ETH Course 402-0248-00L: Electronics for Physicists II (Digital)

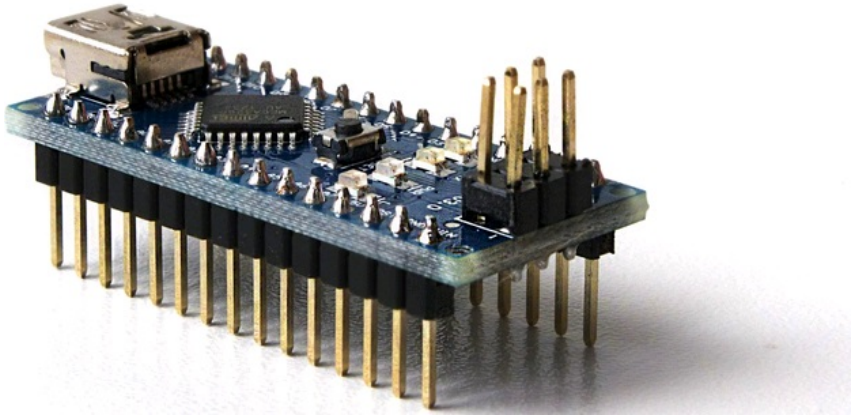
- **Taught by:** Tobi Delbruck, Alejandro Linares
- **Department:** ETH Zurich Department of Physics (D-PHYS)
- **Day/Time:** Weekly on Fridays from 1315 - 1700 in Picaardsaal, ETH Hoenggerberg Campus, HPT Room C103
- **Breaks:** No class in some weeks, check schedule on wiki.
- **Language:** English.
- **Credits:** 4 credit points.
- **Exam**: There is no exam but students must successfully complete the class exercises. Attendance sheet will be used.
- **Class wiki: google** "dig delbruck"

www.ini.uzh.ch/~tobi/wiki/doku.php?id=dig:start

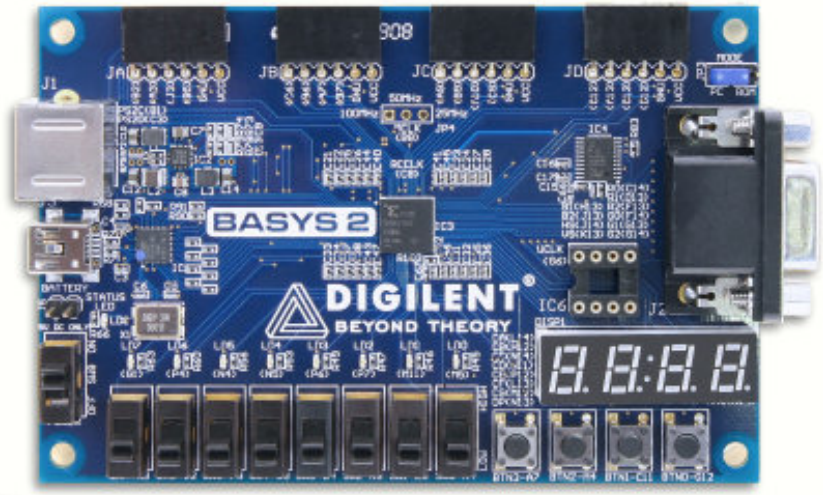
Prerequisites

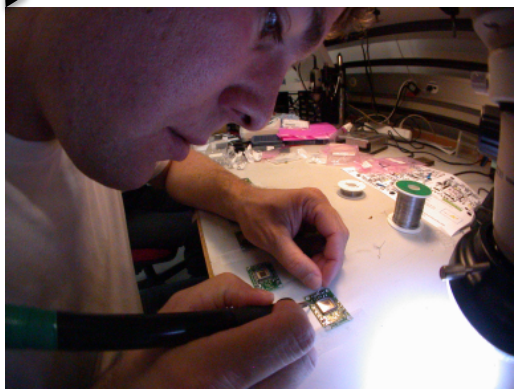
- **Companion course:**
  Electronics for Physicists I (Analog), Fall semester, taught by Roland Horisberger.
- The digital course complements the analog course by teaching how to build systems that convert and process analog information.
- You should have had some programming experience, preferably with C. Students (or at least each group of 2-3 students) need a laptop computer, Windows or Linux (but only Windows supported by Tobi). Mac OS can use VM.

1st half: Embedded systems with microcontrollers

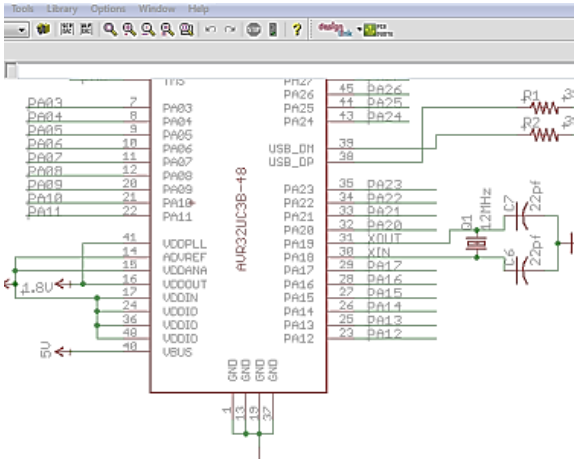


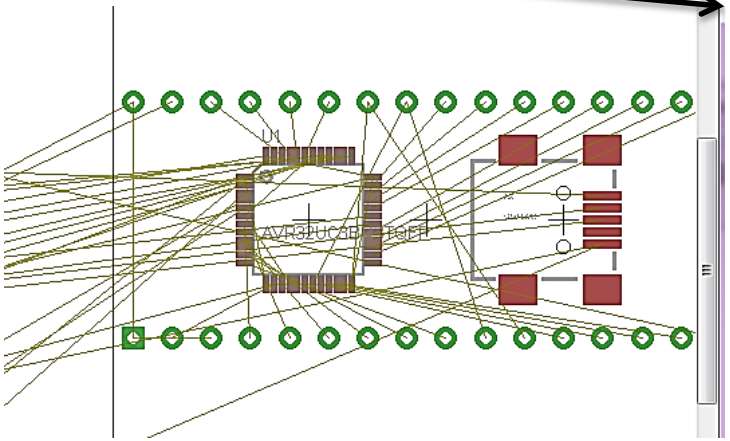
2nd half: Logic design with FPGA





PCB SMD assembly



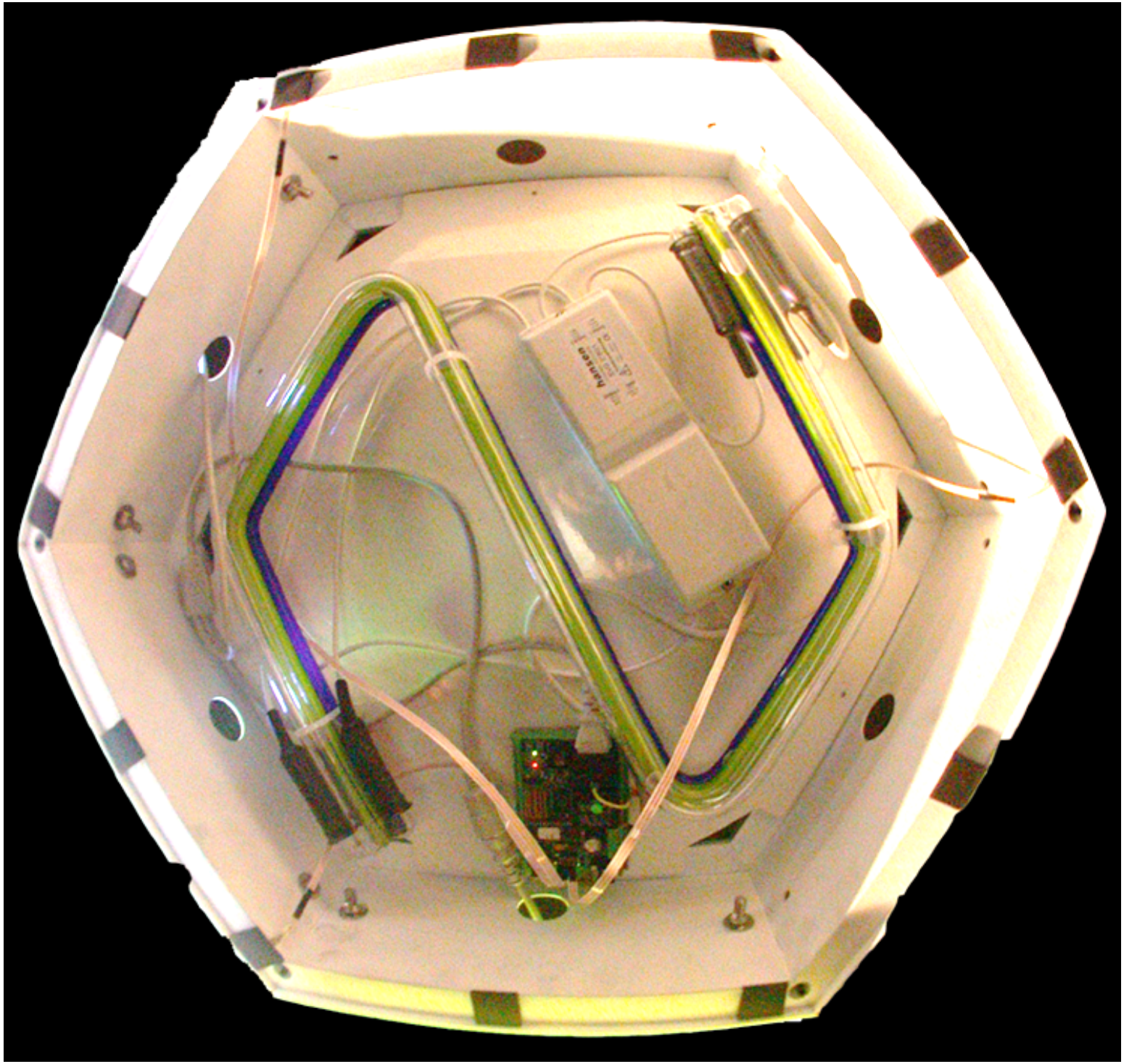


PCB design and layout

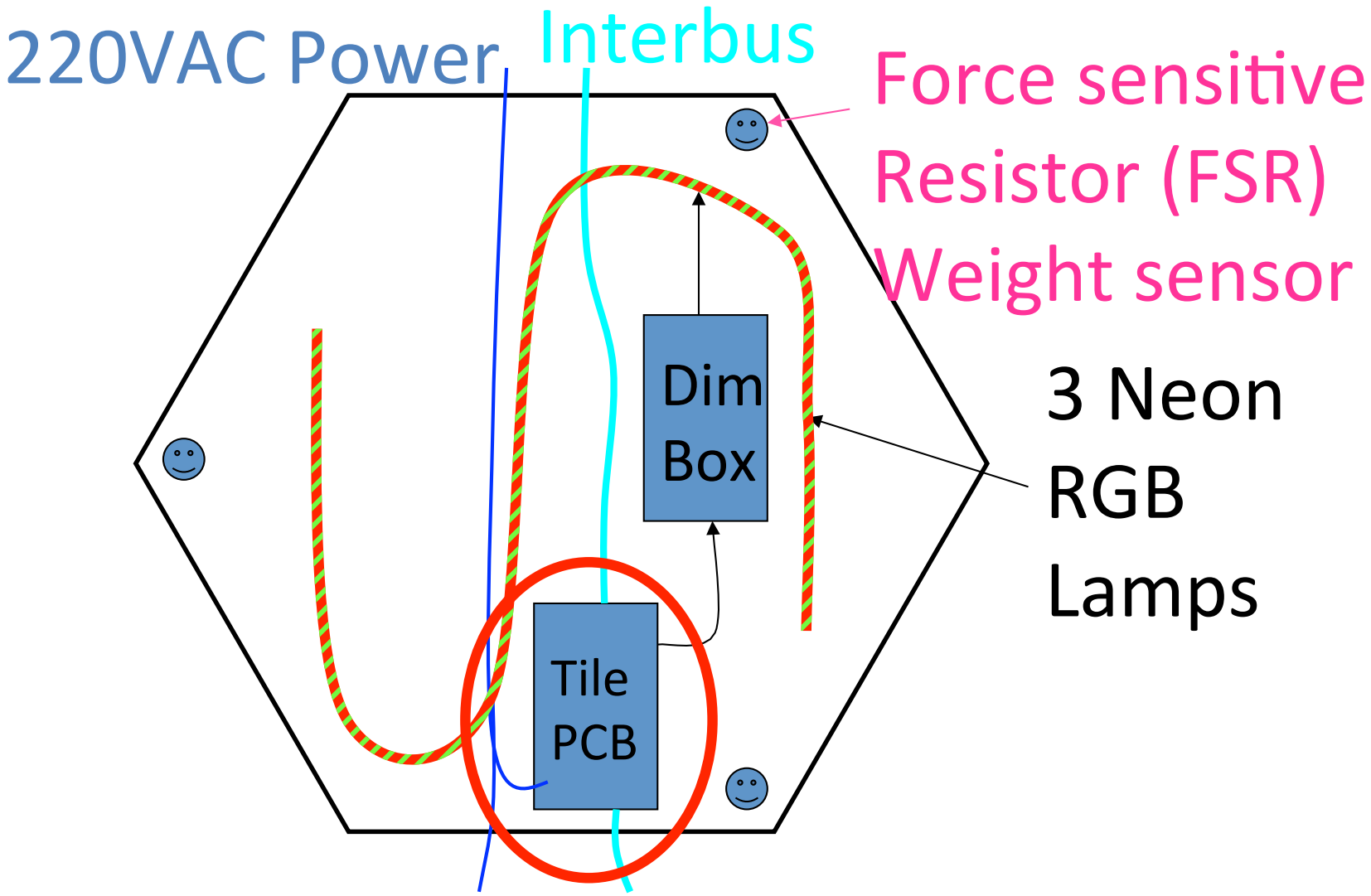
Embedded system design example

Ada's luminous tactile floor

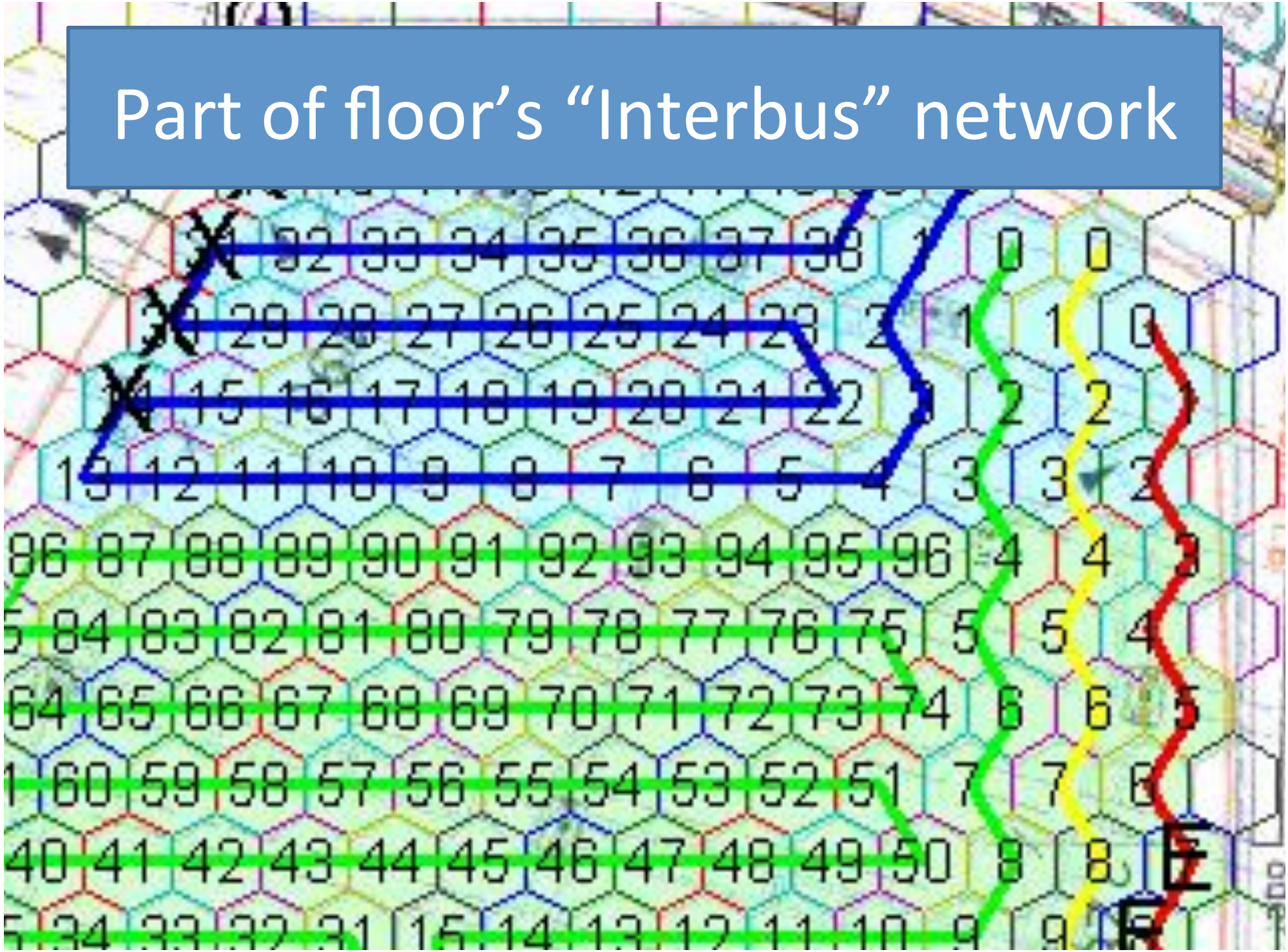
Ada’s luminous tactile floor



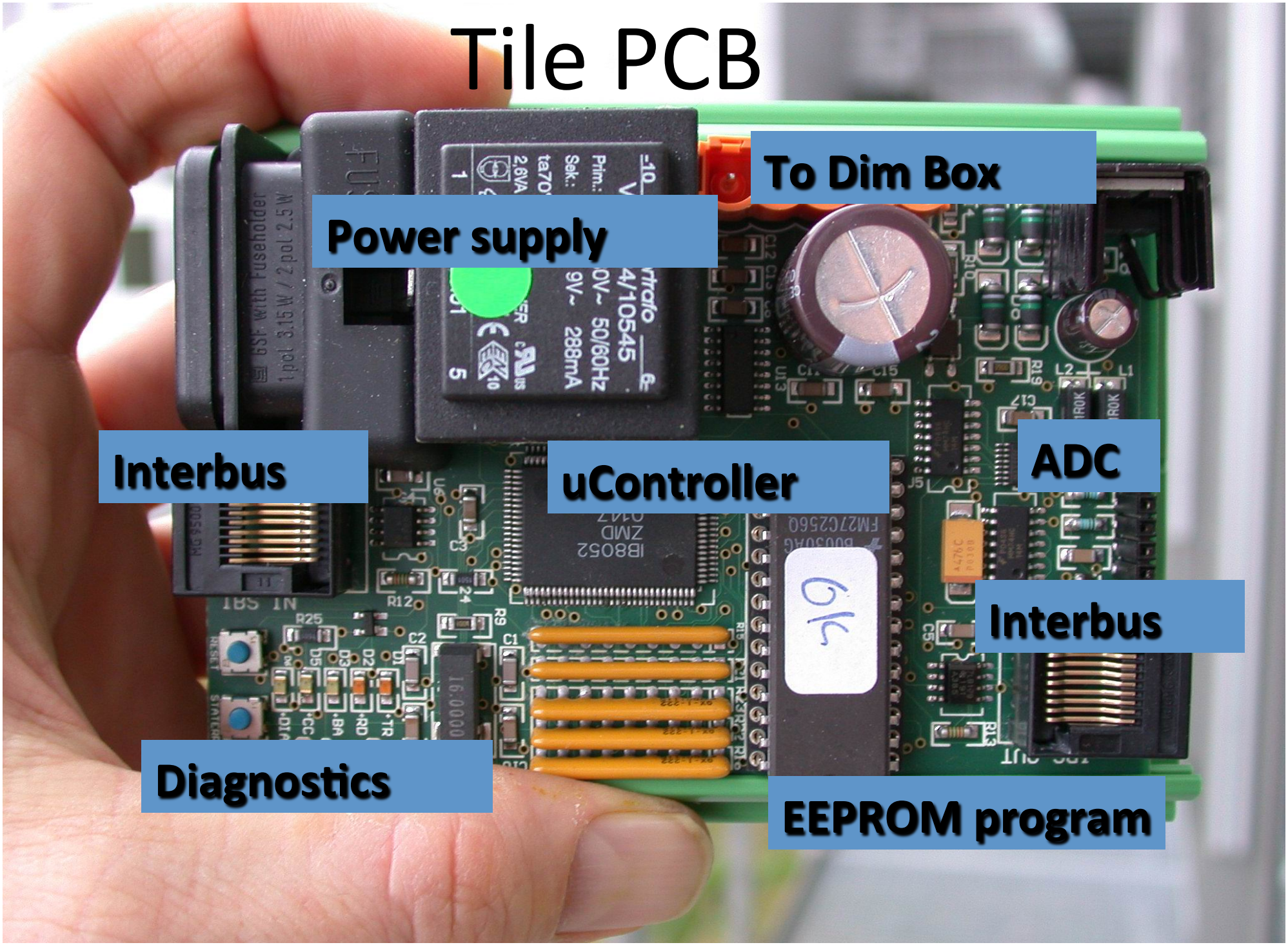
Neon Tile


220VAC Power
Interbus
Force sensitive Resistor (FSR) Weight sensor
Dim Box
3 Neon RGB Lamps
Tile PCB

Part of floor's "Interbus" network



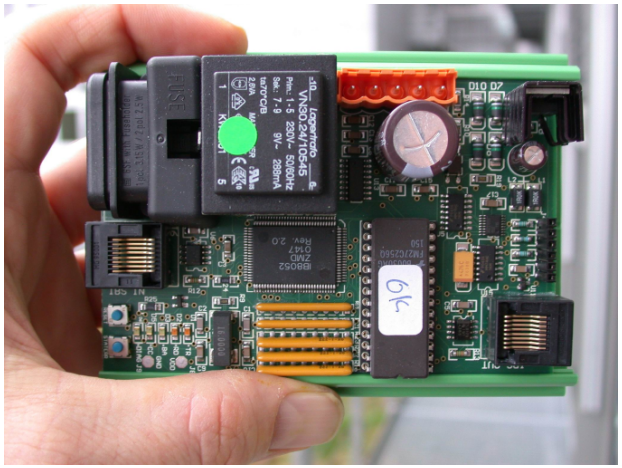
Tile PCB


To Dim Box
Power supply
Interbus
uController
ADC
Interbus
Diagnostics
EEPROM program

PCB assembly

+

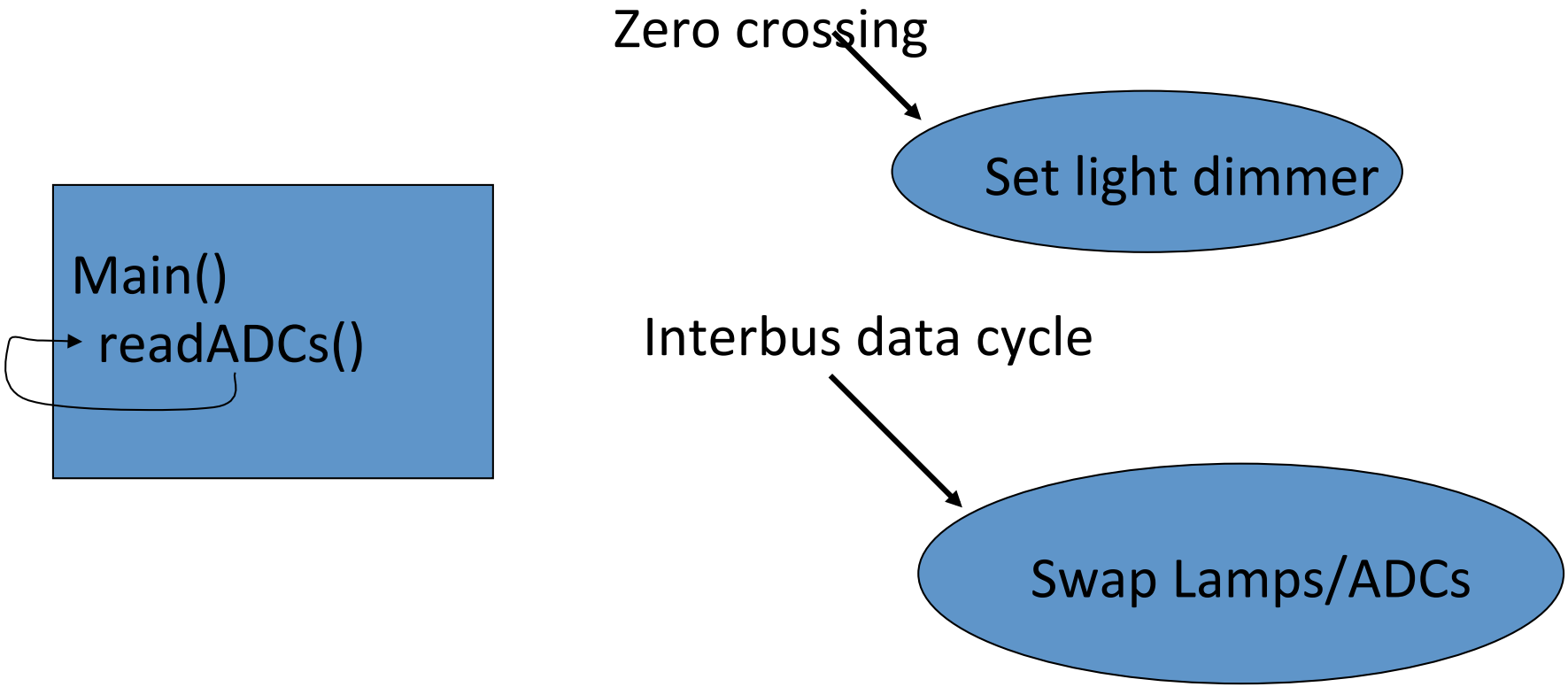
=



X 500 @25 CHF/board

Tile Microcontroller Program

Interrupt service routines (ISRs)



1000 lines C/assembler code running on 8052 derivative
Two demo tiles have been running continuously for >5 years!

The ATmega168P / 328P

- AT = Atmel: Big microcontroller company
- mega: microcontroller family
- 16: 16KB Flash memory / 32: 32KB Flash
- 8: 8-bit architecture
- P: PicoPower Technology. Optional. For low power battery-based applications.

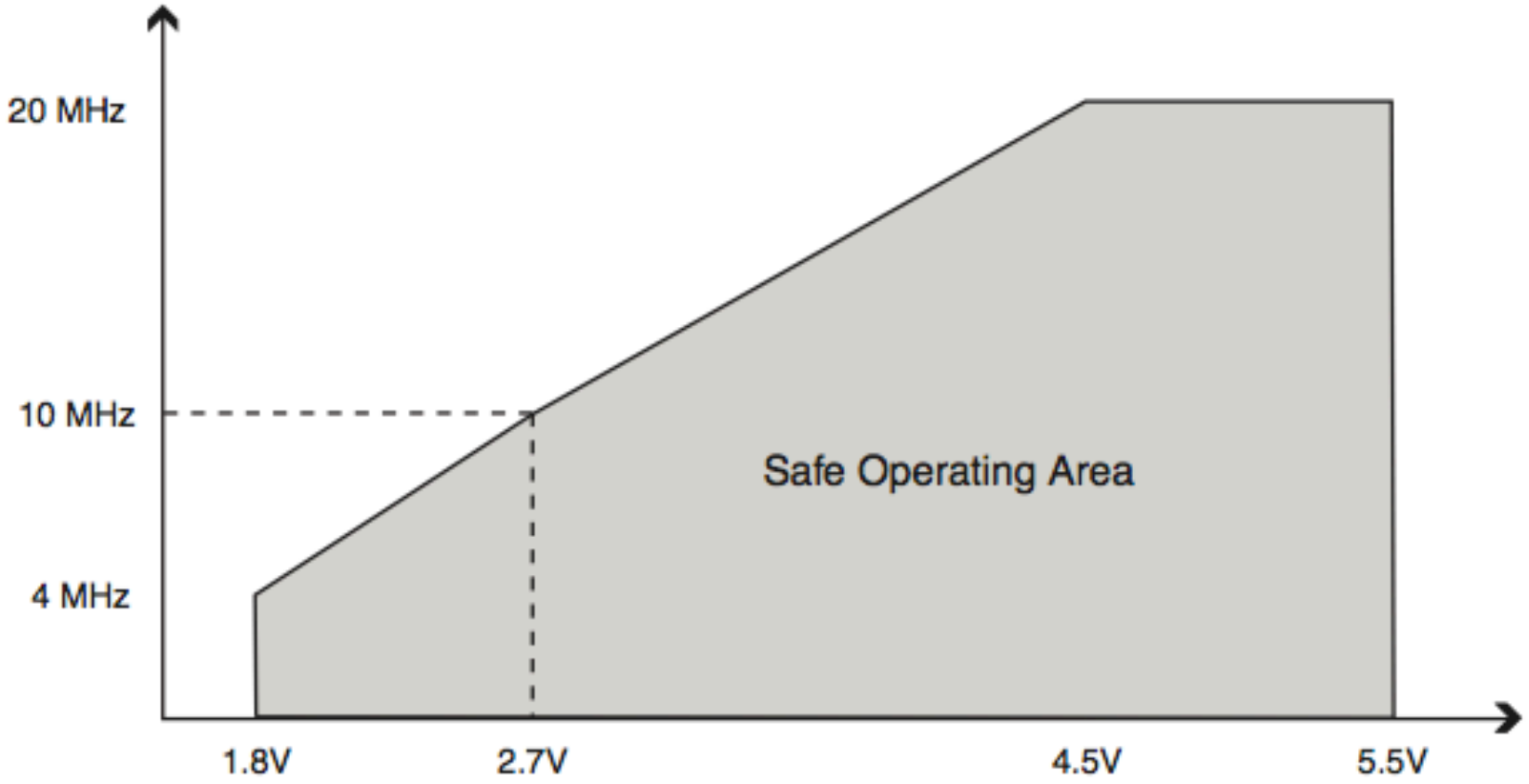
ATmega16/328P capabilities

- **System Functions**
  - Power and Clock Manager
  - Low Freq Internal Oscillator
  - Watchdog Timer
  - Real-Time Clock Timer
- **Interrupt Controller**
  - Fixed priority. One level of interruption. Interruptions with flag (can remember) or without. Global Interrupt Enable (I-bit) is disabled during an interrupt service.
- **NO Universal Serial Bus (USB)**
  - This micro hasn't USB. The nano board provide an USB-USART interface from FTDI company.

- One 16-bit **Timer/ Counter (TC)** with Auto-Reload and PWM
- Two 8-bit **Timer / Counter (TC)** with AR and PWM
- One 8-channel 10-bit **Analog-To-Digital Converter (ADC)**, 76.9ks/s
- SPI, USART, I2C

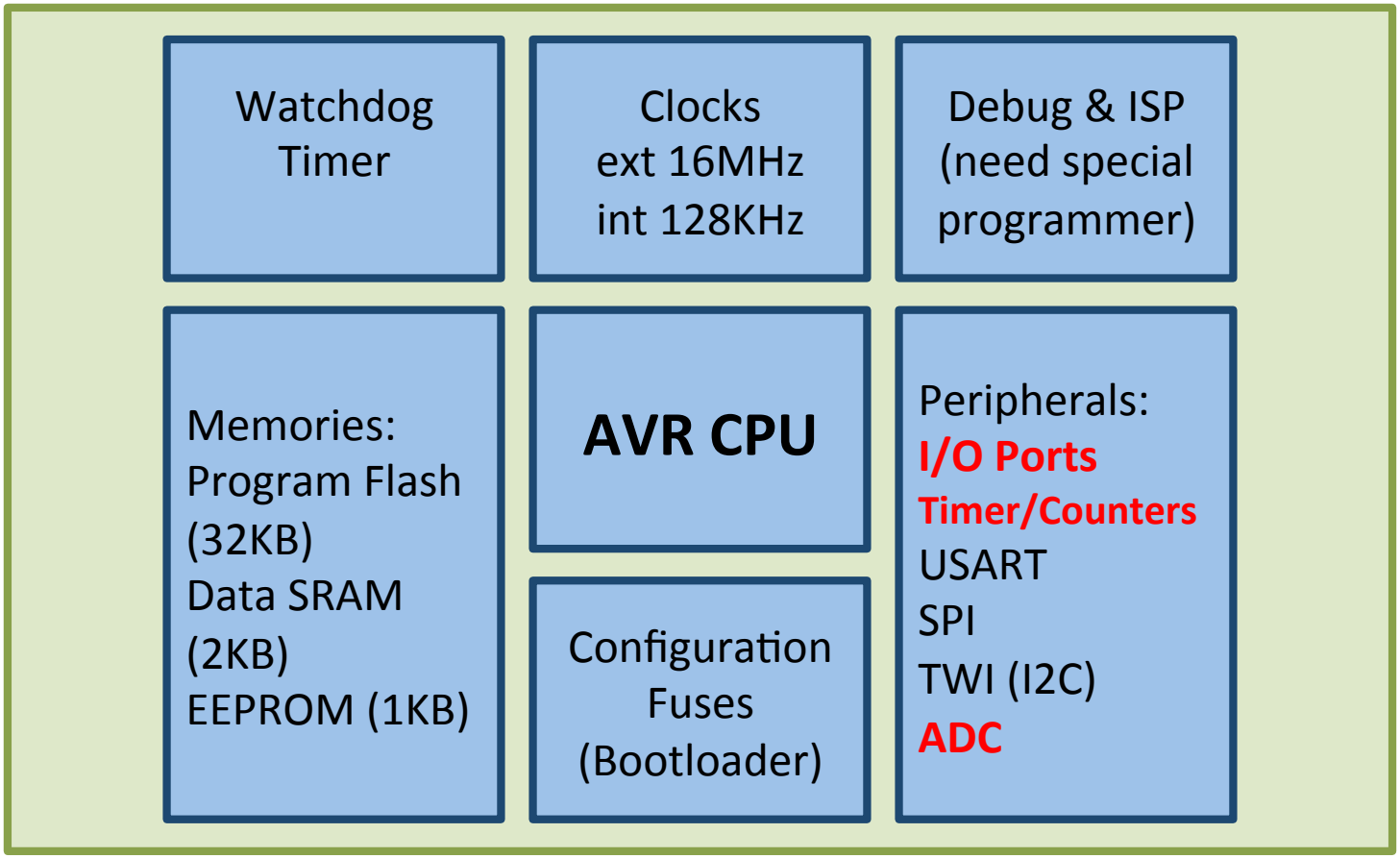
Clocks

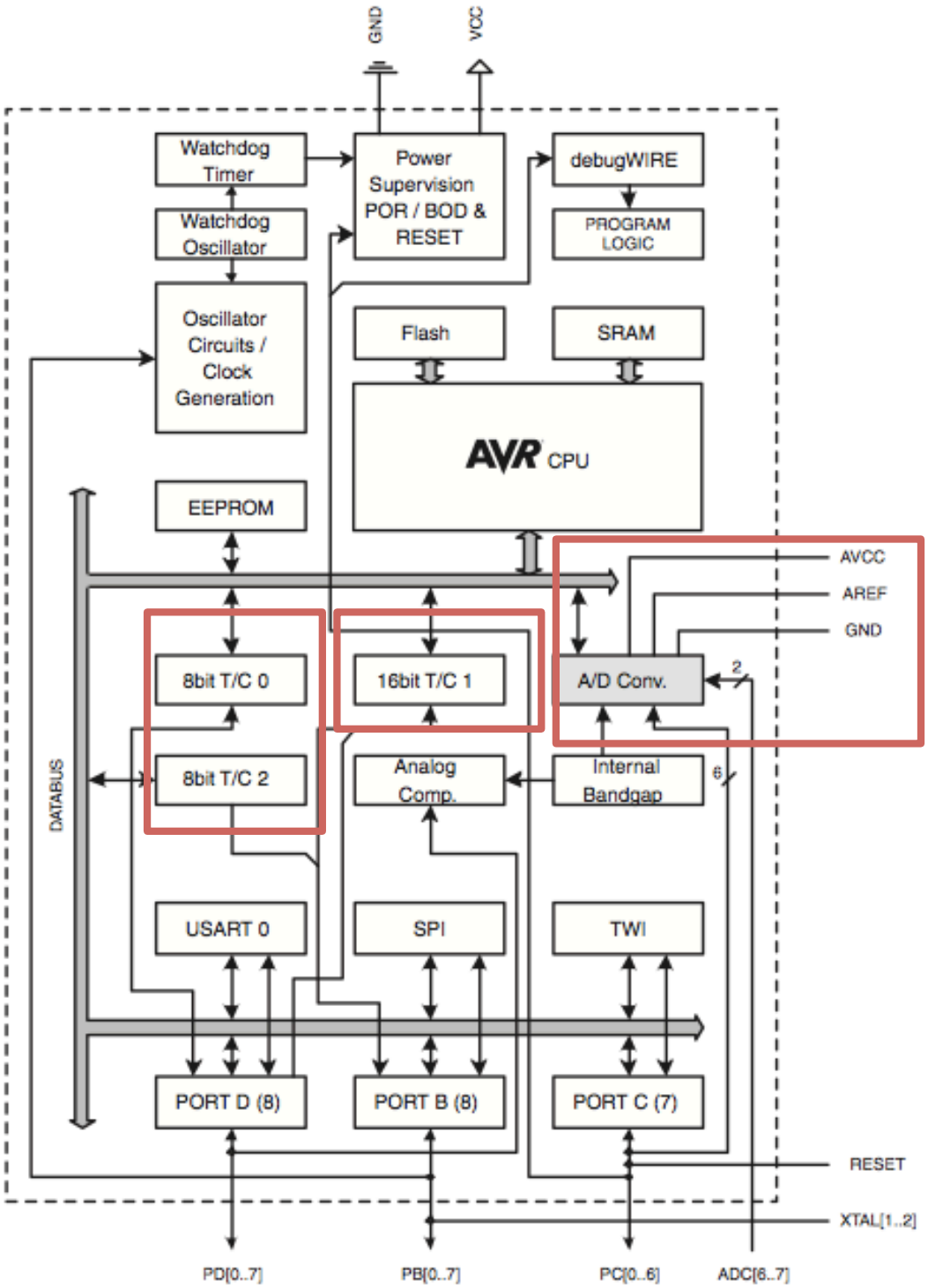
Figure 28-1. Maximum Frequency vs. V_{CC}



Arduino ATmega328P uses a 16MHz Resonator with 5v Vcc, to keep compatibility to ATmega8

ATmega328 simplified block diagram

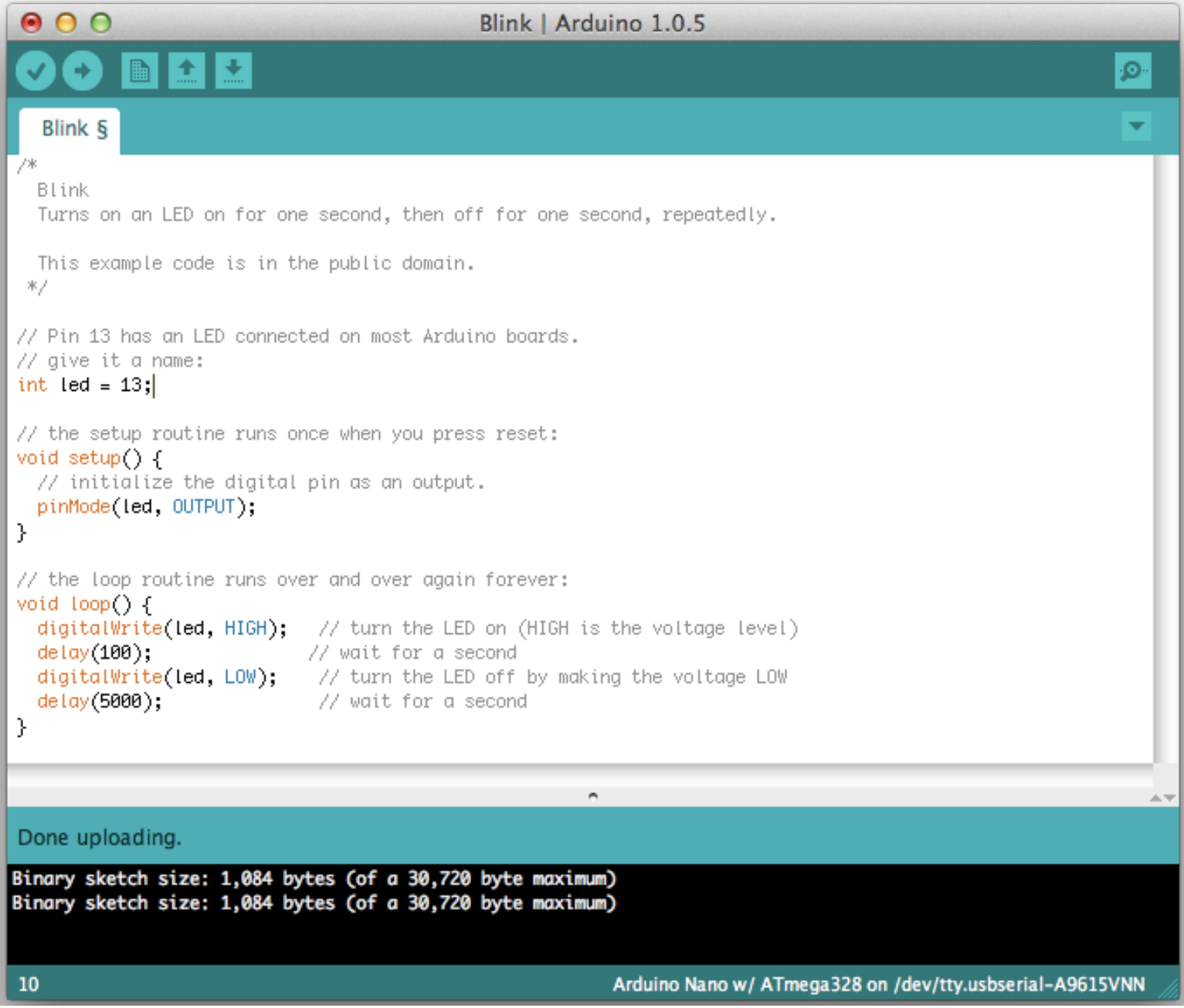



GND
VCC
Watchdog Timer
Watchdog Oscillator
Power Supervision POR / BOD & RESET
debugWIRE
PROGRAM LOGIC
Oscillator Circuits / Clock Generation
Flash
SRAM
AVR CPU
EEPROM
AVCC
AREF
GND
8bit T/C 0
16bit T/C 1
A/D Conv.
2
8bit T/C 2
Analog Comp.
Internal Bandgap
6
DATABUS
USART 0
SPI
TWI
PORT D (8)
PORT B (8)
PORT C (7)
RESET
XTAL[1..2]
PD[0..7]
PB[0..7]
PC[0..6]
ADC[6..7]

Atmega168/328P datasheet

- 440 pages
- Useful for architecture comprehension
- Peripheral descriptions
- Not all details are necessary since Arduino bootloader make things easier!!

Arduino Sketch



C programming for Arduino

ANSI C STYLE

```
void setup(void);
void loop(void);

void main(void) {
  setup(); //perform one-time initializations
  while(1) {
    loop();  //repeat this over and over
  }
}

void setup(void) {
}
void loop(void) {
}
```

ARDUINO CODE STYLE

```
void setup() {
}

void loop() {
}
```

Any other necessary stuff is included by Arduino IDE during compilation time and it Is transparent for the user / programmer (you)

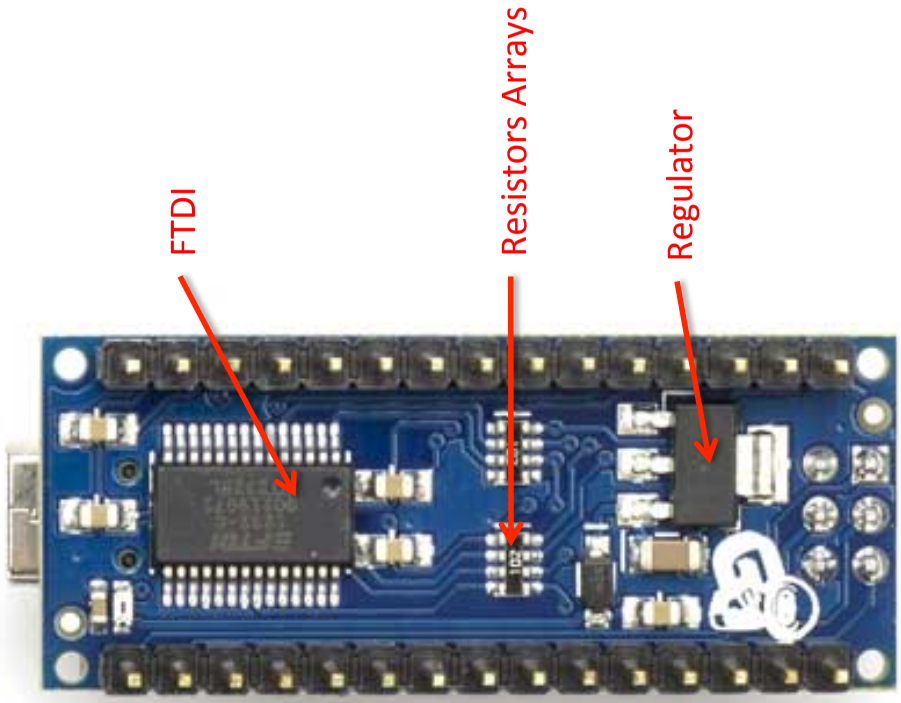
- Managing a LED:
  - Setup: pinMode(13, OUTPUT); // bitSet(DDRB,5);
  - Loop: digitalWrite(13, HIGH); //or LOW
- Managing Serial port:
  - Setup: Serial.begin(rate); //Serial.end();
  - Loop: Serial.println(data);
    Serial.println(data, data_type); //DEC,BIN,HEX,OCT, BYTE
    Serial.print(data, data_type);
    n=Serial.available(); //n=number of bytes (max 128B)
    b=Serial.read(); // Serial.write(b);
    b=Serial.peek();
    Serial.flush()
  - void serialEvent() {}

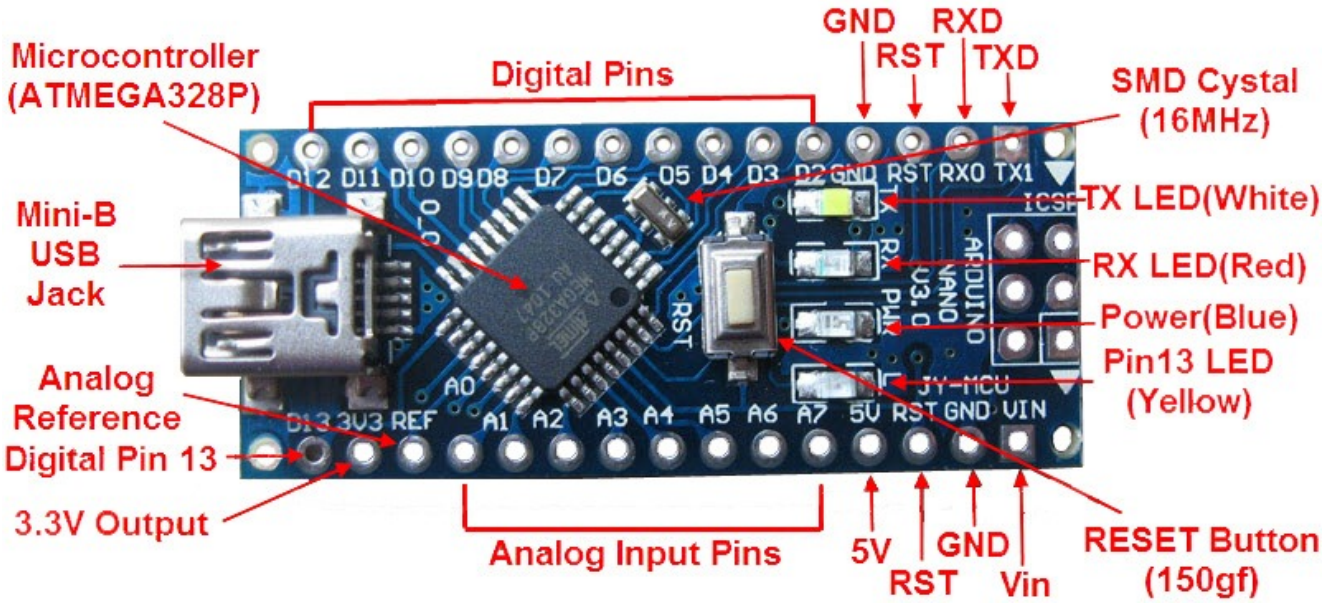
Standard AVR code

```
#include <stdio.h>
#include <avr/io.h>

#ifndef F_CPU
#       error Must define F_CPU or pass it as compiler argument
#endif

FILE uart_out = FDEV_SETUP_STREAM(uart_putChar, NULL, _FDEV_SETUP_WRITE);
void main(void) __attribute__((noreturn));

void uart_init(){
#       define BAUD 9600
#       include <util/setbaud.h>
        UBRR0H = UBRRH_VALUE;
        UBRR0L = UBRRL_VALUE;
#       if USE_2x
                UCSR0A |= _BV(U2X);
#       else
                UCSR0A &= ~_BV(U2X);
#       endif
        UCSR0B |= _BV(TXEN);                    // enable transmit
}

int uart_putChar(char c, FILE *unused){
        if (c == '\n')                          // a line feed character also
                uart_putChar('\r', unused);     // requires a carriage return
        loop_until_bit_is_set(UCSR0A, UDRE0);   // wait for UDR0 to be ready
        UDR0 = c;                               // write character
        return 0;                               // return
}

void main(void){
        uart_init();
        fprintf(&uart_out, "Hello, UART!\n");
        stdout = &uart_out;                     // set up stdout
        printf("UART demo...\n");
        for (uint8_t i = 0; i < 10; i++)
                printf("Number %i ", i);
        while(1);
}
```

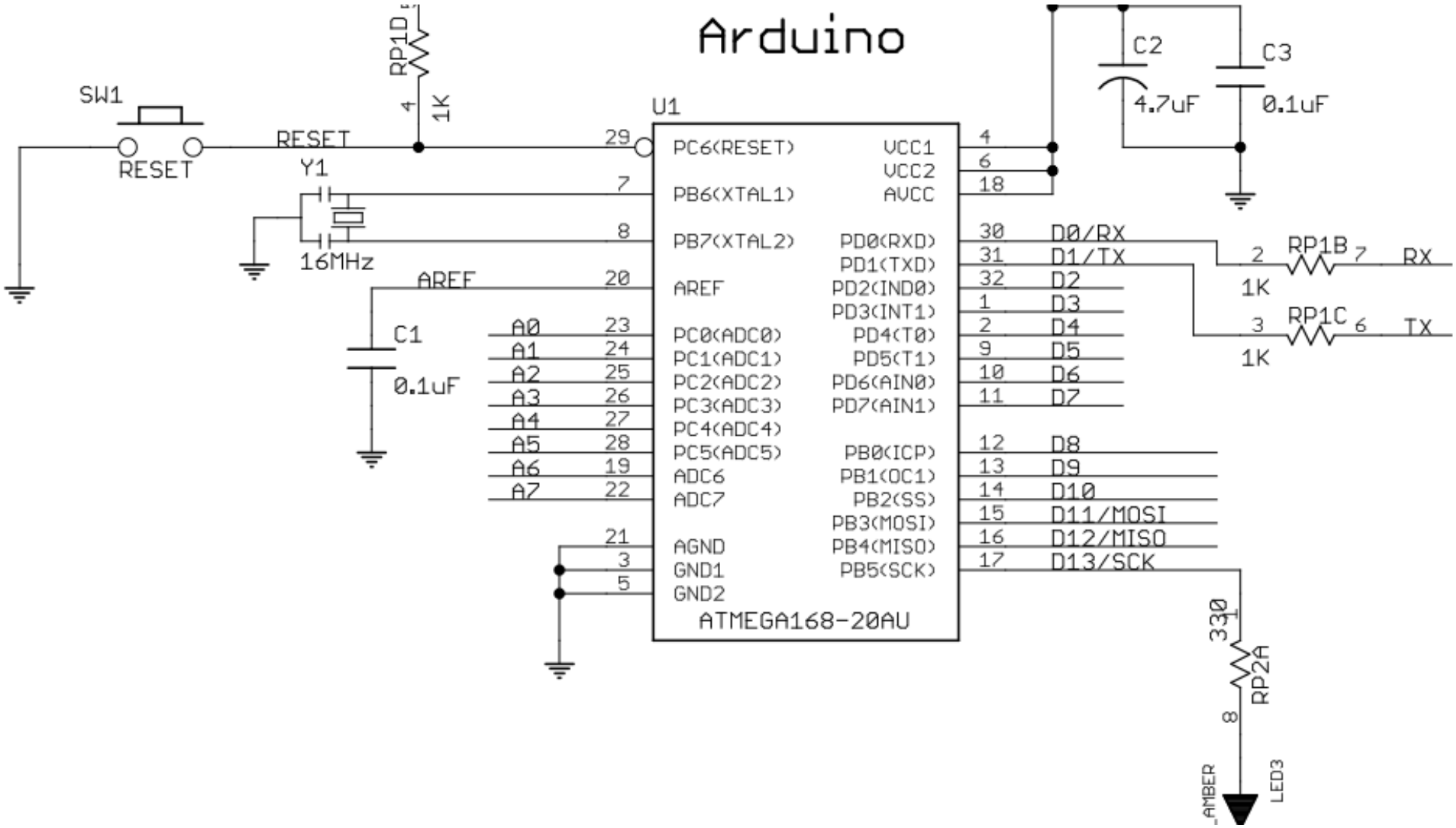
Arduino Serial code

```
int led = 13;

// the setup routine runs once when you press reset:
void setup() {
  // initialize the digital pin as an output.
  pinMode(led, OUTPUT);
  Serial.begin(9600);
}

// the loop routine runs over and over again forever:
void loop() {
  digitalWrite(led, HIGH);   // turn the LED on (HIGH is the voltage level)
  delay(1000);               // wait for a second
  Serial.println("Hello UART");
  digitalWrite(led, LOW);    // turn the LED off by making the voltage LOW
  delay(1000);               // wait for a second
}
```


FTDI
Resistors Arrays
Regulator


Microcontroller
(ATMEGA328P)
Digital Pins
GND
RXD
RST
TXD
SMD Cystal
(16MHz)
Mini-B
USB
Jack
TX LED(White)
RX LED(Red)
Power(Blue)
Pin13 LED
(Yellow)
Analog
Reference
Digital Pin 13
3.3V Output
Analog Input Pins
5V
GND
RST
Vin
RESET Button
(150gf)

Arduino Nano EFP2 RTC/INI schematics

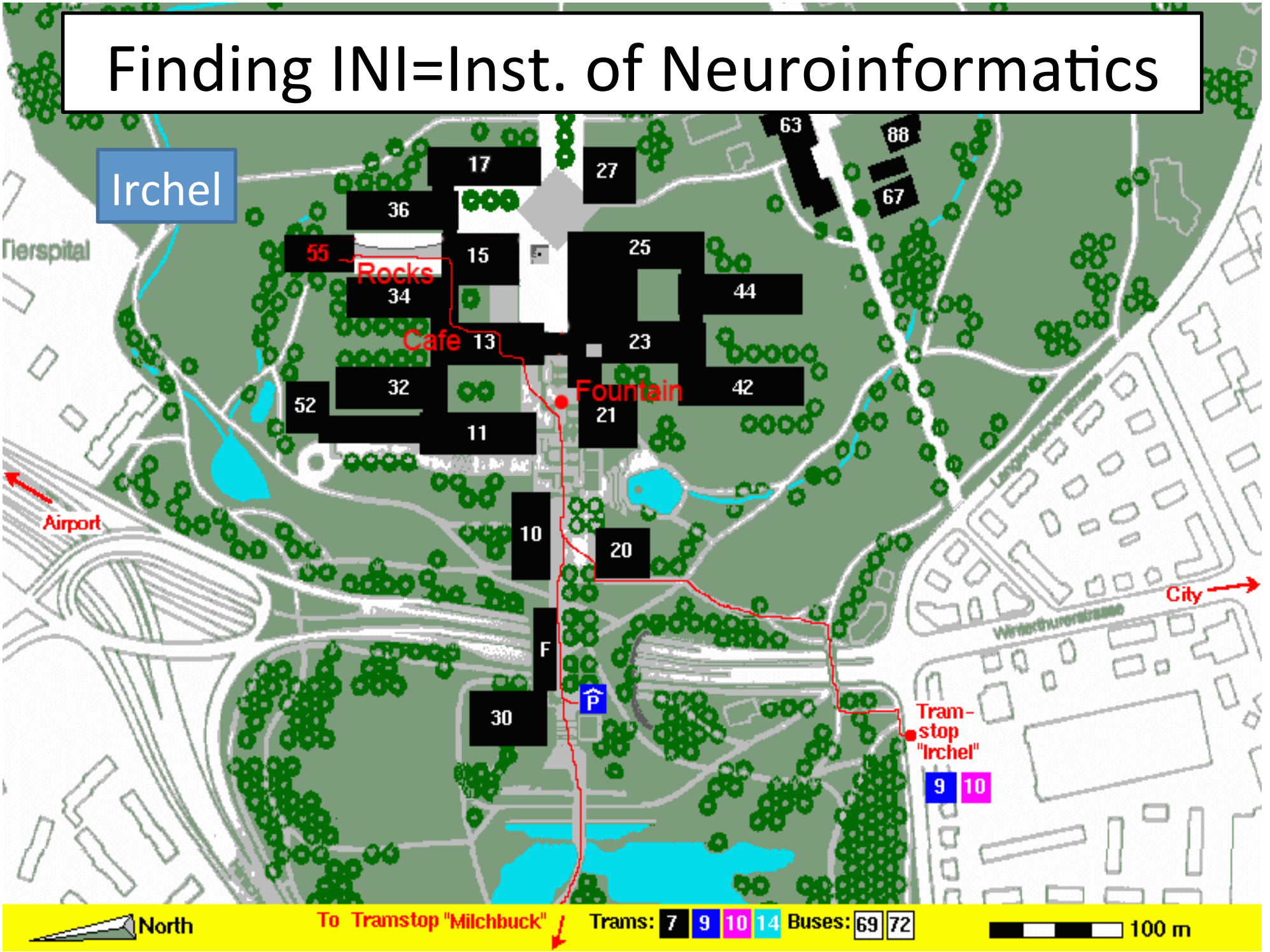


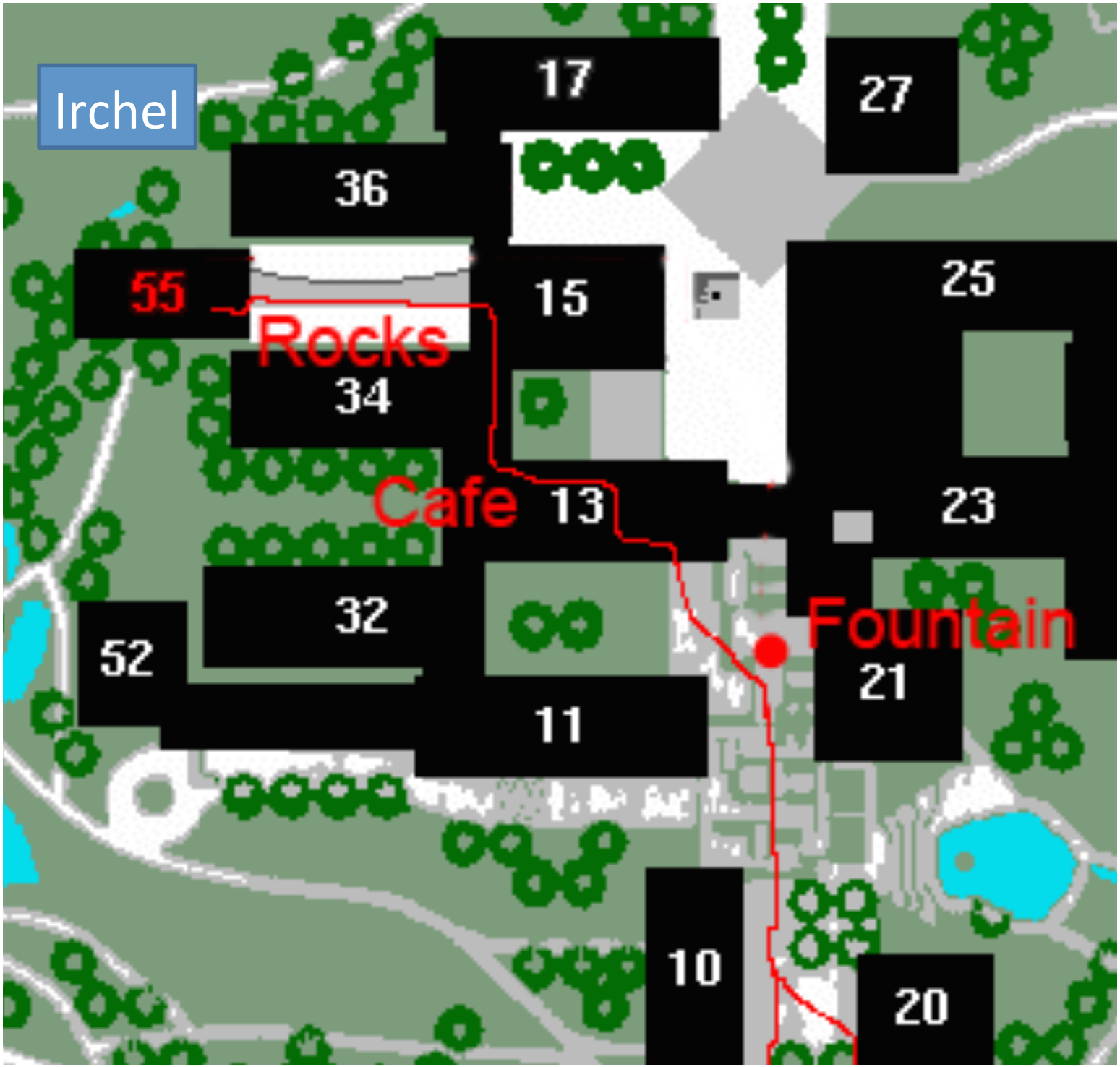
Exercise 1

- Installing and running Arduino tools.
- Opening and understanding basic blinking Example Sketch and run it.
- Add Serial communication to Serial Monitor for “debugging” your Sketch.
- Arranging time for soldering your own Arduino Nano board and make it compatible with Sketch.
- Exercise 2: probably debugging and repairing your own Arduino Nano board

Surface mount soldering exercise

Finding INI=Inst. of Neuroinformatics




Irchel
17
27
36
55
15
25
Rocks
34
Cafe
13
23
32
52
Fountain
21
11
10
20