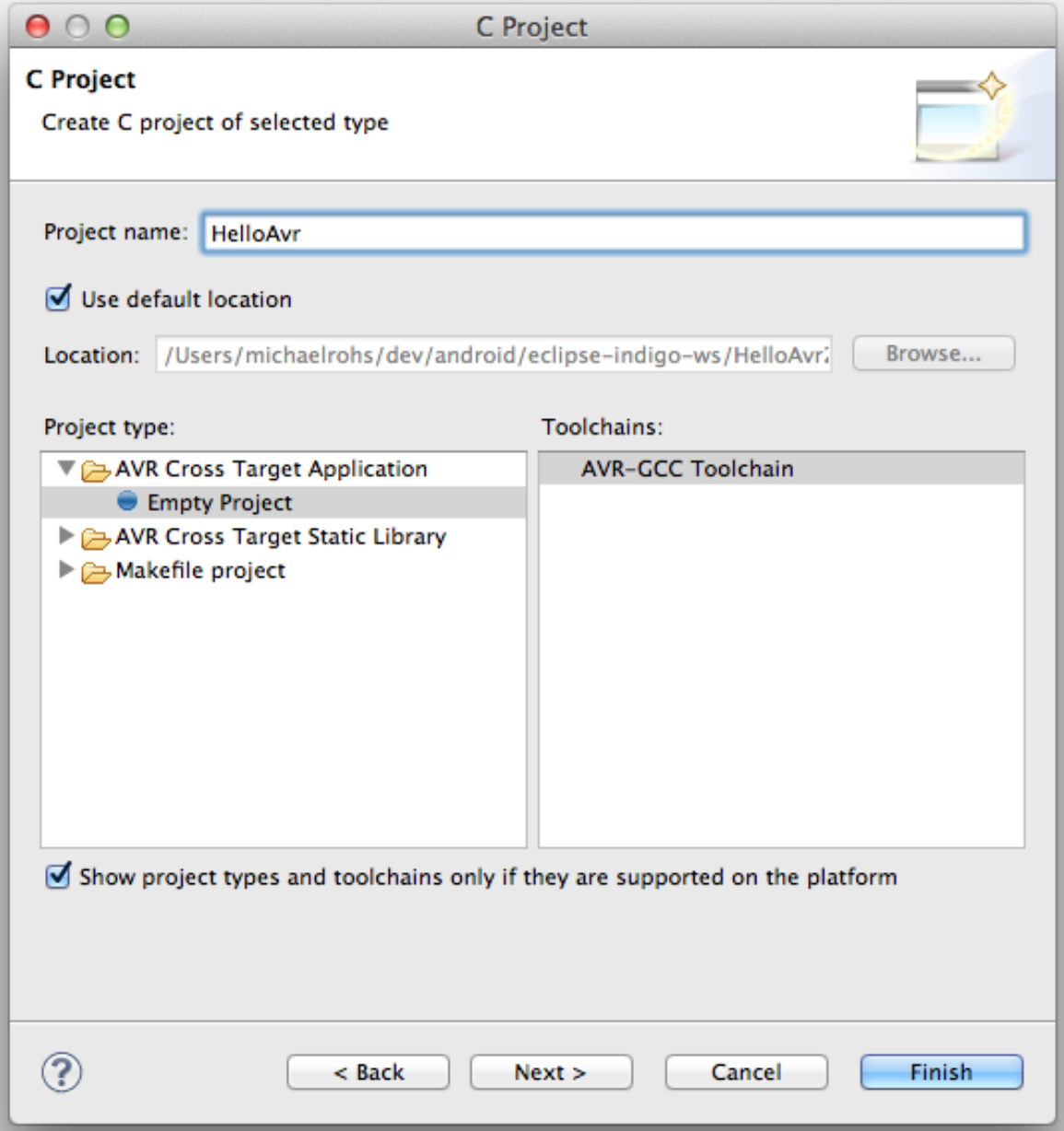
AVR ECLIPSE PLUGIN

AVR Development Toolchain & IDEs

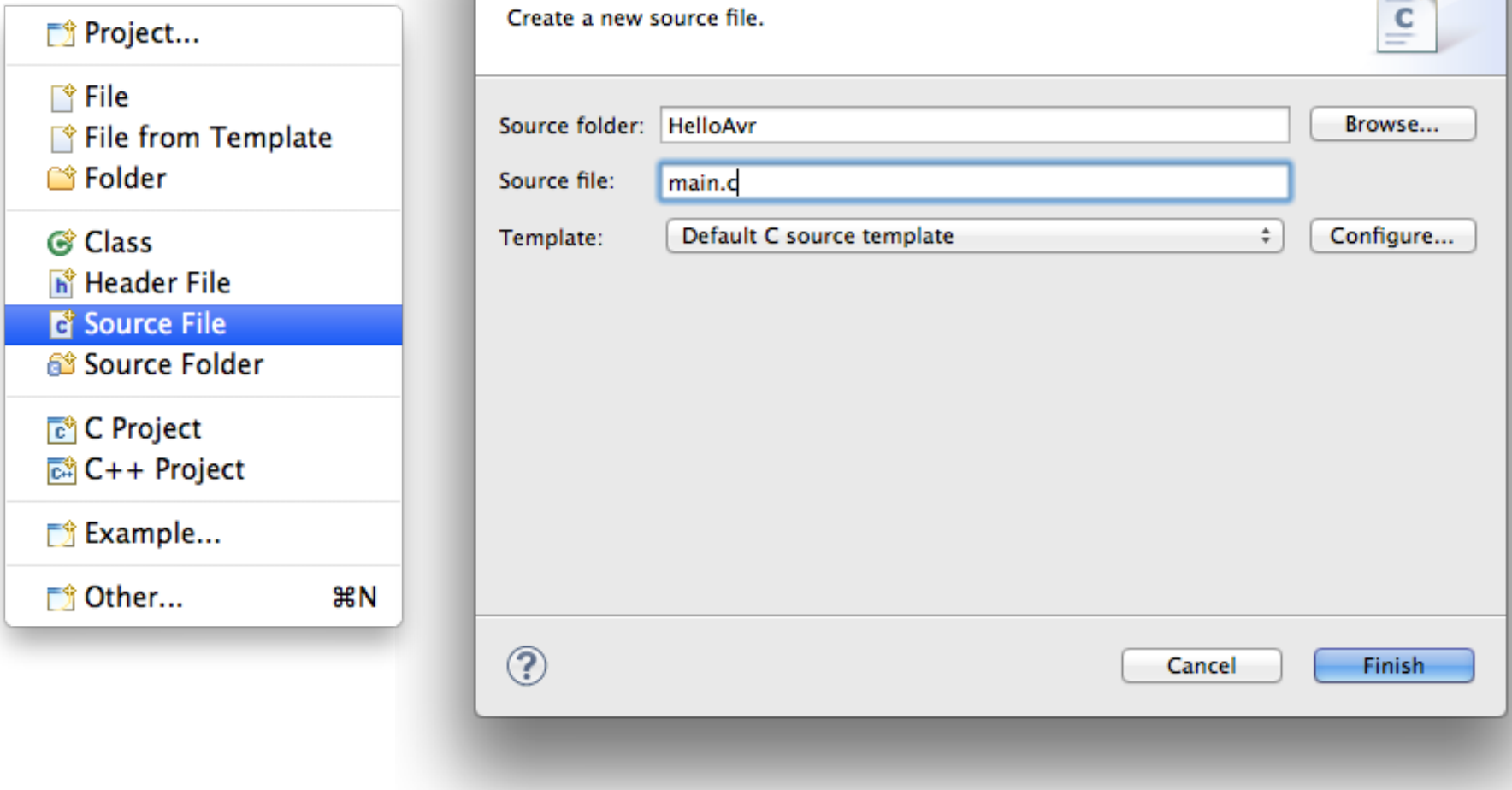
- Free AVR-GCC toolchain
  - GNU C compiler + linker: avr-gcc (gcc.gnu.org)
  - C library: avr-libc (www.nongnu.org/avr-libc/)
  - Down-/uploader: avrdude (www.nongnu.org/avr-libc/)
- Eclipse (cross platform)
  - http://avr-eclipse.sourceforge.net
- CrossPack for Mac OS X
  - http://www.obdev.at/products/crosspack/index.html
- WinAVR for Windows
  - http://winavr.sourceforge.net
- Atmel AVR Studio
  - http://www.atmel.com

Creating a Project with AVR Eclipse Plugin

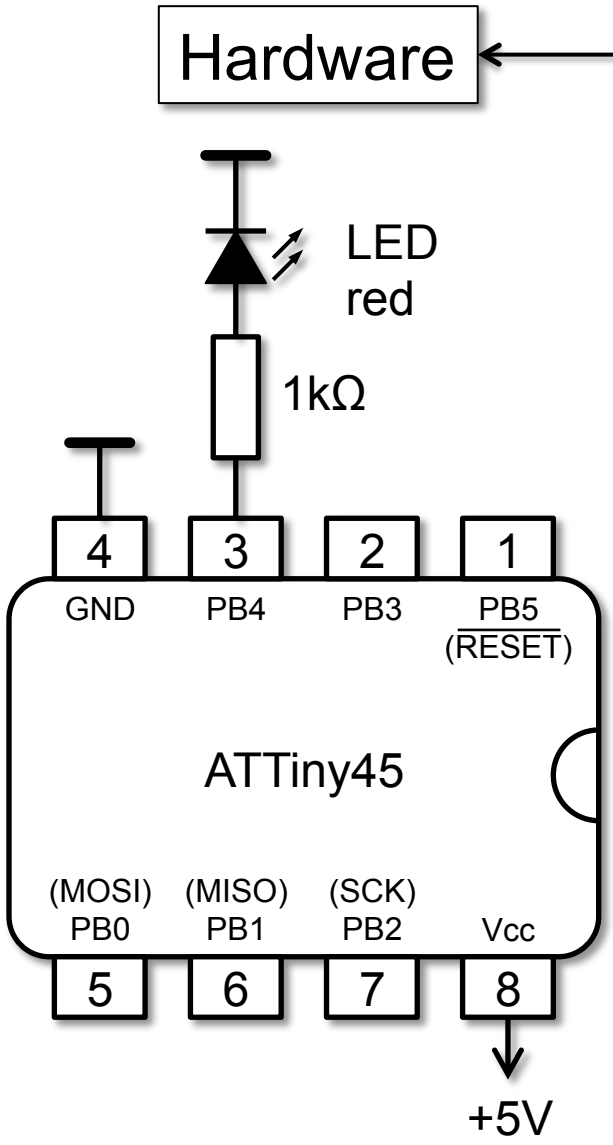
- Need to install AVR-GCC toolchain separately
- Documentation
  - http://avr-eclipse.sourceforge.net/user%20manual/home.html
  - http://avr-eclipse.sourceforge.net/user%20manual/gettingstarted/gs_tutorials.html
- Create project
  - File | New | Project… | C/C++ | C Project | AVR Cross Target Application
- AVR Target Hardware
  - MCU Type: ATtiny45
  - MCU Frequency (Hz): 1000000


C Project
C Project
Create C project of selected type
Project name:
HelloAvr
Use default location
Location:
/Users/michaelrohs/dev/android/eclipse-indigo-ws/HelloAvr
Browse...
Project type:
AVR Cross Target Application
Empty Project
AVR Cross Target Static Library
Makefile project
Toolchains:
AVR-GCC Toolchain
Show project types and toolchains only if they are supported on the platform
< Back
Next >
Cancel
Finish

New C Source File



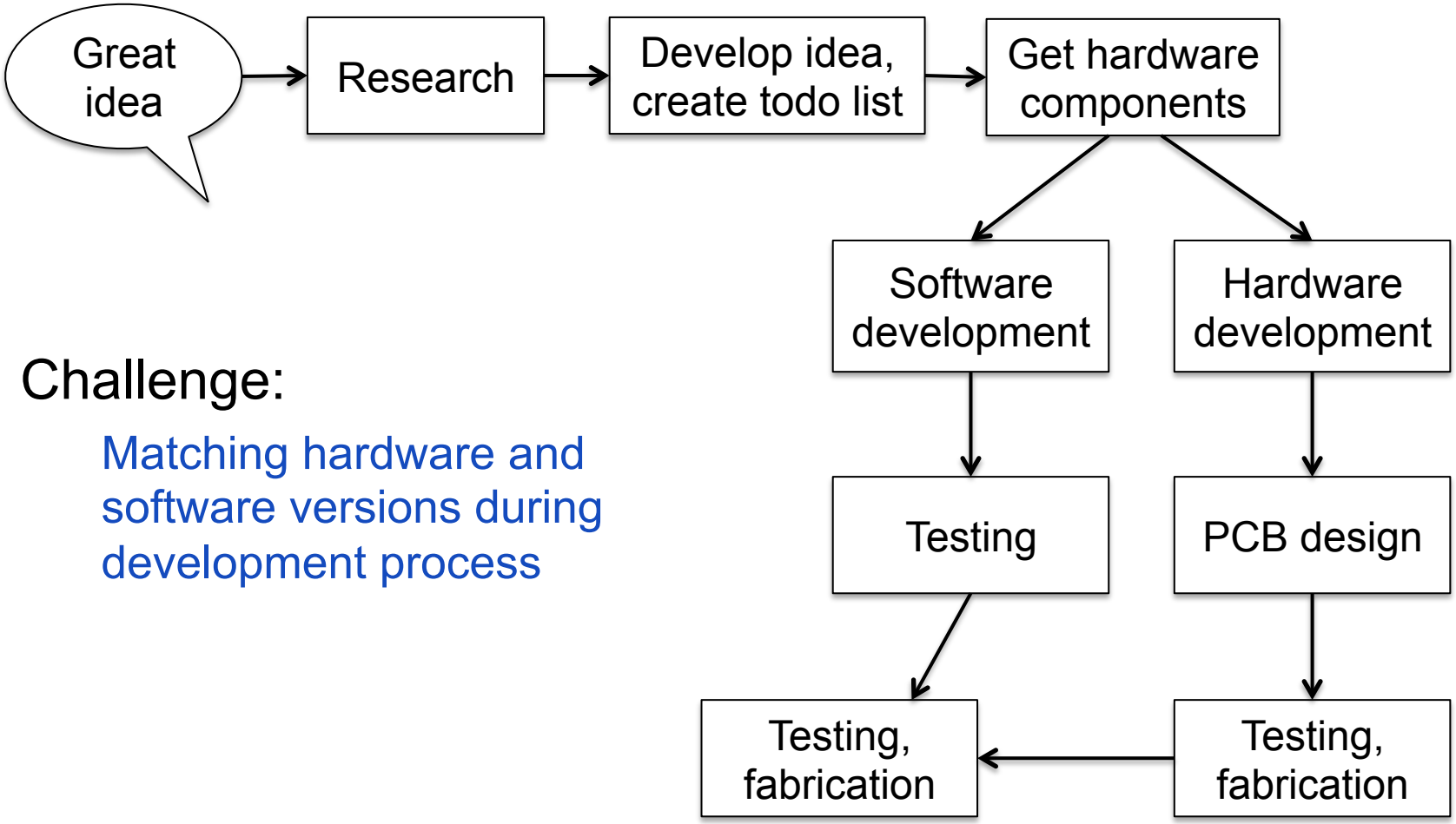
“µC Hello World”: Blinking LED




```
#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;
}
```

Development Process



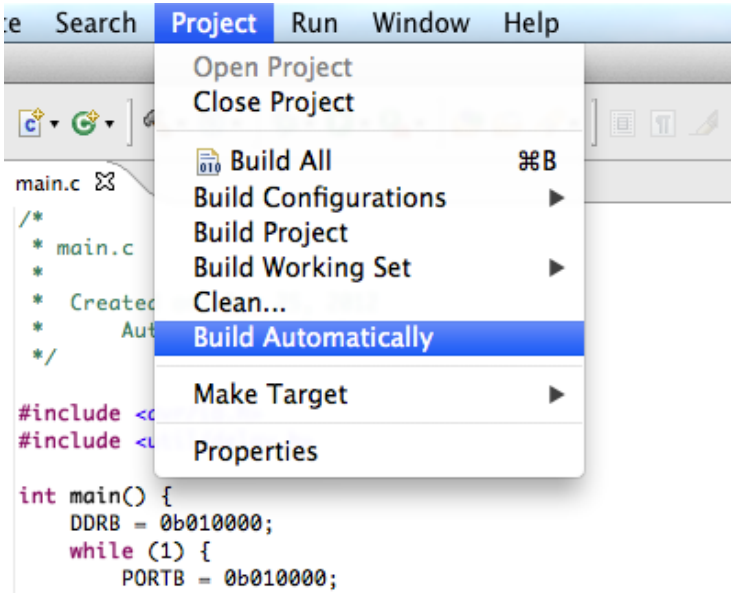
Challenge:

Matching hardware and software versions during development process

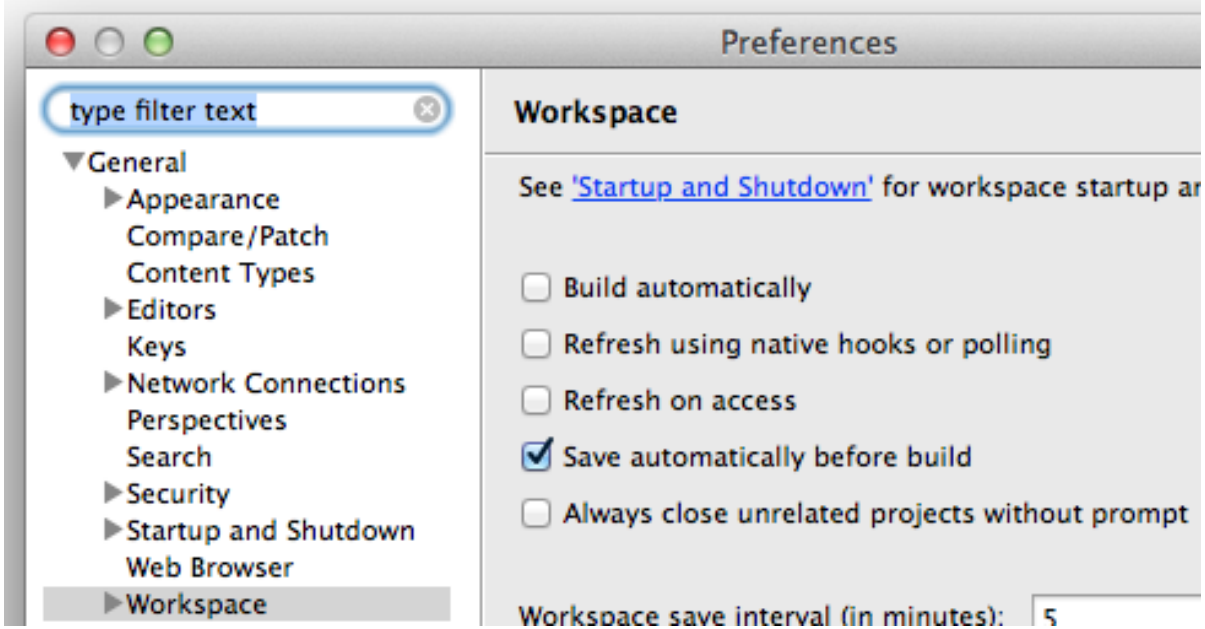
Source: Gadre, Malhotra: tinyAVR projects

Build Settings

- uncheck “build automatically”

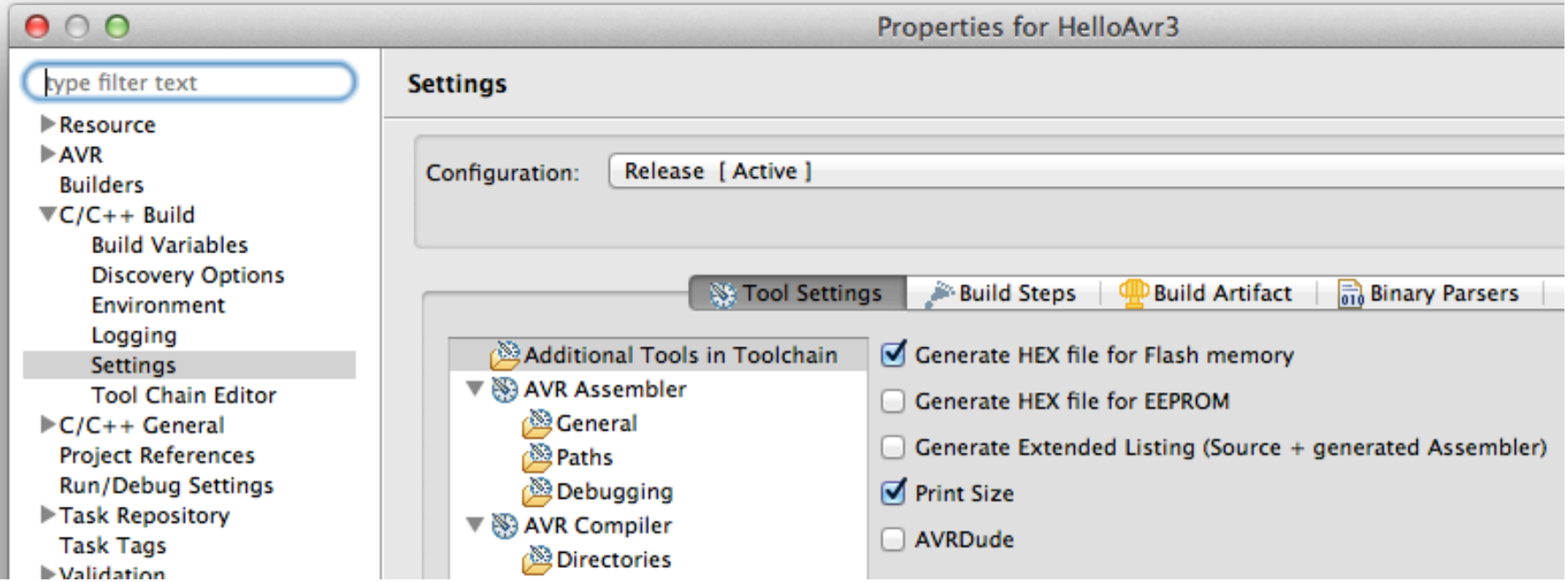


- check “save automatically”



Build Settings

- uncheck EEPROM file
- uncheck Assembler listing



Building the Project

- Right-click project name, “Build Project”
- Console output

```
**** Build of configuration Release for project HelloAvr2 ****

make all
Building file: ../main.c
Invoking: AVR Compiler
avr-gcc -Wall -Os -fpack-struct -fshort-enums -std=gnu99 -funsigned-char -funsigned-bitfields -mmcu=attiny45 -DF_CPU=1000000UL -MMD -MP -MF"main.d" -MT"main.d" -c -o "main.o" "../main.c"
Finished building: ../main.c

Building target: HelloAvr2.elf
Invoking: AVR C Linker
avr-gcc -Wl,-Map,HelloAvr2.map -mmcu=attiny45 -o "HelloAvr2.elf"  ./main.o
Finished building target: HelloAvr2.elf

Create Flash image (ihex format)
avr-objcopy -R .eeprom -O ihex HelloAvr2.elf  "HelloAvr2.hex"
Finished building: HelloAvr2.hex

Invoking: Print Size
avr-size --format=avr --mcu=attiny45 HelloAvr2.elf
AVR Memory Usage
----------------
Device: attiny45

Program:     146 bytes (3.6% Full)
(.text + .data + .bootloader)

Data:          0 bytes (0.0% Full)
(.data + .bss + .noinit)

Finished building: sizedummy

**** Build Finished ****
```

AVR Compiler
avr-gcc main.c → main.o

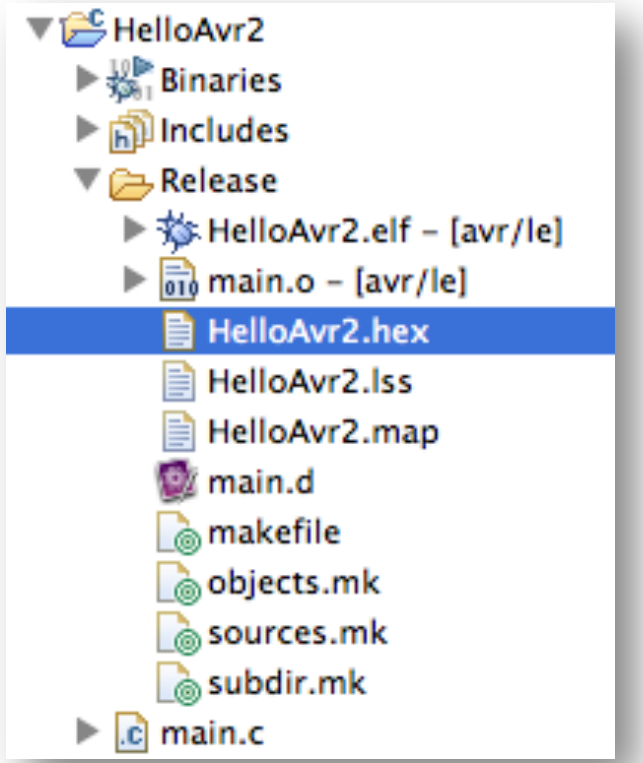
AVR Linker
avr-gcc main.o → HelloAvr2.elf

Create flash image
avr-objcopy HelloAvr2.elf → HelloAvr2.hex

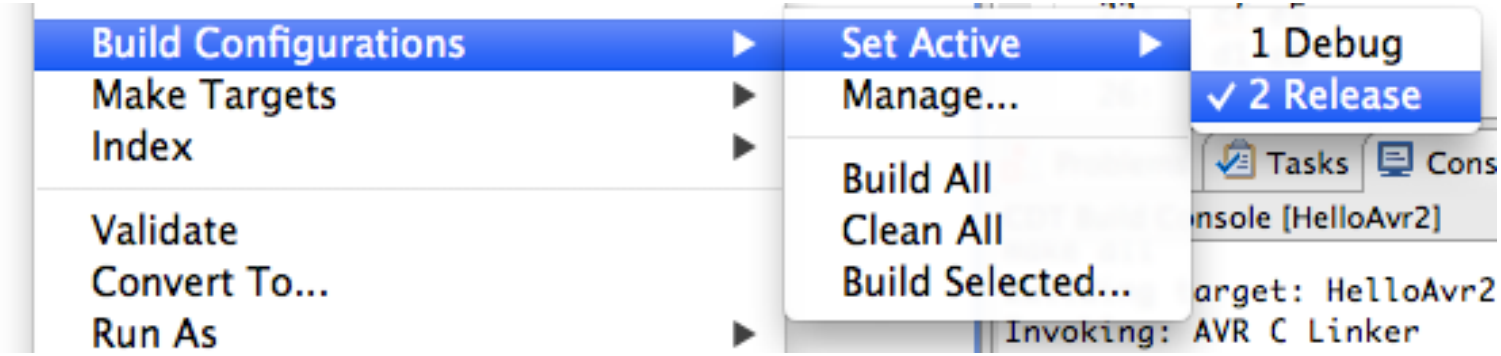
Print memory usage
avr-size

Build Result

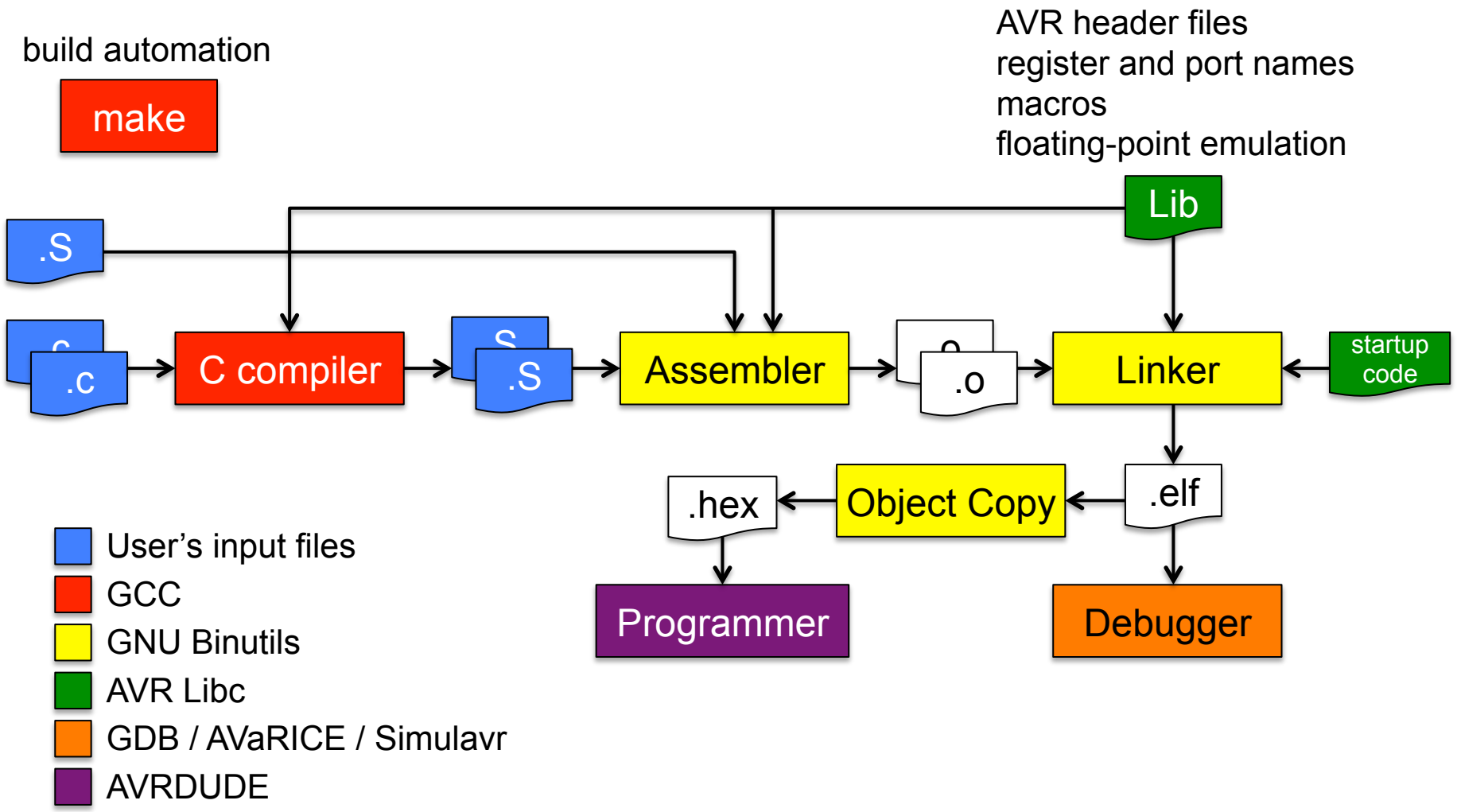
- Generated files
  - Debug folder
  - Release folder



- Build configurations
  - Switch to “release configuration” to install on hardware



AVR-GCC Toolchain Overview



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

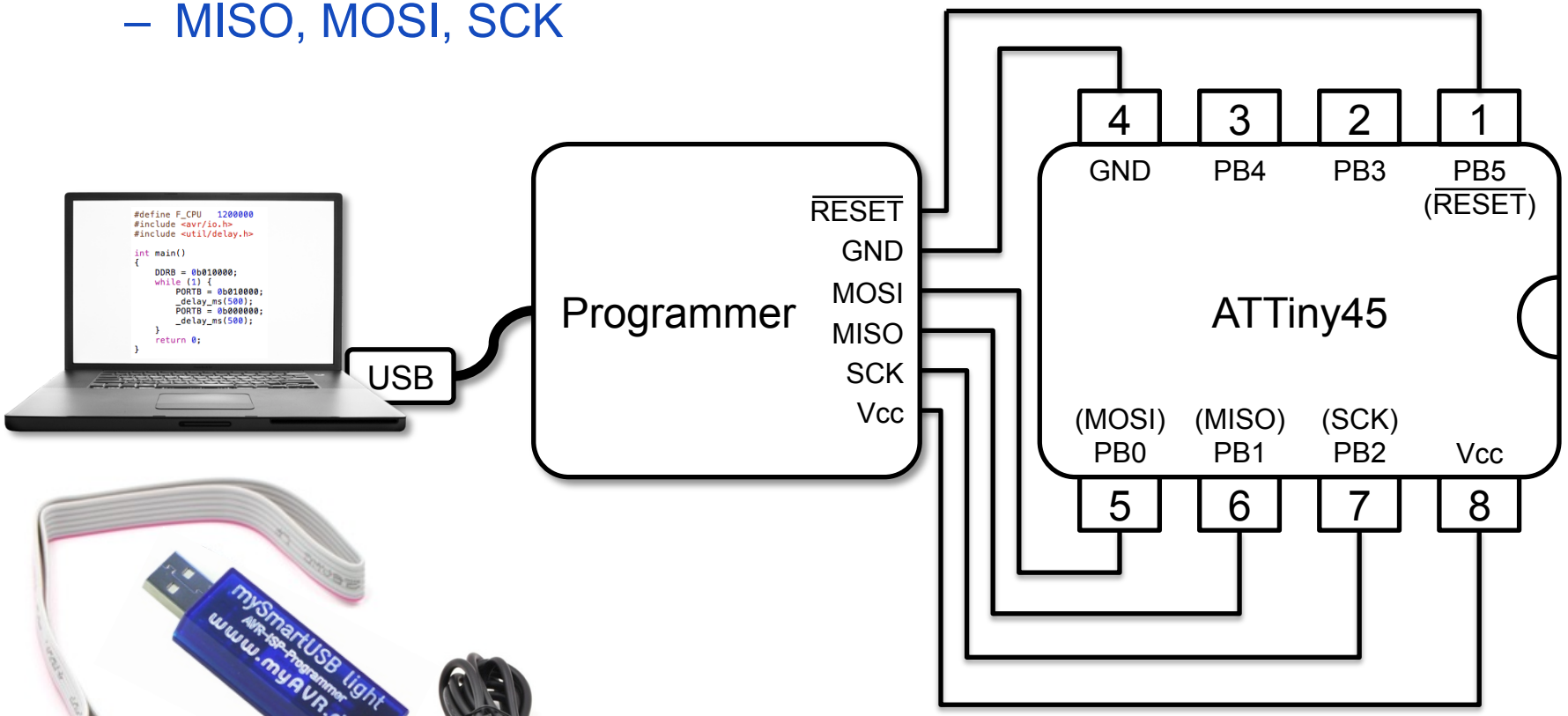
Assembly Language

- ATtiny, Atmega
  - simple instruction sets
  - for example: ATtiny13 has 120 instructions
  - reasonably simple to program
- http://avra.sourceforge.net/index.html

CONFIGURING AND UPLOADING

Uploading the Program to the µC

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



USB Drivers for “mySmartUSB light”

- USB chip CP2102 from Silicon Laboratories
- Windows

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

  background information, command set, etc.
- Mac OS X, Linux

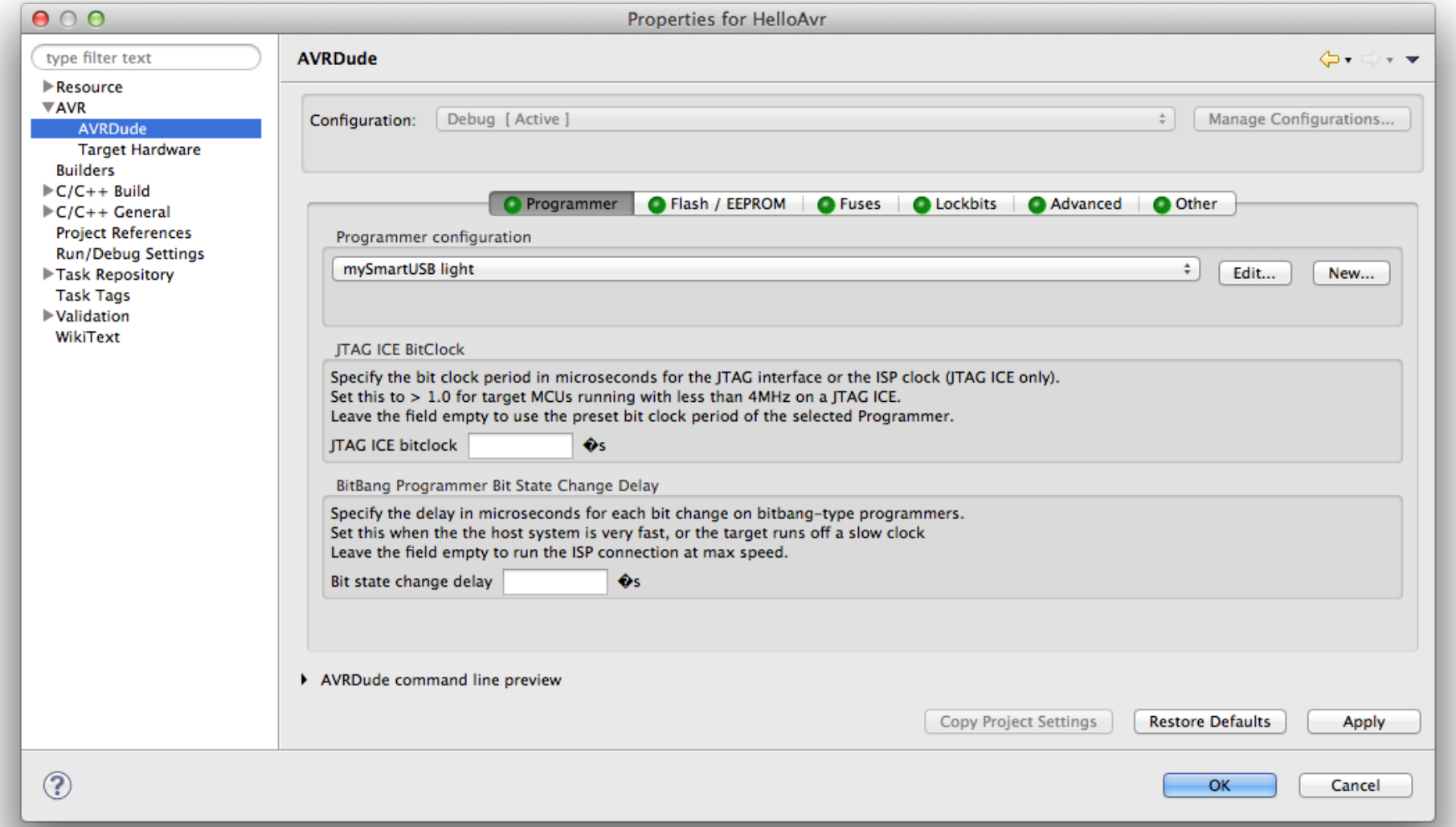
  http://www.silabs.com/products/mcu/pages/usbtouartbridgevcpdrivers.aspx

  VCP Driver Kit

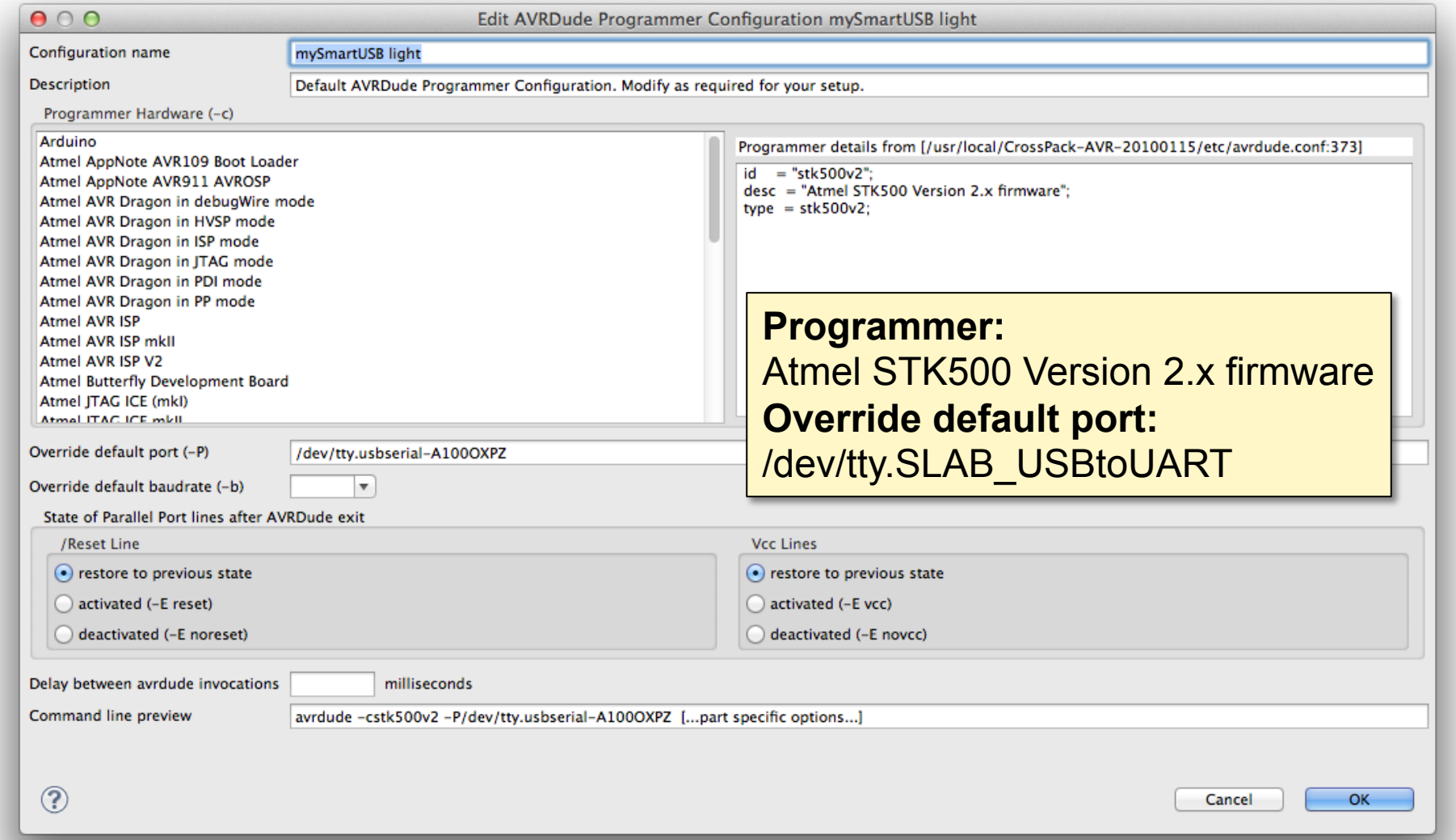
  List serial devices: ls /dev/tty.*

  Java Serial: http://rxtx.qbang.org

Programmer Configuration



Programmer Configuration



Programming the µC

- 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

Configuring the µC

- Configuring the µC = setting “fuse bits”
  - Clock rate, programmability, low-voltage detection, etc.
  - Caution: Wrong fuse bit settings may render chip unusable!
- Only needed once (e.g. when clock rate changes)
- “Fuse bits” described in datasheet
- Simpler with calculators / tools
  - Online fuse calculator
    - http://www.engbedded.com/fusecalc/
  - AVRFuses tool
    - http://www.vonnieda.org/software/avrfuses

Online Fuse Calculator

http://www.engbedded.com/fusecalc/

Device selection

Select the AVR device type you want to configure. When changing this setting, default fuse settings will automatically be applied. Presets (hexadecimal representation of the fuse settings) can be reviewed and even be set in the last form at the bottom of this page.

AVR part name: ATtiny45 Select (141 parts currently listed)

Feature configuration

This allows easy configuration of your AVR device. All changes will be applied instantly.

Features

Int. RC Osc. 8 MHz; Start-up time PWRDWN/RESET: 6 CK/14 CK + 64 ms; [CKSEL=0010 SUT=10]; default value

- [ ] Clock output on PORTB4; [CKOUT=0]
- [x] Divide clock by 8 internally; [CKDIV8=0]

Brown-out detection disabled; [BODLEVEL=111]

- [ ] Preserve EEPROM memory through the Chip Erase cycle; [EESAVE=0]
- [ ] Watch-dog Timer always on; [WDTON=0]
- [x] Serial program downloading (SPI) enabled; [SPIEN=0]
- [ ] Debug Wire enable; [DWEN=0]
- [ ] Reset Disabled (Enable PB5 as i/o pin); [RSTDISBL=0]
- [ ] Self Programming enable; [SELFPRGEN=0]

Low	High	Extended
0x 62	0x DF	0x FF *

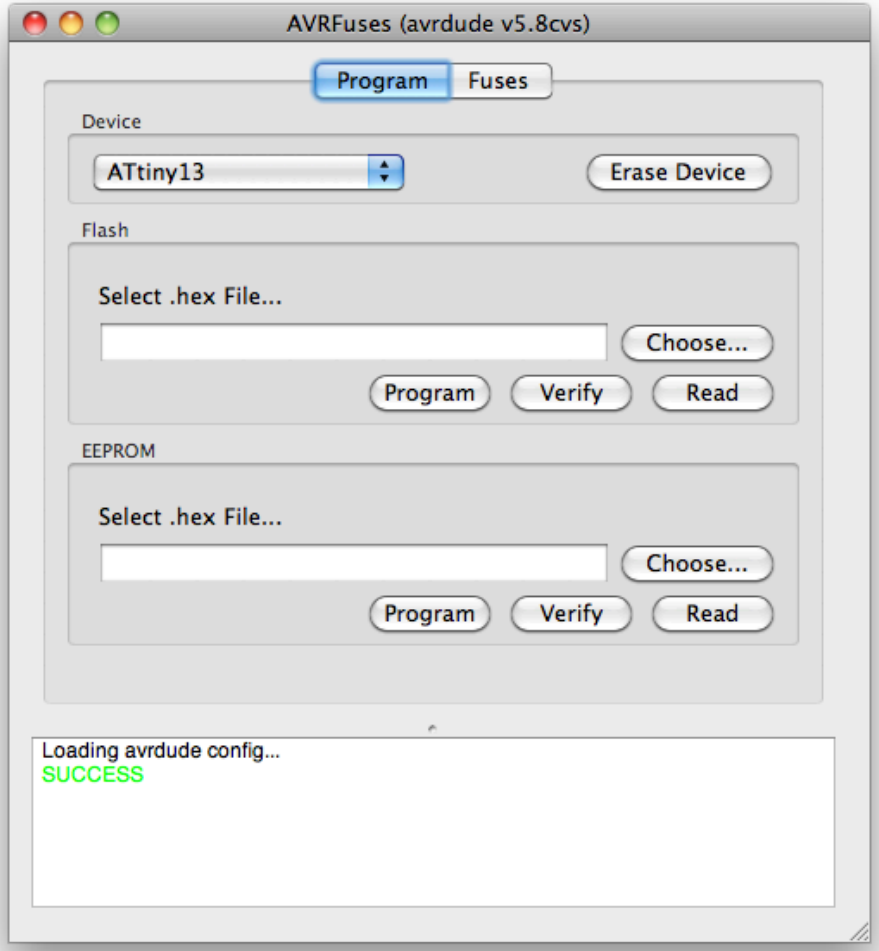
AVR Clock Options

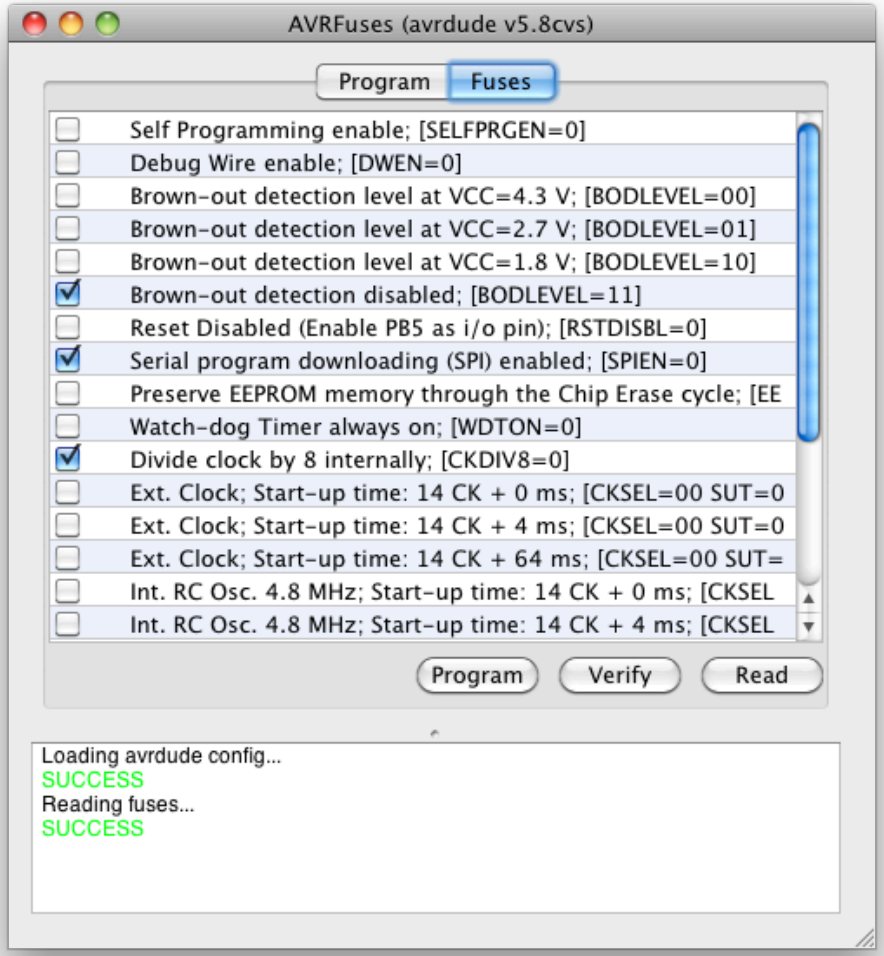
- Clock frequency can be chosen
  - Application requirements, power consumption
  - Clock prescaler register (divide clock by factor)
  - Component clocks can be disabled to reduce power consumption
- Clock source can be chosen
  - Internal resistor capacitor (RC) oscillator
    - Convenient, but not 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

AVRFuses Tool (optional)

Caution: Wrong fuse bit settings may render chip unusable!

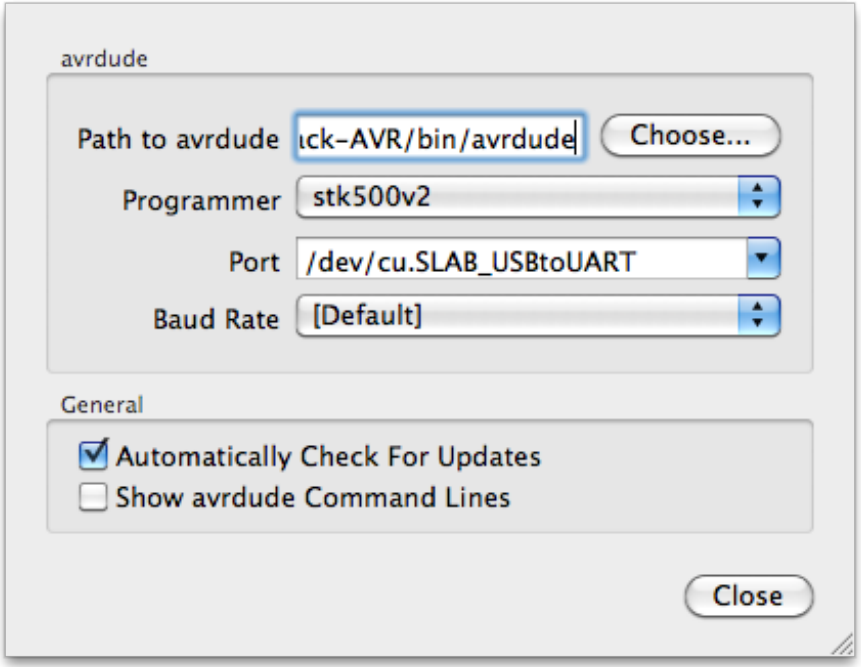
Tool: AVRFuses (www.vonnieda.org/AVRFuses/)





Configuring AVRFuses for the Programmer and USB Port

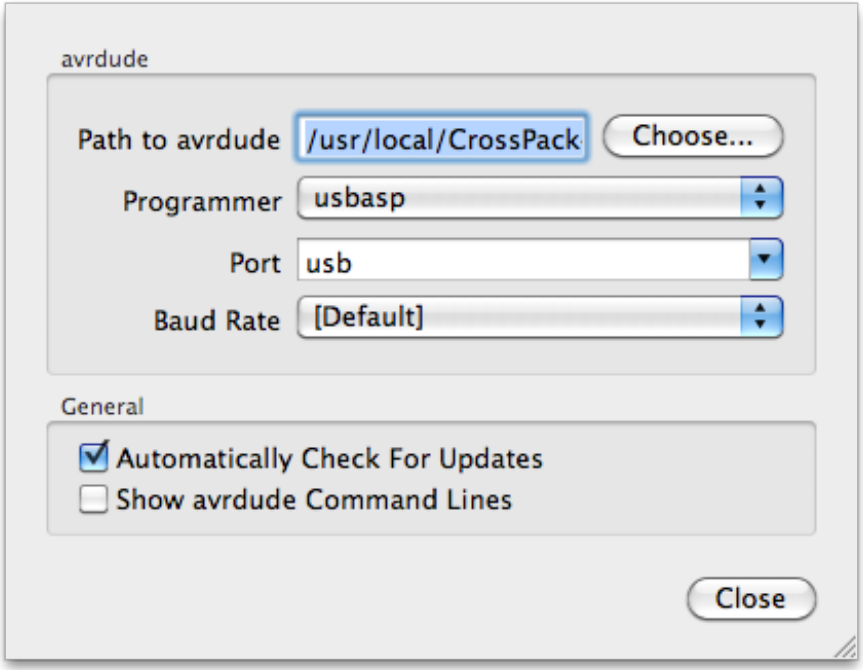
mySmartUSB light:



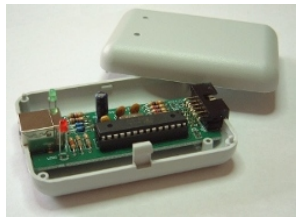
/dev/cu.SLAB_USBtoUART

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

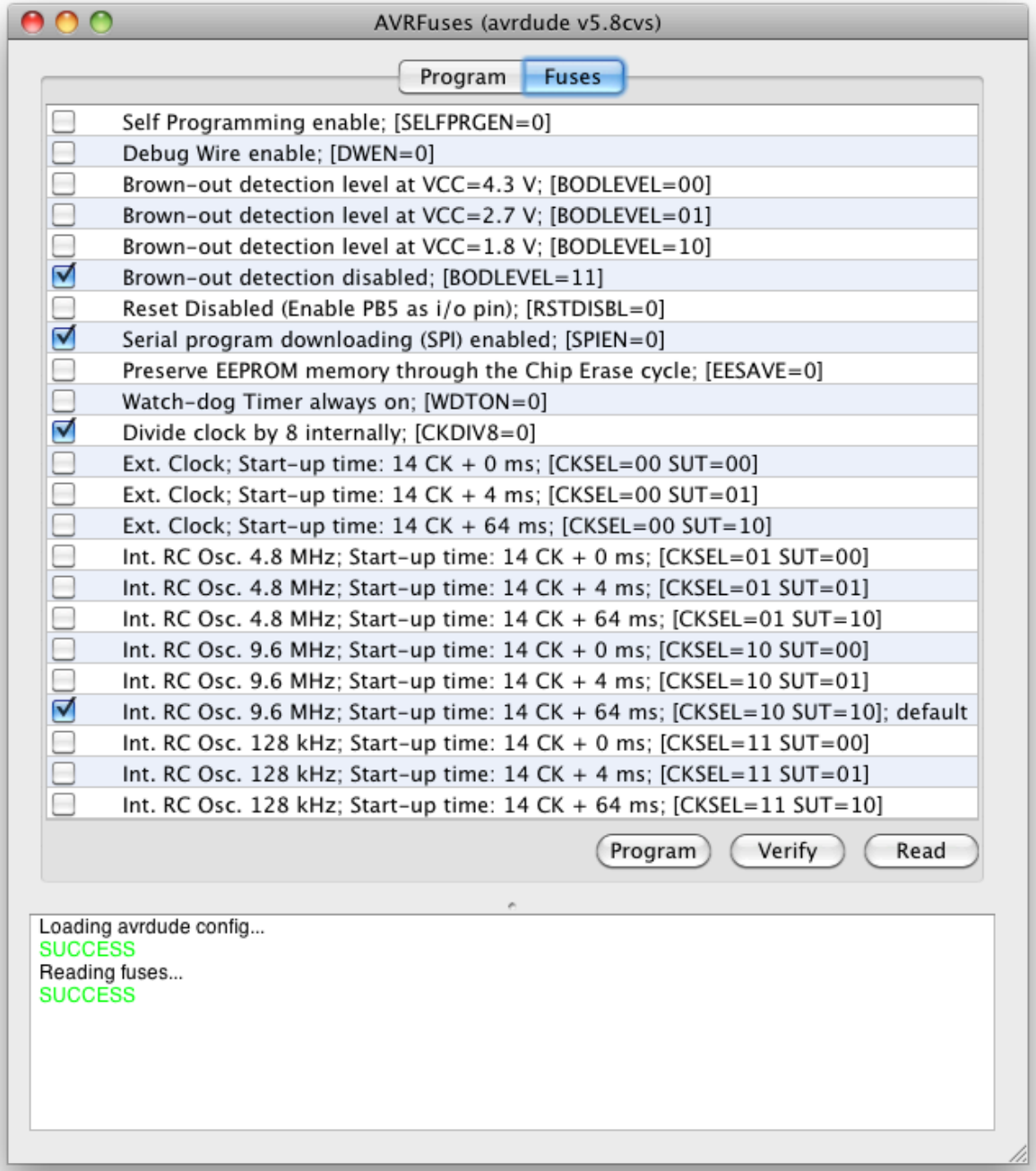
USBasp:



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

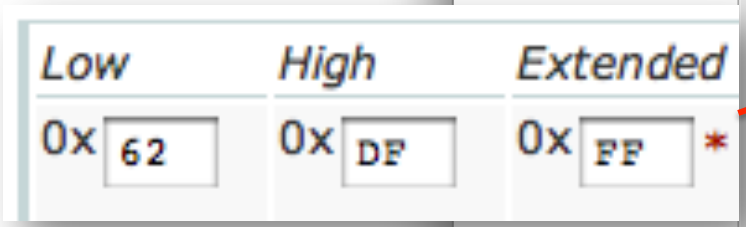


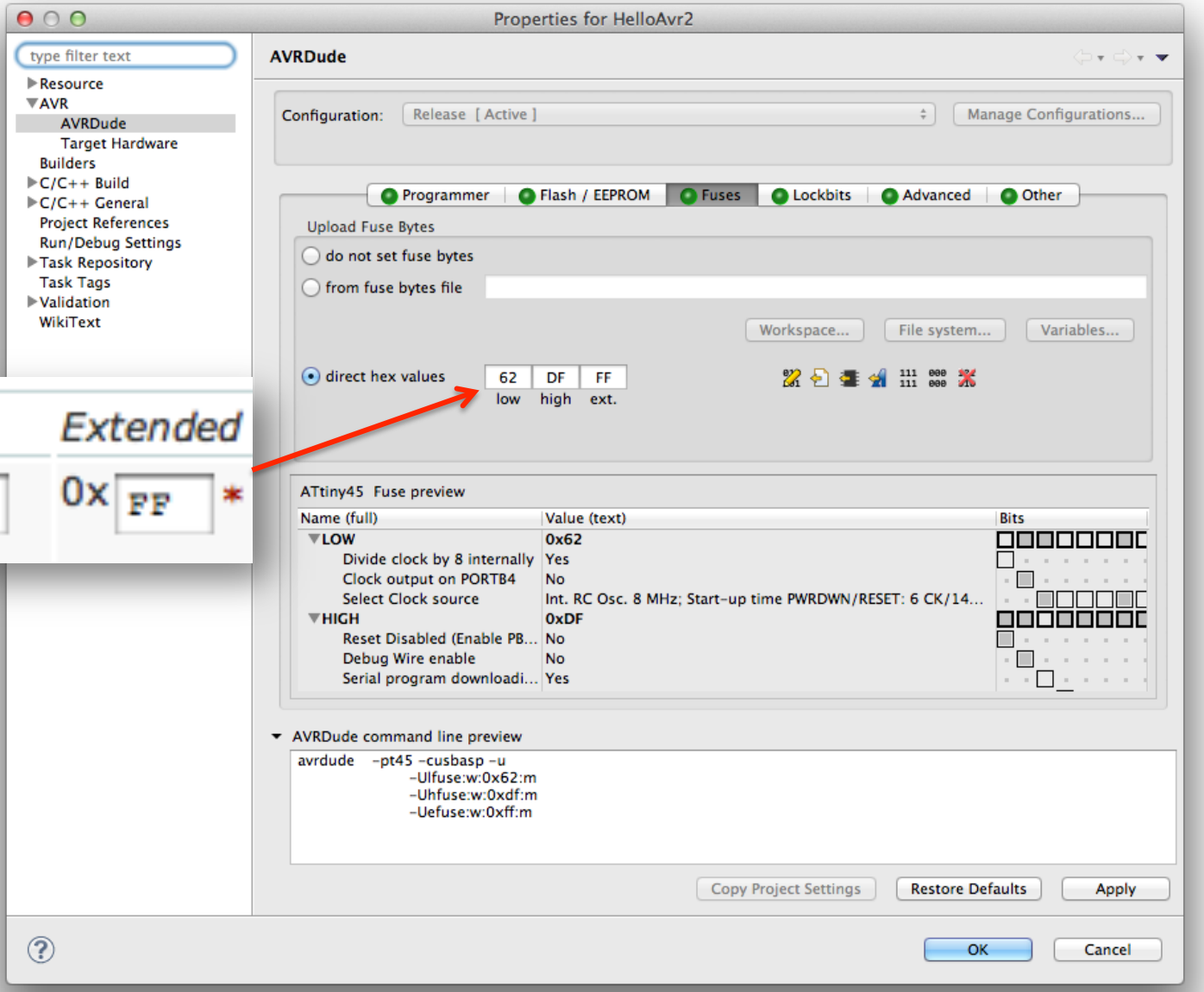
- Fuses show factory configuration of ATtiny13
- Brown-out detection
  - reset when Vcc below level
- Reset disabled
  - use reset pin as I/O pin: dangerous!
- Start-up time
  - delay until conditions are stable



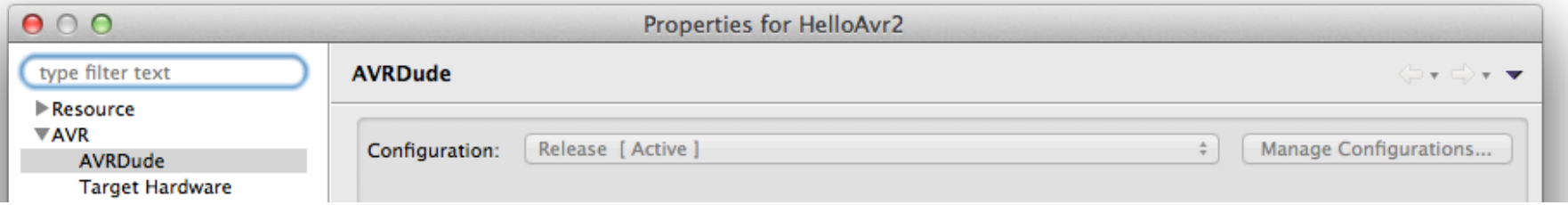
Setting Fuses with Eclipse: ATtiny45

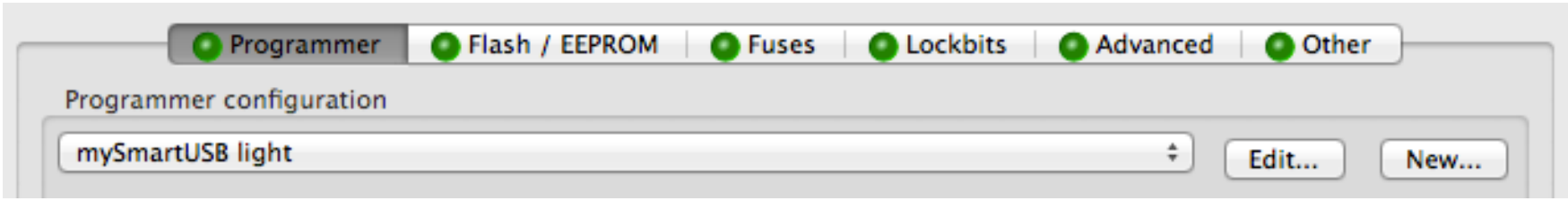
for ATtiny45:

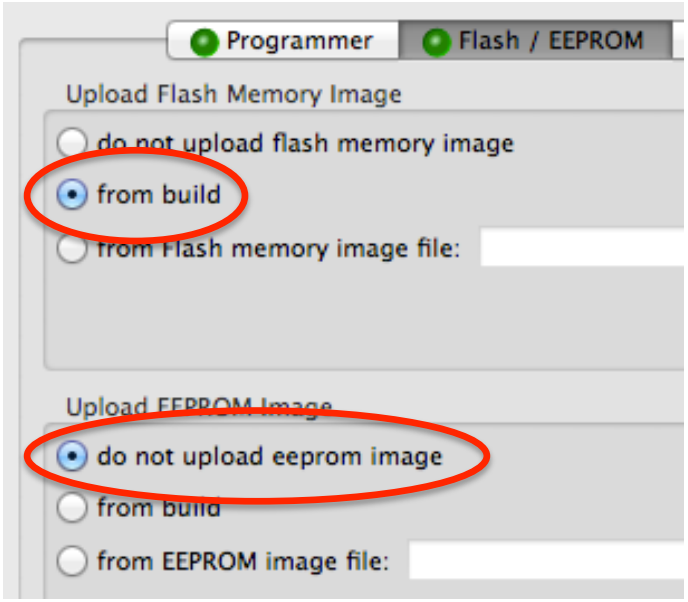


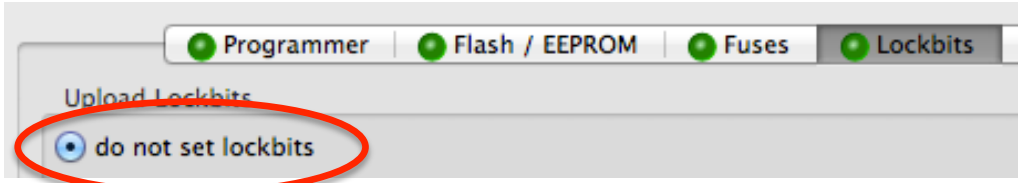


AVRDude Settings





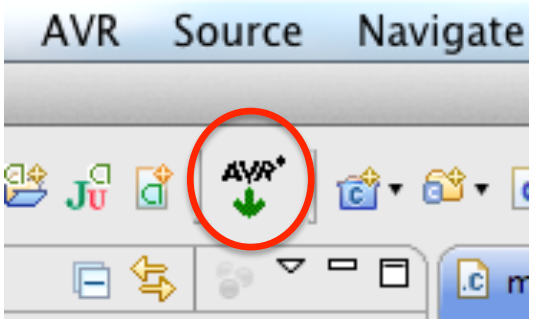




Uploading Program with Eclipse

- Console output

```
Launching /usr/local/CrossPack-AVR/bin/avrdude -pt45 -cusbasp -Uflash:w:HelloAvr2.hex:a
Output:
avrdude: AVR device initialized and ready to accept instructions
Reading | ################################################## | 100% 0.02s
avrdude: Device signature = 0x1e9206
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 "HelloAvr2.hex"
avrdude: input file HelloAvr2.hex auto detected as Intel Hex
avrdude: writing flash (146 bytes):
Writing | ################################################## | 100% 1.20s
avrdude: 146 bytes of flash written
avrdude: verifying flash memory against HelloAvr2.hex:
...
Reading | ################################################## | 100% 0.82s
avrdude: verifying ...
avrdude: 146 bytes of flash verified
avrdude done.  Thank you.
avrdude finished
```



AVR Eclipse Plugin – Advanced Settings

- Target Hardware: Specify target microcontroller
  - MCU Type: ATtiny45 (later will also use ATmega8)
  - MCU Clock Frequency: typical values are 1 MHz (internal), 8 MHz (external quartz) , 16 MHz (external quartz)
- AVRDude: Install program on microcontroller
  - Programmer: Atmel STK500 Version 2.x firmware
  - Override default port: /dev/tty.usbserial-A100OXPZ

Command Line Without Eclipse

- Compiling
  - avr-gcc -Os -mmcu=attiny45 main.c
- Format conversion
  - avr-objcopy -R .eeprom -O ihex a.out a.hex
- Uploading
  - avrdude -pt45 -cstk500v2 -P/dev/ttyUSB0 -Uflash:w:a.hex:a

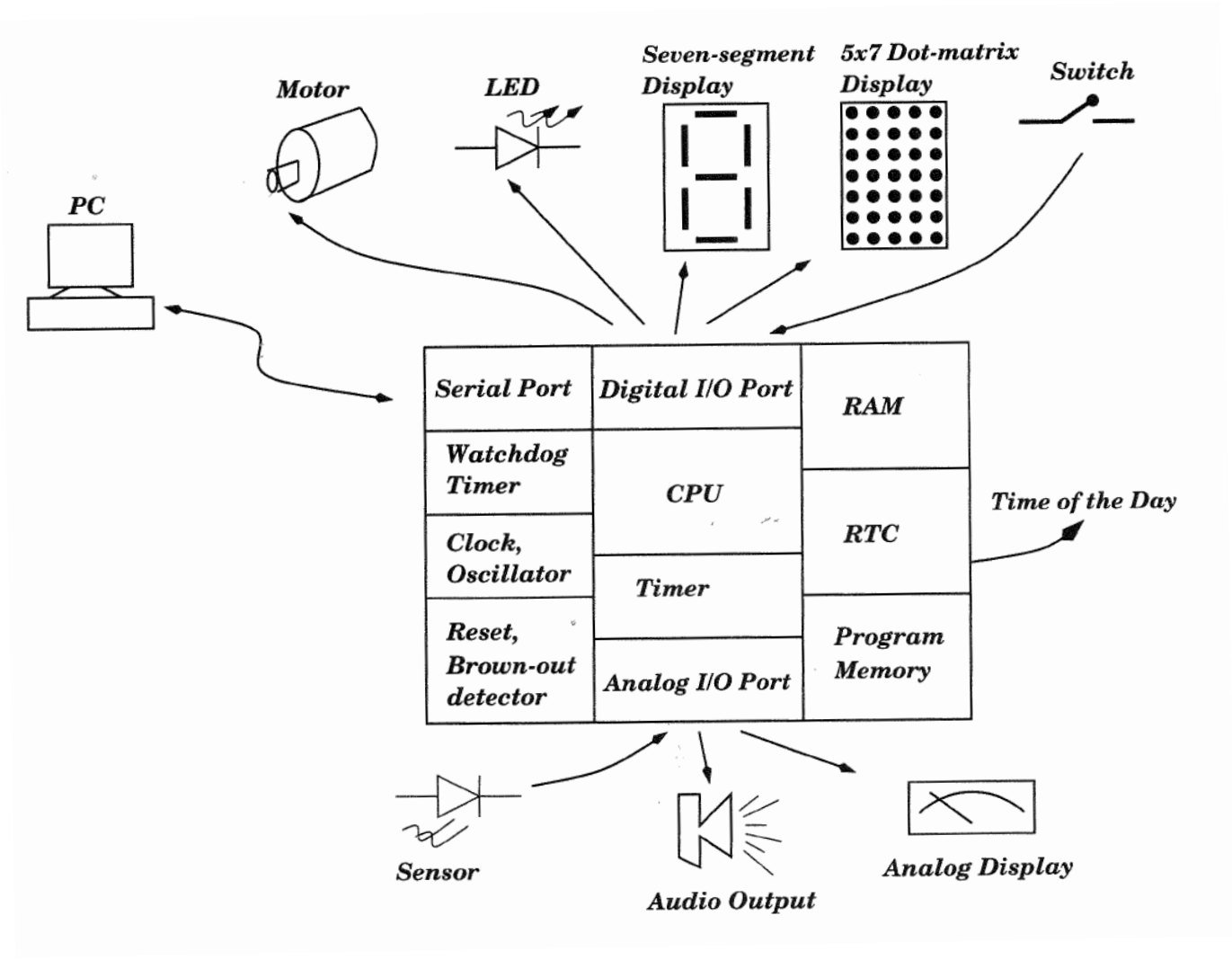
Source: Mikołaj Dądela

MICROCONTROLLERS

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



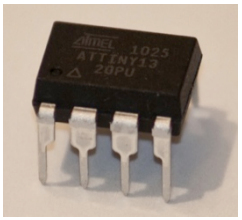
Source: Gadre, Malhotra: tinyAVR projects

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

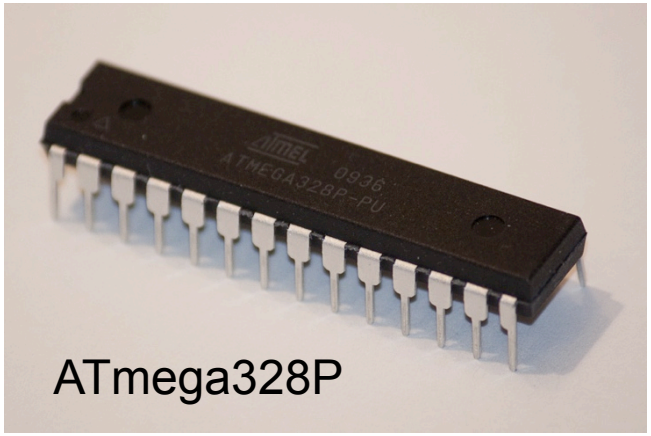
- 8-bit RISC chip, Harvard architecture
- ATtiny
  - 1–8 kB program memory
  - 6–32-pin package



ATtiny13

www.atmel.com/dyn/products/param_table.asp?category_id=163&family_id=607&subfamily_id=791

- ATmega
  - 4–256 kB program memory
  - 28–100-pin package
  - Extended instruction set
    - Multiply instructions
    - Handling larger program memories

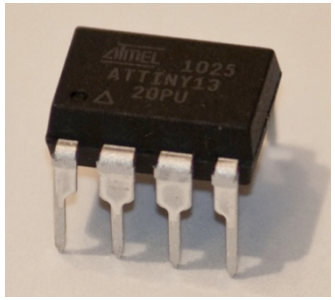


ATmega328P

www.atmel.com/dyn/products/param_table.asp?category_id=163&family_id=607&subfamily_id=760

- Large family of devices, specific features

Many types of AVRs: Choose depending on required features



ATtiny13

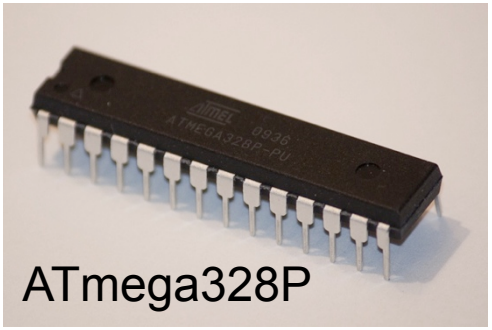
ATtiny13

- 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

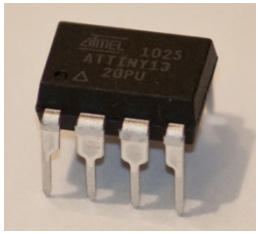
ATmega8

- 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

ATtiny45 Data Sheet



- 8 pins, 236 pages datasheet!

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
- Non-volatile Program and Data Memories
  - 2/4/8K Bytes of In-System Programmable Program Memory Flash
    - Endurance: 10,000 Write/Erase Cycles
  - 128/256/512 Bytes In-System Programmable EEPROM
    - Endurance: 100,000 Write/Erase Cycles
  - 128/256/512 Bytes Internal SRAM
  - Programming Lock for Self-Programming Flash Program and EEPROM Data Security
- Peripheral Features
  - 8-bit Timer/Counter with Prescaler and Two PWM Channels
  - 8-bit High Speed Timer/Counter with Separate Prescaler
    - 2 High Frequency PWM Outputs with Separate Output Compare Registers
    - Programmable Dead Time Generator
  - USI – Universal Serial Interface with Start Condition Detector
  - 10-bit ADC
    - 4 Single Ended Channels
    - 2 Differential ADC Channel Pairs with Programmable Gain (1x, 20x)
    - Temperature Measurement
  - 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
  - Six Programmable I/O Lines
  - 8-pin PDIP, 8-pin SOIC, 20-pad QFN/MLF, and 8-pin TSSOP (only ATtiny45/V)
- Operating Voltage
  - 1.8 - 5.5V for ATtiny25V/45V/85V
  - 2.7 - 5.5V for ATtiny25/45/85
- Speed Grade
  - ATtiny25V/45V/85V: 0 – 4 MHz @ 1.8 - 5.5V, 0 - 10 MHz @ 2.7 - 5.5V
  - ATtiny25/45/85: 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: 300 µA
  - Power-down Mode:
    - 0.1 µA at 1.8V

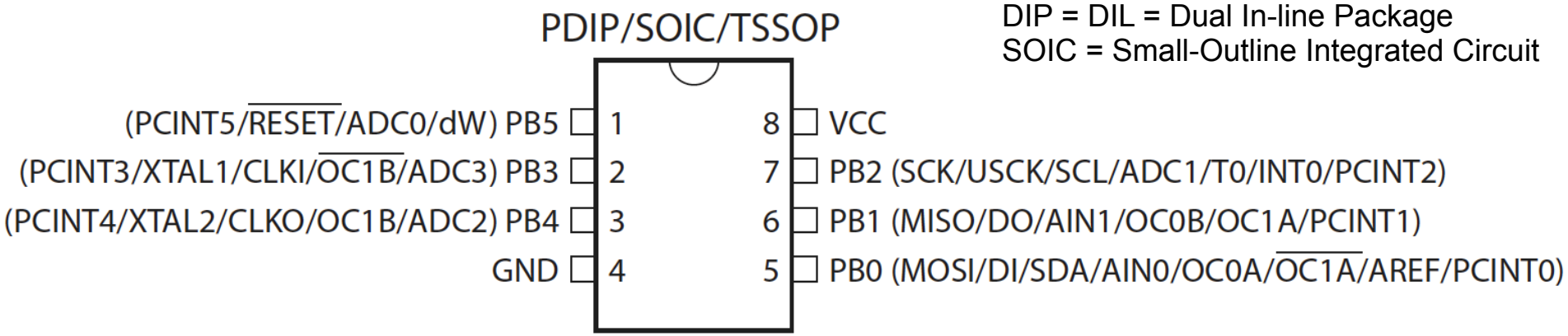
8-bit AVR® Microcontroller with 2/4/8K Bytes In-System Programmable Flash

ATtiny25/V
ATtiny45/V
ATtiny85/V *

*** Preliminary**

Rev. 2586M–AVR–07/10

Pinout ATtiny45

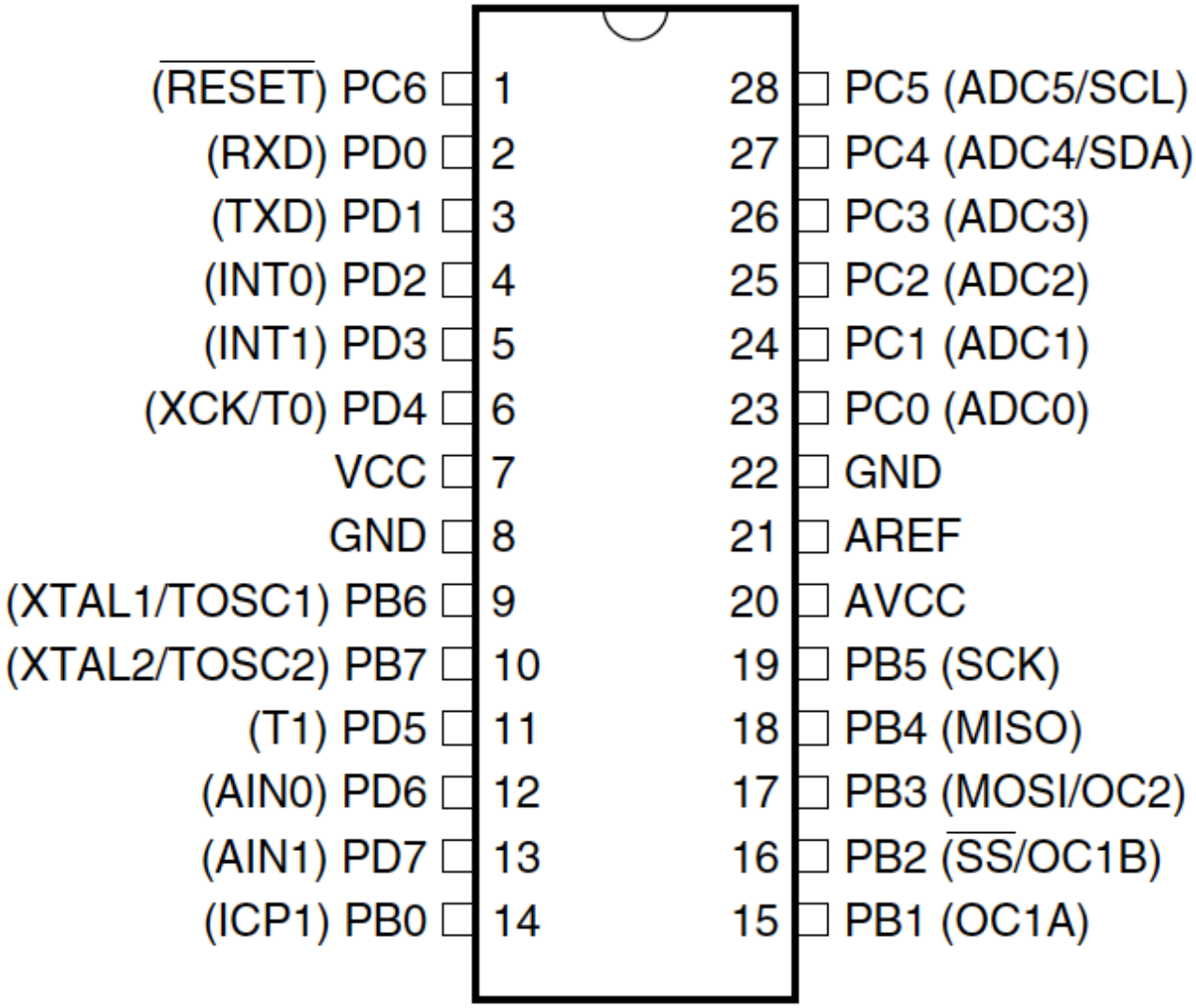


DIP = DIL = Dual In-line Package
SOIC = Small-Outline Integrated Circuit

Source: Atmel data sheet

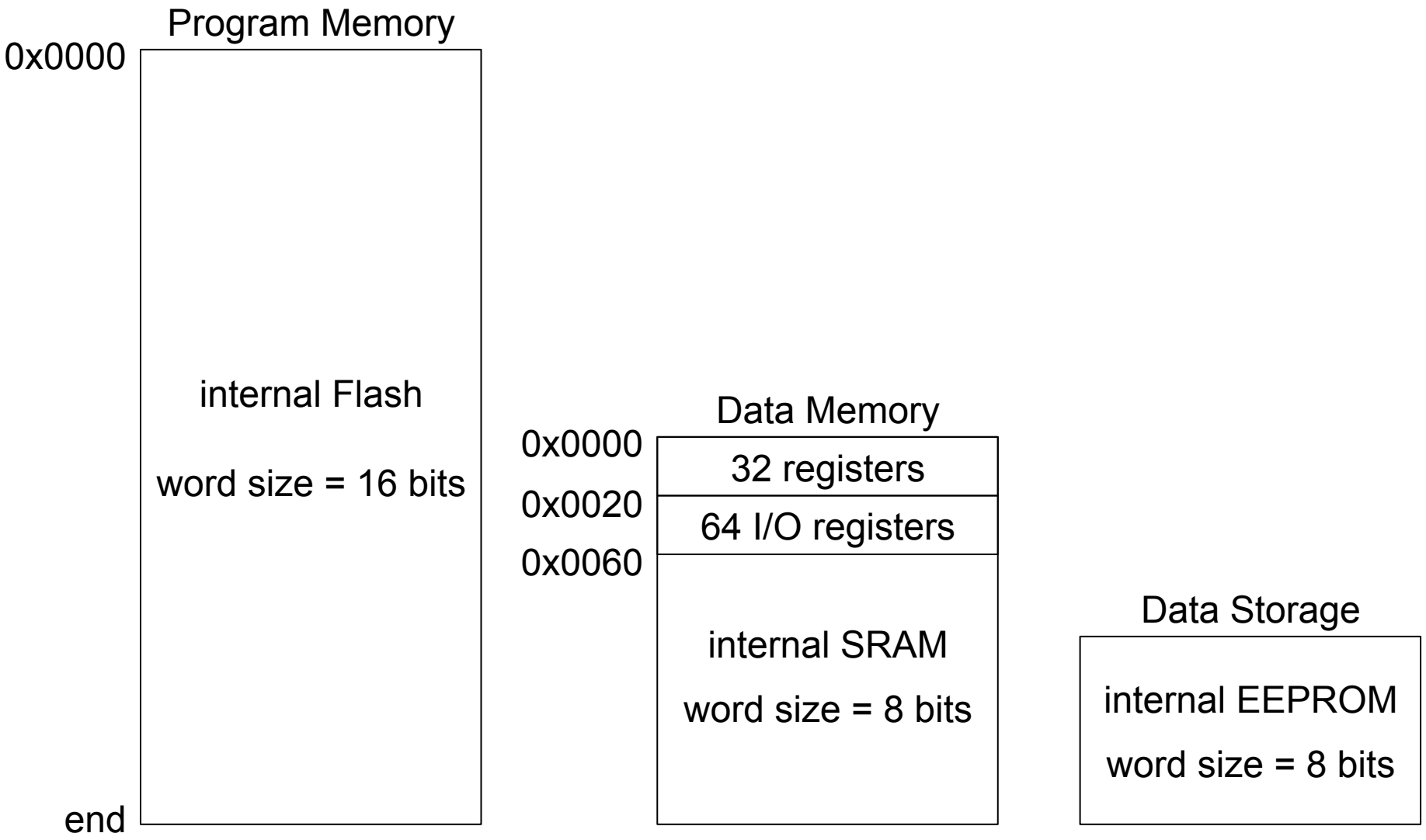
- Multiplexed pin functions, software configurable
  - Example: Flash/EEPROM programming via SPI:
    MOSI = master out, slave in (from programmer to ATtiny)
    MISO = master in, slave out (from ATtiny to programmer)
    SCK = serial clock
  - Example: ADC1 = ADC input channel 1
  - Example: PCINT3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

Pinout ATmega8



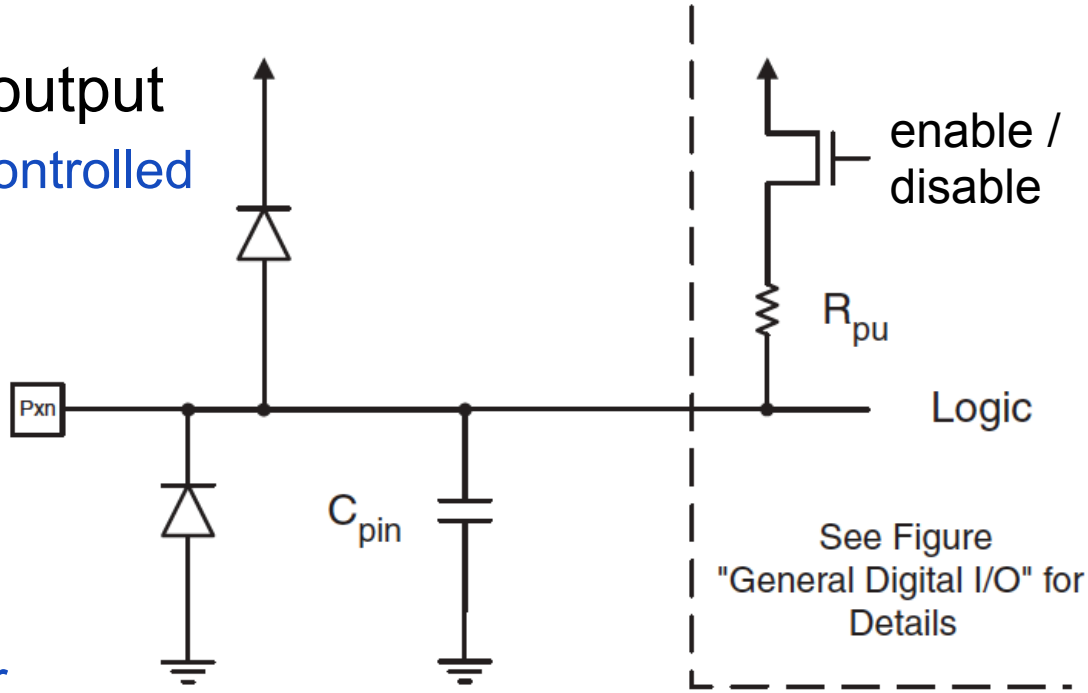
Source: Atmel data sheet

AVR Memory Layout



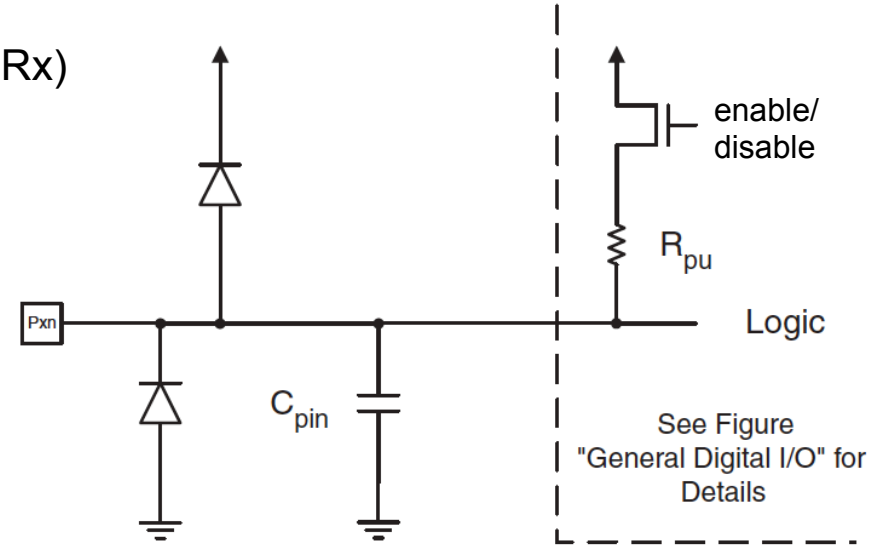
AVR I/O Ports

- 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

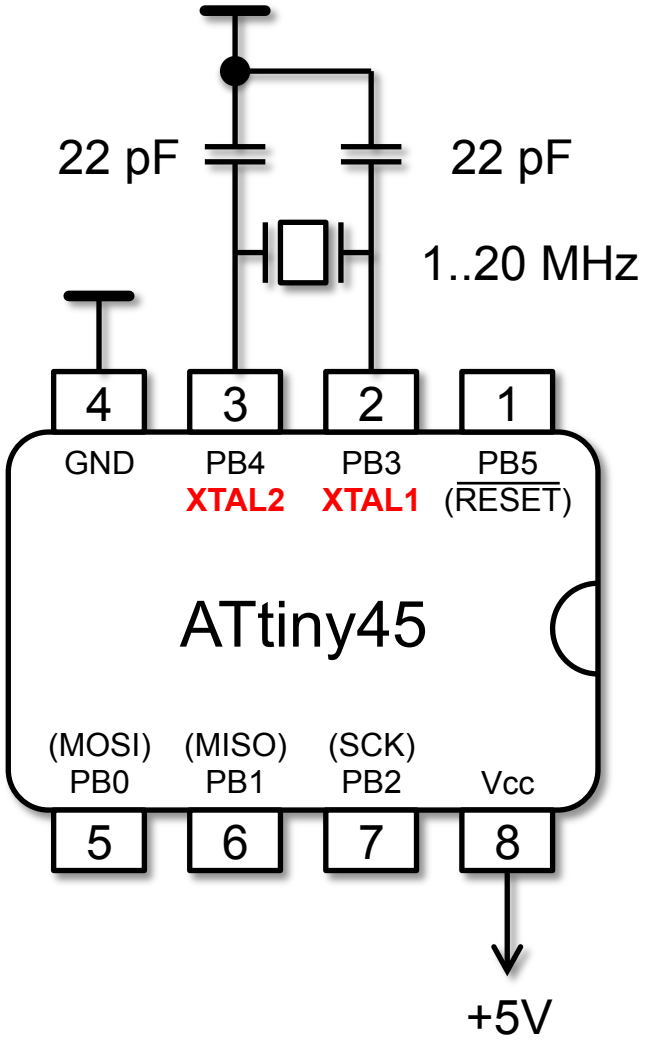
```
ldi r16, (1<<PB4) | (1<<PB1) | (1<<PB0)
ldi r17, (1<<DDB3) | (1<<DDB2) |
         (1<<DDB1) | (1<<DDB0)
out PORTB,r16
out DDRB,r17
nop        // synchronization
in r16,PINB
```

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;
```

External Clock: Quartz Crystal Oscillators



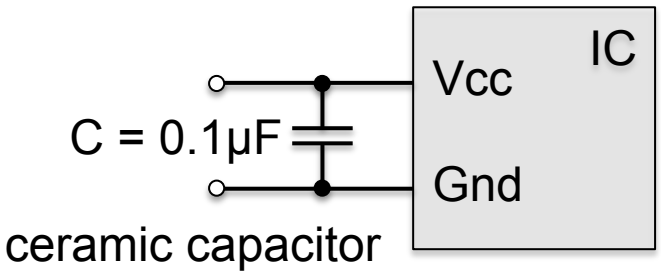
- More precise than internal oscillators
- Quartz 1..20 MHz
- Ceramic capacitors 12-22pF
- Place quartz and capacitors close to AVR pins
- Change CLKSEL fuse bits

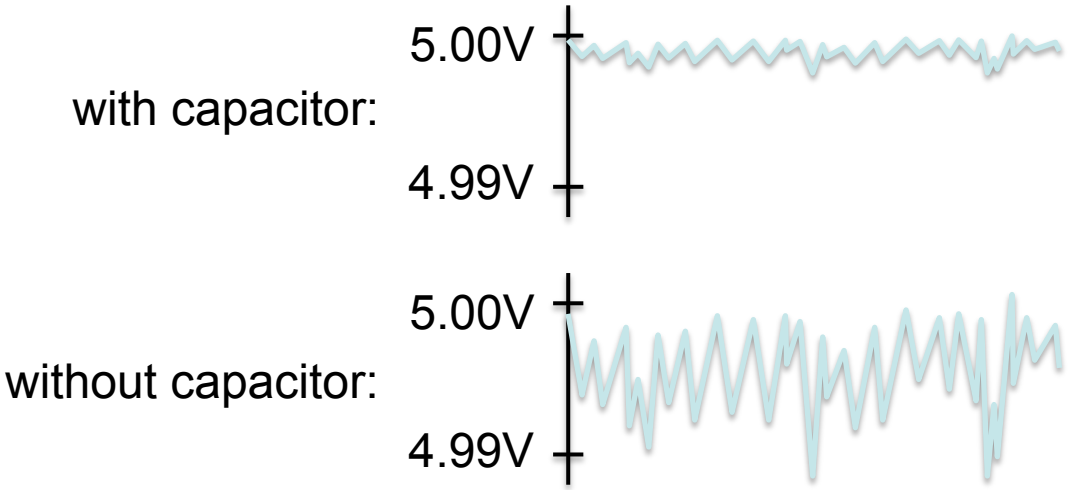
Stabilizing and Decoupling Capacitors (Stütz- und Abblockkondensatoren)

- Sudden fluctuation in current caused by
  - switching on/off LEDs, motors, relays causes
  - changing state of AVR pins
- Power supply alone cannot compensate for these
- Solution: stabilizing capacitors between VCC and ground
  - no current flow through them after charging (if voltage stable)
  - local energy source
  - filter spikes
- Higher frequency ripple requires smaller capacitor

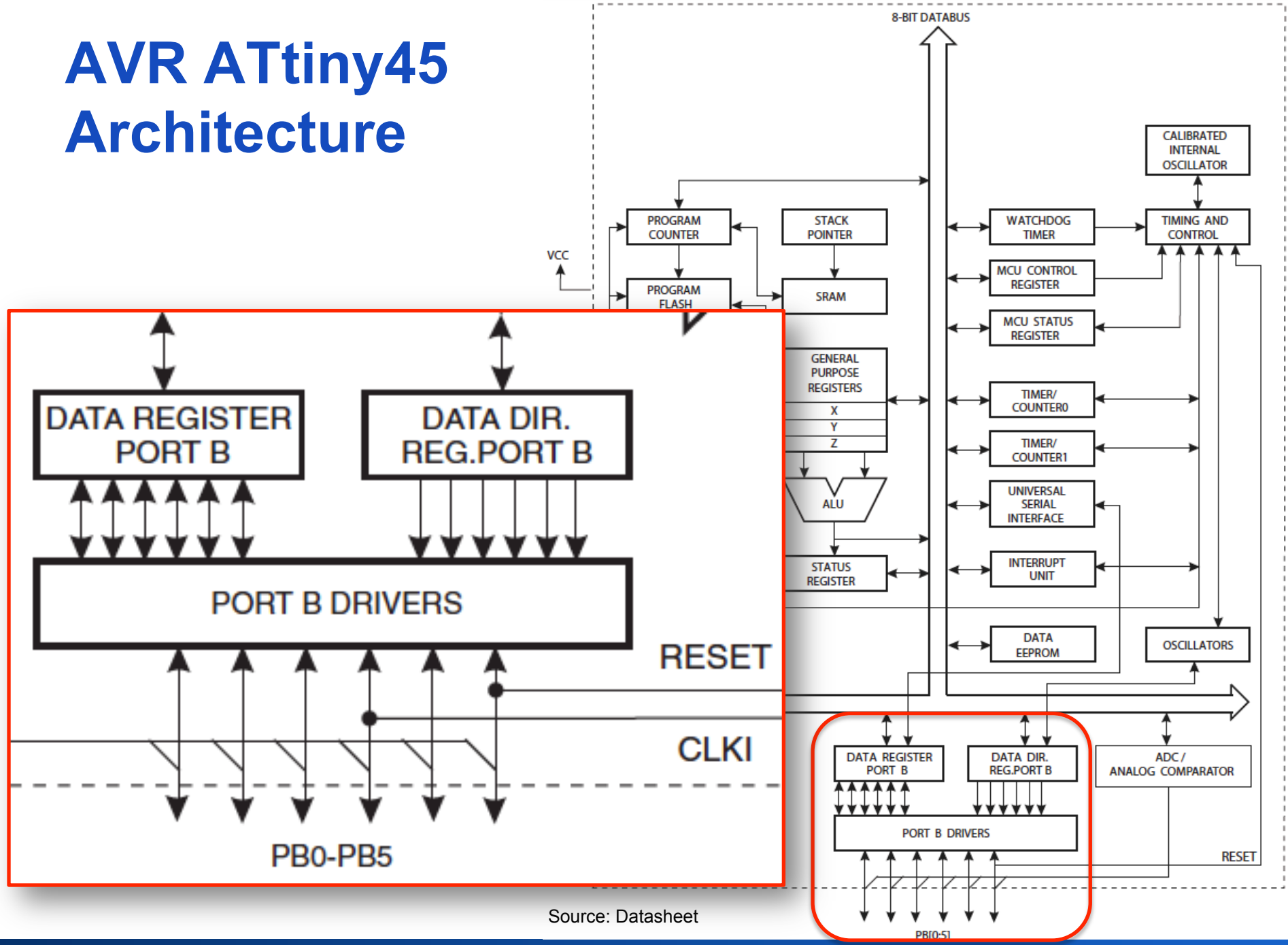
Stabilizing and Decoupling Capacitors (Stütz- und Abblockkondensatoren)

- Larger capacitors (10µF..100µF) as a local energy source
  - Electrolytic, high capacitance, high leakage, not suited for high frequencies, polar (!)
- Smaller capacitors (10nF..100nF) for filtering spikes
  - Ceramic, low capacitances, suited for high frequencies
- Place capacitors between GND and VCC of ICs
  - Place close to IC pins

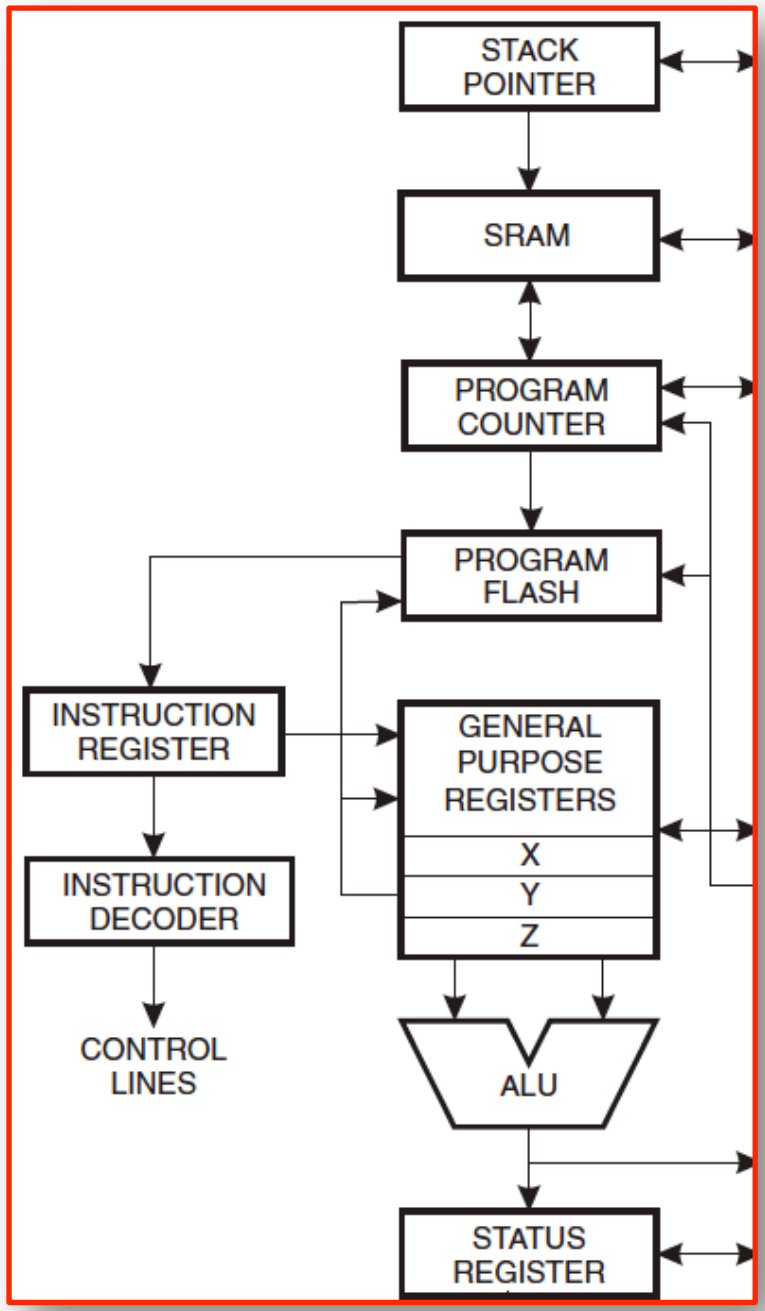


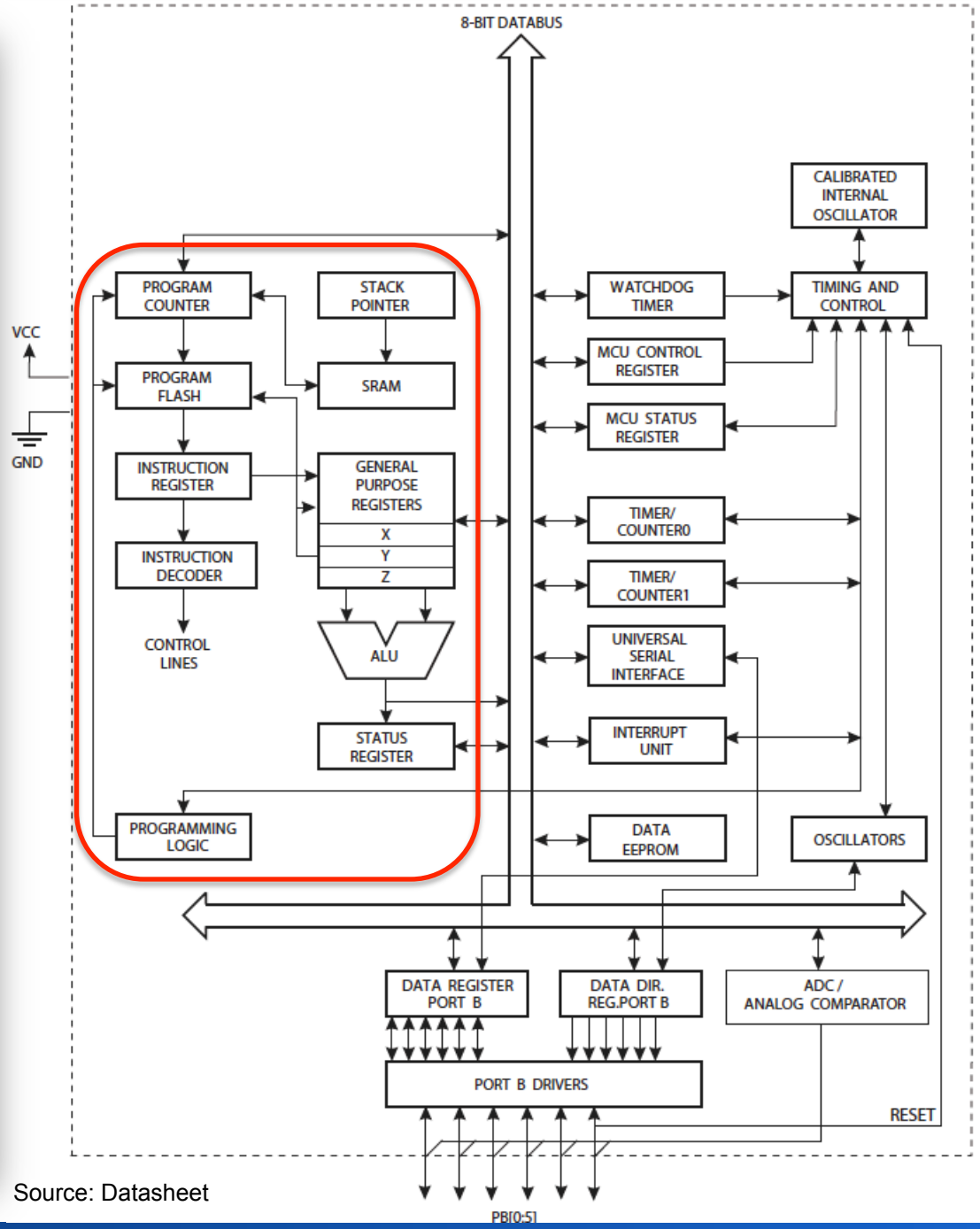


AVR ATtiny45 Architecture



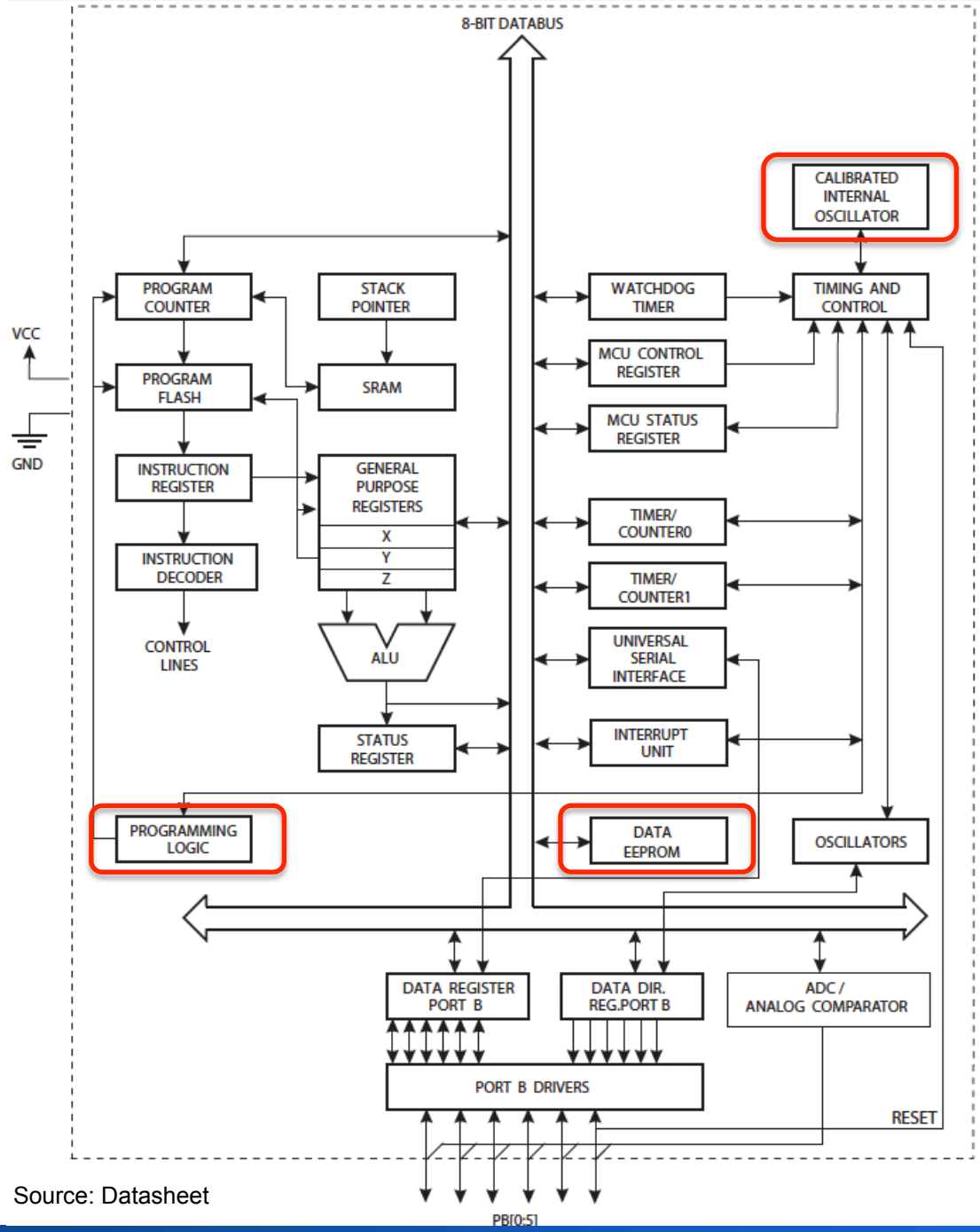
Source: Datasheet





Source: Datasheet

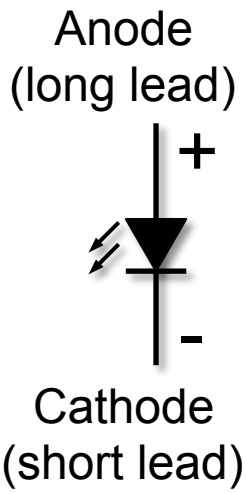
AVR ATtiny45 Architecture



Source: Datasheet

LEDS & BUTTONS

LEDs



- Quickly switchable, power-efficient light sources
  - different types covering different parts of the visible spectrum (and beyond: IR LEDs, UV LEDs)
- Anode (long lead) goes to positive potential
- Cathode (short lead) goes to negative potential
- LEDs operate like voltage-controlled switches
  - little current below turn-on voltage (silicon: 0.7V)
  - very high current above → LEDs need current-limiting resistors
- LEDs are diodes: no current in reverse direction
- Typical forward current: 20mA, typical forward voltage 2V

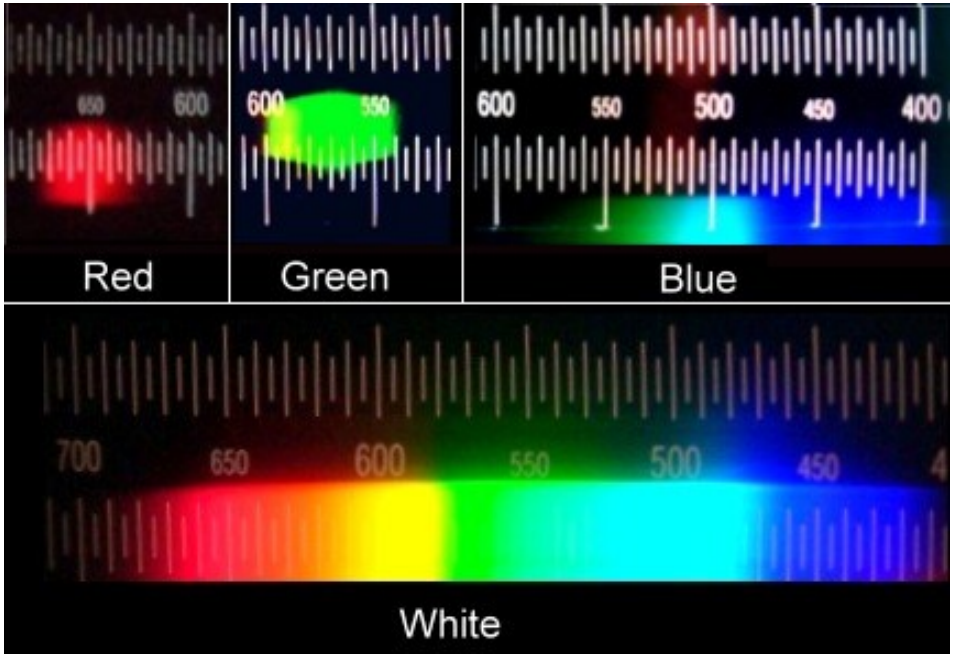
LEDs

- Intensity of light proportional to current
  - can also use PWM to control brightness
  - light covers narrow spectrum only, except for white LEDs
- Forward voltage drop depends on color, e.g.:

Color	Fwd. current	Fwd. voltage
red	20mA	2.0V
green	20mA	3.5V
blue	20mA	3.7V
white	20mA	3.5V

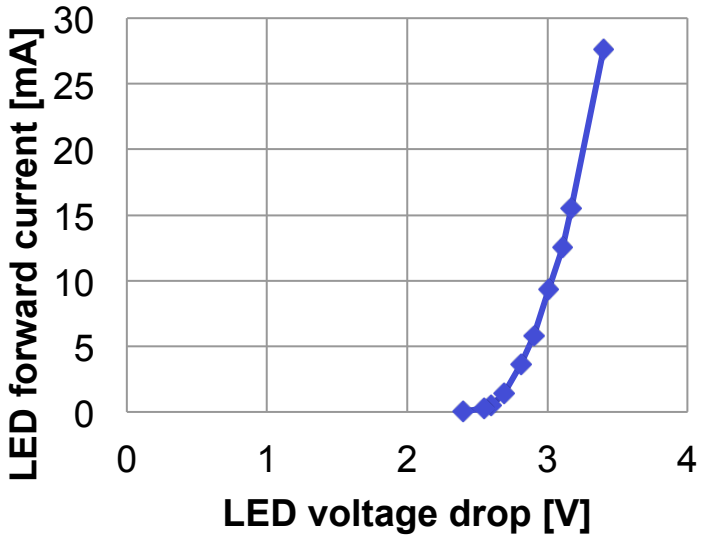
- Can go up to 100mA (peak current)

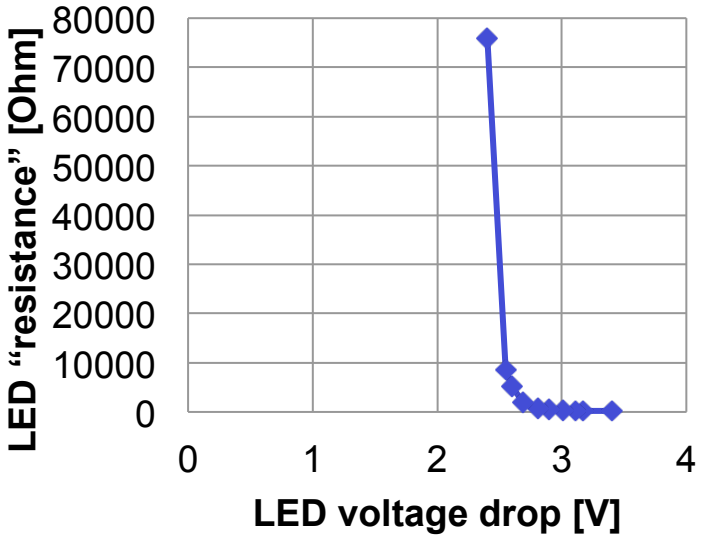
LED light spectra



Example: Blue LED Voltage Drop

- U_f = 3.2V, I_f = 20mA
- Current limiting resistor: $U_R = U - U_f = 5 – 3.2 = 1.8V$
  $R = U_R / I = 1.8V / 0.020A = 90\Omega$

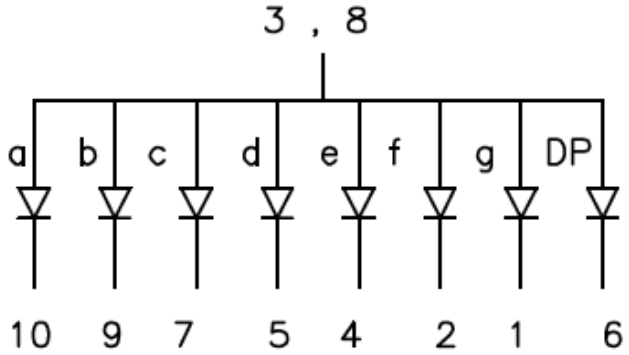




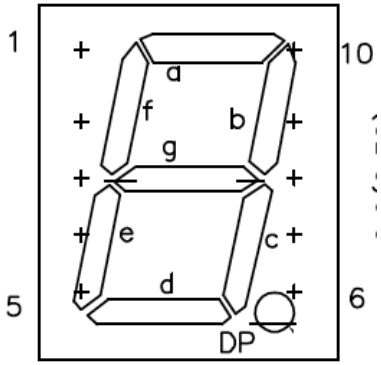
$R_f = U_f / I$

LED Displays: 7-Segment, 10-Bar

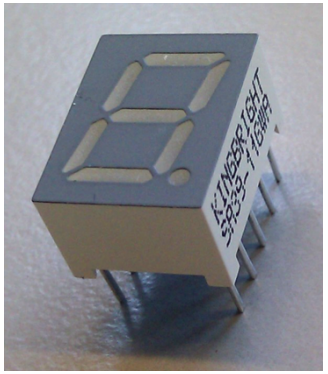
- 7-segment display (green)
  - U_f = 2.2V, I_f = 20mA



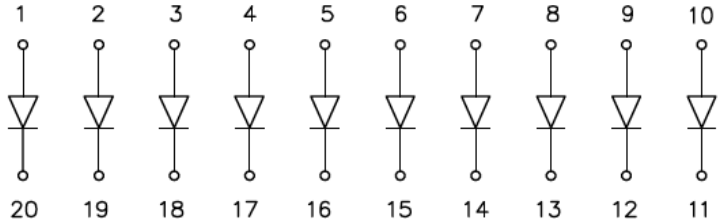
Source: Kingbright Datasheet



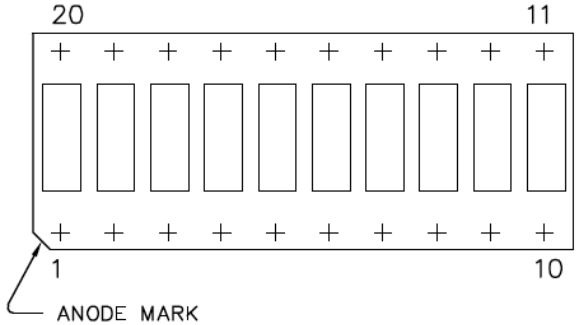
Source: Kingbright Datasheet



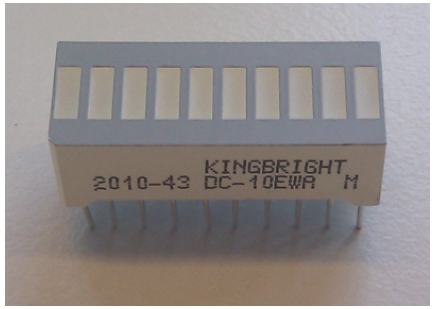
- 10-bar display (red)
  - U_f = 2.0V, I_f = 20mA



Source: Kingbright Datasheet

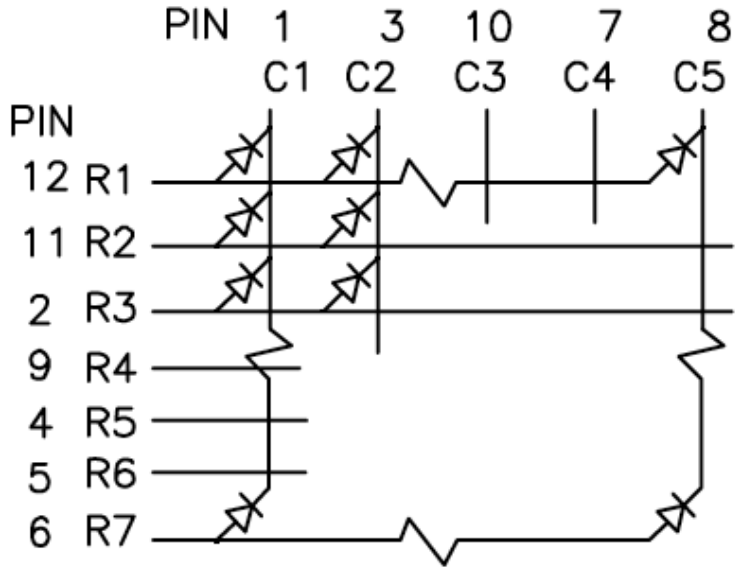


Source: Kingbright Datasheet

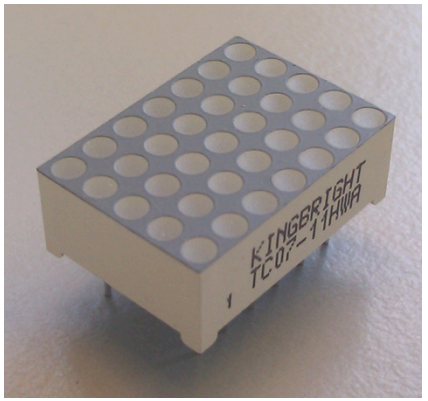


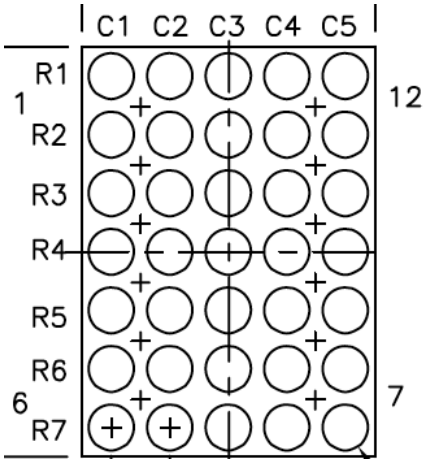
LED Displays: 5x7-Matrix

- 5x7 dot matrix display (red)
  - U_f = 2.25V, I_f = 20mA



Source: Kingbright Datasheet



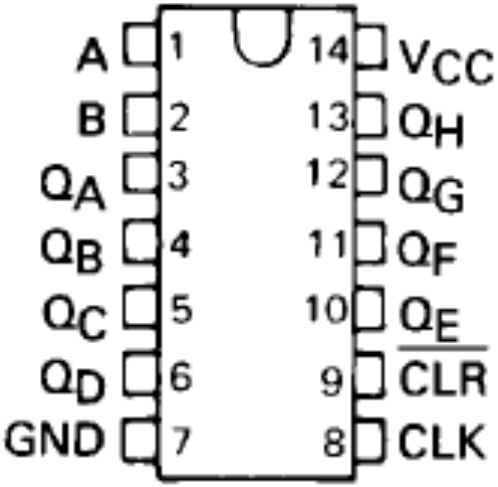


Source: Kingbright Datasheet

- Check total power consumption
  - ATtiny can only drive up to 40mA per pin
    → use transistor if necessary

More LEDs than µC Pins

- 8-bit serial-in, parallel-out shift register 74LS164N



Source: TI Datasheet

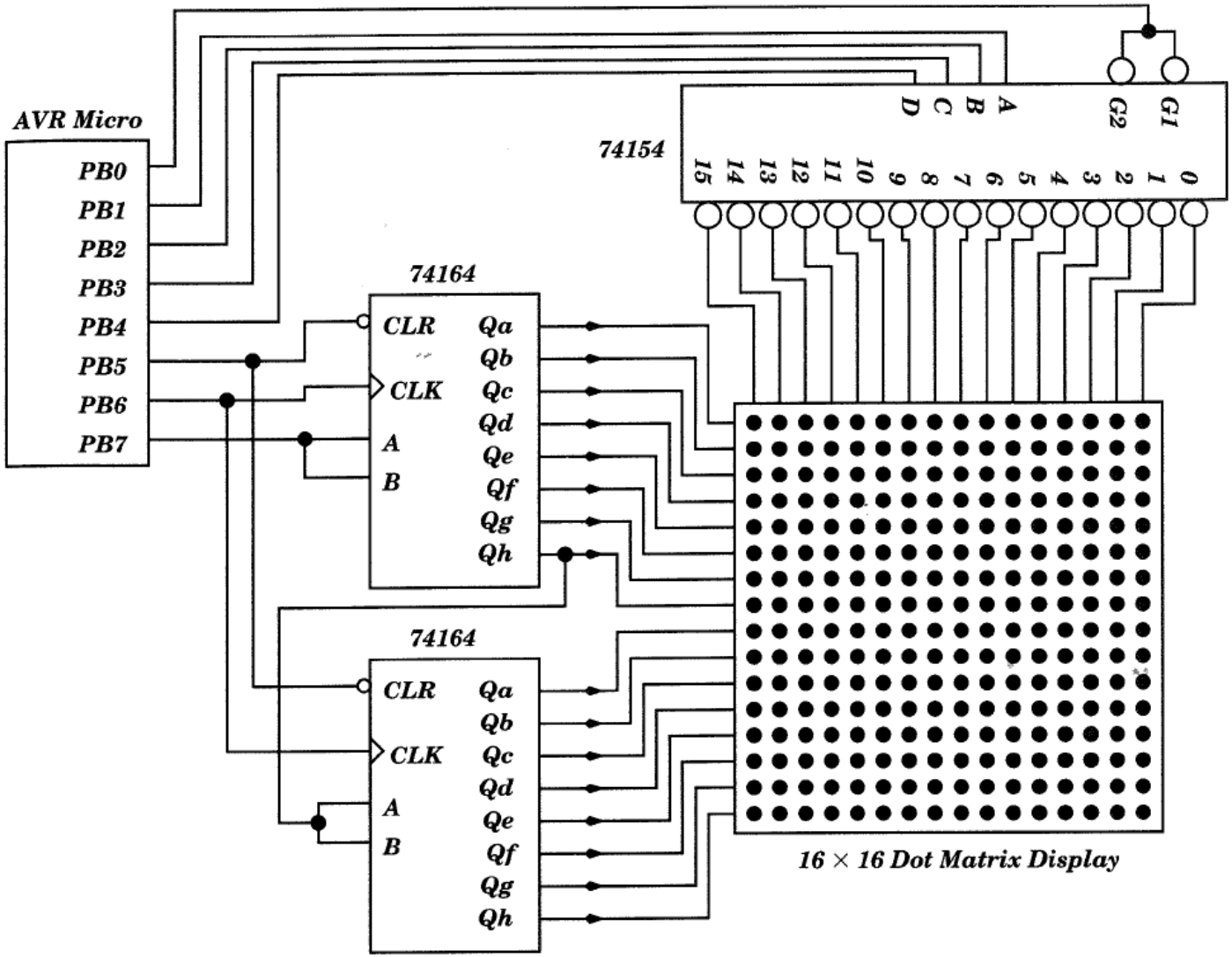
FUNCTION TABLE

INPUTS				OUTPUTS			
$\overline{\text{CLEAR}}$	CLOCK	A	B	Q_A	Q_B	...	Q_H
L	X	X	X	L	L		L
H	L	X	X	Q_{A0}	Q_{B0}		Q_{H0}
H	↑	H	H	H	Q_{An}		Q_{Gn}
H	↑	L	X	L	Q_{An}		Q_{Gn}
H	↑	X	L	L	Q_{An}		Q_{Gn}

Source: TI Datasheet

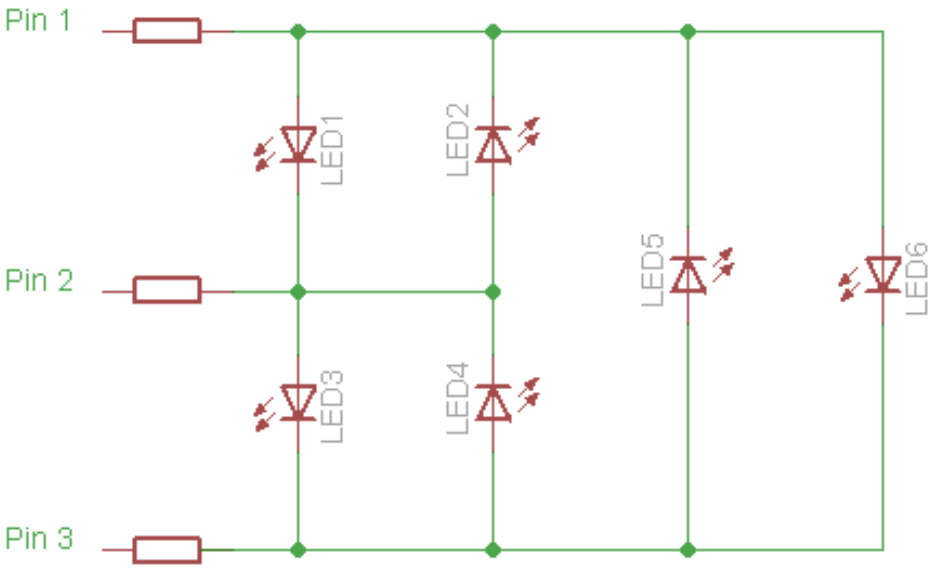
  - Q_A = A and B, unused input must be H
  - CLK: low-to-high shifts data one place right
  - maximum clock frequency: 25 MHz
  - V_{cc} = 5V, I_{CC} = 16mA
  - I_{OS} = -10..-27.5mA (short-circuit output current)

Multiplexing LEDs



Source: Gadre, Malhotra: tinyAVR Microcontroller Projects for the Evil Genios. McGraw-Hill, 2011.

Charlieplexing LEDs

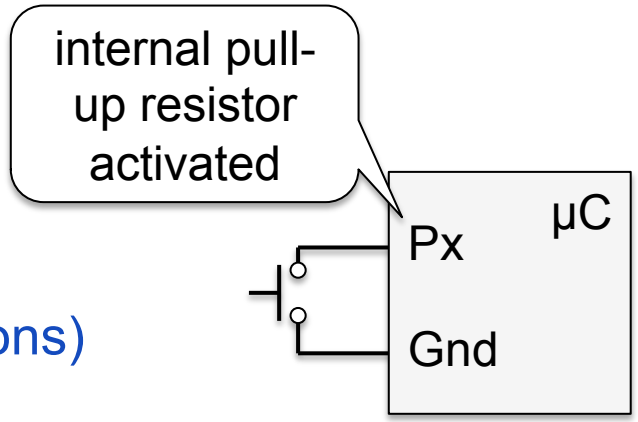


Source: Wikipedia, Author: Dan Kouba, public domain

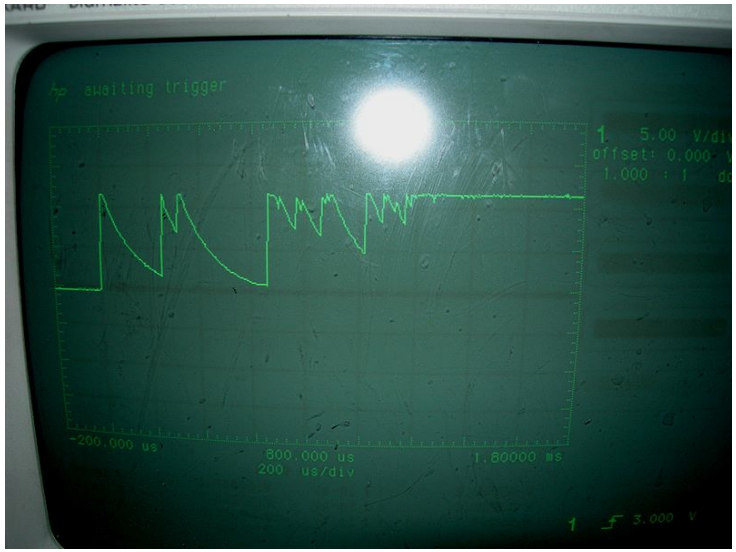
LED	Pin1	Pin2	Pin3
D1	1	0	Z
D3	Z	1	0
D6	1	Z	0
D4	Z	0	1
D2	0	1	Z
D5	0	Z	1

- Enables one LED at a time
  - N LEDs, each only on 1/Nth of the time
- Z = tri-state (high impedance state, “no” current)

Button De-Bouncing



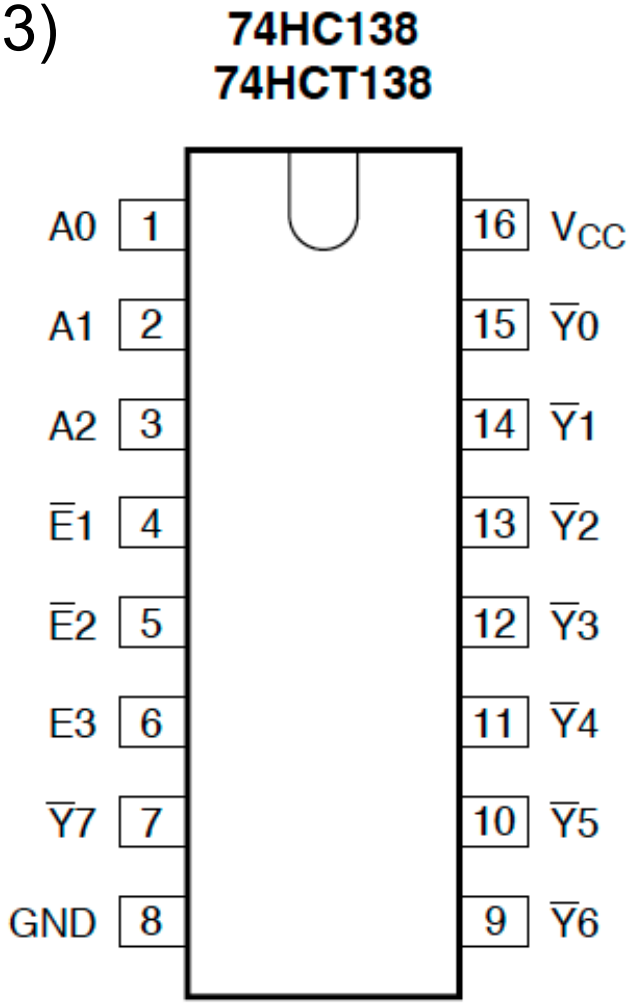
- Activate pull-up resistor on pin
  - Pull-up puts pin into defined state
  - (see previous slides on pin configurations)
- Connect button to GND
  - Pin will be high until button pressed
- De-Bouncing
  - Button contacts bounce, which generates many spikes
  - Hardware solutions: SR latch, capacitor
  - Software solution:
  - wait for 10-20ms after first event



Source: Wikipedia, Author: Tomoldbury, public domain

74HC138:
3-to-8 Line Decoder/Demultiplexer

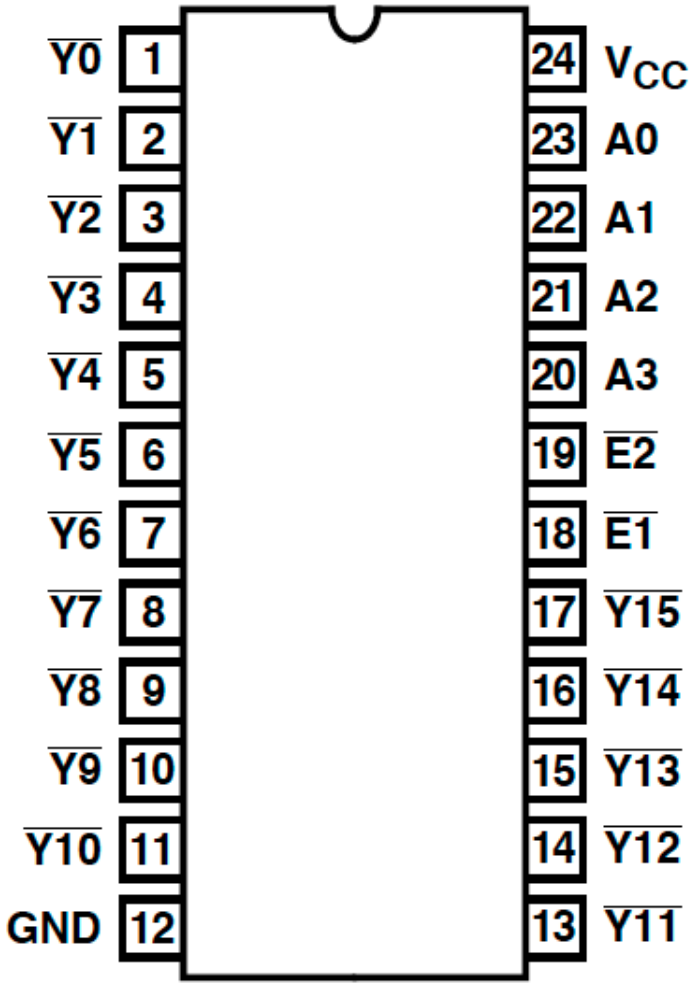
- Input x = (not(E1) and not(E2) and E3)
- Address lines A0,A1,A2 to select output $Y_{A0,A1,A2}$
- Output $Y_{A0,A1,A2}$ = not(x)
- other outputs: $Y_i = 1$
- $V_{cc} = 5V$
- $I_{OUT} = \pm 25mA$



Source: Philips Datasheet

74HC154:
4-to-16 Line Decoder/Demultiplexer

- Input x = (E1 or E2)
- Address lines A0,A1,A2 to select output $Y_{A0,A1,A2}$
- Output $Y_{A0,A1,A2}$ = x
- other outputs: Y_i = 1
- V_{cc} = 5V
- I_{OUT} = ±50mA



Source: Harris Semiconductor Datasheet