CANSAT KURSUS

efterår 2021

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se også

http://jensd.dk/cansat

tentativ agenda

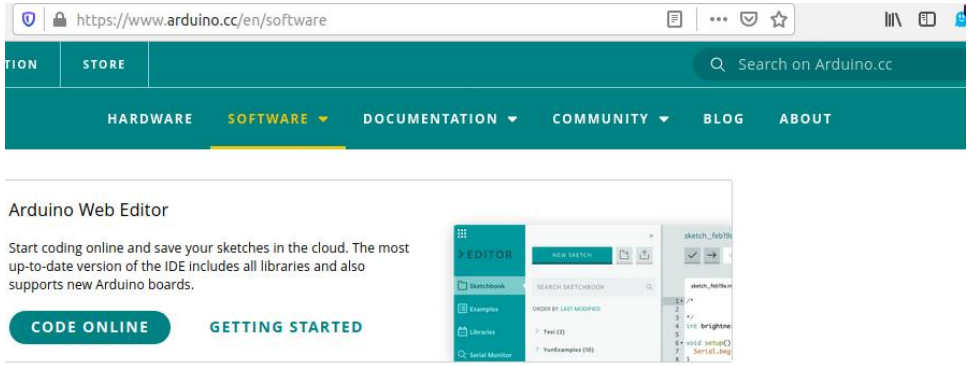
- velkommen

- udlevering af kit
  - install af SW
  - arduino IDE
- gennemgang af cansat shield
  - bibliotekter for cansat shield
- Afdækning af folks programmeringserfaringer
  - gætter på fra ingenting til meget kompetente
- enkle hello world programmer

- start på kit
- trykmåler (bmp085/bmp180/...)
- accelerometer (MPU6050)
- gyro (MPU6050)
- magnetometer (hmc5983)
- logning på sd card
- radiolink
- apc220
- configuration
- den store test
- pewwww

ARDUINO INSTALL

- http://arduino.cc
- https://www.arduino.cc/en/software

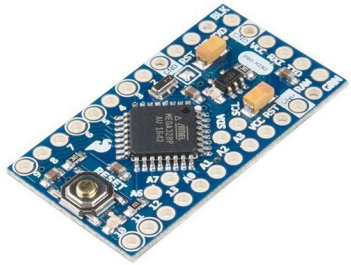


C - a programming language

- Small language

- Used everywhere
  - from micro-controllers running slower than 1MHz in clock
  - to super computers running more than 3 GHz
  - A span of more than 3000 times (not ocounting CPUs)

  - from less than 1 kByte memory in systems
  - to much more than TBytes



- Language for coding linux operating system
- Language for coding MAC OS
- Windows ??

- You name it

nogle links

- https://www.arduino.cc/en/Tutorial/HomePage
- https://microcontrollerslab.com/arduino-programming-tutorial-beginners/
- http://jensd.dk/cansat/c-course
- http://jensd.dk/cansat

Programming in an imperative language

- Imperative language
- Execution of statement programmed by you
- One at a time
- In the order given by you - Order is important - change in order might change result.
- Programs are structured in blocks or functions
- Blocks of functions can execute other blocks

Programming in an imperative language

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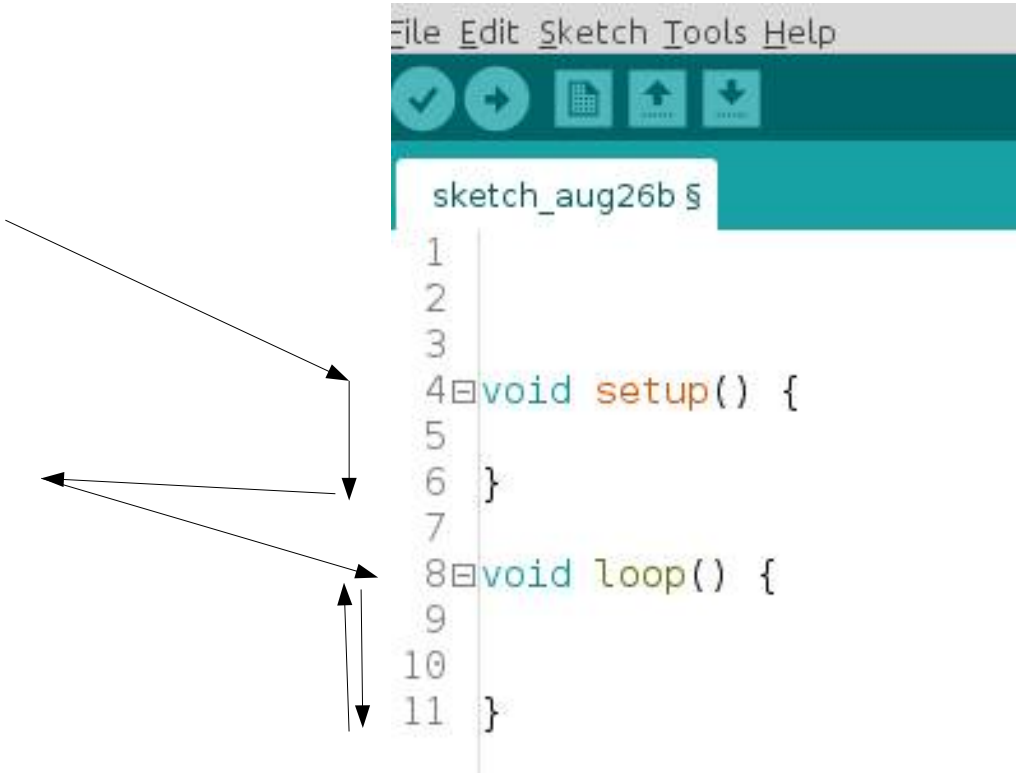
- Blocks of functions can execute other blocks

Seq ordered execution

1) start code (invisible)
2) execute **setup** statement by statement
3) back to invisible part
4) execute loop statement by statement
5) goto 4) and execute again
6) until infinity ...

A statement is either

- execution of a block/function
  - and return back to where it was called
- execution of a statement

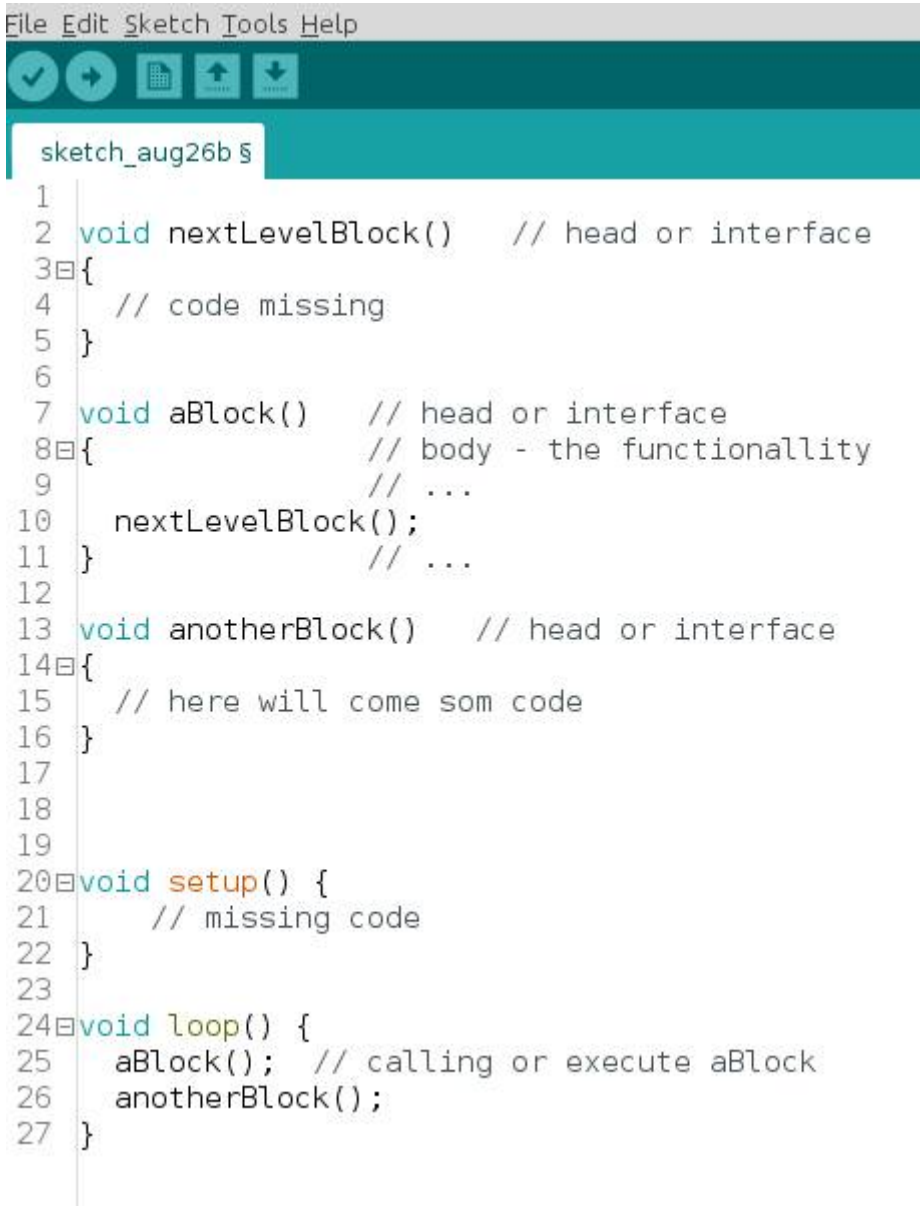


Functions

Order of execution

1) setup
2) loop
    1) aBlock
        1) nextLevelBlock
    2) anotherBlock
3) back to 2)

```
setup
loop
  aBlock
    nextLevelBlock
  anotherBlock
loop  (again)
  aBlock
    nextLevelBlock
  anotherBlock
loop  (again)
  aBlock
    nextLevelBlock
loop  (again)
  aBlock
    nextLevelBlock
  anotherBlock
...
```



Functions “1”

Consists

- a head : your interface to the function
- a body: which holds the code the function execute

head - syntax:

```
void   NAME   ()      - name might be a, bec vrst
                      - case sensitive Jens, jens,jeNS,jENS are different names
                      - you can´t use national letters like  jørgen  (ø :-()
```

examples

```
void setup()   :-)
void myFirstfunction()
```

body - syntax:

```
{
   // statement or calling another function
}
```

Functions “2”

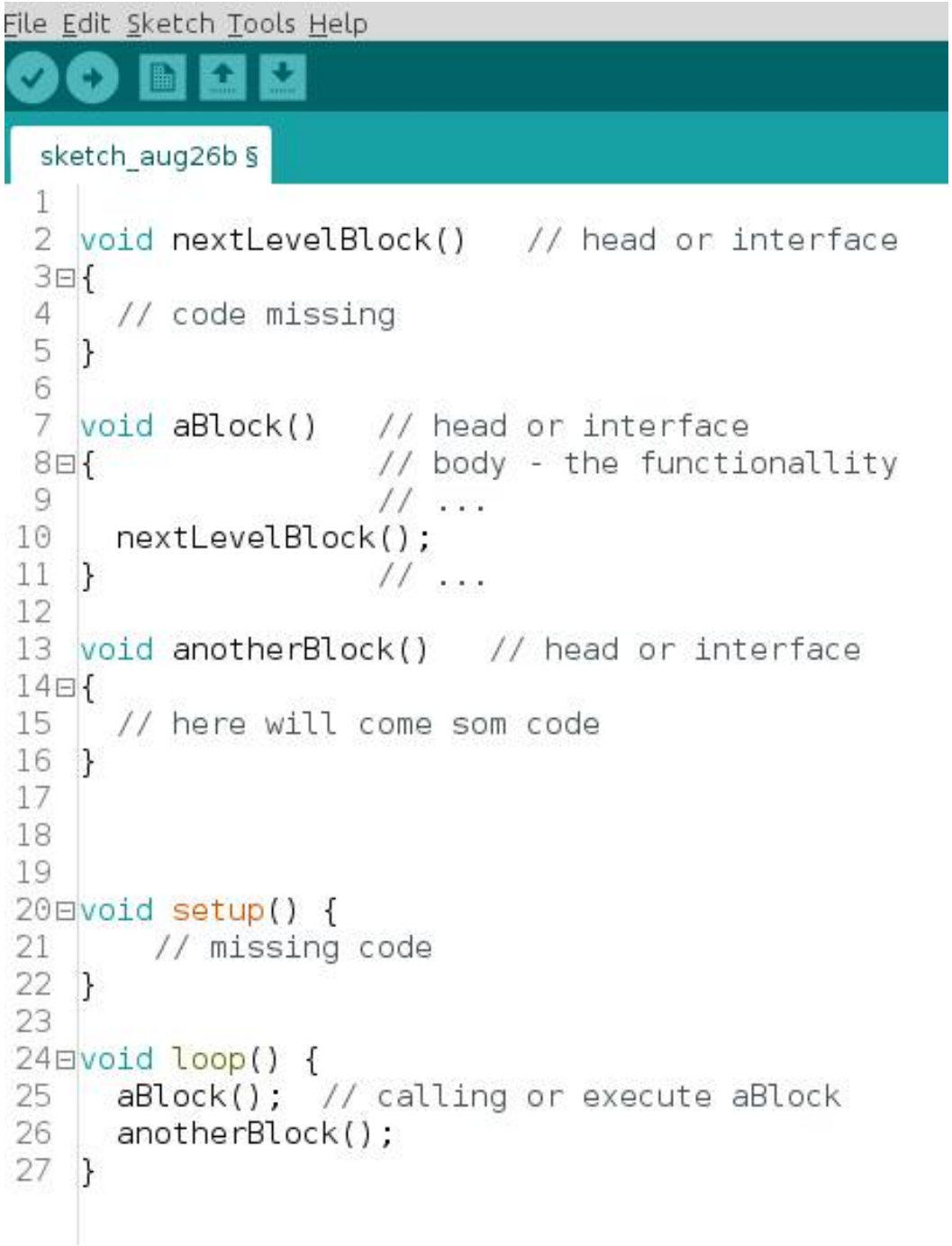
```
void x()
{
  // do something
}

execution of function x

...
x();       // name + () + ;      “;” is end of a statement  (like “.” in danish)
```

the C/function flow

- /&%¤/%&/¤#”&¤%%(/&%

- loop calls aBlock
  - aBlock calls nextLevelBlock
    - nextLevelBlock executes and return to ...
  - aBlock which returns to ...
- loop
- loop calls anotherBlock
  - anaotherBlocks executes and return to ...
- loop
- loop return (after last statement)
- loop “loops” to start of loop and
- loop calls aBlock (first bullet)
- ... etc

Line numbers
24
25->7 (call aBlock)
    8,9,10->2
       2,3,4,5 return to 10+
    11 return to 25+
26->13 (call anotherBlock)
    14,15,16 return to 26+
27 loop to 24



Need some debugging - need to see what is going on

File Edit Sketch Tools Help

aaaa

```
1  void setup() {
2    Serial.begin(115200);
3    delay(1000);  // relax
4  }
5
6  void aaa()
7  {
8    Serial.println("aaa");
9    delay(1000);  // wait one second here
10   return;
11 }
12
13 void aa()
14 {
15   Serial.println("aa");
16   delay(1000);  // wait one second here
17   aaa();
18   return;
19 }
20
21 void a()
22 {
23   Serial.println("a");
24   delay(1000);  // wait one second here
25   aa();
26   return;
27 }
28
29 void loop() {
30   Serial.println("loop");
31   a(); // calls function a
32   delay(5000);   // calls delay which delay execution by 5000 mill
33 }
```

```
ets Jun  8 2016 00:22:57

rst:0x1 (POWERON_RESET),boot
configsip: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_dr
mode:DIO, clock div:1
load:0x3fff0018,len:4
load:0x3fff001c,len:1044
load:0x40078000,len:8896
load:0x40080400,len:5816
entry 0x400806ac
loop
a
aa
aaa
loop
a
aa
aaa
loop
a
aa
aaa
loop
a
aa
aaa
loop
a
aa
aaa
loop
a
aa
aaa
```

Serial.println - a function

- prints :-)
- only one item: text or numbers.

- numbers
  - 1 2 456 -34 integers (heltal)
  - 1.23 -1.23e7 floating point (kommatal)

- text
  - “letters in between”

- Serial.println(“ost”); //prints ost and force a linebreak after
- Serial.println(123); // prints 123 and force a ...

- Need to initialize port with writing speed

- Serial.begin(115200); // for ce nerds 115200 bit pr second

aaaa

```
1  void setup() {
2    Serial.begin(115200);
3    delay(1000);  // relax
4  }
5
6  void aaa()
7  {
8    Serial.println("aaa");
9    delay(1000);  // wait one second here
10   return;
11 }
```

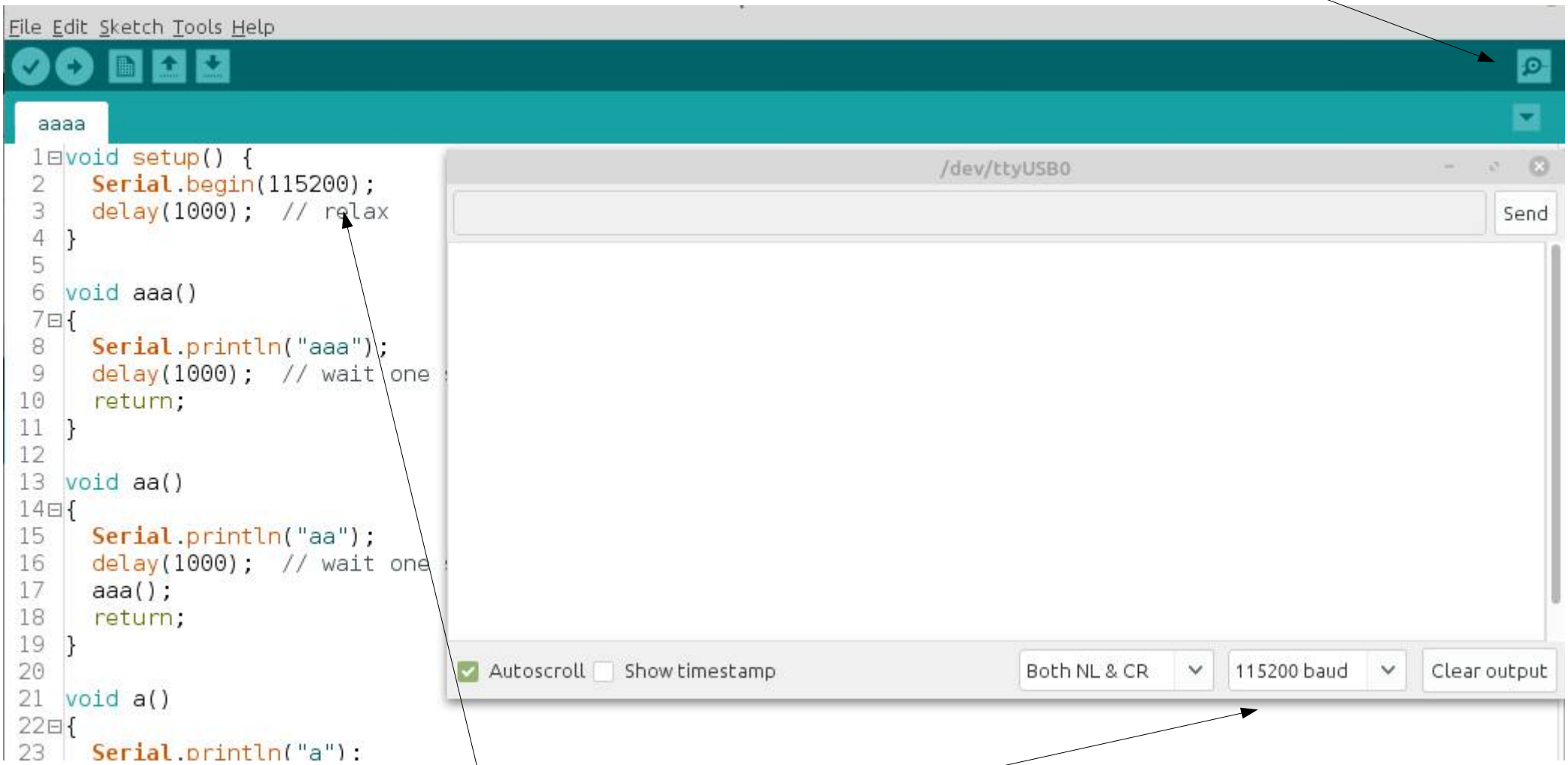
serial interface

- 115200 bits pr second
- delay pause execution
- “return” returns from a functior

aaaa

```
1  void setup() {
2    Serial.begin(115200);
3    delay(1000);  // relax
4  }
5
6  void aaa()
7  {
8    Serial.println("aaa");
9    delay(1000);  // wait one second here
10   return;
11 }
```

serial terminal (in menu “tools”)



TEST -1

- Arduino UNO
- testprogram
- File -> examples -> digital -> BlinkWithoutDelay
- Tools-> Board -> Uno
- Tools -> Port -> den USB port din Arduino sidder på
- ctrl-u (compiler og upload)
- blinker LED
- JA: mission completed

første rigtige program

-
-
- Lav ADC eksempel
- print måling med 5 msec delay imellem
- sæt en ledning til adc indgang og hold ved den
- print og plot og se resultat

- BRUG FUNKTIONER !!!
- med parametre (Jens viser eksempel online)

imp03-ex01

```
1  void setup() {
2    Serial.begin(115200);
3    delay(1000);
4  }
5
6  int maaling;
7  float voltage;
8
9  float omregn(int val, int valMax, float vMax)
10 {
11   return  ( val * vMax / valMax );
12 }
13
14 void loop() {
15   maaling = analogRead(36); // nodeMCU adc0
16   voltage = omregn(maaling, 4095, 3.3);
17   Serial.println(voltage, 3);
18   delay(20);
19 }
20
21 /* TRICKS
22 For at undgaa debug beskedderne når man rebooter
23 kan man sætte GPIO15 til stel(gnd).
24 HVis du vil serial plotte ovenstående så
25
26 1. hold RESET knappen nede
27 2. start upload
28 3. slip RESET knappen lidt efter
29
30 efter upload
31
32 1. hold  EN knappen nede
33 2. start seriel plotter
34 3. slip EN knappen
35
36 JDN
37 */
```

```
1  void setup() {
2    Serial.begin(115200);
3    delay(1000);
4  }
5
6  int maaling;
7  float voltage;
8
9  float omregn(int val, int valMax, float vMax)
10 {
11   return  ( val * vMax / valMax );
12 }
13
14 void loop() {
15   maaling = analogRead(36); // nodeMCU adc0
16   voltage = omregn(maaling, 4095, 3.3);
17   Serial.println(voltage, 3);
18   delay(20);
19 }
```

exercise 2

- *Lav ADC eksempel*
- *print måling med 5 msec delay imellem*
- *sæt en ledning til adc indgang og hold ved den*
- *print og plot og se resultat*
-
- Lav midlingsrutine så du måler 5 gange med 1 millisek imellem og midler
- print
  - alle 5 værdier
  - og midlede værdi 5 gange

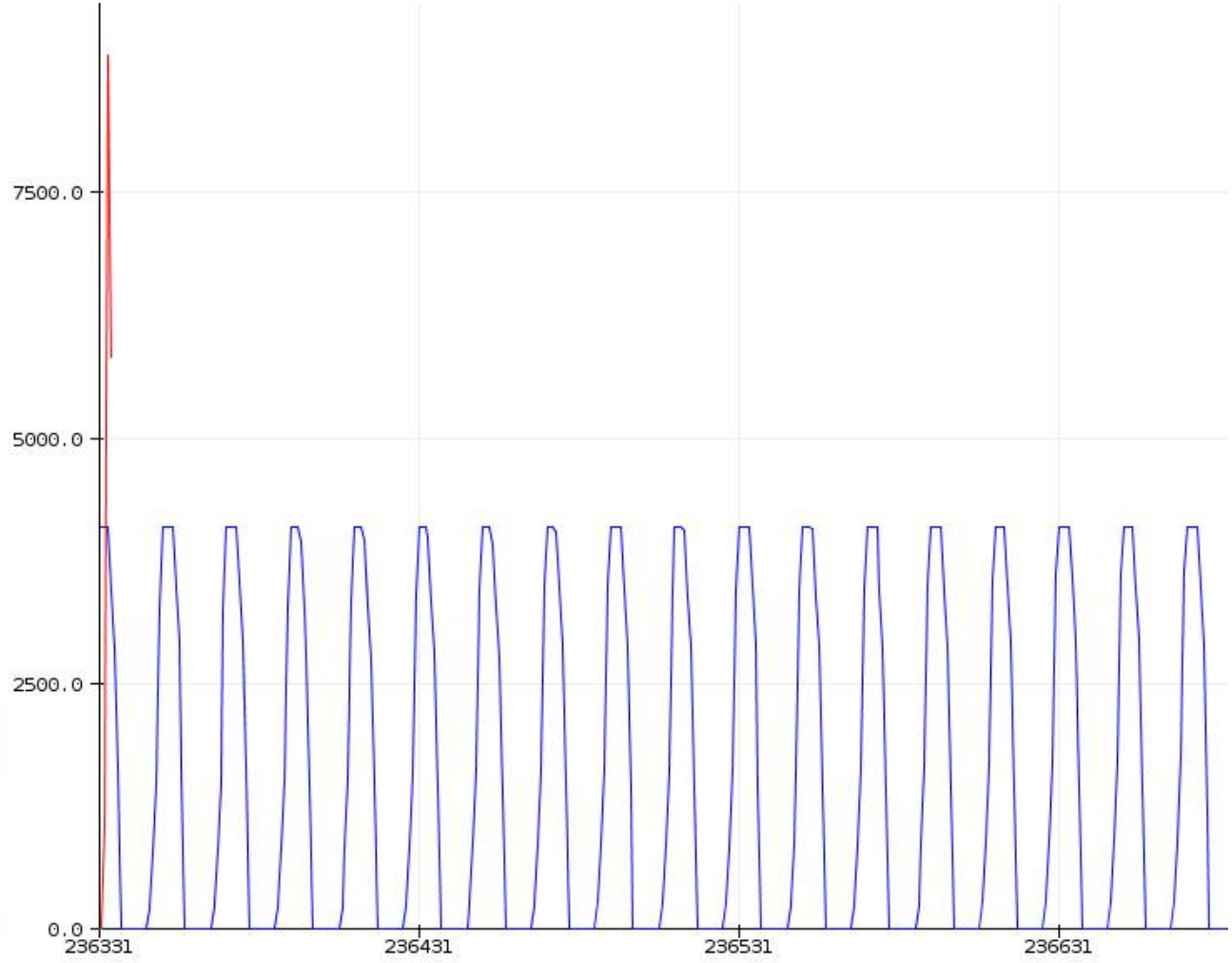
  - hint Serial.print(arr[i]); Serial.print(“ “); Serial.println(average);
  - så kan du plotte dem
- ledning i adc indgang og hold ved ledning

analog Input rå

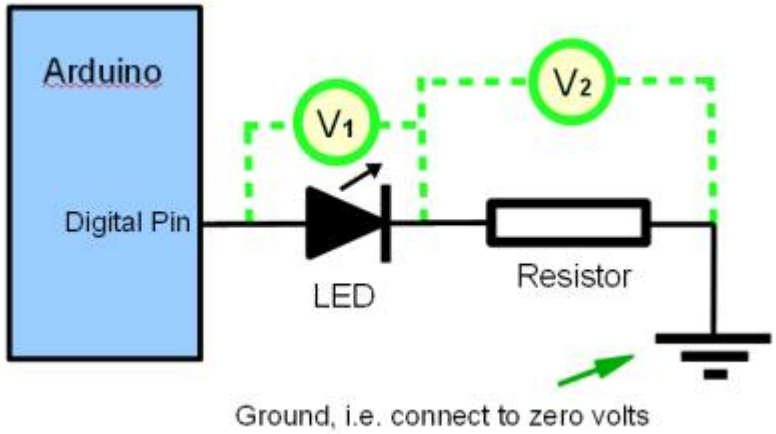
- har i ledning på pin 36 og holder ved enden af ledningen
- jeg opfanger 50 Hz støj fra verden (får port i mætning da maks jo er 1023)
- ACD får i mætning
- fra 236431 til 236531 er der 100 målinger dvs 100 millisekunder ca (se kode)
- der er 5 perioder som varer 5*20 msek = 100 msek (50Hz ~ 20 msek pr periode) :-) (NB figur er fra en micro med 12 bit opløsning dvs 4095 niveauer)

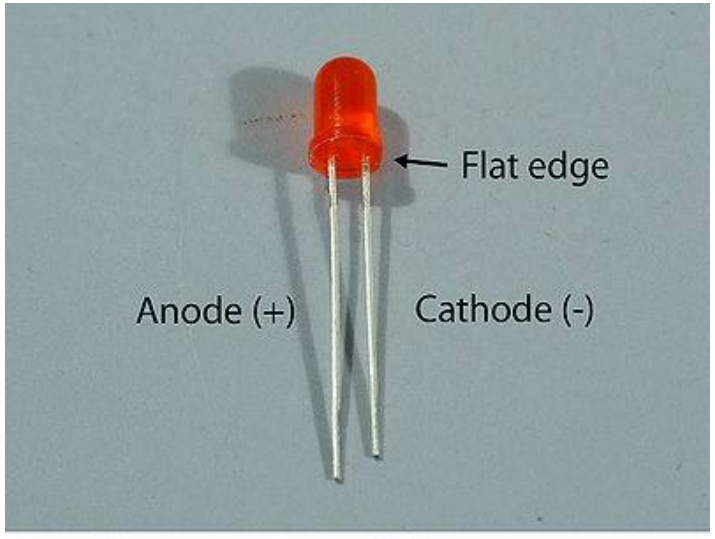
```
1  void setup() {
2    Serial.begin(115200);
3  }
4  // menu tools(værktøjer på dansk) ->
5  // ctrl+shif+l
6
7  void loop() {
8    delay(1);
9    Serial.println(analogRead(36) );
10 }
11
```

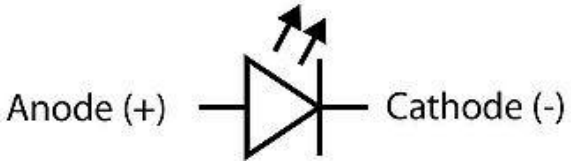
```
Done uploading.

Invalid library found in /home/jdn/q/code
Invalid library found in /home/jdn/q/code

8                                    NodeMCU-32S
```



- ESP32 digital pin HIGH = 3.3V
- LED Voltage drop ~ 2.2V
- 1.1 V left for the diode
- https://ardustore.dk/produkt/led-diode-3m
- from the sheet
  - continuous forward current max 30 mA
- R = (3.3-2.2)/0.03A = 36 ohm
- i = 10 mA -> R = (3.3-2.2)/0.01A = 110 ohm
- higher current == more light
- pin -> LED -> resistor or
- pin -> resistor -> LED - no difference







Variable - hvad er det

- Storage. Vi skal have en måde at gemme data på mens programmet kører
- Program = kode + data !!!

- Variable skal erklæres **FØR** man bruger som (i modsætning til python)
- Du skal angive **hvilken type** variabel det er (i modsætning til python)
- Der er ret **streng typecheck** så kan ikke blander æbler og pærer (i mod...)

variabeltype no 1 - heltal

- heltal - tælletal: 1 2 3 4 654 6875 0 -123 -444 -23

Erklæring:

<typenavn> <variabelNavn>;
...
(std man skriver < > når man forklarer)

int etHeltal;
int et andet helTal, kurt;

```
1  int helTal;
2
3  void setup()
4  {
5    helTal = 33;
6    Serial.begin(115200);
7    delay(1000);
8  }
9
10
11 void loop() {
12
13    Serial.print("tal er ");
14    Serial.println(helTal);
15
16    helTal = helTal + 1;
17     // udregn til højre for lighedstegn
18     // gem i venstre side
19     delay(500);
20 }
```

Variable II

- simpel matematik til rådighed

```
int a,b,c,d,res;

res = (a+b) / (c + d);

eller

res = res * ((a+b) / (c + d));

kan også skrives som

res *= ((a+b) / (c + d));

BRUG RIGELIGT MED PARANTESER

SLØVER IKKE DIN KODE NED !
```

```
1  int helTal;
2
3  int andetTal, hest;
4
5  void setup()
6  {
7    helTal = 33;
8    hest = helTal + 4;
9    andetTal = hest + 4*helTal;   //  + -  * /
10   Serial.begin(115200);
11   delay(1000);
12 }
13
14
15 void loop() {
16
17   Serial.print("tal er ");
18   Serial.println(helTal);
19
20   helTal = helTal + 1;
21   // udregn til højre for lighedstegn
22   // gem i venstre side
23   delay(500);
24 }
```

paranteser

- De to følgende er ens da der er rækkefølge i udførelse af regneoperationer.
- kaldes på engelsk operator precedence
  - https://www.tutorialspoint.com/cprogramming/c_operators_precedence.htm
- * og / udføres FØR + -
- Sidste operator der udføres er =

Category	Operator	Associativity
Postfix	() [] -> . ++ - -	Left to right
Unary	+ - ! ~ ++ - - (type)* & sizeof	Right to left
Multiplicative	* / %	Left to right
Additive	+ -	Left to right
Shift	<< >>	Left to right
Relational	< <= > >=	Left to right
Equality	== !=	Left to right
Bitwise AND	&	Left to right
Bitwise XOR	^	Left to right
Bitwise OR	|	Left to right
Logical AND	&&	Left to right
Logical OR	||	Left to right
Conditional	?:	Right to left
Assignment	= += -= *= /= %=>>= <<= &= ^= |=	Right to left
Comma	,	Left to right

heltal - er der mere ???

- Et heltal har max positiv og max negativ værdier den kan holde

- Arduino
  - **int**: fylder 16 bit - dvs der er 2^16 værdier = 65536 værdier
  - 32768 negative tal: -32768 til -1
  - 0 (tallet 0)
  - 32767 positive tal: 1 til 32767
  - ialt 65536 tal

- ESP32
  - **int**: fylder 32 bit dvs der er 2^32 værdier = 4294967296 værdier (ca 4 mia)
  - -2147483648 negative tal: -2147483648 til -1
  - 0 (tallet 0)
  - 2147483647 positive tal: 1 til2147483647
  - ialt 4294967296 tal

- 64 bit
  - 2^64 ~=1,8 10^19 eller ca +- 9 * 10^18
  - puhaa mange tal

- *Jordens befolkning er lige nu ca 7800000000   (7,8 mia)*

- *Så den kan representeres vha int 16 ? eller 32 ? eller 64 ?*

kommatal - float

- Man kan regne med kommatal med + - * /

```
float etKommaTal;


etKommaTal = 1.24;
// NB “.” som decimaloperator

etKommaTal = 2* 3.4;

etKommaTal = - 1.4e17;
```

- Er 32 bit float ikke nok
- er der 64 bit double

```
1
2
3  float kommaTal;
4
5  void setup()
6  {
7    Serial.begin(115200);
8    delay(1000);
9  }
0
1
2  void loop() {
3
4    Serial.print("sizeof float ");
5    Serial.println(sizeof(float));
6
7    Serial.print("sizeof double");
8    Serial.println(sizeof(double));
9
0
1    delay(2000);
2  }
```

```
sizeof float 4
sizeof double8
sizeof float 4
sizeof double8
```

Autoscroll Show timestamp

enkle typer

Type & Description
char Typically a single octet(one byte). It is an integer type.
int The most natural size of integer for the machine.
float A single-precision floating point value.
double A double-precision floating point value.
void Represents the absence of type.

Analog input

- Kan måle spændinger 0-5V som udgangspunkt
- 10 bit ADC (analogtilDigitalConverter) dvs 2^10 = 1024 niveaue
- 0 -> 5.0V ==> 0 -> 1023

```
void setup()
{
  Serial.begin(9600);
}

void loop()
{
int i;
  float voltage;
  i = analogRead(A0);  (UNO A0,A1,... A5 - du kan også bare skrive 0,1,...)

  voltage = 5.0*i/1023;

  Serial.println(voltage);

  delay(100);  // sov 100 millisekunder
}
```

rdy - go

- åben serial terminal
- luk serial terminal
- åben serial plotter


BREAK

Digital input/output

- Se arduino comic
-

BMP085 / BMP180

- Trykmåler
- +- 30cm nøjagtige
  - (omregnet til luftryk/højde)

- I2C interface s

```
#include <Wire.h>
#include <bmp085.h>

/*
1. call bmp085_init
   - parameter pressure at sealevel (in Pascal) or 0
     if 0 then 101325 (std pressure at sea level) is used

2. Measurement by
  a. call bmp085_measure()
  b. now pressure and temperature is in float variables bmp085_temp and br
*/


void setup()
{
  Serial.begin(9600);
  Wire.begin();

  bmp085Init(101300.0); // ress at sealevel today
}

float temp, atm, alt, pres;


#define LOOPTIME 200
unsigned long t1, t3;

void loop()
{
float tryk, temp, hojde;
  bmp085Measure(&temp, &tryk, &hojde);

  Serial.print("temp(C) "); Serial.print(temp);
  Serial.print("\t tryk(Pa) "); Serial.print(tryk);
  Serial.print("\t hojde(m)"); Serial.println(hojde);
  delay(100);
}
```

```
1  #include <Wire.h>
2  #include <bmp085.h>
14
15 void setup()
16 {
17   Serial.begin(9600);
18   Wire.begin();
19
20   bmp085Init(101300.0); // ress at sealevel today
21 }
22
23 float temp, atm, alt, pres;
24
25 void loop()
26 {
27 float tryk, temp, hojde;
28   bmp085Measure(&temp, &tryk, &hojde);
29
30   Serial.print("temp(C) "); Serial.print(temp);
31   Serial.print("\t tryk(Pa) "); Serial.print(tryk);
32   Serial.print("\t hojde(m)"); Serial.println(hojde);
33   delay(100);
34 }
```

så var der lige Openlogger

- Logger alt hvad der bliver skrevet hvis
  - openlog er konfigureret til rette hastighed (med tomt sd-kort kører den 9600)
  - Jumper J4 er sat på

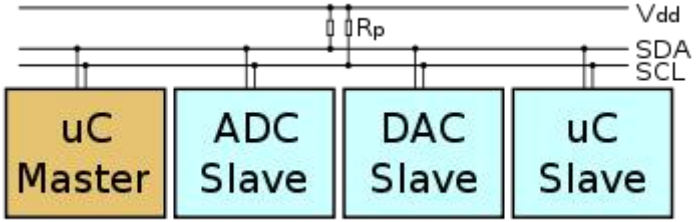
- hvad er dagens lufttryk i Bjerringbro ?
- Ret i koden i bmp08test
- compiler og upload kode
- Sæt jumper på J4
- Sæt SDcard i Openlogger
- Sæt batteri til

- gå en tur ned ad trappen og op igen
- fjern batteri

- Hvad er der på sd kort ?

MPU6050

- 3 akses acceleration og gyro
- I2C interface
-
-



- example: accgyrotes in MPU6050
- to code

```
3
4  #include "MPU6050.h"
5  #include "Wire.h"
6   MPU6050 accelgyro(0x68);
7
8  int16_t gx, gy, gz;
9  int16_t ax, ay, az;
10
11 #define LED_PIN 13
12 bool blinkState = false;
13
14 void setup() {
15   Serial.begin(38400); // start serial port
16
17   Wire.begin();  // start i2c bnetwork
18
19   accelgyro.initialize(); // initalize mpu6050
20
21   if (accelgyro.testConnection())  {
22     Serial.println("MPU6050 ok ");
23   }
24   else {
25     Serial.println("MPU6050 fail ");
26     while (1);  // stop here
27   }
28
29    pinMode(LED_PIN, OUTPUT);
30 }
31
32 void loop() {
33
34   // read raw accel/gyro measurements from device
35   accelgyro.getMotion6(&ax, &ay, &az, &gx, &gy, &gz);
36   Serial.print("a/g:\t");
37   Serial.print(ax); Serial.print("\t");
38   Serial.print(ay); Serial.print("\t");
39   Serial.print(az); Serial.print("\t");
40   Serial.print(gx); Serial.print("\t");
41   Serial.print(gy); Serial.print("\t");
42   Serial.println(gz);
43
44   // blink LED to indicate activity
45   blinkState = !blinkState;
46   digitalWrite(LED_PIN, blinkState);
47 }
48
```

HMC5983

- 3 akses magnetometer
- Husk feltet over Danmark peger ned med en vinkel på ca 60 grader

```
#include <HMC5983.h>
#include <Wire.h>

HMC5983 compass;

void setup () {
  Serial.begin(9600);
  Serial.println(" heading  /  x y z composanter");
  delay(3000);
  compass.begin(); // use "true" if you need some debug information
}

void loop() {
  float x, y, z;
  float c = -999;
  c = compass.readAll(&x, &y, &z);
  if (c == -999) {
    Serial.print("Reading error, discarded");
    return;
  } else {
    Serial.print(c);
  }
  Serial.print(" ");
  Serial.print(x); Serial.print(" ");
  Serial.print(y); Serial.print(" ");
  Serial.println(z);
}
```

HMC5983

- output x,y,z -2048 - 2047
- et count == 0.92 mG
- range default is +- 1.3 Gauss

- earth magn field 0.25 - 0.65 Gauss


BREAK

RADIO - APC220

- transmitterer alt hvad der skrives mpå serielle port
- kan også modtage kommunikation den anden vej

- J2 hvsi du vil sende data hjem
- J3 hvis du vil modtage data hjemmefra

- kommunikations til Arduino 1200 og op til 57600 baud
- kommunikation i luften 2400 og op til 19200
  - højere hastighed i luften == kortere rækkevidde

- ANBEFALING

- I luft max 9600 - gerne 4800 hvis databudget er til det
- Internt max 19200

- Frekvenser 433,05 MHz – 434,79 MHz (center 433,92 MHz) (stærkt benyttet)

- Radio kan 418-455 MHz - beware !!!

- Kan/er (lidt) anderledes i udlandet.

endelig

- velkommen

- udlevering af kit
  - install af SW
  - arduino IDE
- gennemgang af cansat shield
  - bibliotekter for cansat shield
- Afdækning af folks programmeringserfaringer
  - gætter på fra ingenting til meget kompetente
- enkle hello world programmer

- start på kit
- trykmåler (bmp085/bmp180/...)
- accelerometer (MPU6050)
- gyro (MPU6050)
- magnetometer (hmc5983)
- logning på sd card
- radiolink
- **apc220**
- **configuration**
- **den store test**
- **pewwww**