



Arduino

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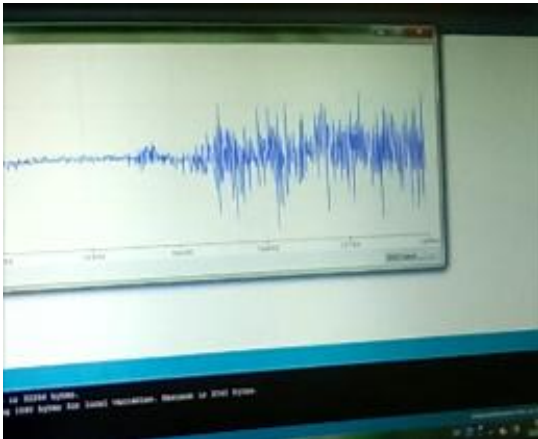
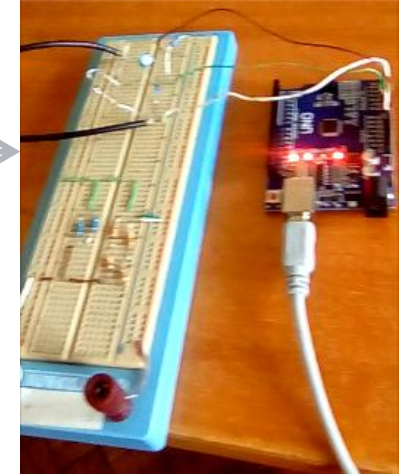
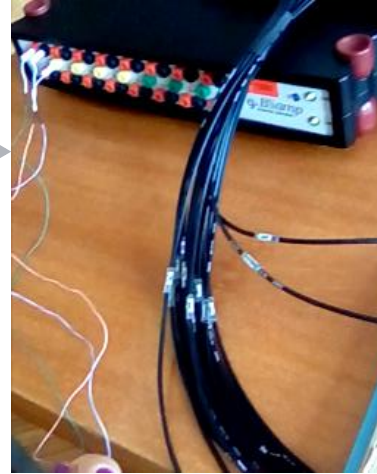
For this presentation following materials were used: Alan G. Smith, Introduction to Arduino: A piece of cake!, [Online], Assessed December 8, 2018, <https://www.introtoarduino.com/downloads/IntroArduinoBook.pdf>, 2011.

Also, materials from Measurement Computing Devices course are used: <http://automatika.etf.bg.ac.rs/sr/13e053msr>.

I also recommend Technology Tutorials available at: <http://www.toptechboy.com/>, Assessed Dec., 8, 2018.

HOW CAN YOU BENEFIT FROM USING ARDUINO?
LIVE DEMOS

Muscle contraction measurement



- Electrophysiological amplifier (g.tec, Austria), conditioning circuit, and UNO R3 microcontroller board are connected to the Ag/AgCl electrodes for measurement of electrical muscle activity of *abductor policis brevis* (lat.).
- Simple and efficient measurement with UNO R3 hardware and Arduino software.

Closer look to EMG signal

01 Definicija merenja i merni instrumenti 2017 - Microsoft PowerPoint

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analogReadBezKasnjnja | Arduino 1.8.3

File Edit Sketch Tools Help

analogReadBezKasnjnja

```
/*
AnalogReadSerial + BlinkWithoutDelay
kombinacijom ova dva koda nastao je ovaj jedan
ideja je da frekvencija odabiranja bude fiksna, odnosno
da se na svakih interval milisekundi šalje po jedan
odbirak na serijski port, a da se o
*/

unsigned long previousMillis = 0;
const long interval = 5; // ako je 10 // jedan 10

// the setup routine runs once when you open the IDE editor
void setup() {
  // initialize serial communication at 9600 bauds
  Serial.begin(9600);

  // the loop routine runs over and over again
}

Done uploading.
Sketch uses 1858 bytes (5%) of program memory.
Global variables use 192 bytes (9%) of dynamic memory.
```

COM12

9600 baud

Click to add notes

Slide 1 of 38 "Office Theme" English (United States)

67%

15:12 26.9.2017

ECG measurements

01 Definicija merenja i merni instrumenti 2017 - Microsoft PowerPoint

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Slides Outline

1 O predmetu

2 MSR?

- MSR (Maksimalna Serijska Razlika) je maksimalna razlika između dva uzastopna izmjerenja iste veličine na istom mjestu.
- MSR se izražava u milisekundi (ms).
- MSR je važan parametar za procjenu kvalitete mjerenja.
- MSR je određena za svaki tip mjerenja.

3

4 Kako se polaže MSR?

- MSR se polaže na osnovu razlike između dva uzastopna izmjerenja iste veličine na istom mjestu.
- MSR se izražava u milisekundi (ms).
- MSR je važan parametar za procjenu kvalitete mjerenja.
- MSR je određena za svaki tip mjerenja.

5

Click to add notes

analogReadBezKasnjnja | Arduino 1.8.3

File Edit Sketch Tools Help

```
analogReadBezKasnjnja

/*
  AnalogReadSerial + BlinkWithoutDelay
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  odabirak na serijski port, a da se o
*/

unsigned long previousMillis = 0;
const long interval = 10; // ako je 10 // jednak 10

// the setup routine runs once when you open the IDE editor
void setup() {
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Done uploading.
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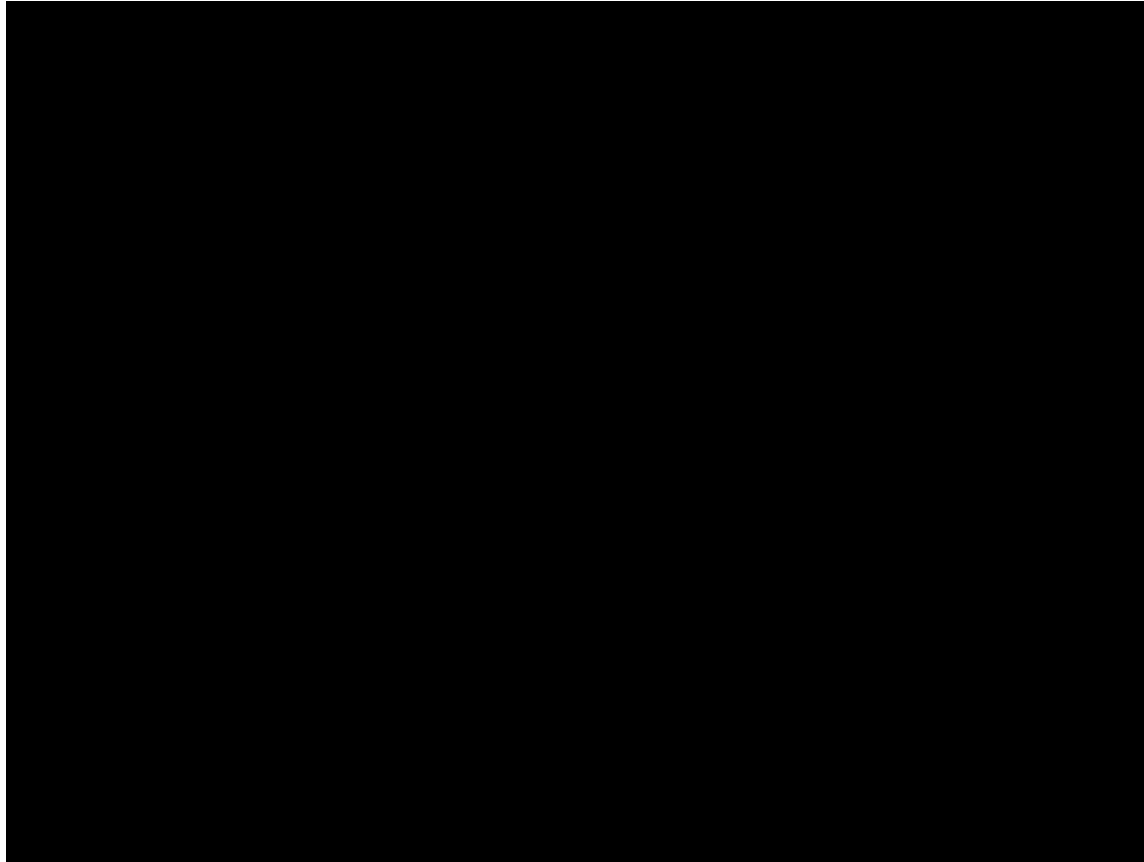
COM12

9600 baud

Slide 1 of 38 "Office Theme" English (United States)

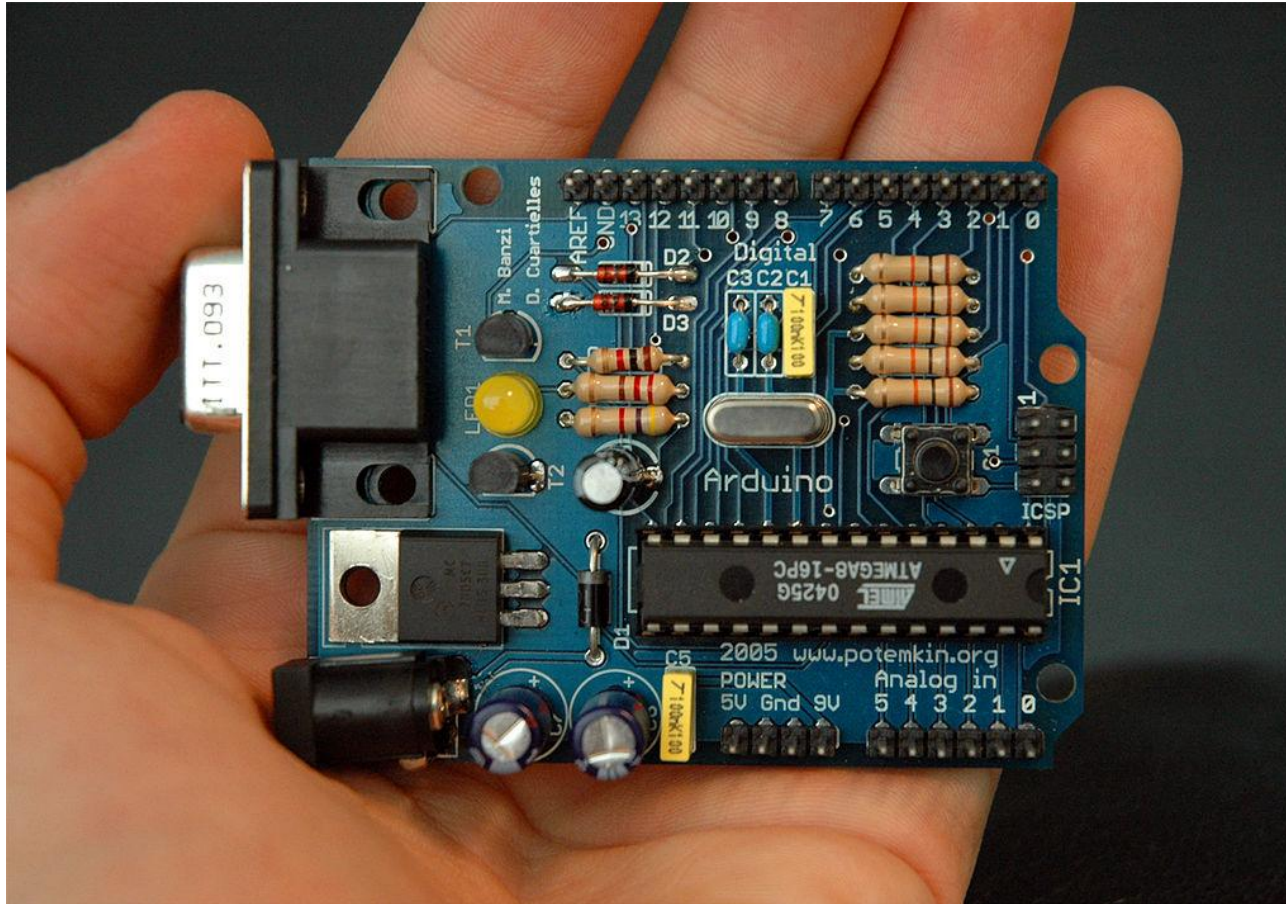
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Measurement Computing Devices



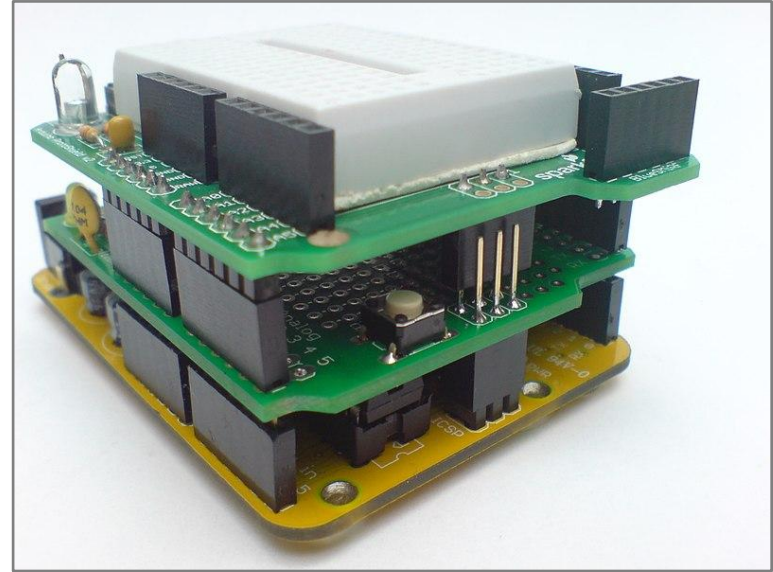
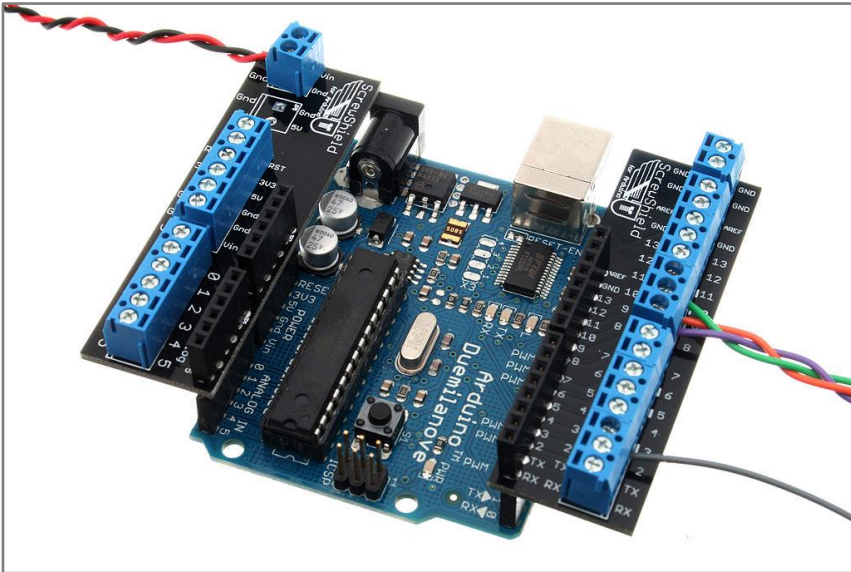
- Course on Measurement Computing Devices MCD was introduced in 2017. More at: <http://automatika.etf.bg.ac.rs/sr/13e053msr>.
- Video of selected solutions from MCD Challenge held in 2017 is available at: <https://www.youtube.com/watch?v=C-opCv-skYM&feature=youtu.be>.

Few historical & interesting facts...



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...

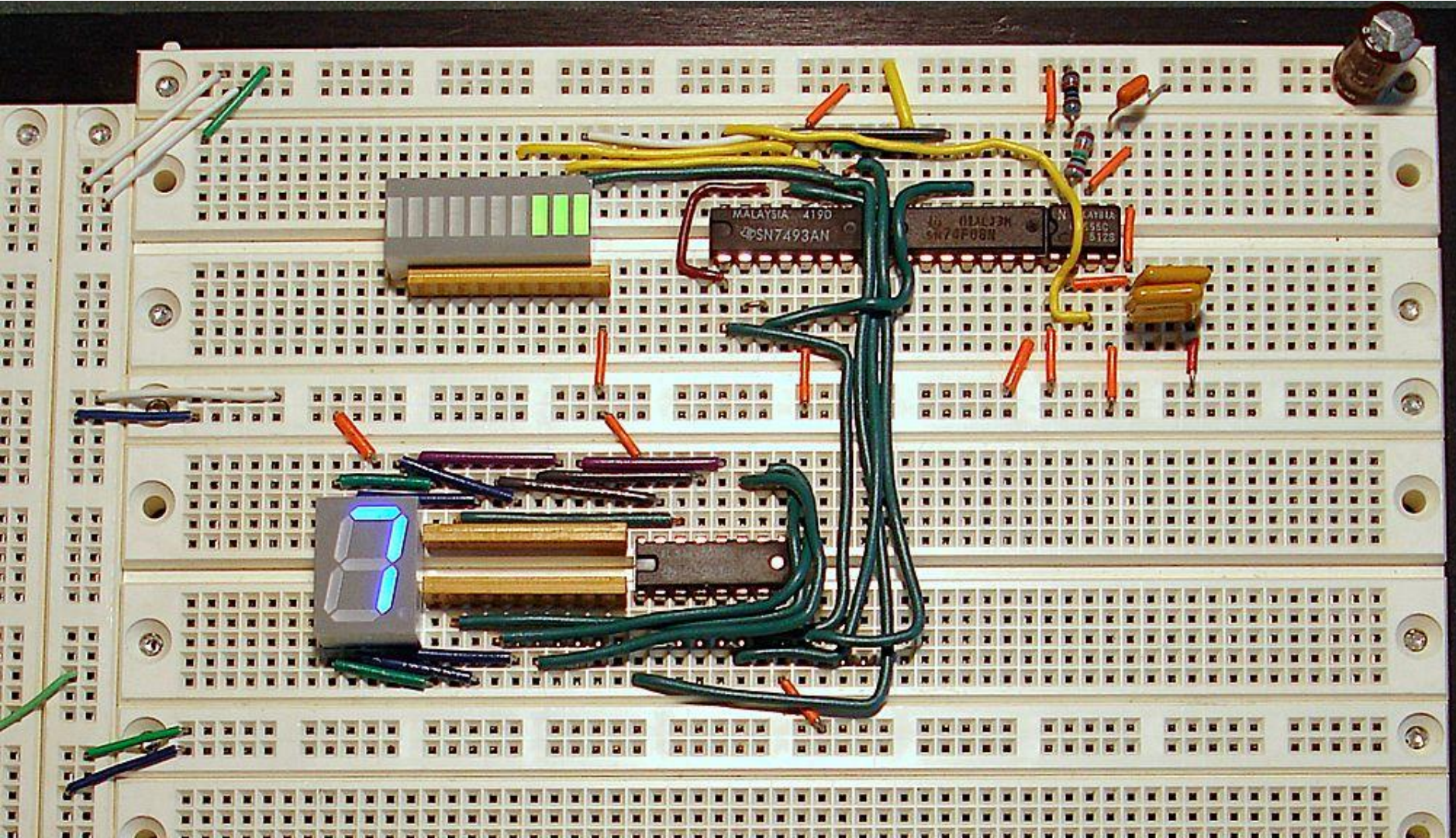


Left panel:

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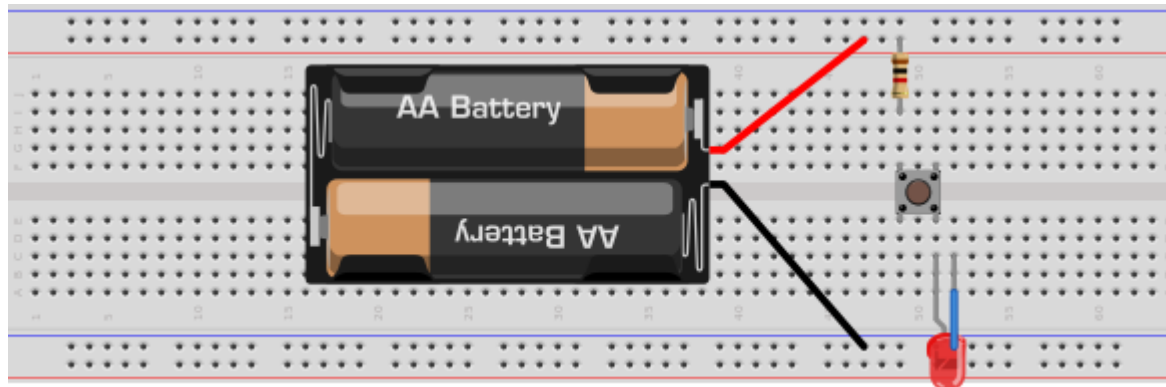
Right panel:

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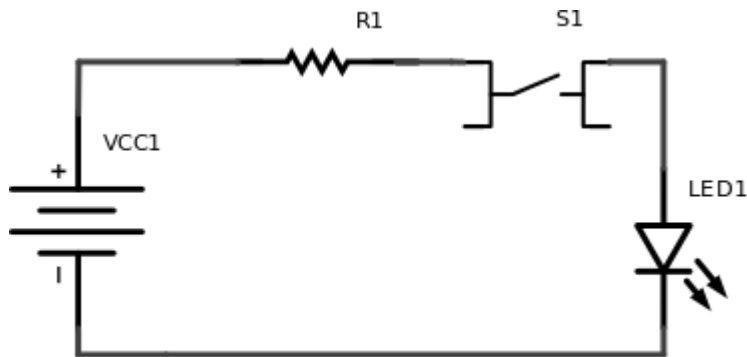


By en>User:Fulladder - en:Image:Breadboard counter.jpg, Copyrighted free use,
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Fritzing, <http://fritzing.org/home/>



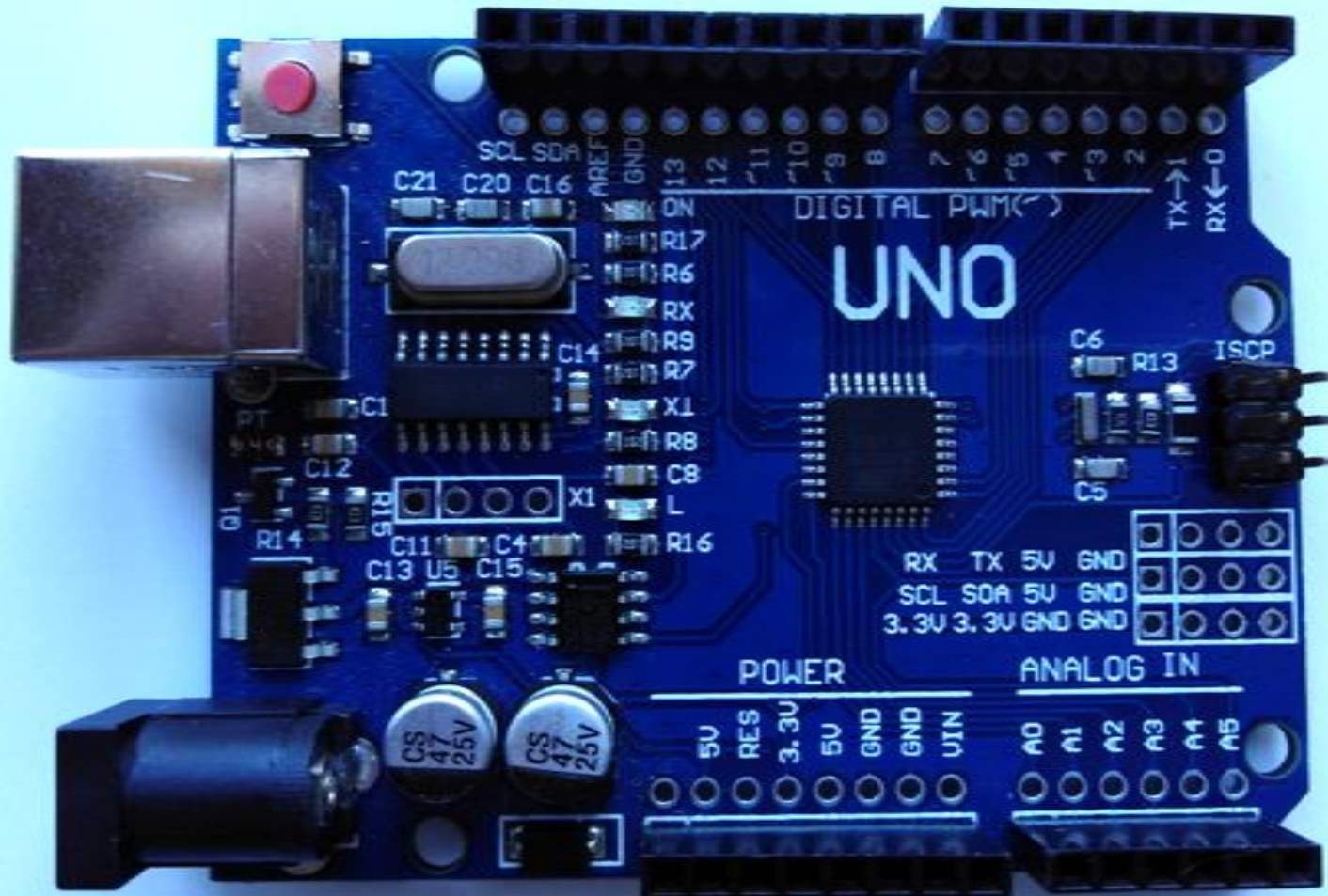
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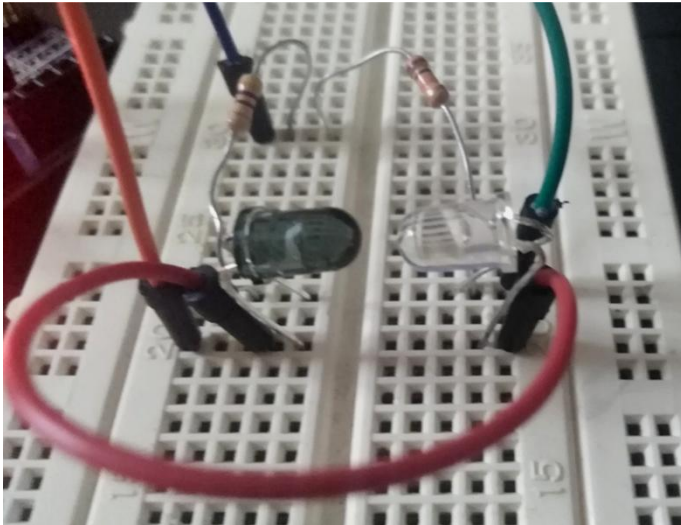
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Lower panel: By LA2 - Own work, CC BY-SA 3.0,
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UNO R3 board



Sensor



Infrared sensor designed for lab. assignment for Measurement Computing Devices course at the University of Belgrade.

Transducer (<https://en.wikipedia.org/wiki/Transducer>) is device that converts a signal from one form of energy to other form.

Sensor (<https://en.wikipedia.org/wiki/Sensor>) is a transducer that converts signal from any form of energy to electrical energy.

There is relatively large number of sensor types

(https://en.wikipedia.org/wiki/List_of_sensors) used in a variety of applications... including IoT

(https://en.wikipedia.org/wiki/Internet_of_things)...

Sensor characteristics

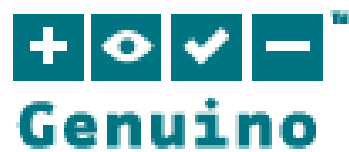
Basic static characteristics are:

1. Range (minimal and maximal measurable quantities)
2. Stability
3. Accuracy & precision
4. Hysteresis
5. Resolution (the smallest change it can detect in the quantity that it is measuring, see: <https://en.wikipedia.org/wiki/Sensor#Resolution>)*
6. Repeatability
7. Linearity (output is a linear function of the input)

* For digital sensors, resolution is determined by the resolution of A/D conversion. If the resolution is 12 bits and voltage range 0-5 V, then the resolution equals $5/2^{12} = 0.0012$ V.

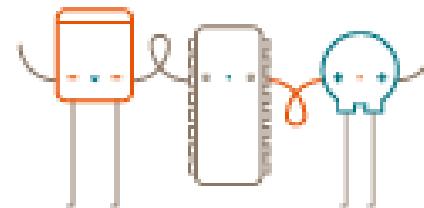
Arduino IDE

- Arduino hardware can be programmed from any programming language, but Arduino IDE is commonly used.
- Integrated Development Environment – IDE
- It is written in Java, C, and C++. It can be installed on Windows, macOS and Linux (cross-platform application), <https://en.wikipedia.org/wiki/Arduino>.
 - Arduino programming is very similar to C++.
- NOTE: If you decide to use built-in examples and functions, you should check their compatibility with the available hardware.



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AND SUPPORTED BY ARDUINO.CC AND
THE ARDUINO COMMUNITY WORLDWIDE

LEARN MORE ABOUT THE CONTRIBUTORS
OF **ARDUINO.CC** on arduino.cc/credits



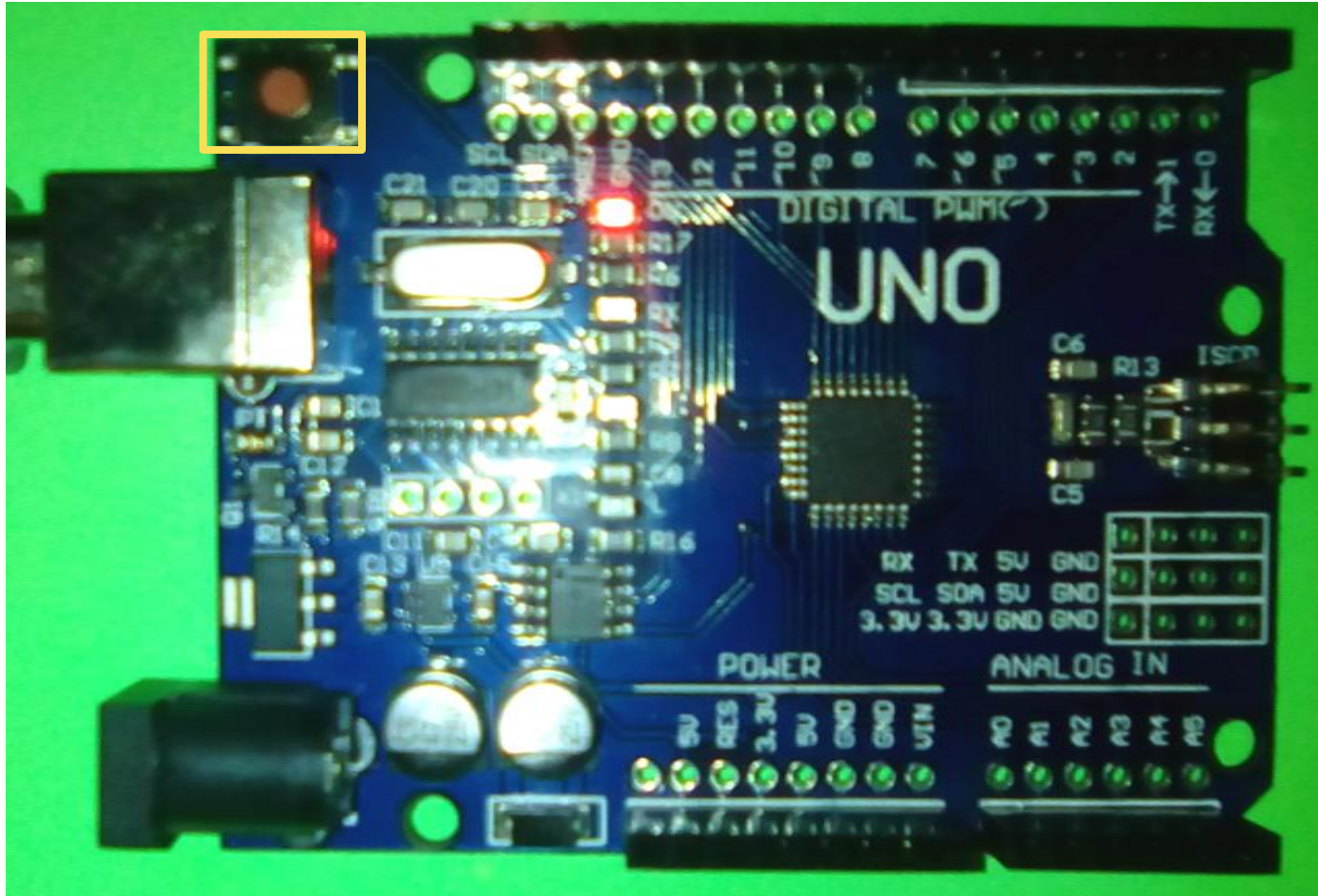
Arduino sketch

```
// the setup function runs once when you press reset or power the board
void setup() {
  // initialize digital pin LED_BUILTIN as an output.
  pinMode(LED_BUILTIN, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
  digitalWrite(LED_BUILTIN, HIGH);    // turn the LED on (HIGH is the volt
  delay(1000);                        // wait for a second
  digitalWrite(LED_BUILTIN, LOW);     // turn the LED off by making the vo
  delay(1000);                        // wait for a second
}
```

- Program written in Arduino IDE is called sketch.
- Sketches are saved with **.ino** extension in separate folders.
- Minimal sketch contains two functions:
 - *setup()* that commonly contains code for initialization and
 - *loop()* executes repeatedly.
- Image represents simple built-in **Blink.ino** sketch.

RESET button



- Reinitializes program.
- Similar to power off.

- UNO R3 microcontroller board and Arduino UNO contain built-in SMD (surface-mount technology) LED (light-emitting diode) marked as “L” on the board (pin 13).
- Image shows Arduino UNO schematic with built-in diode, [Online], Assessed Dec. 8, 2018, https://www.arduino.cc/en/uploads/Main/Arduino_Uno_Rev3-schematic.pdf.
- Very useful for testing the board. Let’s try it.

How to define variables?

```
int ledPin = 8;  
const int cledPin = 8;
```

- Global:
 - Before *setup()* function or before *loop()* function, if there is no need for initialization in *setup()*.
 - Integer variables are presented in image above (digital pin number).
 - Usually, names of constants can begin with letter “c”.
- Local:
 - Inside functions (*setup()*, *loop()* or other user-defined functions).

Control structures

Control Structures

- if
- if...else
- for
- switch case
- while
- do... while
- break
- continue
- return
- goto

- Types of control structures are presented in Table.
- More at:
<https://www.arduino.cc/en/Reference/HomePage>.

if structure

```
int ledPin = 8;
void setup() {
  if (ledPin < 0) {
    ledPin = 13;
  }
  pinMode(ledPin, OUTPUT);
}
```

- Presented in image above.
- Begin and end are marked with curly brackets “{}”.
- What is the function of the code above?

if else structure

```
if (pinLed >= 13) {  
    delay(200);  
}  
else {  
    delay(800);  
}
```

- Presented in image above.
- Begin and end are marked with curly brackets “{}”.
- Auto-fill option is ON: when you type the “begin” sign “{” and press ENTER for new line, the “end” sign is automatically generated “}”.
We all like to be spoiled sometimes.

switch structure

```
switch (range) {  
  case 0:    // your hand is on the sensor  
    Serial.println("dark");  
    break;  
  case 1:    // your hand is close to the sensor  
    Serial.println("dim");  
    break;  
  case 2:    // your hand is a few inches from the sensor  
    Serial.println("medium");  
    break;  
  case 3:    // your hand is nowhere near the sensor  
    Serial.println("bright");  
    break;  
}
```

- The built-in example from ***switchCase.ino*** is presented.
- Sample case structure is presented in image above.

while loop

```
// while the button is pressed, take calibration readings:  
while (digitalRead(buttonPin) == HIGH) {  
    calibrate();  
}
```

- Sample *while* loop is presented in image above.
- Built-in example code is presented from ***WhileStatementConditional.iso***.

for loop

```
const int kPinLed = 13;

void setup() {
    pinMode(kPinLed, OUTPUT);
}

void loop() {
    for (int ind = 0; ind < 5; ind++){
        digitalWrite(kPinLed, HIGH);
        delay(150);
        digitalWrite(kPinLed, LOW);
        delay(150);
    }
    delay(1500);
}
```

- Sample *for* loop is presented in image.
- What is the result of this code?
- Code is adopted/inspired from: Alan G. Smith, Introduction to Arduino: A piece of cake!, 2011.

What does this program do?

```
void loop() {  
    delayT = delayT - 50;  
    if (delayT <= 0) {  
        delayT = 1500;  
    }  
    digitalWrite(kPinLed, HIGH);  
    delay(delayT);  
    digitalWrite(kPinLed, LOW);  
    delay(delayT);  
}
```

- Code is adopted/inspired from: Alan G. Smith, Introduction to Arduino: A piece of cake!, 2011.
- Usability of this code? Holidays are approaching...

Arithmetic & comparison operators

Arithmetic Operators

- = (assignment operator)
- + (addition)
- - (subtraction)
- * (multiplication)
- / (division)
- % (modulo)

Comparison Operators

- == (equal to)
- != (not equal to)
- < (less than)
- > (greater than)
- <= (less than or equal to)
- >= (greater than or equal to)

- More at: <https://www.arduino.cc/en/Reference/HomePage>.
- Integer division is performed by "/" if numerator and denominator are integers. Be very careful! Let's see an example.

Built-in analog read serial

```
// the setup routine runs once when you press reset:
void setup() {
  // initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
}

// the loop routine runs over and over again forever:
void loop() {
  // read the input on analog pin 0:
  int sensorValue = analogRead(A0);
  // print out the value you read:
  Serial.println(sensorValue);
  delay(1);        // delay in between reads for stability
}
```

- Let's test this code.
- Let's test the sensor.
- I prepared photo resistor with voltage divider, but you can use any other sensor or circuit. You will measure voltage with A0.

Built-in read analog voltage

```
// the setup routine runs once when you press reset:
void setup() {
  // initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
}

// the loop routine runs over and over again forever:
void loop() {
  // read the input on analog pin 0:
  int sensorValue = analogRead(A0);
  // Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V):
  float voltage = sensorValue * (5.0 / 1023.0);
  // print out the value you read:
  Serial.println(voltage);
}
```

- The same circuit.
- Different code.
- How different?

Data types

Data Types

- void
- boolean
- char
- unsigned char
- byte
- int
- unsigned int
- word
- long
- unsigned long
- short
- float
- double
- string - char array
- String - object
- array

- More at:
<https://www.arduino.cc/en/Reference/HomePage>.
- For conversion use recommended functions.

Conversion

- char()
- byte()
- int()
- word()
- long()
- float()

Serial port

- Serial port is used for communication between the microcontroller board and computer or other devices.
- Serial Monitor and Serial Plotter can be used to check the content of the serial port (note that baud rates should be the same in the Serial Monitor/Plotter and your Arduino sketch).
- More at:
<https://www.arduino.cc/reference/en/language/functions/communication/serial/>.

Logical & compound operators

Boolean Operators

- `&&` (and)
- `||` (or)
- `!` (not)

Bitwise Operators

- `&` (bitwise and)
- `|` (bitwise or)
- `^` (bitwise xor)
- `~` (bitwise not)
- `<<` (bitshift left)
- `>>` (bitshift right)

Compound Operators

- `++` (increment)
- `--` (decrement)
- `+=` (compound addition)
- `-=` (compound subtraction)
- `*=` (compound multiplication)
- `/=` (compound division)
- `%=` (compound modulo)
- `&=` (compound bitwise and)
- `|=` (compound bitwise or)

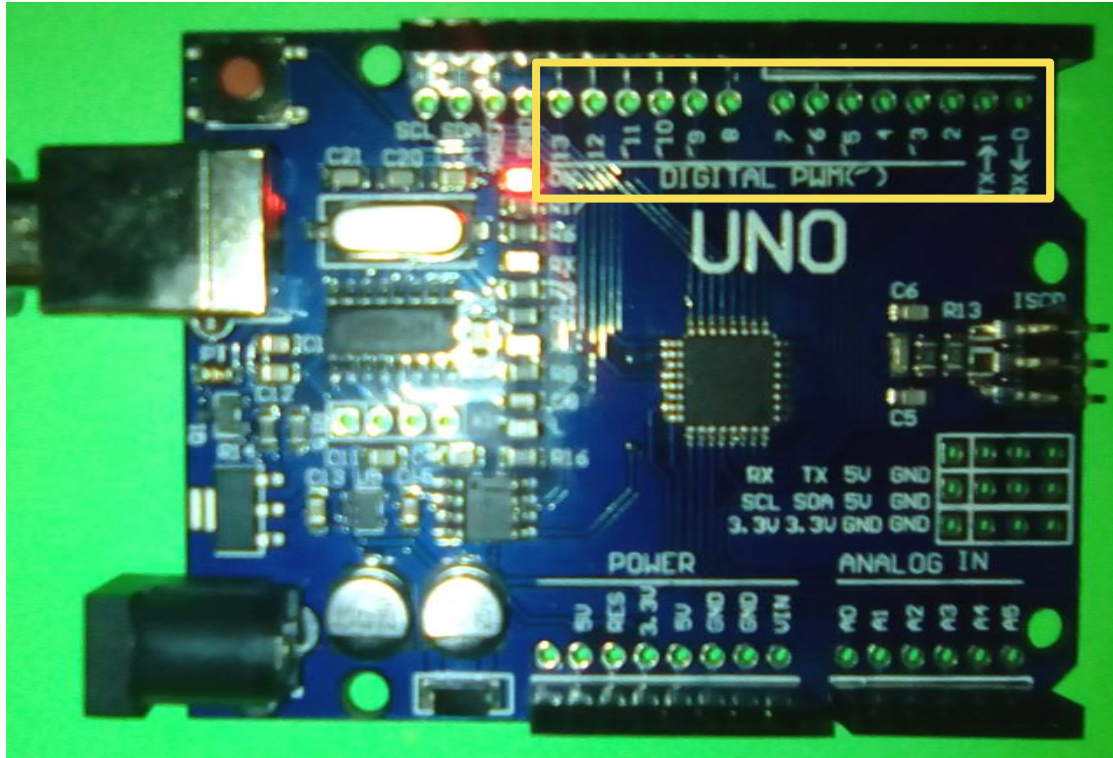
More at: <https://www.arduino.cc/en/Reference/HomePage>.

What does the program do?

```
int ledState = LOW;
void loop() {
    ledState = !ledState;
    digitalWrite(kPinLed, ledState);
    delay(1000);
}
```

- Code is adopted/inspired from: Alan G. Smith, Introduction to Arduino: A piece of cake!, 2011.
- LOW and HIGH are default logical variables. Instead, you can use FALSE and TRUE.

Pulse Width Modulation PWM



```
void loop() {  
    digitalWrite(LED_BUILTIN, HIGH);  
    delay(1000);  
    digitalWrite(LED_BUILTIN, LOW);  
    delay(1000);  
}
```

- Instead *digitalWrite()*, *analogWrite()* is used.
- “DIGITAL PWM” on microcontroller board next to digital pins.
- NOTE: UNO board does not have analog output/s.

PWM definition(s)

- [Pulse Width Modulation](https://learn.sparkfun.com/tutorials/pulse-width-modulation) (PWM) is a fancy term for describing a type of digital signal. Pulse width modulation is used in a variety of applications including sophisticated control circuitry (<https://learn.sparkfun.com/tutorials/pulse-width-modulation>).
- Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a [modulation](https://en.wikipedia.org/wiki/Pulse-width_modulation) technique used to encode a [message](https://en.wikipedia.org/wiki/Pulse-width_modulation) into a [pulsing signal](https://en.wikipedia.org/wiki/Pulse-width_modulation) ([https://en.wikipedia.org/wiki/Pulse-width modulation](https://en.wikipedia.org/wiki/Pulse-width_modulation)).
- Pulse Width Modulation, or PWM, is a technique for getting analog results with digital means. Digital control is used to create a square wave, a signal switched between on and off. This on-off pattern can simulate voltages in between full on (5 Volts) and off (0 Volts) by changing the portion of the time the signal spends on versus the time that the signal spends off (<https://www.arduino.cc/en/Tutorial/PWM>).

PWM

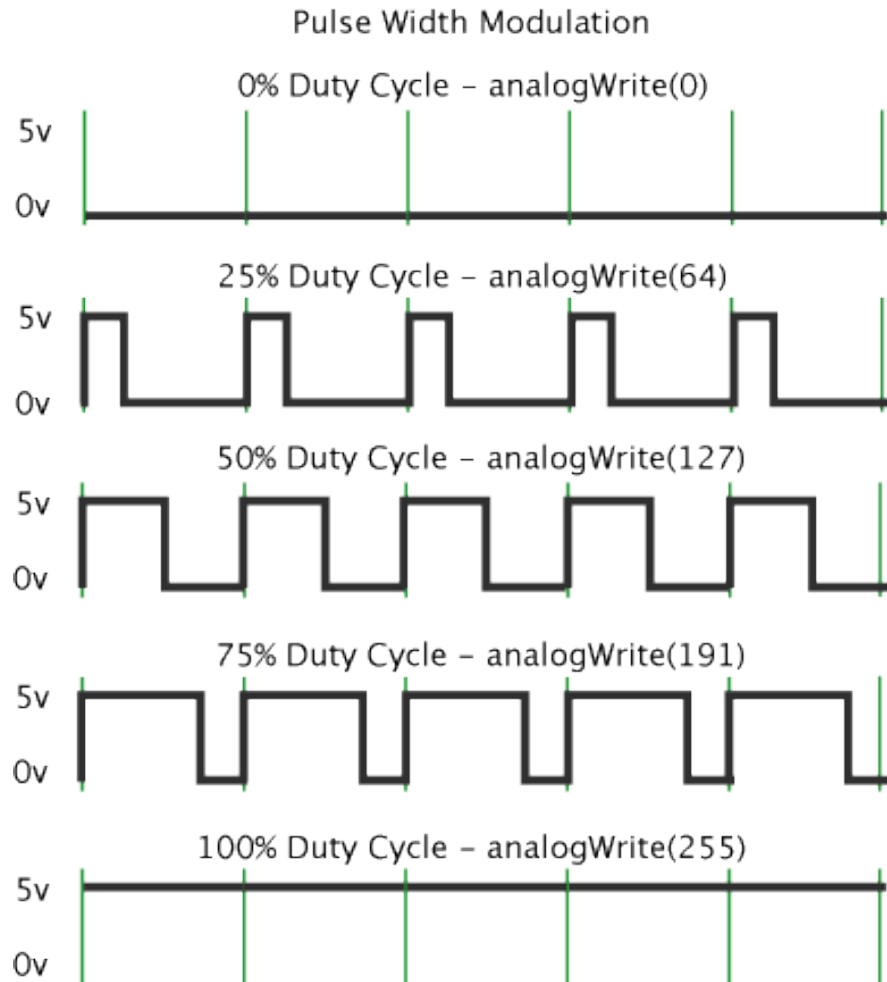


Image is adopted from: <https://www.arduino.cc/en/uploads/Tutorial/pwm.gif>.

analogWrite() example

```
int led = 9;           // the PWM pin the LED is attached to
int brightness = 0;    // how bright the LED is
int fadeAmount = 5;    // how many points to fade the LED by

// the setup routine runs once when you press reset:
void setup() {
  // declare pin 9 to be an output:
  pinMode(led, OUTPUT);
}

// the loop routine runs over and over again forever:
void loop() {
  // set the brightness of pin 9:
  analogWrite(led, brightness);

  // change the brightness for next time through the loop:
  brightness = brightness + fadeAmount;

  // reverse the direction of the fading at the ends of the fade:
  if (brightness <= 0 || brightness >= 255) {
    fadeAmount = -fadeAmount;
  }
  // wait for 30 milliseconds to see the dimming effect
  delay(30);
}
```

- Built-in ***Fade.ino*** sketch is presented in image.
- What does this sketch do?
- You can control LED brightness, but also motors by digital ports.

Time functions

Time

`delay()`

`delayMicroseconds()`

`micros()`

`millis()`

- Why you shouldn't use `delay()`?
- Be aware of constraints.
- I recommend ***BlinkWithoutDelay.ino*** from:
<https://www.arduino.cc/en/Tutorial/BlinkWithoutDelay>.
- Text for this slide is adopted from:
<https://www.arduino.cc/reference/en/language/functions/time/delay/>.

Notes and Warnings

While it is easy to create a blinking LED with the `delay()` function, and many sketches use short delays for such tasks as switch debouncing, the use of `delay()` in a sketch has significant drawbacks. No other reading of sensors, mathematical calculations, or pin manipulation can go on during the delay function, so in effect, it brings most other activity to a halt. For alternative approaches to controlling timing see the `millis()` function and the sketch cited below. More knowledgeable programmers usually avoid the use of `delay()` for timing of events longer than 10's of milliseconds unless the Arduino sketch is very simple.

Certain things do go on while the `delay()` function is controlling the Atmega chip however, because the delay function does not disable interrupts. Serial communication that appears at the RX pin is recorded, PWM (`analogWrite`) values and pin states are maintained, and interrupts will work as they should.

Other Arduino libraries

101 Only Libraries

- [CurieBLE](#) - Interact with smartphones and tablets with Bluetooth Low Energy (BLE).
- [CurieIMU](#) - Manage the on-board accelerometer and gyro.
- [CurieTimerOne](#) - Allows to use Timer functions.
- [CurieTime](#) - Allows to control and use the internal RTC (Real Time Clock)

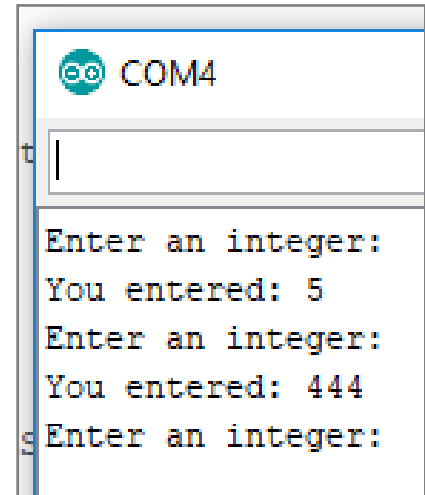
- Some libraries are intended for use with specialized hardware only.
- In order to import libraries choose from *Sketch* drop-down menu option *Import Library*. Usually in **.zip** format.
- More at: <https://www.arduino.cc/en/Hacking/LibraryTutorial>.
- Advice: Never trust completely libraries downloaded from unknown or unreliable sources! Test them yourself and be careful.

In case you need interactivity

```
int Num;

void setup() {
  // initialize serial communication and set data rate for serial
  // data communication
  Serial.begin(9600);
}

void loop() {
  // print inquiry at the serial port (see Serial monitor)
  Serial.println("Enter an integer: ");
  while(Serial.available() == 0) { // wait for user to enter number
  }
  Num = Serial.parseInt(); // read number from serial port
  // Print entered value
  Serial.print("You entered: ");
  Serial.println(Num);
}
```



- Serial port can be used for both output & input.
- Use *Serial.parseInt()* function: <https://www.arduino.cc/en/Serial/parseInt>.
- Sample code is presented.
- Let's try it?
- What will happen if user enters 1.3?



Arduino

Thanks EESTEC for inviting me to joint this workshop!

Good luck with your projects!

Special thanks to Prof. Predrag Pejović (<http://tnt.etf.rs/~peja/>) and Prof. Igor Tartalja both from University of Belgrade – School of Electrical Engineering for supporting my work in introducing Arduino to the ETF curriculum.

Slides and materials for this presentation are available online at: <https://github.com/NadicaSm/>.

More code and materials (in Serbian) at: <http://automatika.etf.bg.ac.rs/sr/13e053msr>.