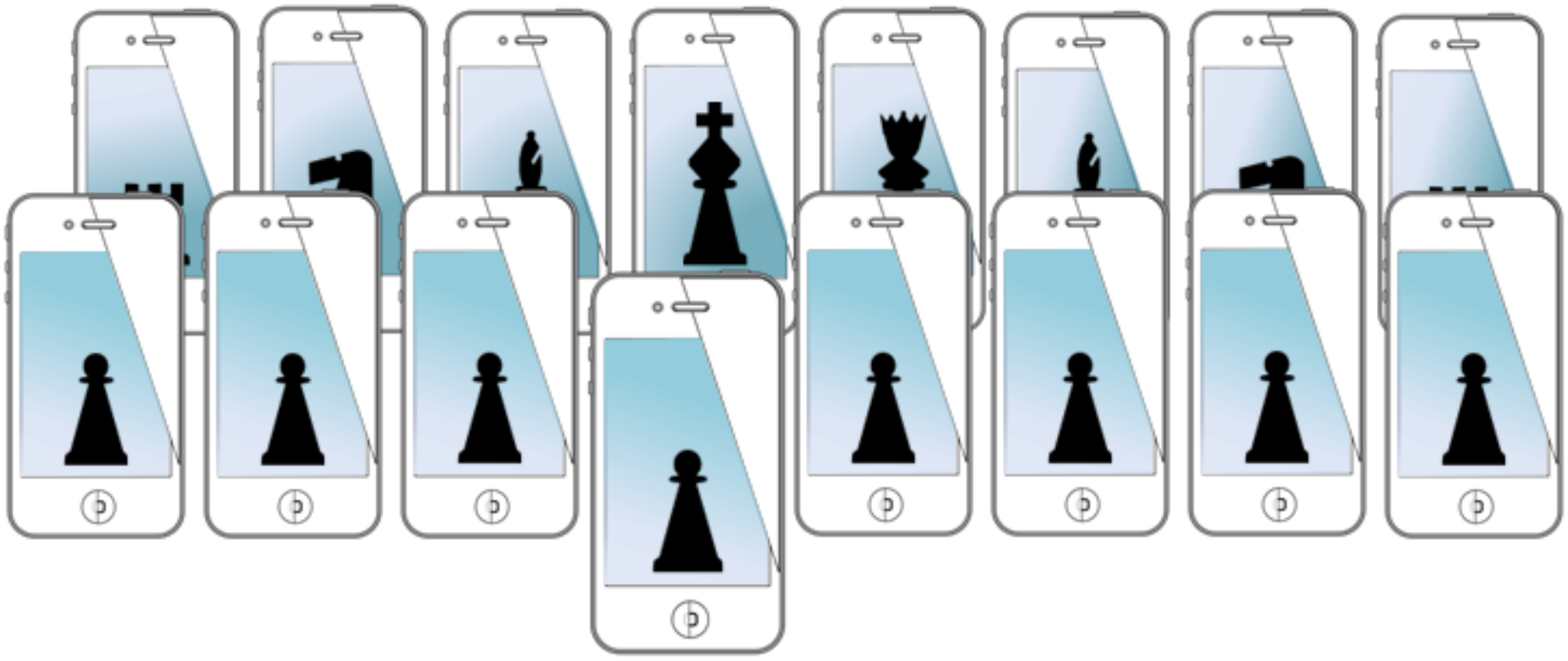
MOBILE SENSING LEARNING



CSE5323 & 7323

Mobile Sensing and Learning

week 7 and 8: microcontroller basics

Eric C. Larson, Lyle School of Engineering,
Computer Science and Engineering, Southern Methodist University

course logistics

- Grades are coming for A3
- A4 is due next Friday!
- No night lab next week, fall break …

agenda

- microcontrollers
  - architecture
  - peripherals
  - common usage
- Arduino sketches
  - the Atmega328

embedded systems

- cameras
- microcontrollers
- FPGAs
- internet of things
- many, many, things

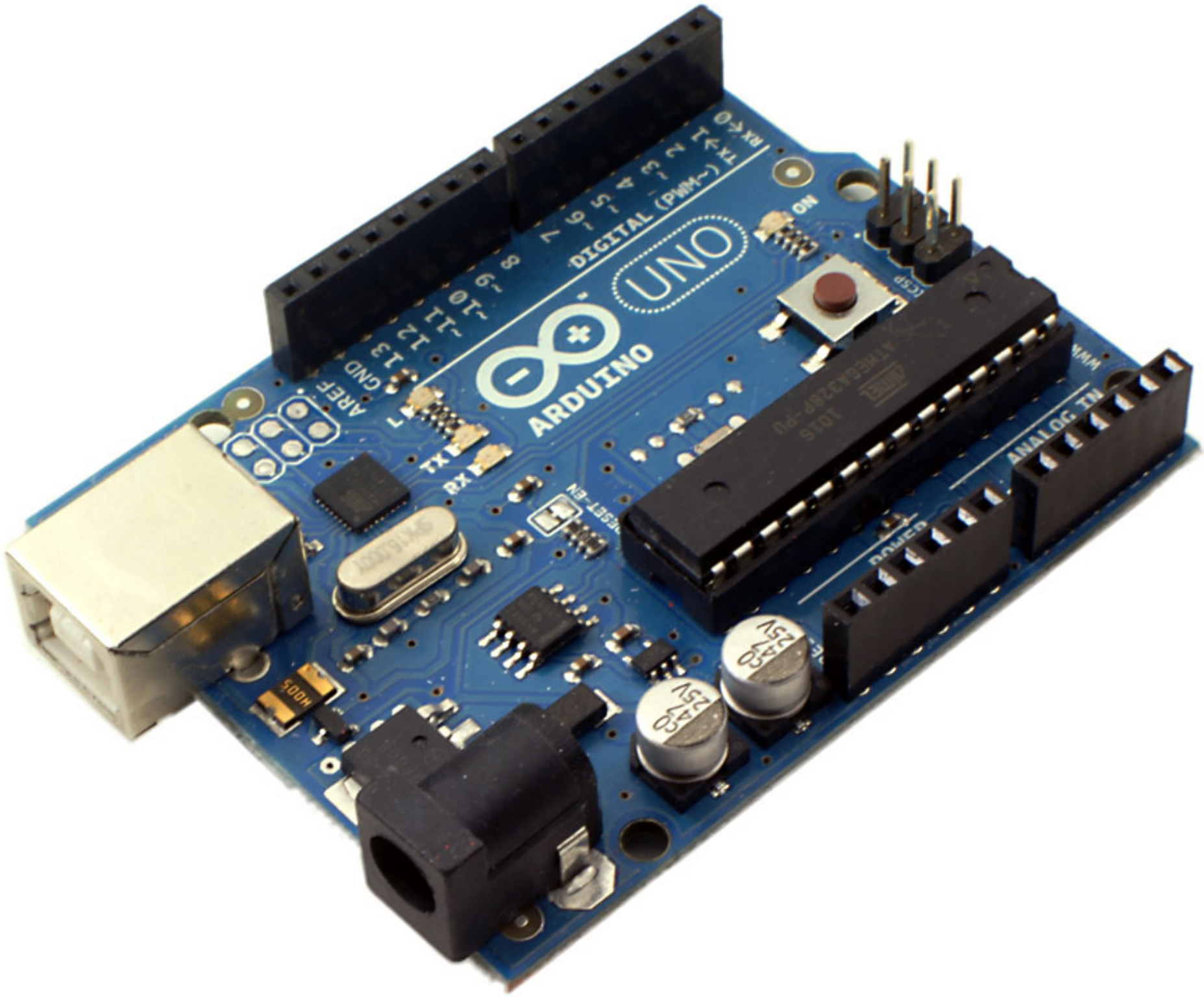
embedded system: a computer system with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints


FOX
LNK
10M
PWR
OK
ultra II
2.0 GB


nest
75
IN 20 MIN
72

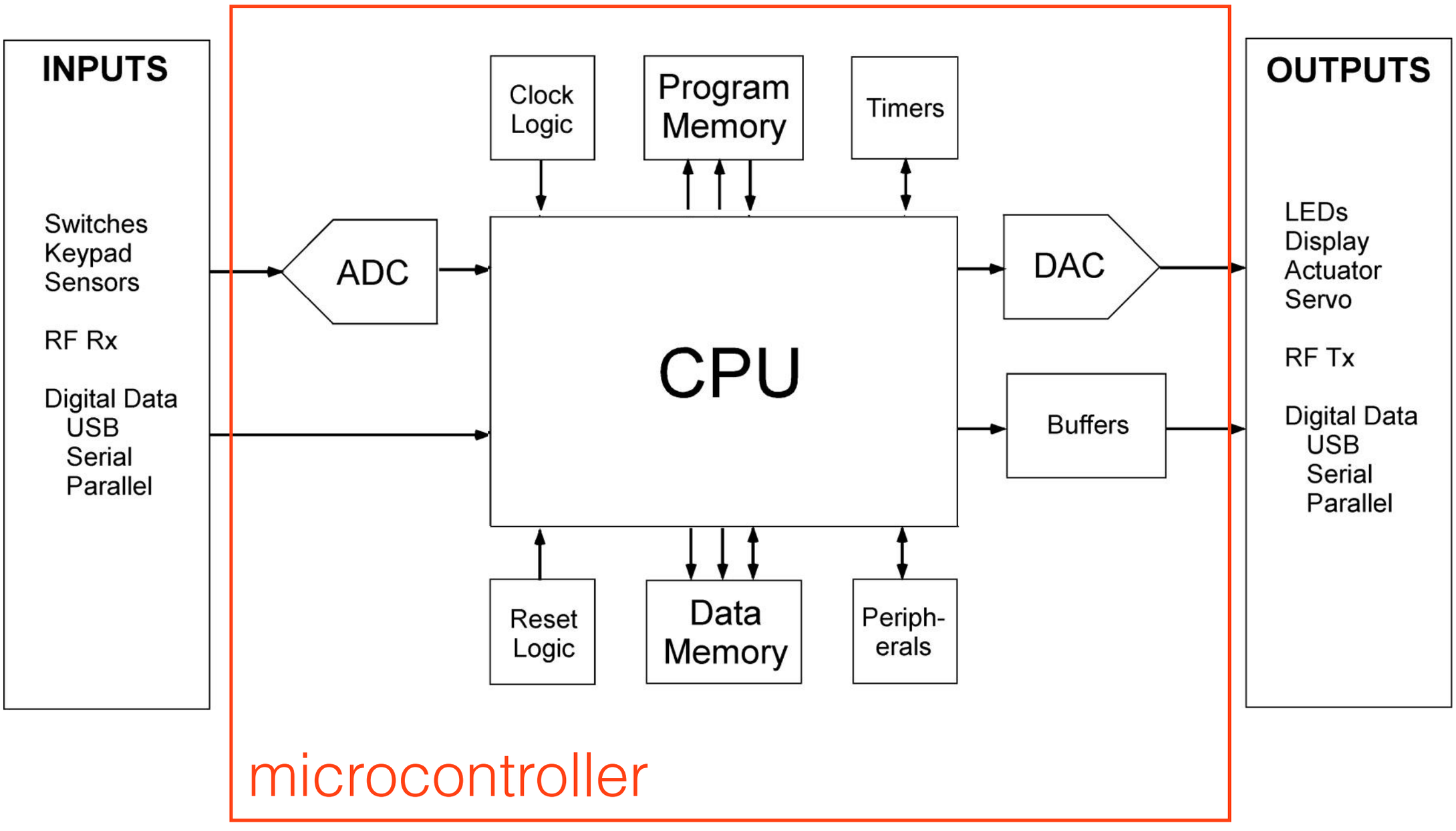

nest
75
IN 20 MIN
72


WPS
BELKIN

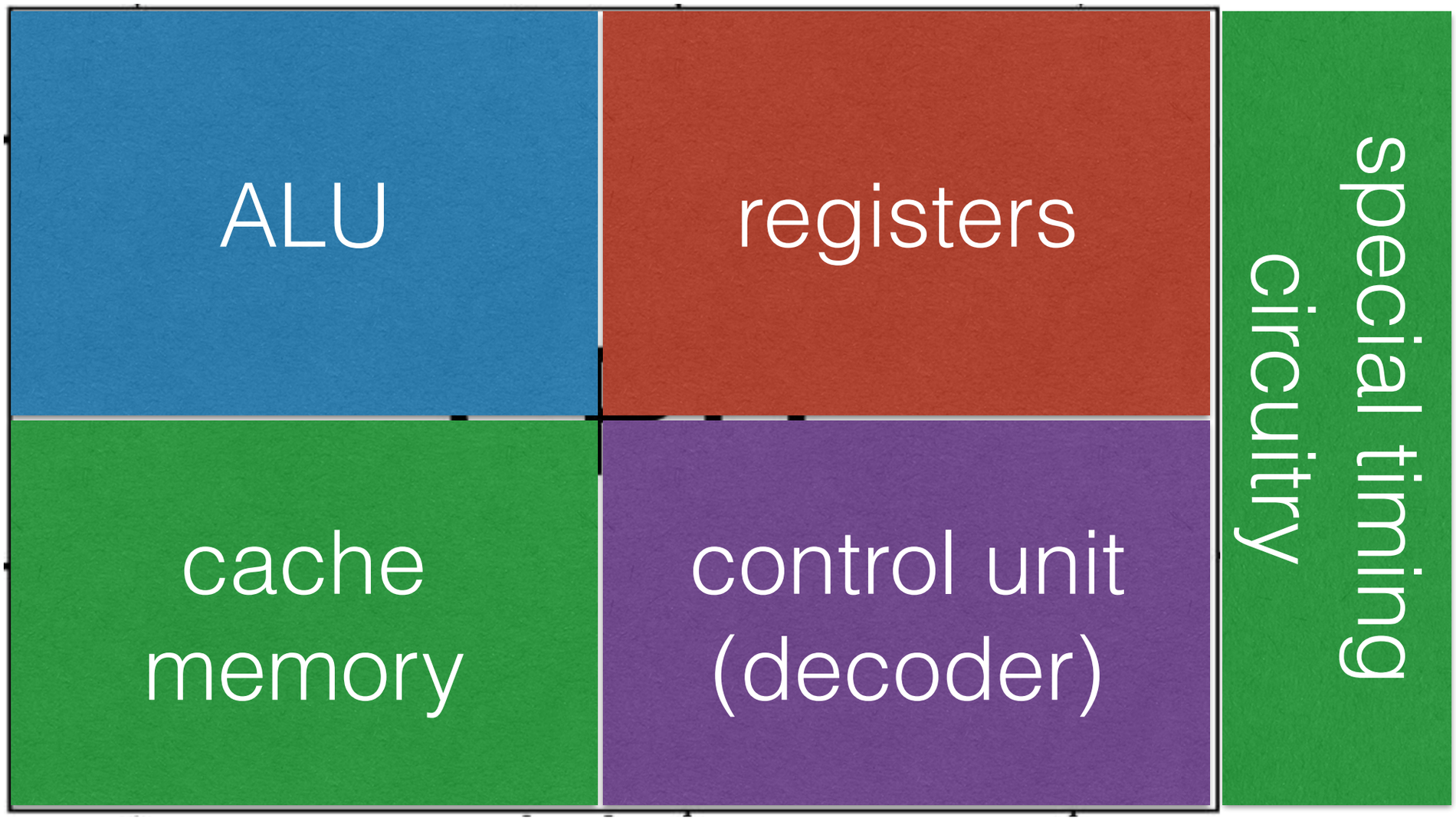

DIGITAL (PWM~)
UNO
ARDUINO
ON
POWER
ANALOG IN


No SIM
9:11 PM
Messages
Tuesday
24
Calendar
Photos
Camera
Weather
Clock
Maps
Videos
Notes
Reminders
Stocks
142
Game Center
Newsstand
iTunes Store
App Store
Passbook
Compass
Settings
Phone
368
Mail
Safari
Music
iMore

embedded systems

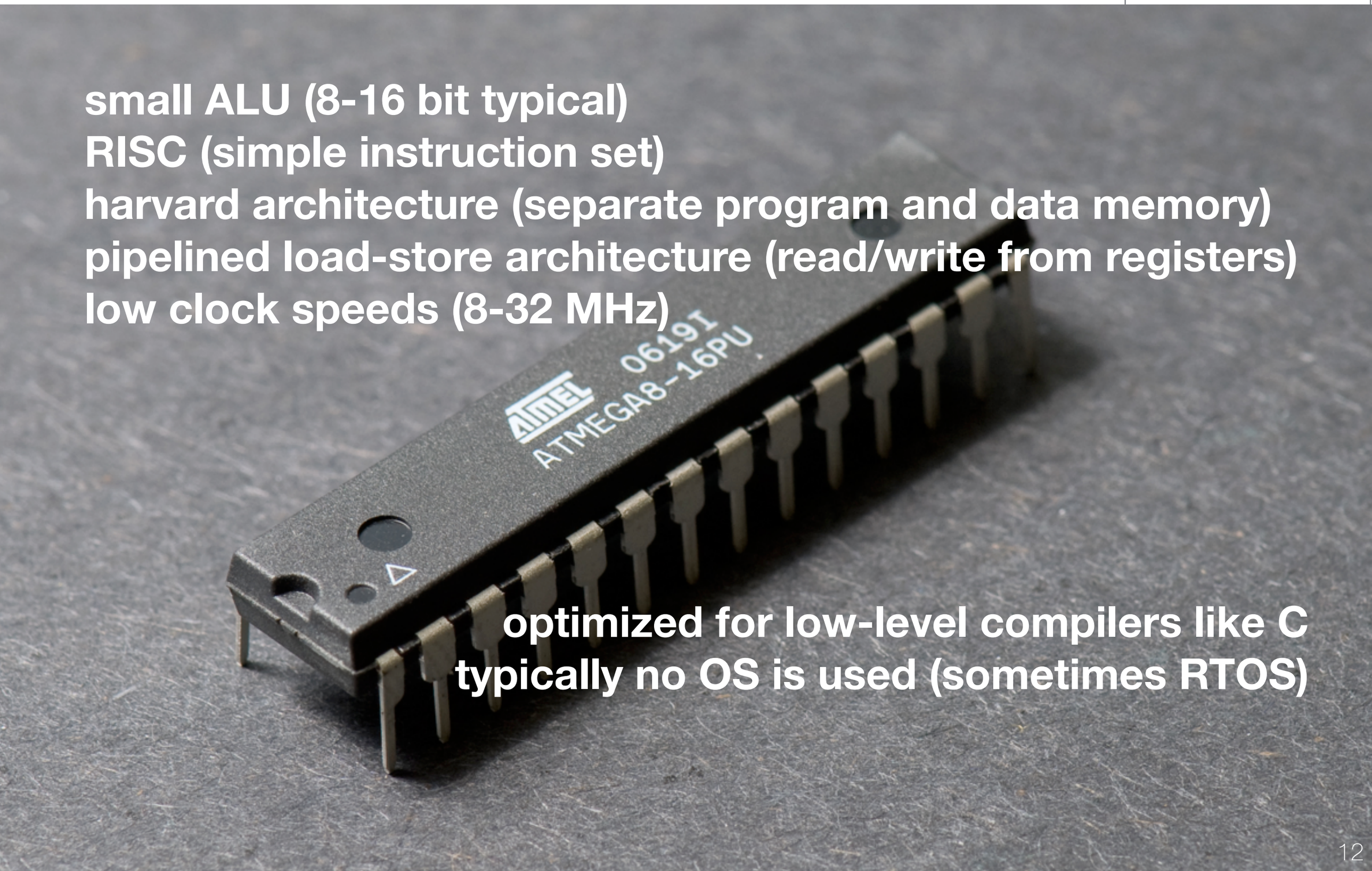


microcontroller



MCU

atmega CPU



small ALU (8-16 bit typical)
RISC (simple instruction set)
harvard architecture (separate program and data memory)
pipelined load-store architecture (read/write from registers)
low clock speeds (8-32 MHz)

optimized for low-level compilers like C
typically no OS is used (sometimes RTOS)

microcontroller

ucontroller?

- (UNO) Atmega328
  - 16MHz
  - 16 bit ALU
  - 2KB SRAM
  - 32KB flash
  - 1KB EEPROM
  - 14 GPIO (6 PWM)
  - 6 analog inputs
  - hardware UART
  - hardware SPI
- ARM Cortex-M3
  - 120MHz
  - 32 bit ALU
  - 128KB SRAM
  - 1MB flash
  - Emul. EEPROM
  - 18 GPIO (13 PWM)
  - 24 analog inputs
  - 4x hardware UART
  - 3x hardware SPI
  - 15 serial comm ports+USB

excellent tutorials:
http://www.adafruit.com/category/17

Arduino

arduino sketch

- written in c, simplifies board access
- use arduino functions

Blink

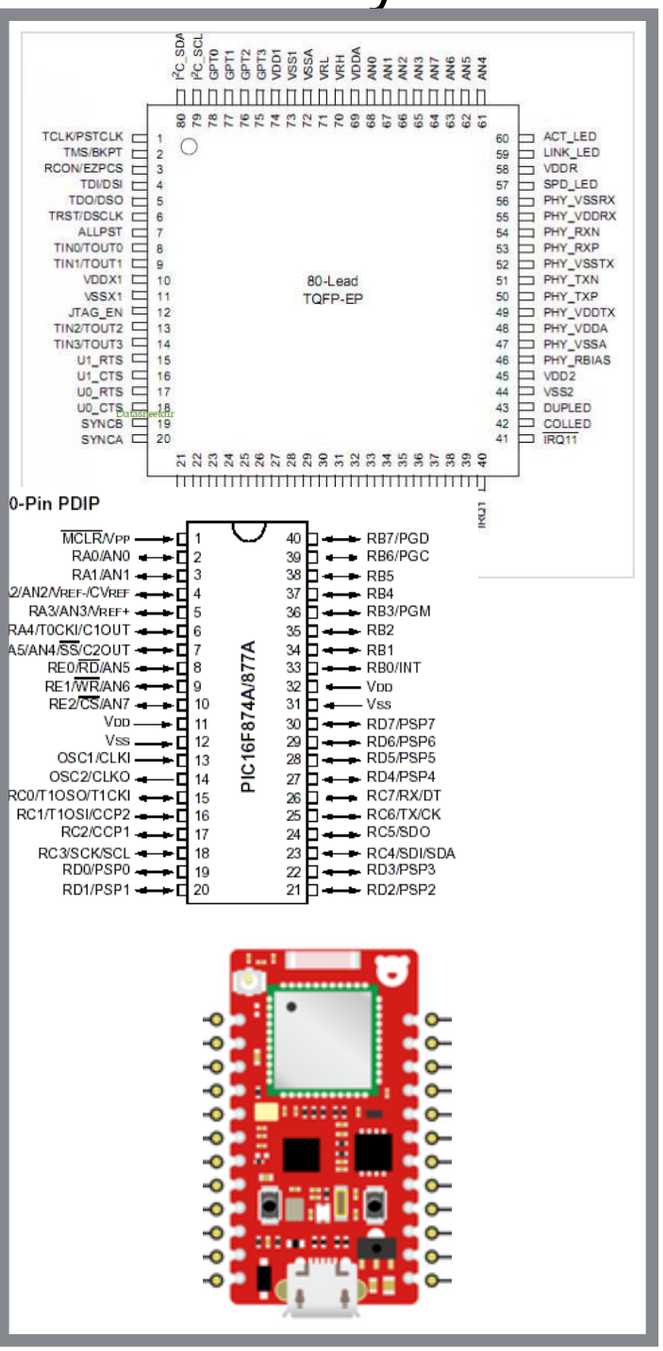
```
/*
  Blink
  Turns on an LED on for one second, then off for one second, repeatedly.

  This example code is in the public domain.
 */

// Pin 13 has an LED connected on most Arduino boards.
// give it a name:
int led = 13;

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

// 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
  digitalWrite(led, LOW);    // turn the LED off by making the voltage LOW
  delay(1000);               // wait for a second
}
```

called on startup or reset

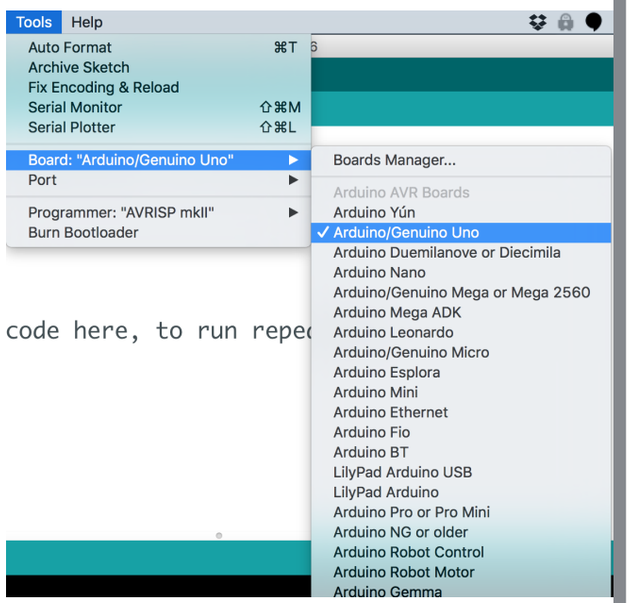
run forever

arduino sketch

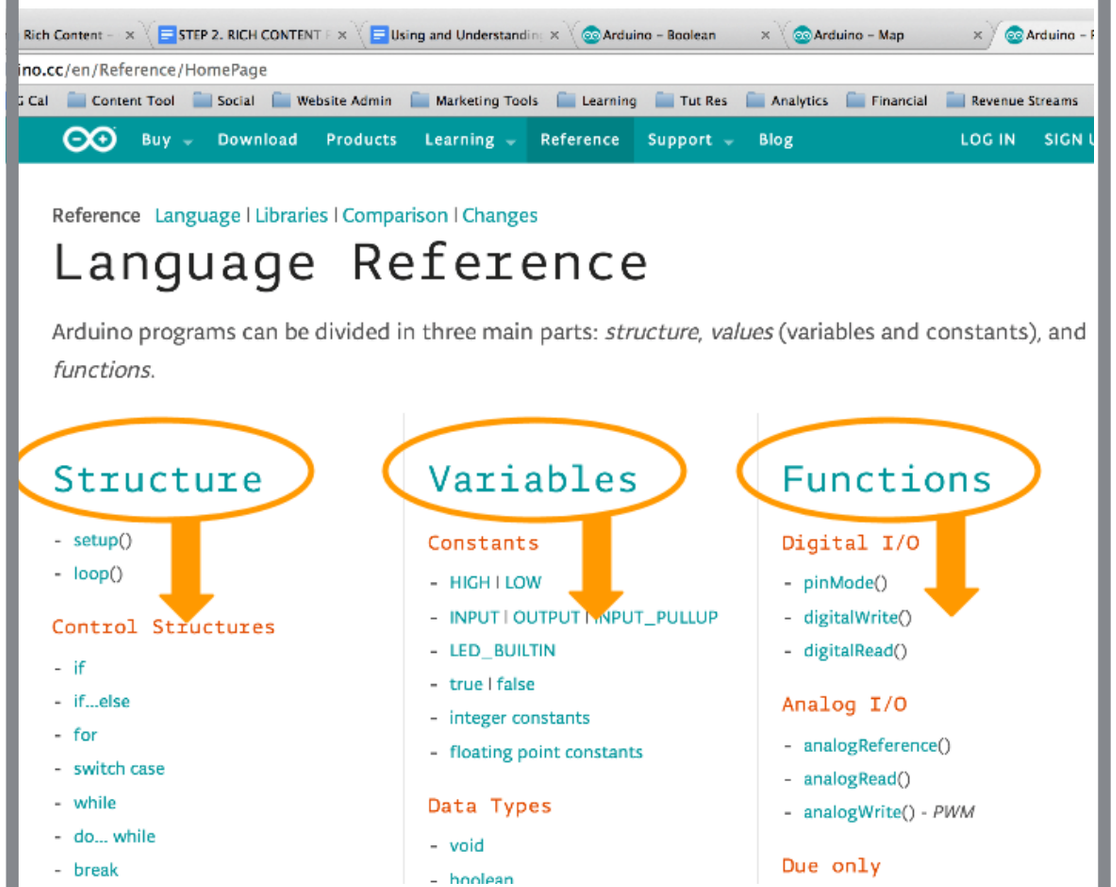
- arduino is easy because it maps common functions for many different board layouts



boards manager



common functions, written for you



arduino serial comm

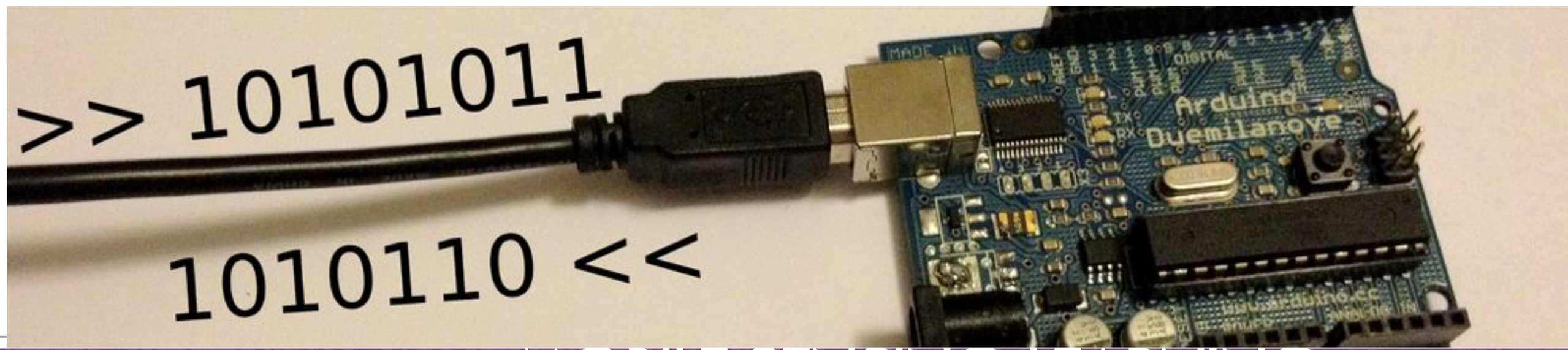
- really, really simple (UART serial)
- the Rx and Tx are on pins 0 and 1

```
Serial.begin(9600);


float resistance;

Serial.print(resistance);
Serial.print(" kohms\n");
```

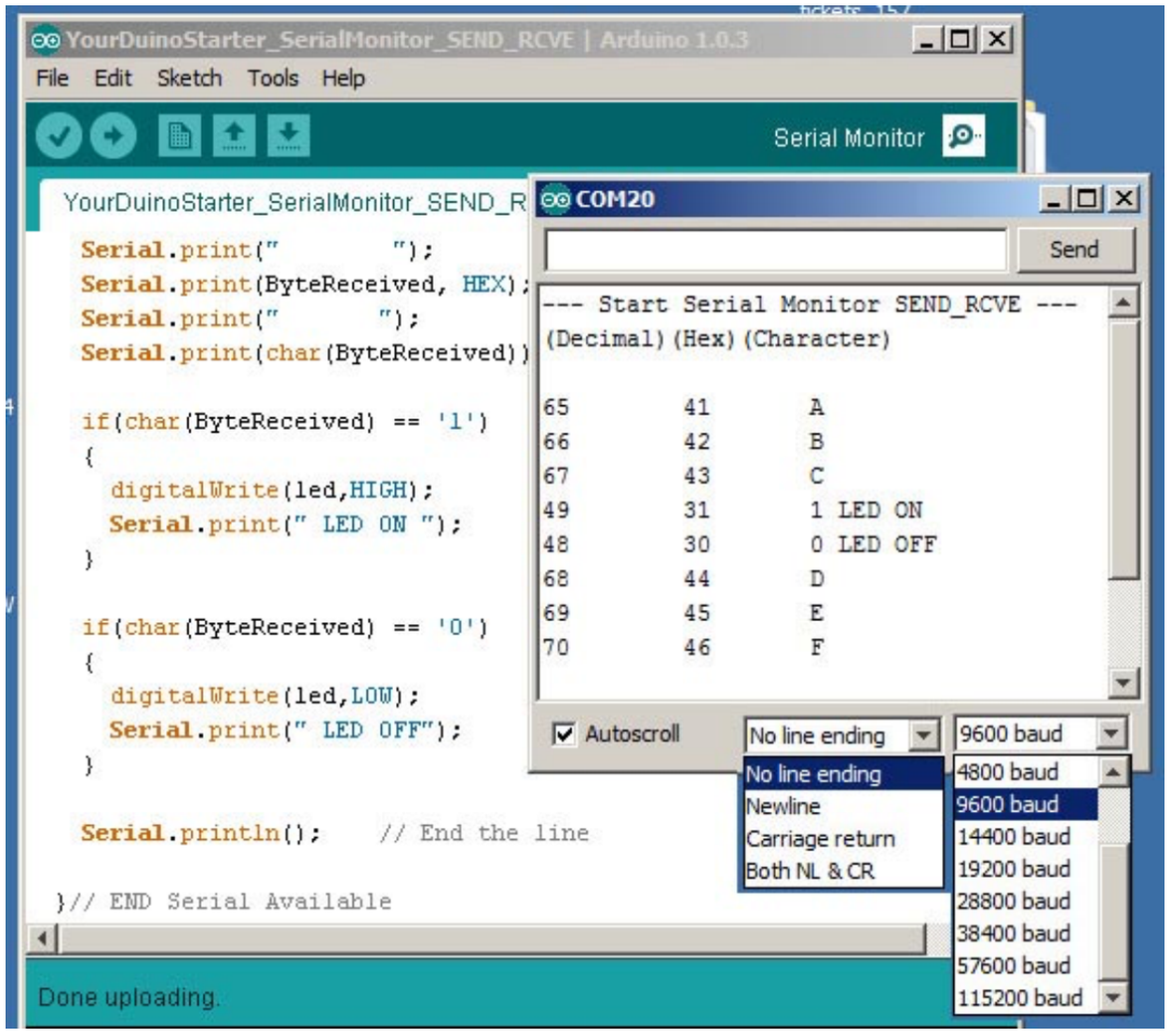
baud rate
9600 pulses/sec

send a float!

send a string!



arduino serial comm



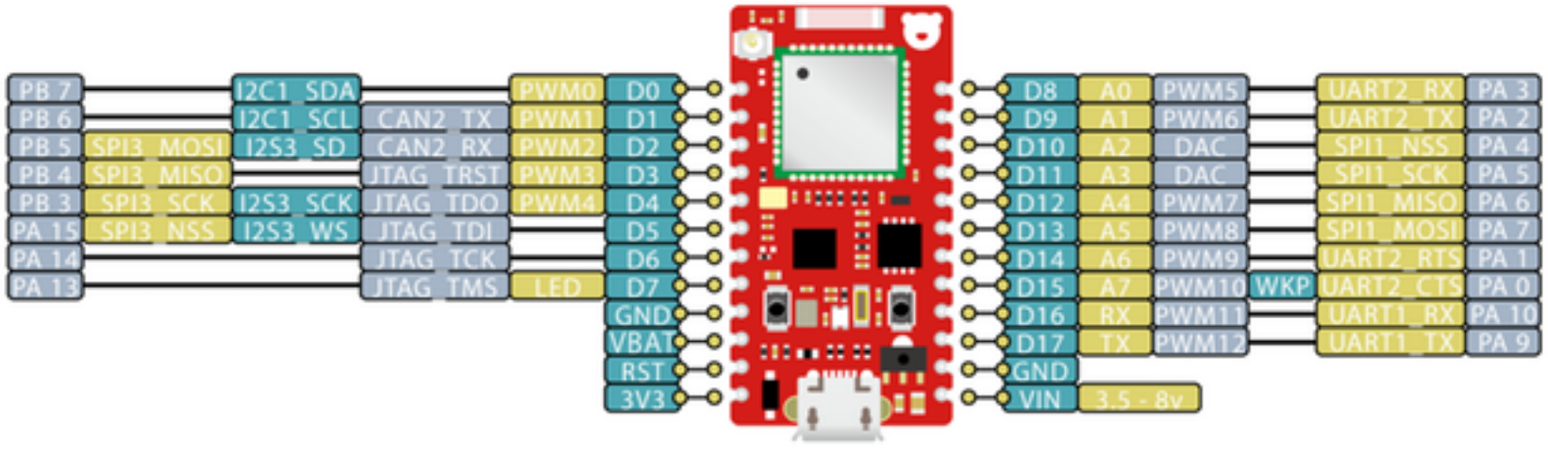

```
// print it out as ASCII
Serial.print(78);          gives "78"
Serial.print(1.23456);     gives "1.23"
Serial.print("N");          gives "N"
```

```
void loop(){
  Serial.write(45); // send a byte with
                    //the value 45

  int bytesSent = Serial.write("hello");
      //send the bytes in the
      //string "hello" and return
      //the length of the byte array.
}
```

http://arduino-info.wikispaces.com/YourDuino-Serial-Monitor

serial demo

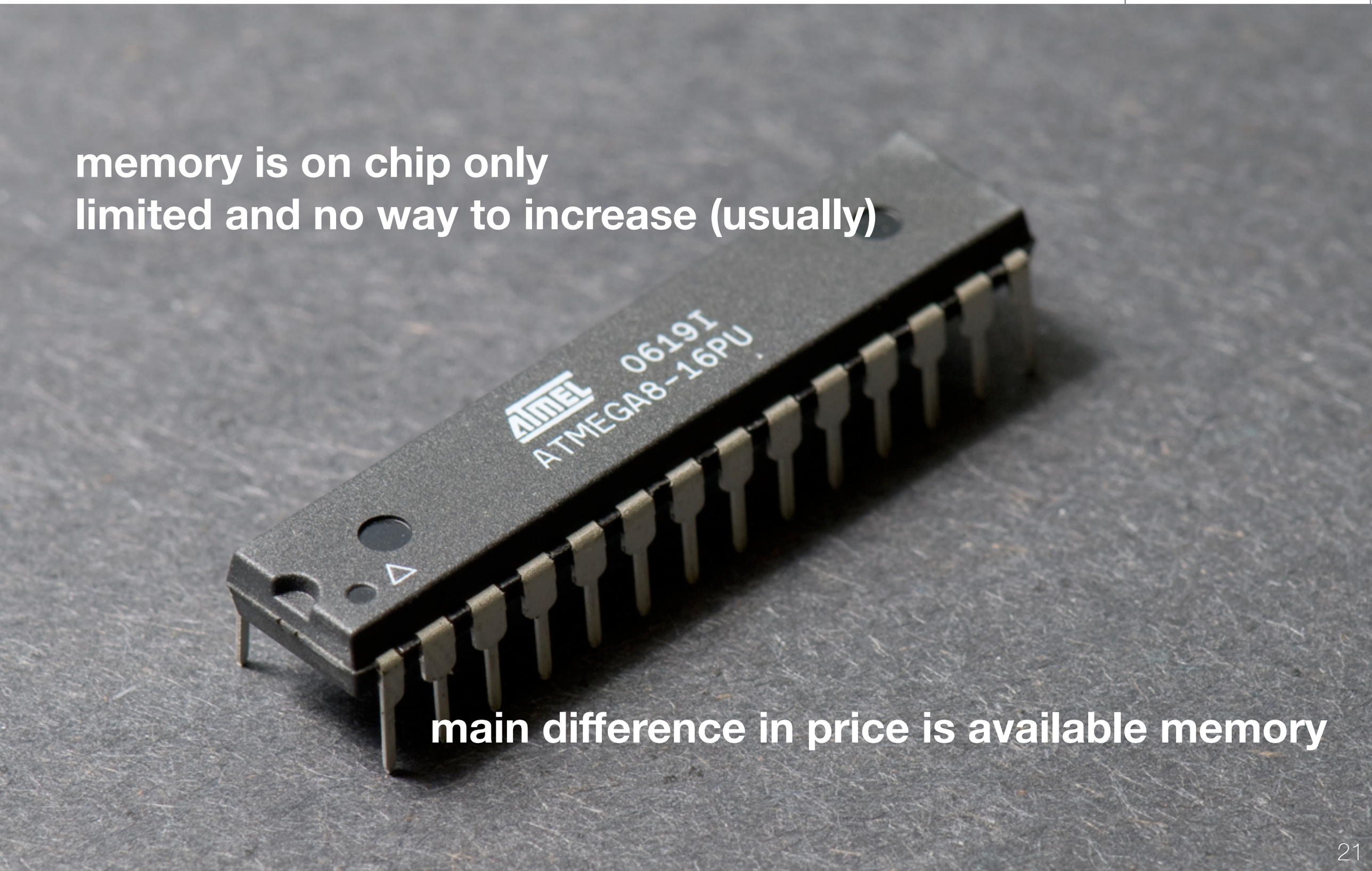
- what to do?



Arduino

Memory Management

ARM memory

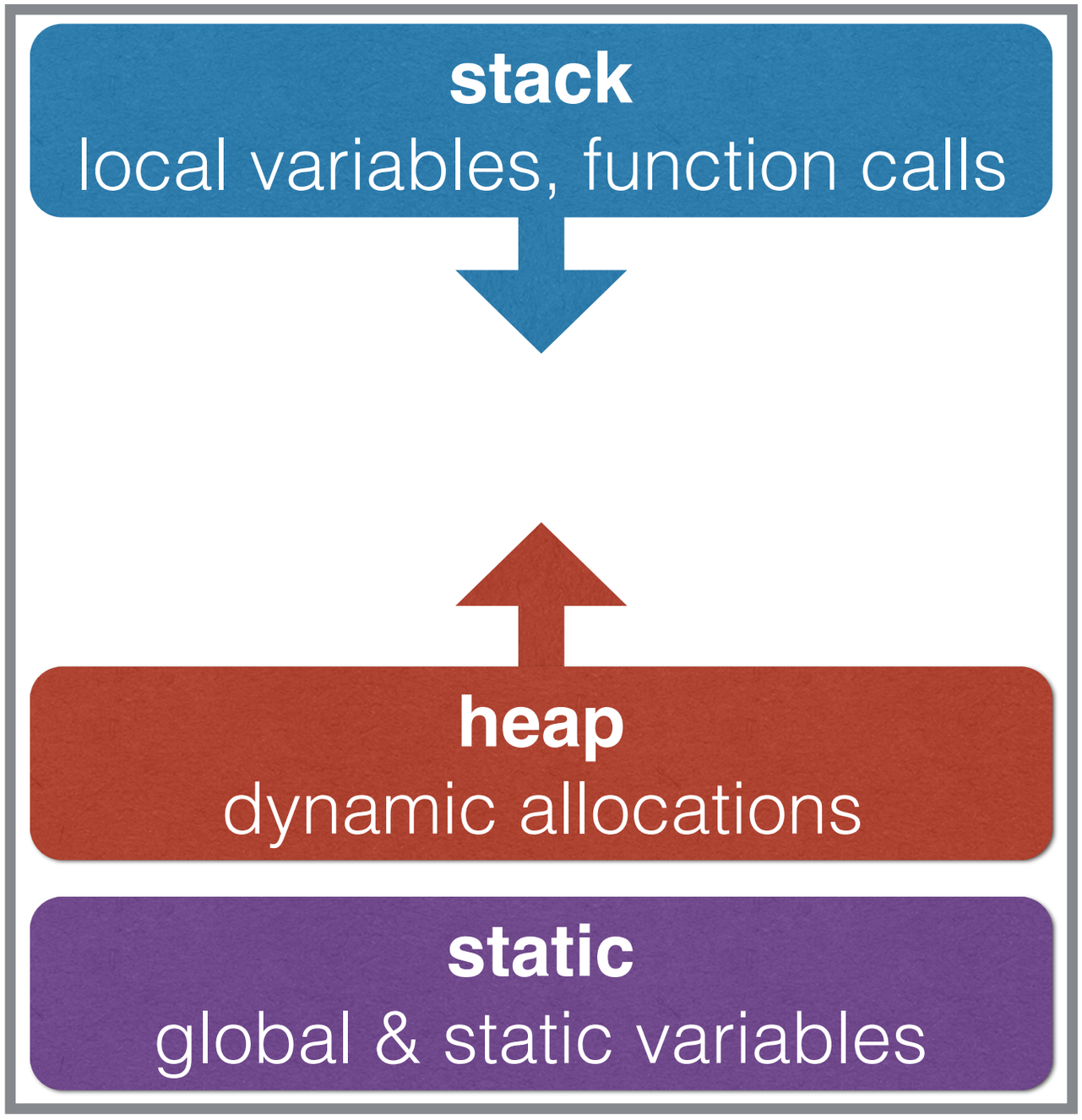

memory is on chip only
limited and no way to increase (usually)
ATMEL
0619I
ATMEGA8-16PU
main difference in price is available memory

ARM memory

- three memory spaces
- volatile
  - SRAM
- non-volatile
  - EEPROM
- flash (program memory)

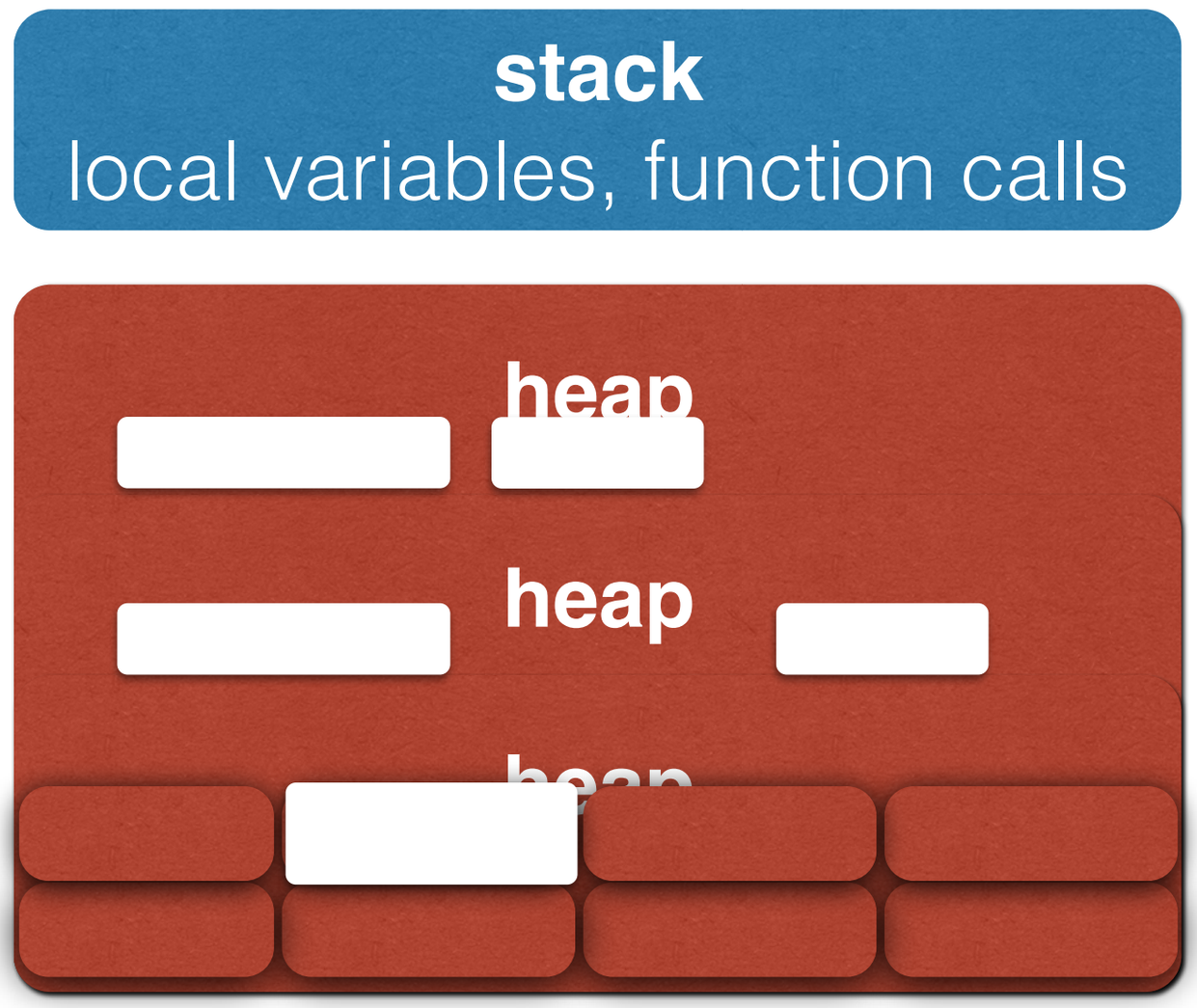
ARM SRAM

- SRAM divided into three areas



its easy to do

- fragmented memory in the heap
  - its not an OS, garbage collection is **VERY primitive**



ARM SRAM

- guidelines to avoid fragmentation
  - do not use dynamic memory if it is not necessary
    - `malloc, calloc, realloc`
  - prefer local variables over global
  - place interim calculations in a function
    - after function call, local variables in stack are released completely and immediately

ARM SRAM

- guidelines to avoid fragmentation
  - do
    -
  - pre
  - pla
  -

```
int tmpSensorData[512];
int *moreSensorData;

// the setup routine runs once when you press reset:
void setup() {
      moreSensorData = (int*)malloc(512);
}

// the loop routine runs over and over again forever:
void loop() {
  int f = analogRead(1);

}
```

ARM non-volatile

reference slide

- EEPROM
  - electronically erasable programmable memory
  - stays in memory when power turns off
  - good for saving a “state”
  - infinite number of reads
  - ~100,000 writes / erases
  - one write takes ~3.3ms, per byte

EEPROM reference

reference slide

eeprom_write §

```
 * turned off and may be retrieved later by another sketch.
 */

#include <EEPROM.h>
int addr = 0;
void setup()
{
}
void loop()
{
  // value from 0 to 255.
  int val = analogRead(0) / 4;

  // write the value to the appropriate byte of the EEPROM.
  EEPROM.write(addr, val);

  // advance to the next address.  there are 512 bytes in
  // the EEPROM, so go back to 0 when we hit 512.
  addr = addr + 1;
  if (addr == 512)
    addr = 0;

  delay(100);

  byte value = EEPROM.read(addr);
}
```

write a byte to "address", 0-511

read a byte from "address"

ARM non-volatile

- program memory (flash)
  - where your code instructions are saved
  - flash memory
  - great for variables that do not change
  - like strings!
  - not stored in the SRAM until copied over

PROGMEM reference

reference slide

```
#include <avr/pgmspace.h>


  // save some unsigned ints
  PROGMEM  prog_uint16_t charSet[]  = { 8400, 77, 42};

  // save some chars
  PROGMEM prog_uchar signMessage[]  = {"PROGRAM MEMORY STRING"};

  unsigned int displayInt;
  int k;    // counter variable
  char myChar;

  // read back a 2-byte int
   displayInt = pgm_read_word_near(charSet + k)

  // read back a char
  myChar =  pgm_read_byte_near(signMessage + k);

  for (int i = 0; i < 6; i++)
  {
    strcpy_P(buffer, (char*)pgm_read_word(&(string_table[i]))); // copy
    Serial.println( buffer );
    delay( 500 );
  }
```

http://arduino.cc/en/Reference/PROGMEM#.UyKZldztJg0

Arduino

Clock Management

ARM osc & reset

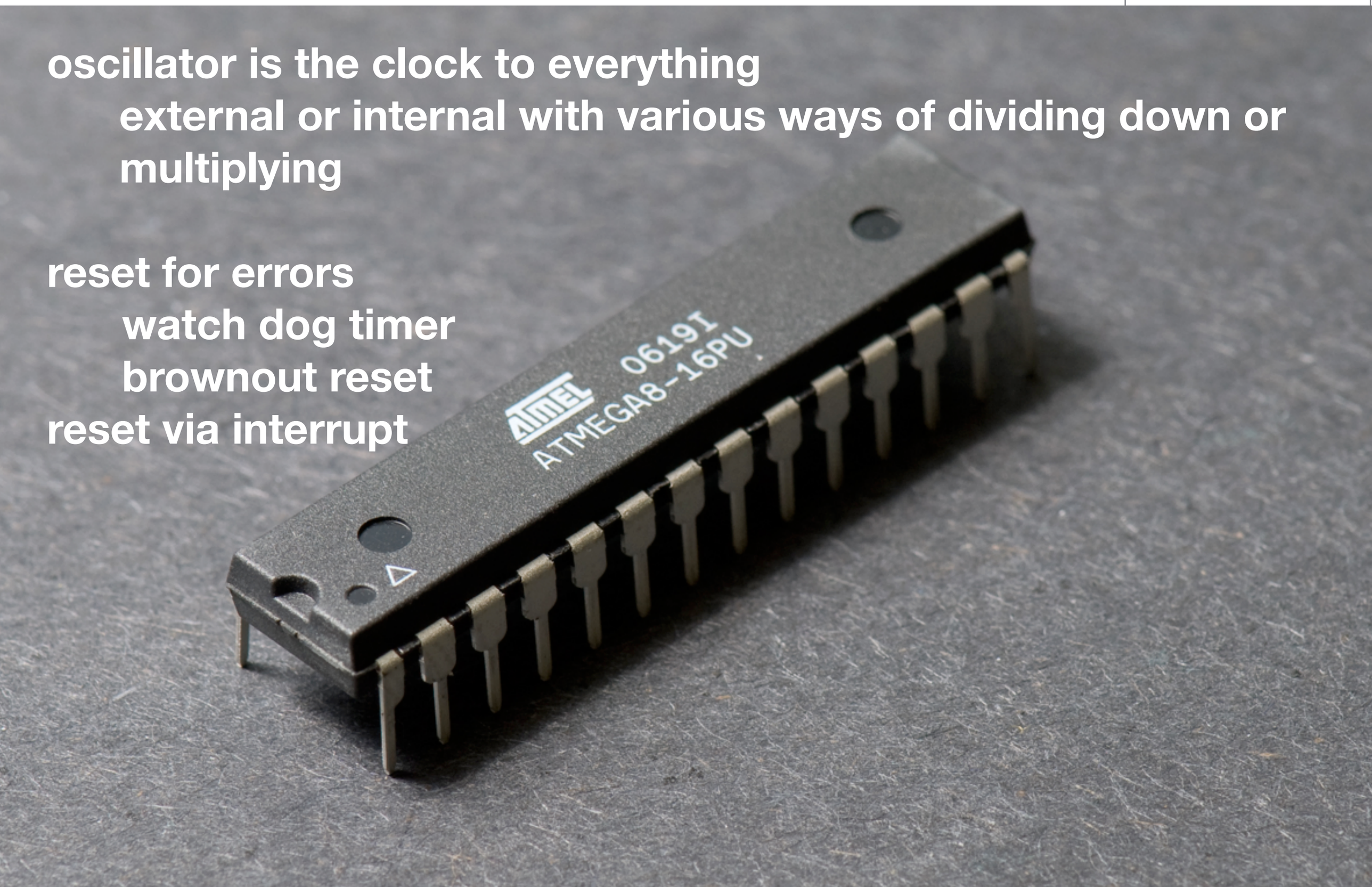
oscillator is the clock to everything

- **external or internal with various ways of dividing down or multiplying**

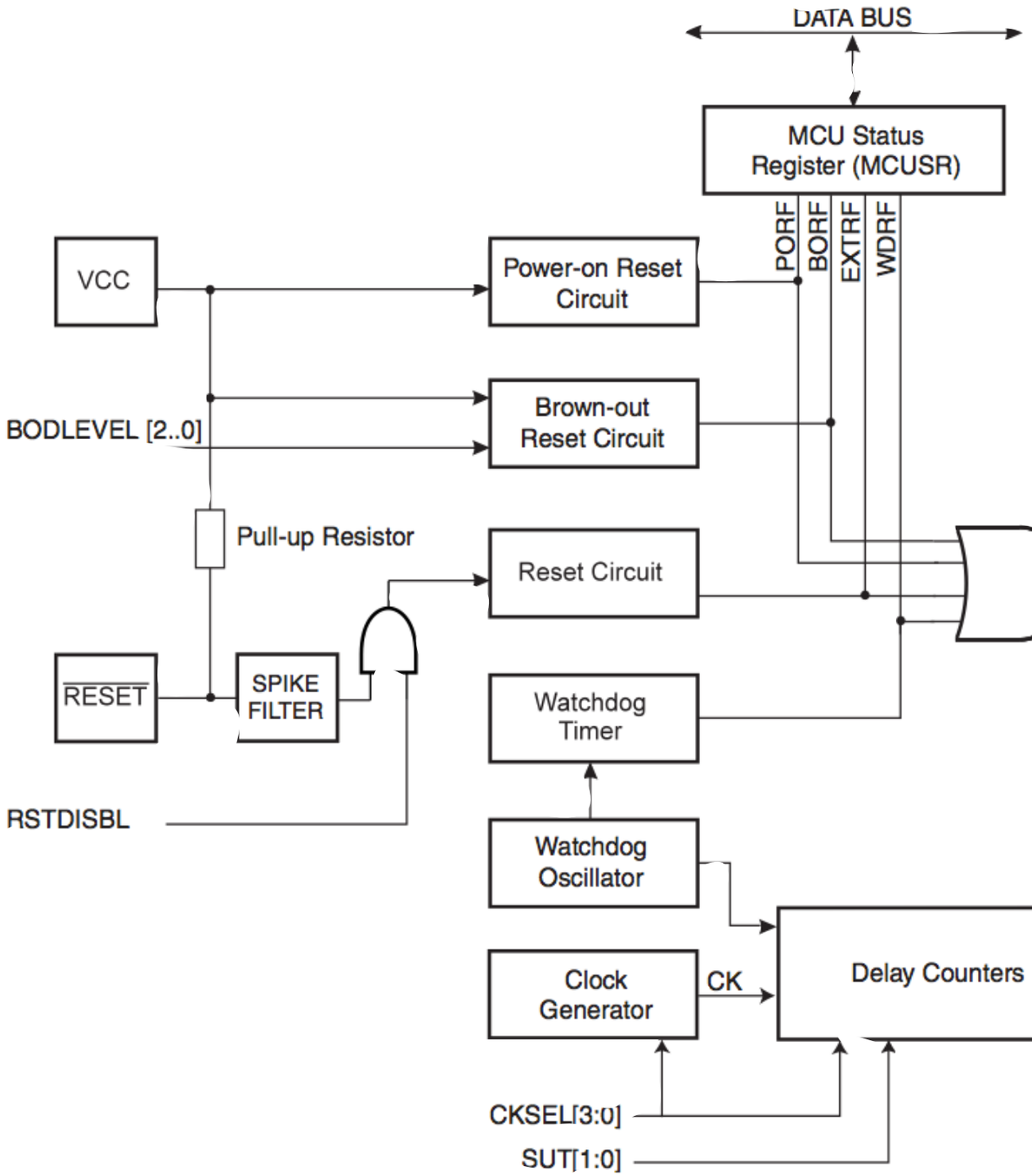
reset for errors

- **watch dog timer**
- **brownout reset**

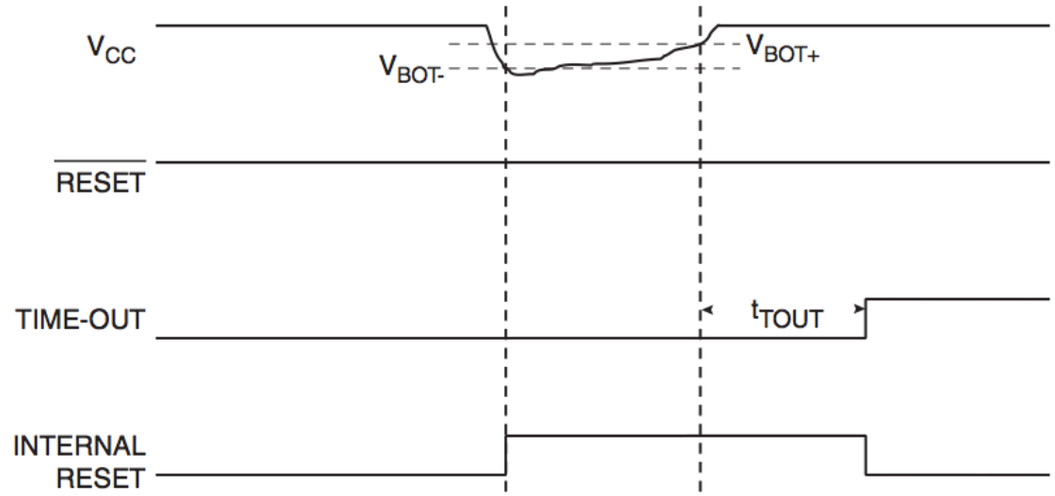
reset via interrupt

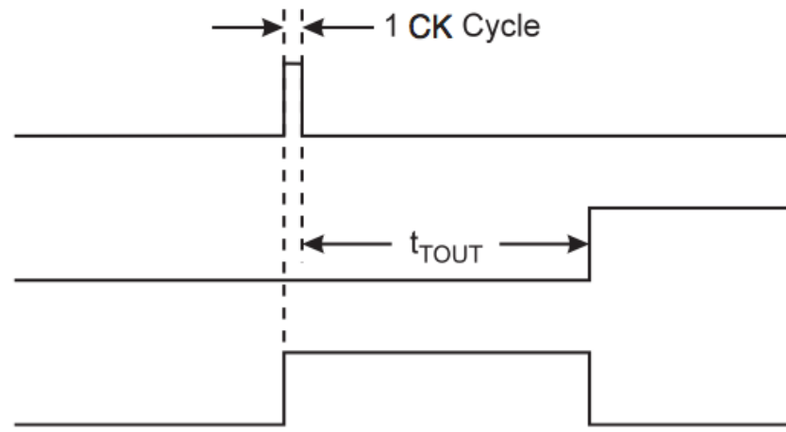


reset



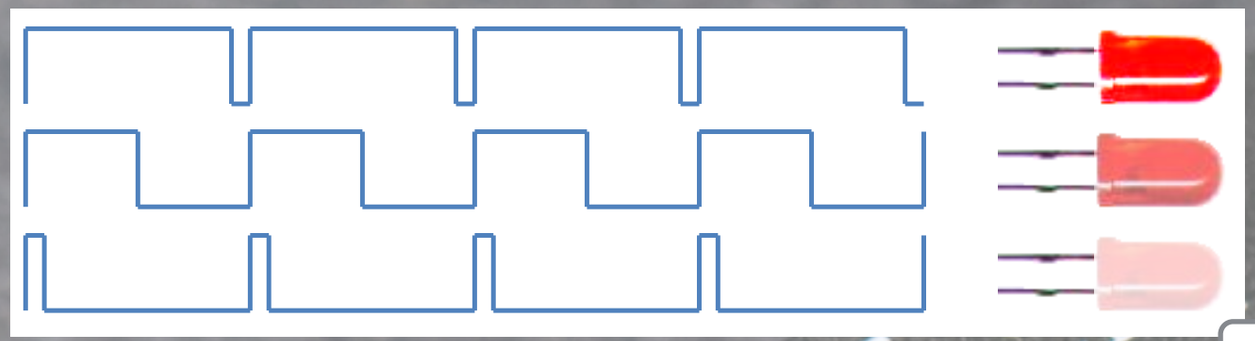
Brown-out Reset During Operation





timers

WDT, real-time clock,
pulse width modulation: square wave output



bright

dim

controls duty cycle

clock

register value

comparator

output enable

hardware divider

counter

controls frequency of wave

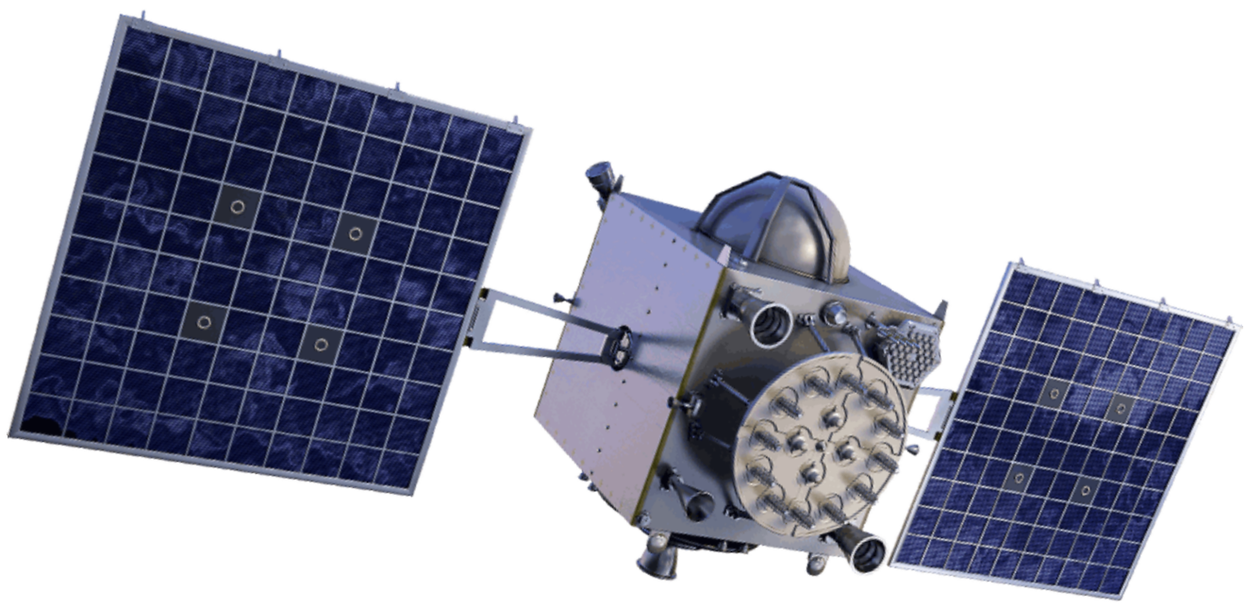
watch dog timer

- enable or disable

```
if(USE_WDT==1)
  wdt_enable(WDTO_8S); // watch dog set at 8 seconds, don't go much lower
else
  wdt_disable();
```

- must set back to zero periodically or reset occurs

```
void SW_ISR() {
  // if you do not interrupt the WDT, then the board will reset
  wdt_reset();
}
```

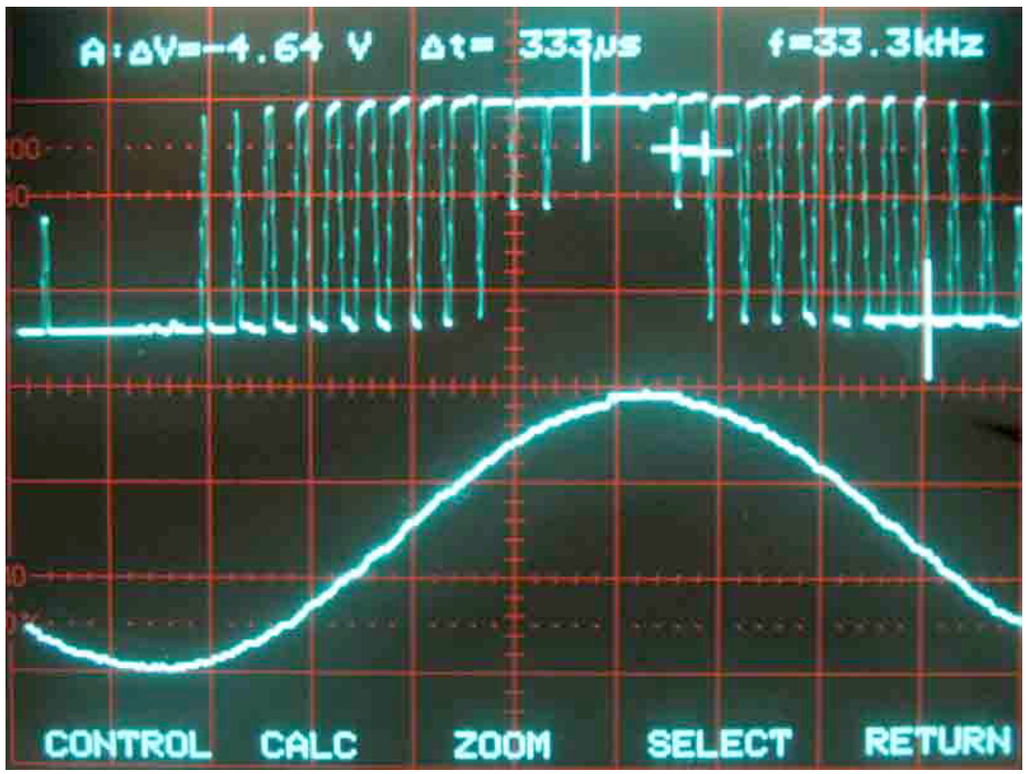


Arduino

PWM

PWM

- servo control and motor control
  - width of pulse matters
- digital to analog conversion
  - smooth a square wave
- LED brightness control
  - “duty cycle” matters




```
ledBrightness += delta;     // change brightness setting
analogWrite(LED_PWM, ledBrightness); // set new brightness
```

pin to write to
(must be PWM)

value to write (0-255)

PWM

change in duty cycle

15% 35% 75% 95% 100%

10% 25% 50% 85% 99%

PWM

after low pass filter

```
/* mainloop - runs forever */
void loop() {
  for(int analogValue = 0; analogValue<255; analogValue++){
      analogWrite(1,analogValue);
      delay(10);
  }
  for(int analogValue = 254; analogValue>0; analogValue--){
      analogWrite(1,analogValue);
      delay(10);
  }
}
```

what would this do?

normal PWM: constant duty cycle

this example: time varying duty cycle

PWM: the problem

```
ledBrightness += delta;    // change brightness setting
analogWrite(LED_PWM, ledBrightness); // set new brightness
```

- not much control over PWM signal…
- solution 1: manually set registers based on data sheet
- solution 2: use servo class for PWM control

PWM with registers

reference slide

- registers control most peripherals on a uC

```
pinMode(3, OUTPUT);
pinMode(11, OUTPUT);
TCCR2A = _BV(COM2A1) | _BV(COM2B1) | _BV(WGM21) | _BV(WGM20);
TCCR2B = _BV(CS22);
OCR2A = 200;
OCR2B = 120;
```

in this register

set bit with this name

TCCR2A – Timer/Counter Control Register A

Bit	7	6	5	4	3	2	1	0	
(0xB0)	COM2A1	COM2A0	COM2B1	COM2B0	–	–	WGM21	WGM20	TCCR2A
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

TCCR2B – Timer/Counter Control Register B

Bit	7	6	5	4	3	2	1	0	
(0xB1)	FOC2A	FOC2B	–	–	WGM22	CS22	CS21	CS20	TCCR2B
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

opt 1: PWM with registers

reference slide

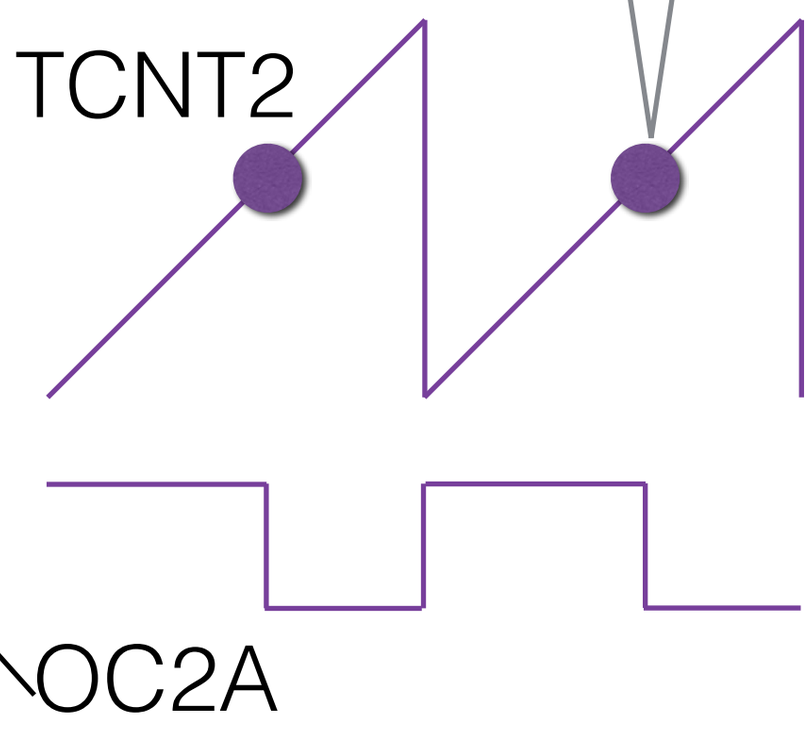
- registers control most peripherals on a uC

```
pinMode(3, OUTPUT);
pinMode(11, OUTPUT);
TCCR2A = _BV(COM2A1) | _BV(COM2B1) | _BV(WGM21) | _BV(WGM20);
TCCR2B = _BV(CS22);
OCR2A = 200;
OCR2B = 120;
```

compare value

Table 18-4. Compare Output Mode, Phase Correct PWM Mode(1)

COM2A1	COM2A0	Description
0	1	WGM22 = 0: Normal Port Operation, OC2A Disconnected. WGM22 = 1: Toggle OC2A on Compare Match.
1	0	Clear OC2A on Compare Match when up-counting. Set OC2A on Compare Match when down-counting.
1	1	Set OC2A on Compare Match when up-counting. Clear OC2A on Compare Match when down-counting.



opt 1: PWM with registers

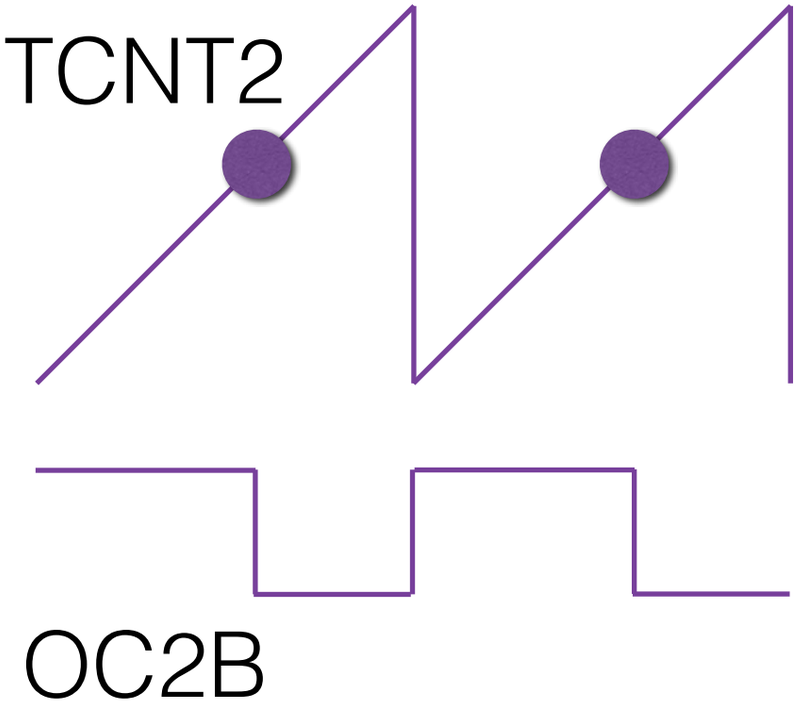
reference slide

- registers control most peripherals on a uC

```
pinMode(3, OUTPUT);
pinMode(11, OUTPUT);
TCCR2A = _BV(COM2A1)  _BV(COM2B1) | _BV(WGM21) | _BV(WGM20);
TCCR2B = _BV(CS22);
OCR2A = 200;
OCR2B = 120;
```

Table 18-6. Compare Output Mode, Fast PWM Mode(1)

COM2B1	COM2B0	Description
0	0	Normal port operation, OC2B disconnected.
0	1	Reserved
1	0	Clear OC2B on Compare Match, set OC2B at BOTTOM, (non-inverting mode).
1	1	Set OC2B on Compare Match, clear OC2B at BOTTOM, (inverting mode).



opt 1: PWM with registers

reference slide

- registers control most peripherals on a uC

```
pinMode(3, OUTPUT);
pinMode(11, OUTPUT);
TCCR2A = _BV(COM2A1) | _BV(COM2B1) | _BV(WGM21) | _BV(WGM20);
TCCR2B = _BV(CS22);
OCR2A = 200;
OCR2B = 120;
```

Table 18-8. Waveform Generation Mode Bit Description

Mode	WGM22	WGM21	WGM20	Timer/Counter Mode of Operation	TOP	Update of OCRx at	TOV Flag Set on(1)(2)
0	0	0	0	Normal	0xFF	Immediate	MAX
1	0	0	1	PWM, Phase Correct	0xFF	TOP	BOTTOM
2	0	1	0	CTC	OCRA	Immediate	MAX
3	0	1	1	Fast PWM	0xFF	BOTTOM	MAX
4	1	0	0	Reserved	–	–	–
5	1	0	1	PWM, Phase Correct	OCRA	TOP	BOTTOM
6	1	1	0	Reserved	–	–	–
7	1	1	1	Fast PWM	OCRA	BOTTOM	TOP

opt 1: PWM with registers

reference slide

- registers control most peripherals on a uC

```
pinMode(3, OUTPUT);
pinMode(11, OUTPUT);
TCCR2A = _BV(COM2A1) | _BV(COM2B1) | _BV(WGM21) | _BV(WGM20);
TCCR2B = _BV(CS22);
OCR2A = 200;
OCR2B = 120;
```

Table 18-9. Clock Select Bit Description

CS22	CS21	CS20	Description
0	0	0	No clock source (Timer/Counter stopped).
0	0	1	clk_{T2S}/(No prescaling)
0	1	0	clk_{T2S}/8 (From prescaler)
0	1	1	clk_{T2S}/32 (From prescaler)
1	0	0	clk_{T2S}/64 (From prescaler)

two outputs at 16MHz / 64 / 256 = 976.5625Hz

opt 1: PWM with registers

reference slide

- registers control most peripherals on a uC

```
pinMode(3, OUTPUT);
pinMode(11, OUTPUT);
TCCR2A = _BV(COM2A1) | _BV(COM2B1) | _BV(WGM21) | _BV(WGM20);
TCCR2B = _BV(CS22);
OCR2A = 200;
OCR2B = 120;
```

OCR2A – Output Compare Register A

Bit	7	6	5	4	3	2	1	0	
(0xB3)	OCR2A[7:0]								OCR2A
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

The Output Compare Register A contains an 8-bit value that is continuously compared with the counter value (TCNT2). A match can be used to generate an Output Compare interrupt, or to generate a waveform output on the OC2A pin.

OCR2B – Output Compare Register B

Bit	7	6	5	4	3	2	1	0	
(0xB4)	OCR2B[7:0]								OCR2B
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

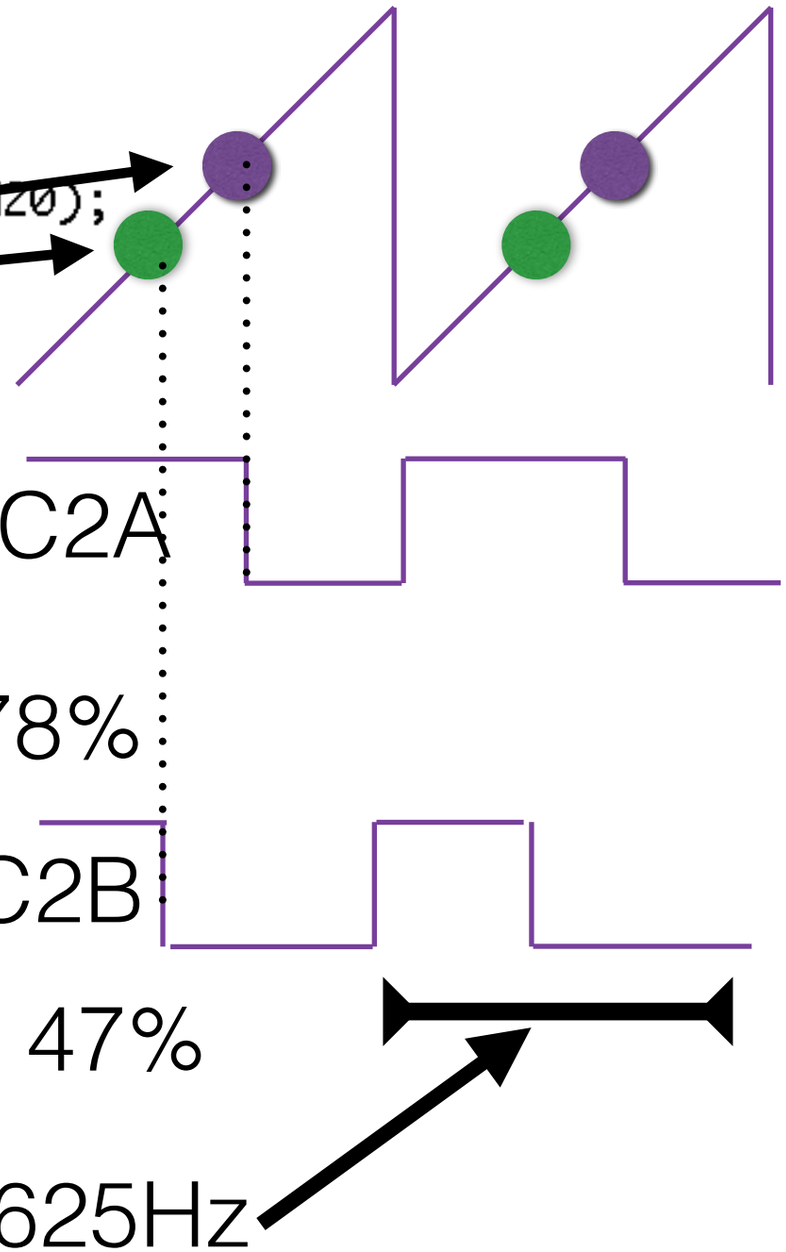
The Output Compare Register B contains an 8-bit value that is continuously compared with the counter value (TCNT2). A match can be used to generate an Output Compare interrupt, or to generate a waveform output on the OC2B pin.

opt 1: PWM with registers

reference slide

- registers control most peripherals on a uC

```
pinMode(3, OUTPUT);
pinMode(11, OUTPUT);
TCCR2A = _BV(COM2A1) | _BV(COM2B1) | _BV(WGM21) | _BV(WGM20);
TCCR2B = _BV(CS22);
OCR2A = 200;
OCR2B = 120;
```



duty cycle of OC2A (pin 3) = 200/256 = 78%

clock frequency

divider

counter value

duty cycle of OC2B (pin 11) = 120/256 = 47%

two outputs at 16MHz / 64 / 256 = 976.5625Hz

opt2: arduino servo class

- makes it really easy for 1-2ms pulsed servos
- `#include <Servo.h>`

```
Servo myservo;  // create servo object to control a servo

int potpin = 0;  // analog pin used to connect the potentiometer
int val;    // variable to read the value from the analog pin

void setup()
{
  myservo.attach(9);  // c                    to the servo object
}

void loop()
{
  val = analogRead(potpin);            // reads the value of the potentiometer (value between 0 and 1023)
  val = map(val, 0, 1023, 0, 179);     // scale it to use it with the servo (value between 0 and 180)
  myservo.write(val);                  // sets the servo position according to the scaled value
  delay(15);                           // waits for the servo to get there
}
```

instance of class
(up to 6 on the uno)
(12 on the duo)

set pwm from a resistor (pot)

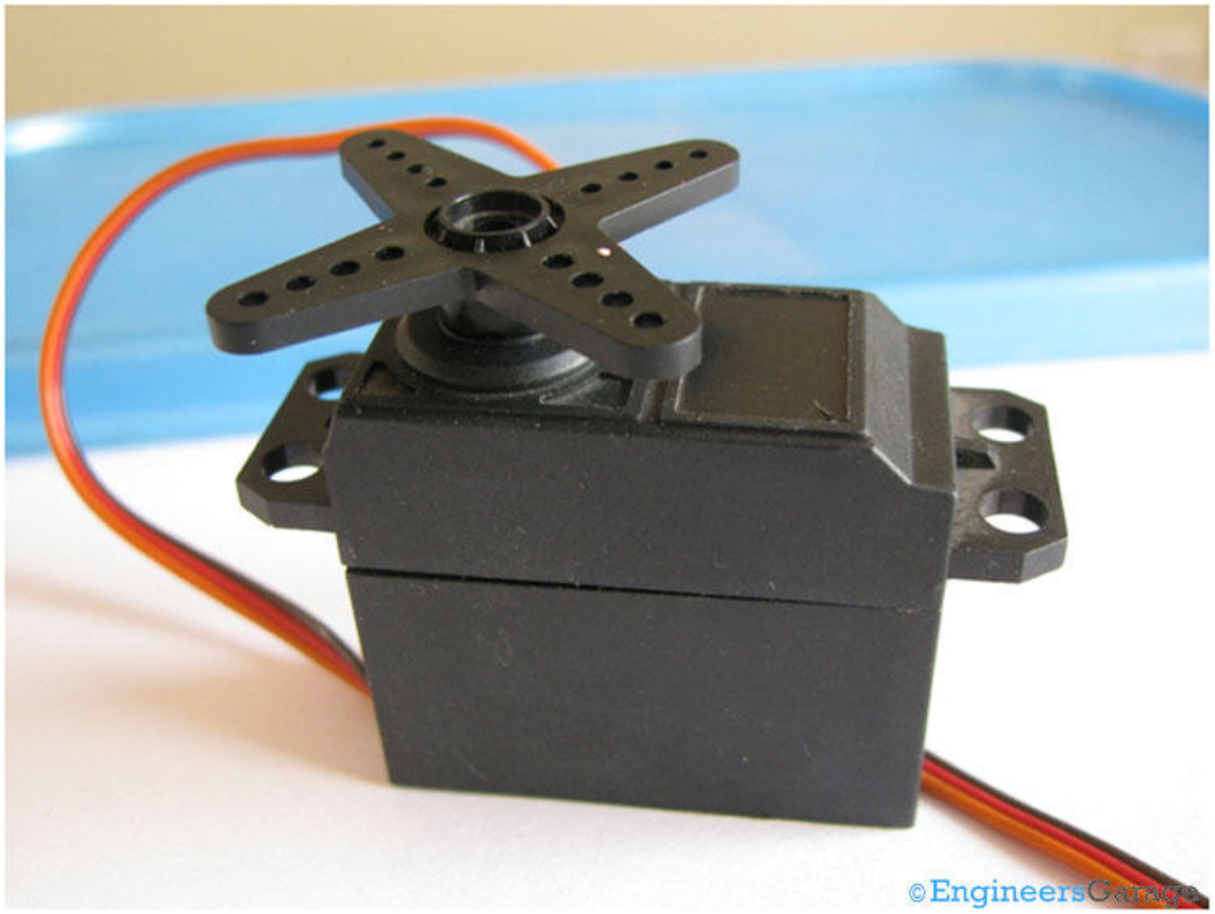
use pin 9
(must be PWM)

this could be **delay forever**
and the PWM will still work!

set the new angle
(and forget it)

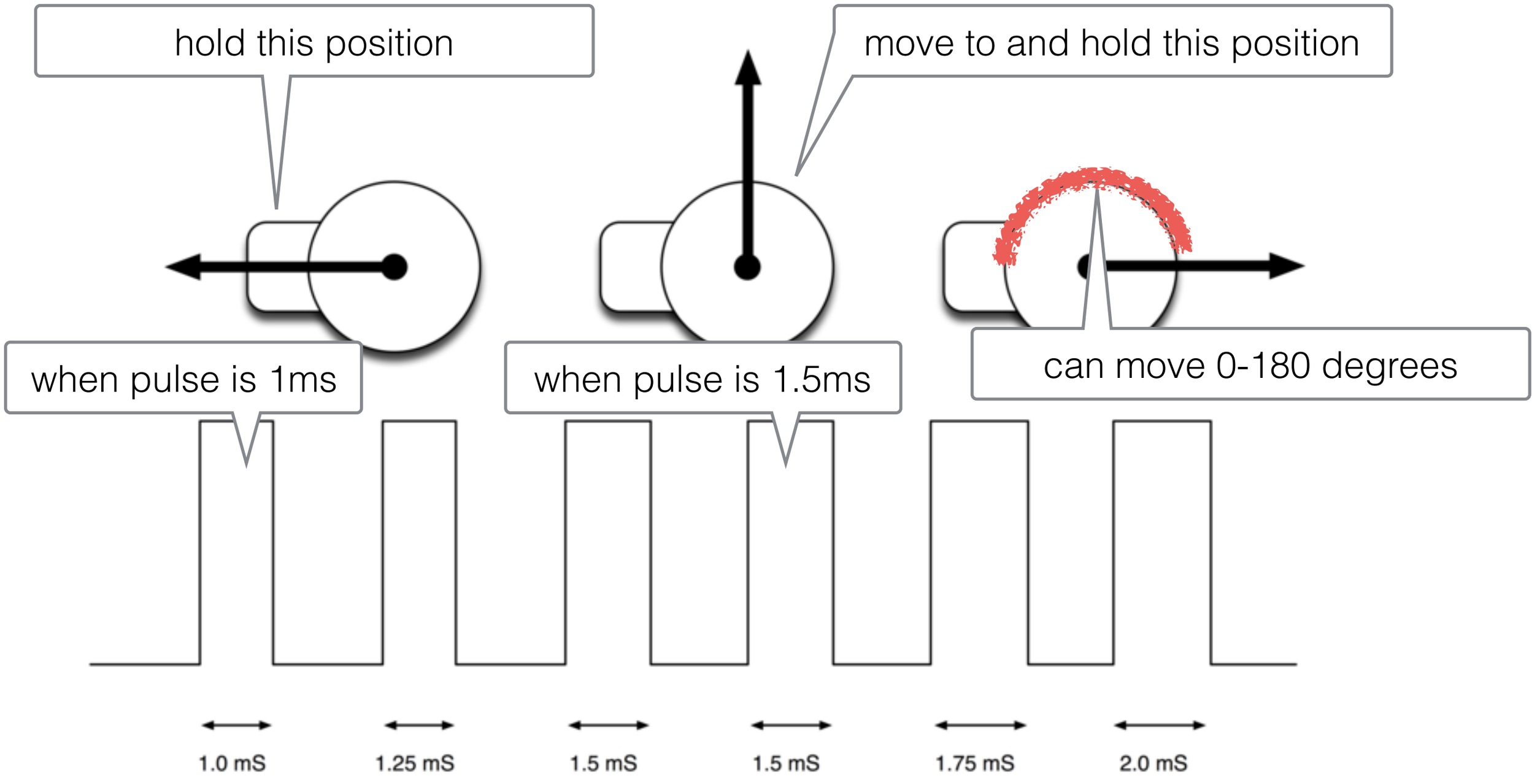
PWM for servos

- two types
  - position: rotate and stay
  - continuous: delta movements
- controlled through pulses



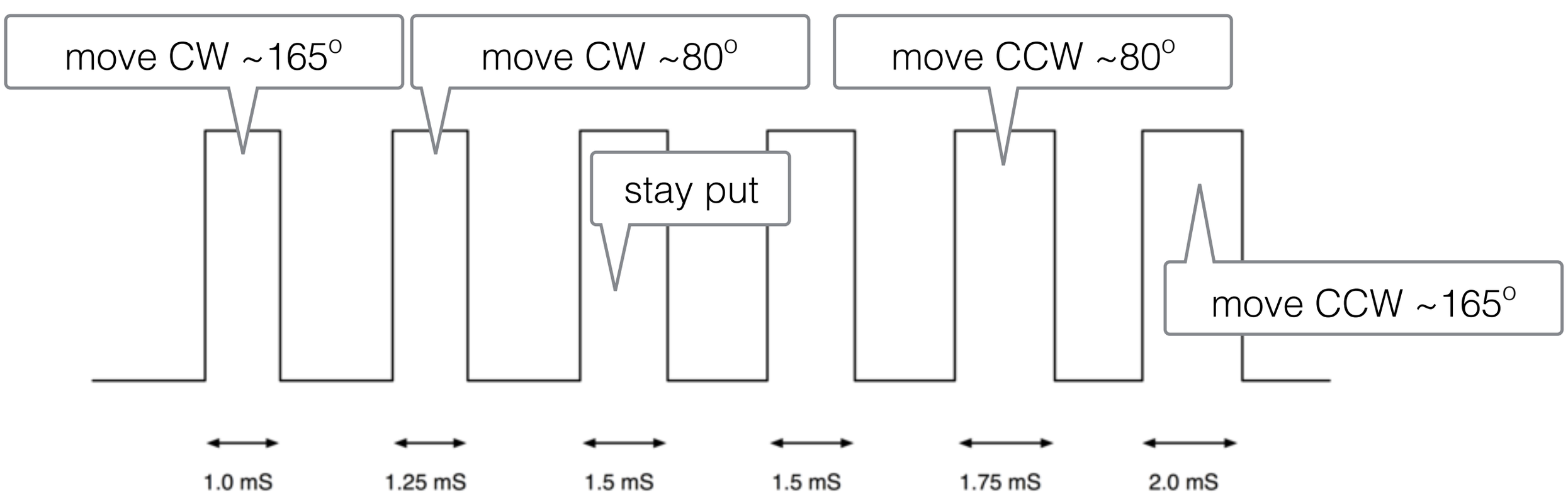
servo 1: rotational servo

- needs repeating pulse train (usually 1-2ms)



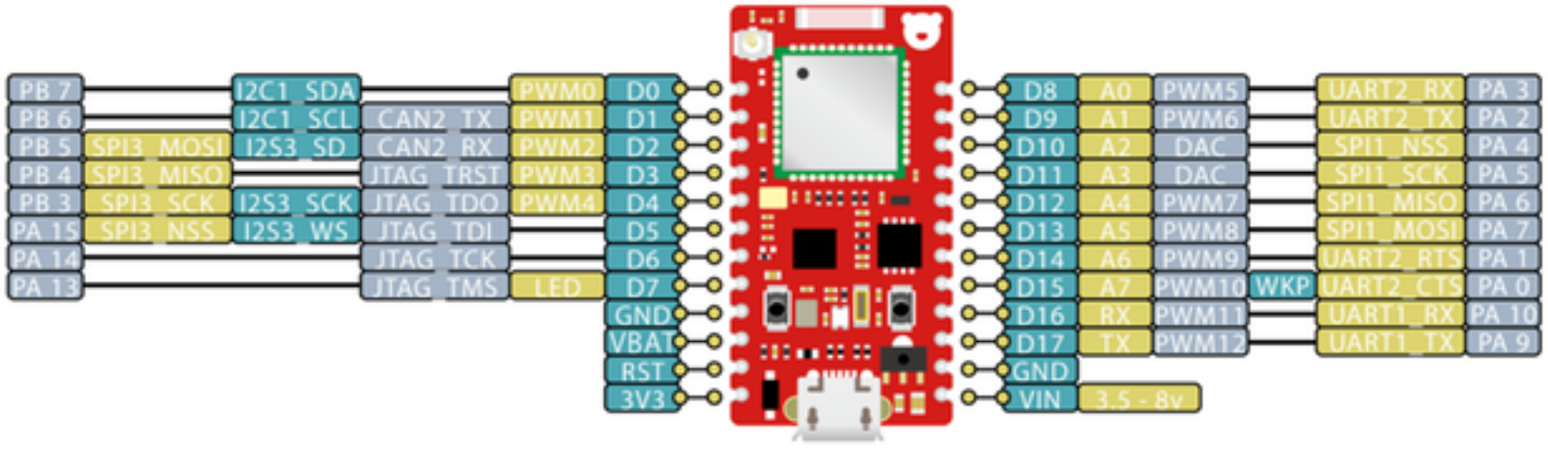
servo 2: continuous

- each pulse is a new command
- pulse width is angle to move from current angle
  - servo can rotate all the way around
  - counter clockwise (CCW) or clockwise (CW)



Servo demo

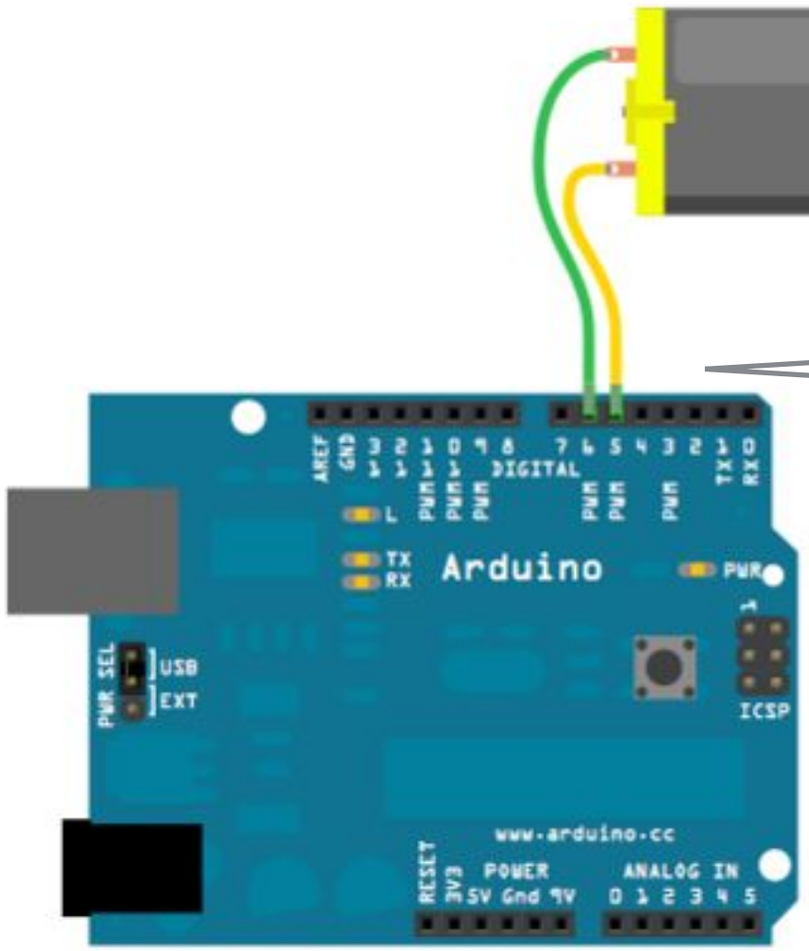
- what to do?



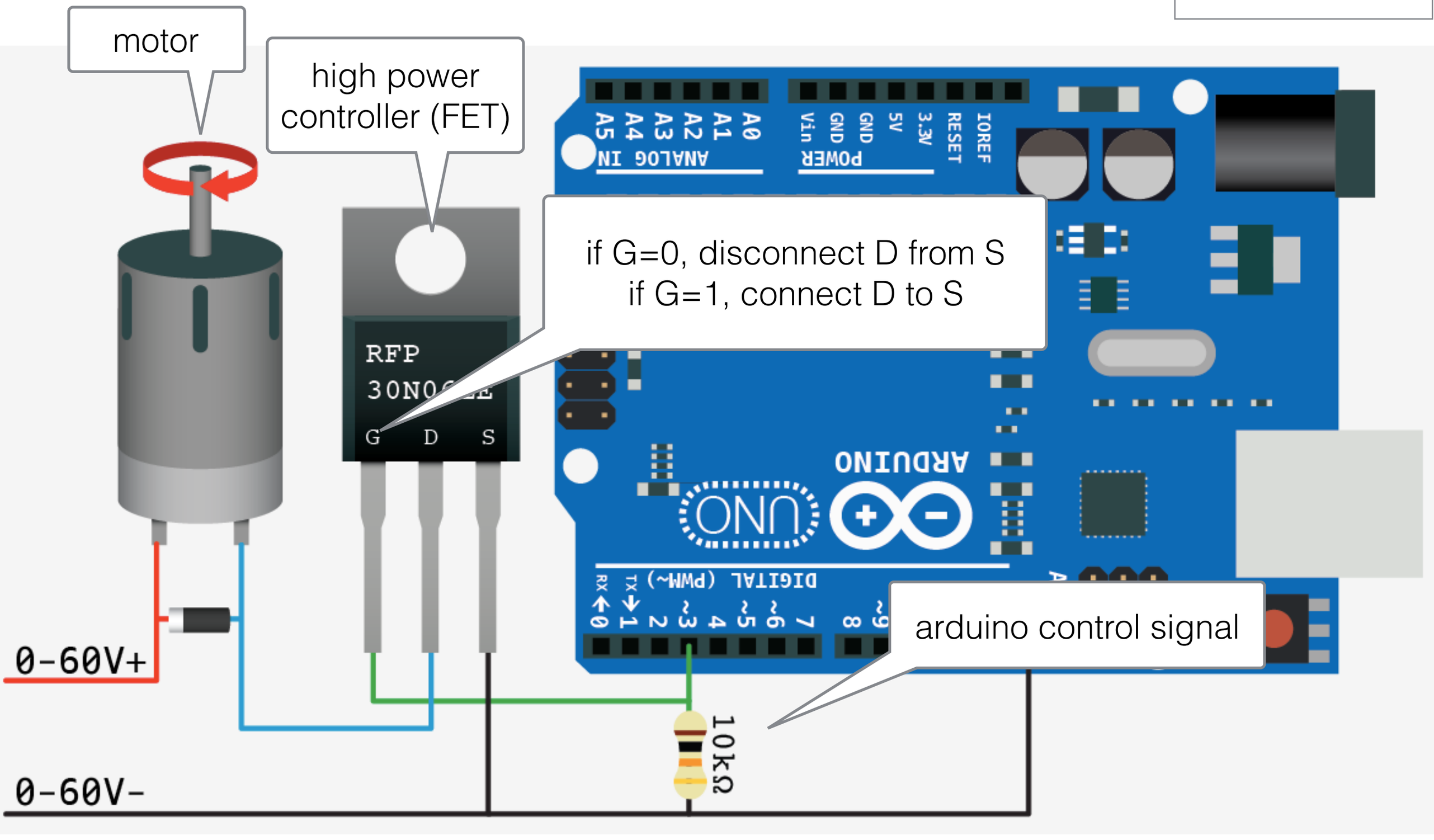
PWM for DC motor control

- give power to the motor in bursts
  - longer bursts == more power!
- just like LED brightness
- …or like the dimmer switch in your home
- motors use a lot of power!
  - arduino board **will not provide enough power**
  - arduino just **provides the control signal**

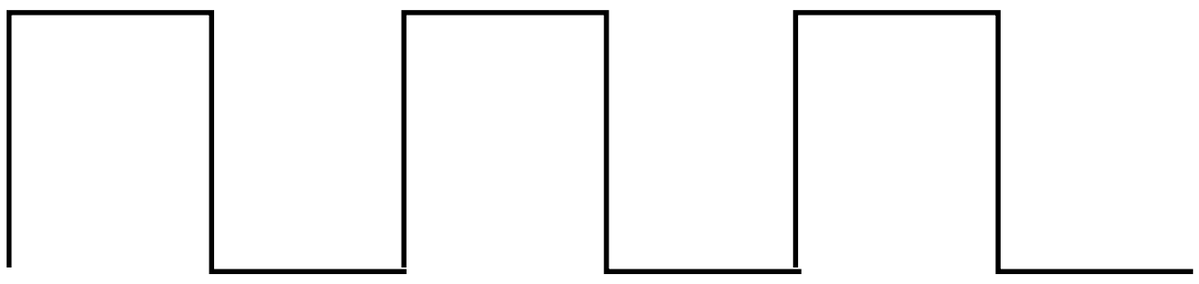
DC motor control



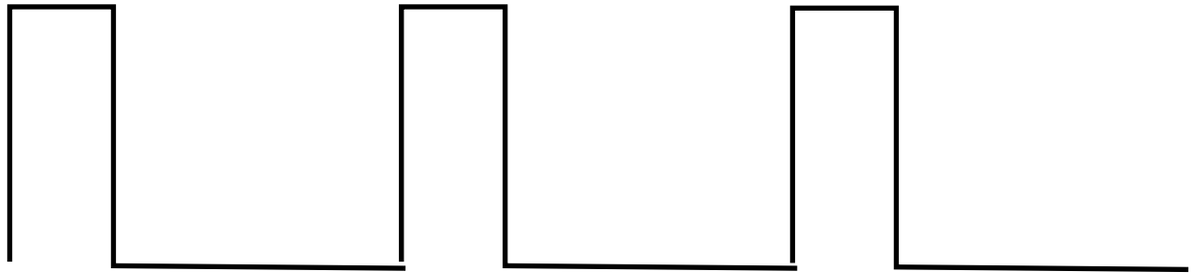
DC motor control



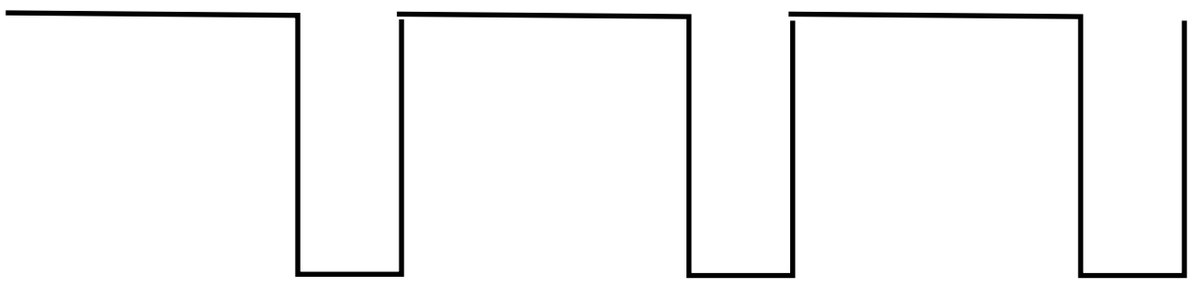
DC motor control



medium

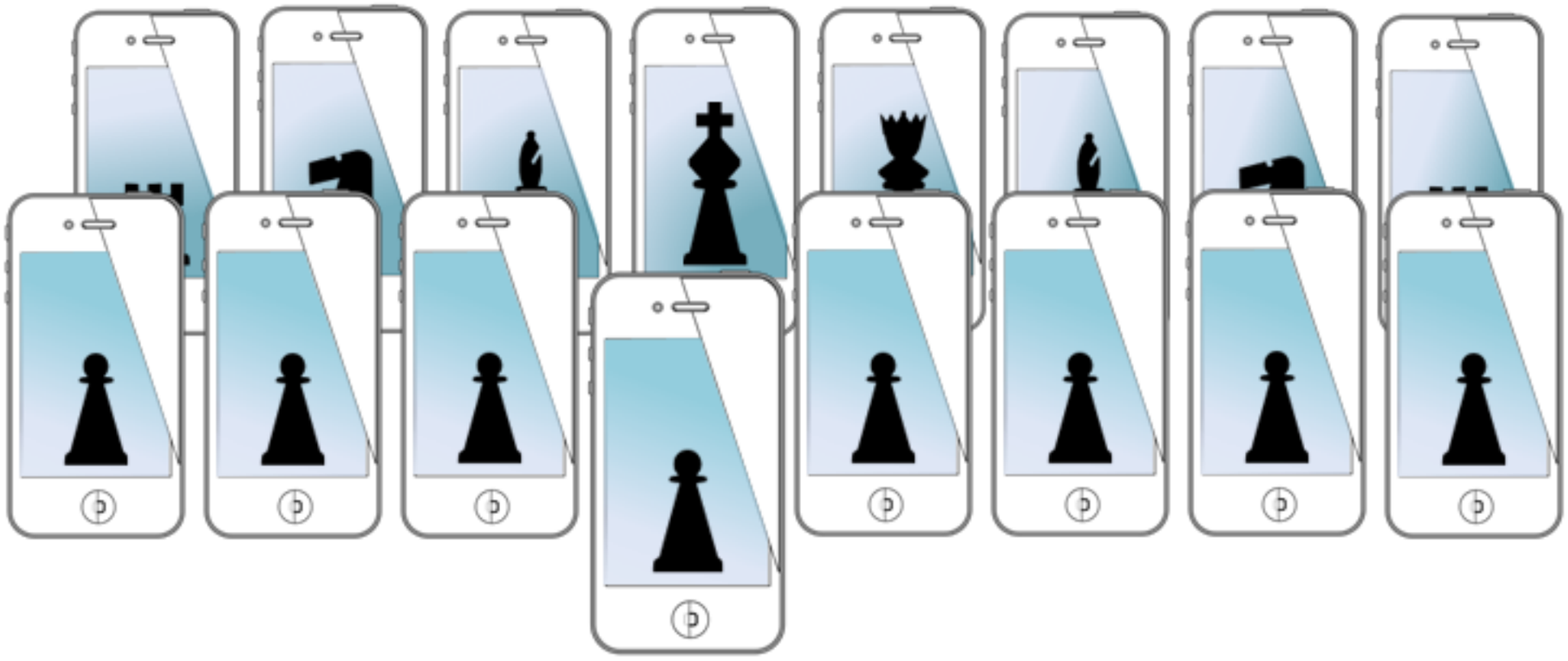


slow



fast

MOBILE SENSING LEARNING



CSE5323 & 7323

Mobile Sensing and Learning

week 7 and 8: microcontroller basics

Eric C. Larson, Lyle School of Engineering,
Computer Science and Engineering, Southern Methodist University

course logistics

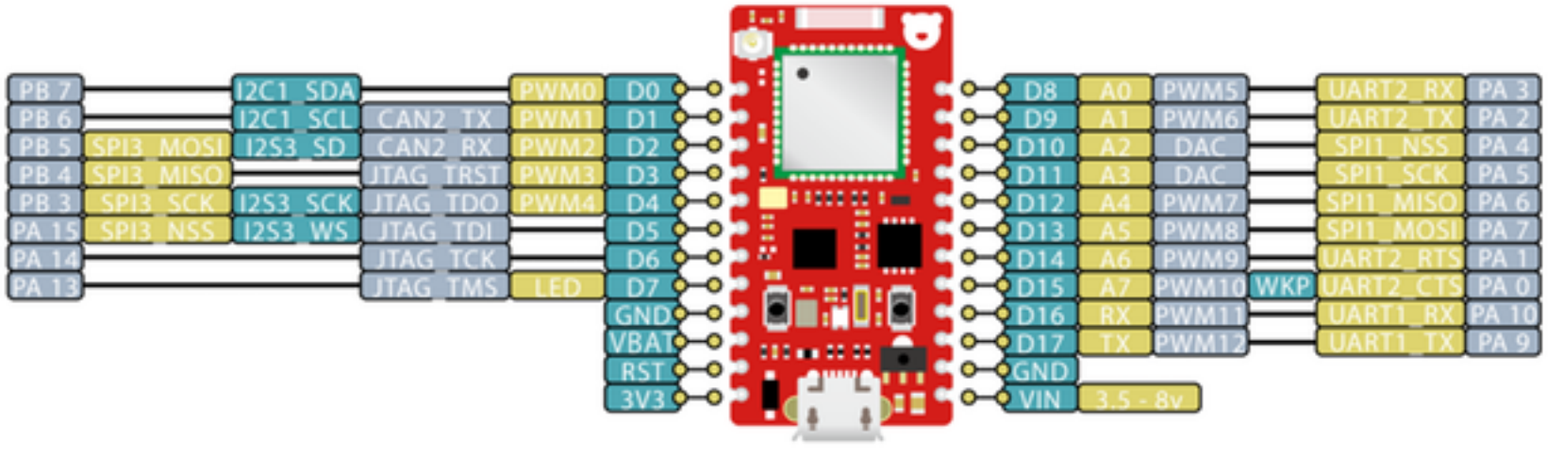
- Grades are coming
- A4 is due Friday! Or is it?
- Next time: in-class assignment, BLE

agenda

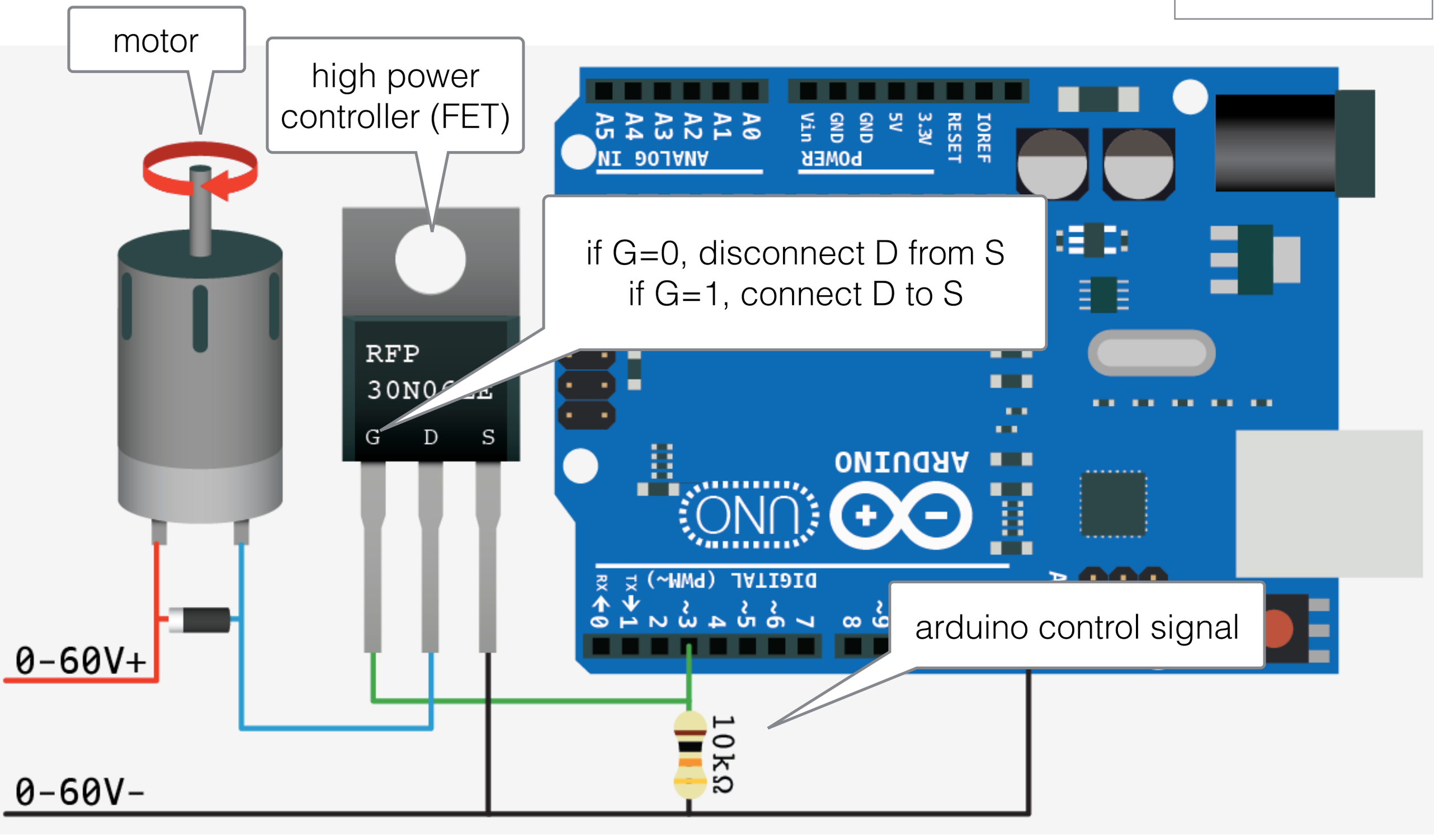
- *microcontrollers*
  - *architecture*
  - *peripherals*
  - *PWM for servo and motor control*
  - ADC
  - GPIO
  - interrupts
  - shields

Starting demo

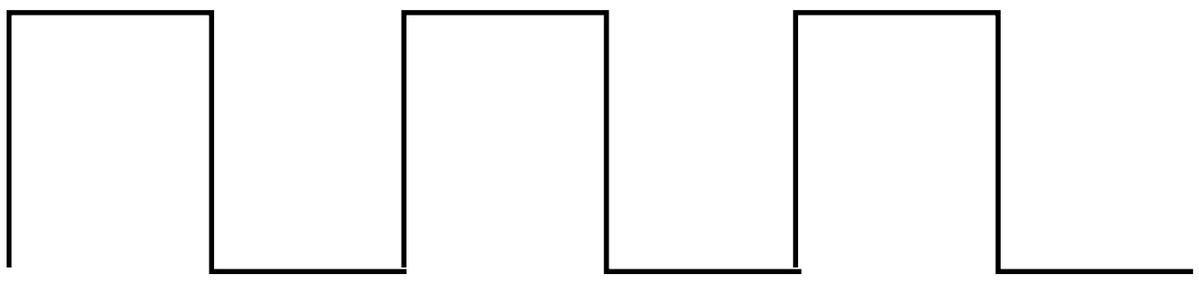
- RGB LED control



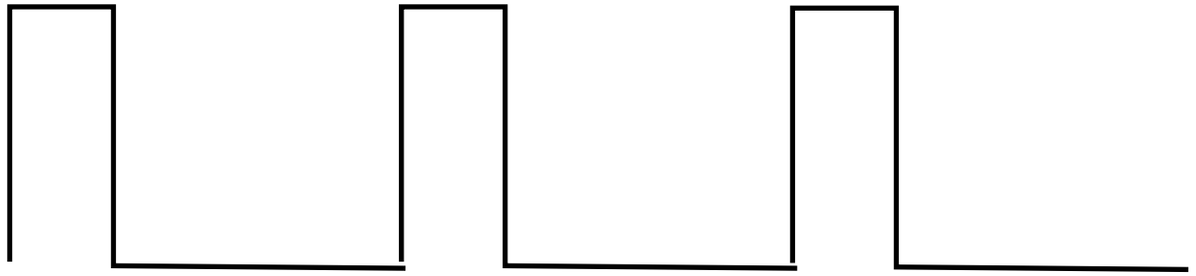
DC motor control



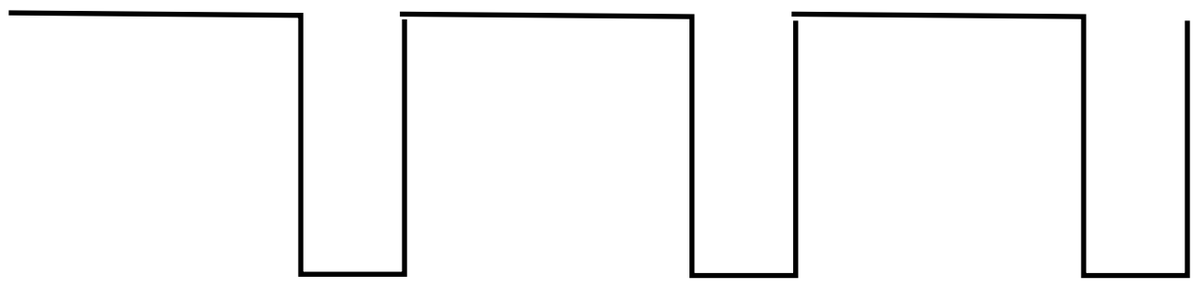
DC motor control



medium



slow



fast

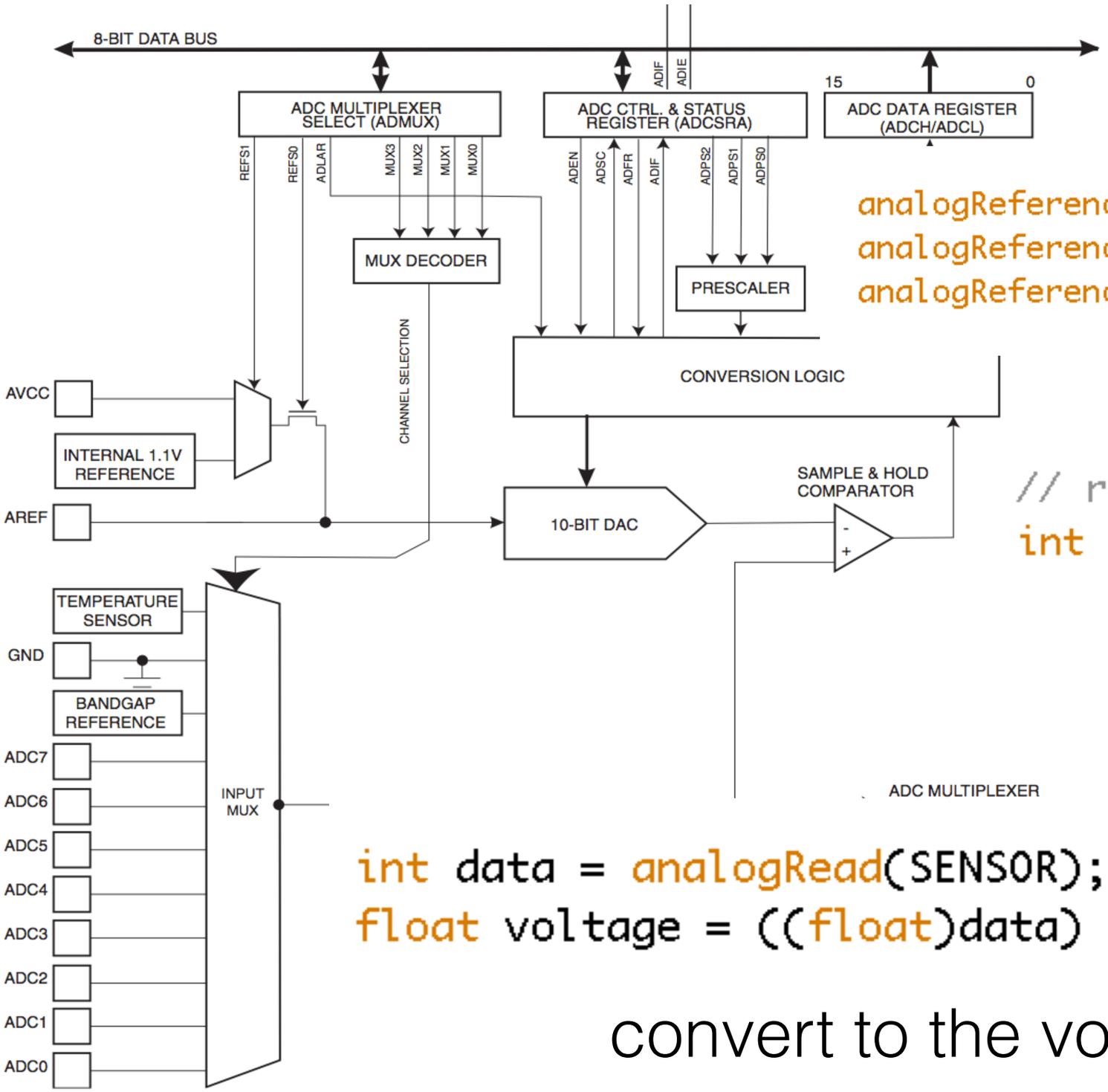
Arduino

Analog to Digital Conversion

ADC

- conversion from analog to digital is more explicit
  - dependent on reference voltage
  - sampling rate
  - dynamic range
- arduino: convert analog value into integer number
  - has 6 analog pins!
    - but they are muxed to one ADC $$
  - can run at 76.9kHz (15 kHz full resolution)
  - max resolution is 10 bits

ADC




```
analogReference(DEFAULT);      //5V reference
analogReference(INTERNAL1V1); //1.1V
analogReference(EXTERNAL);     //Voltage from pin
```

```
// read the input on analog pin 0:
int sensorValue = analogRead(A0);
```

Duo is a 12 bit ADC

4096

```
int data = analogRead(SENSOR);  // read value from ADC
float voltage = ((float)data) / 1024.0*VREF;
```

convert to the voltage

ADC

reference slide

- fairly fast conversion: use prescaler
  - then use analogRead as normal

```
const unsigned char PS_16 = (1 << ADPS2);
const unsigned char PS_32 = (1 << ADPS2) | (1 << ADPS0);
const unsigned char PS_64 = (1 << ADPS2) | (1 << ADPS1);
const unsigned char PS_128 = (1 << ADPS2) | (1 << ADPS1) | (1 << ADPS0);

// set up the ADC
ADCSRA &= ~PS_128;  // remove bits set by Arduino library

// you can choose a prescaler from
// PS_16, PS_32, PS_64 or PS_128
ADCSRA |= PS_64;    // set our own prescal    to 64
```

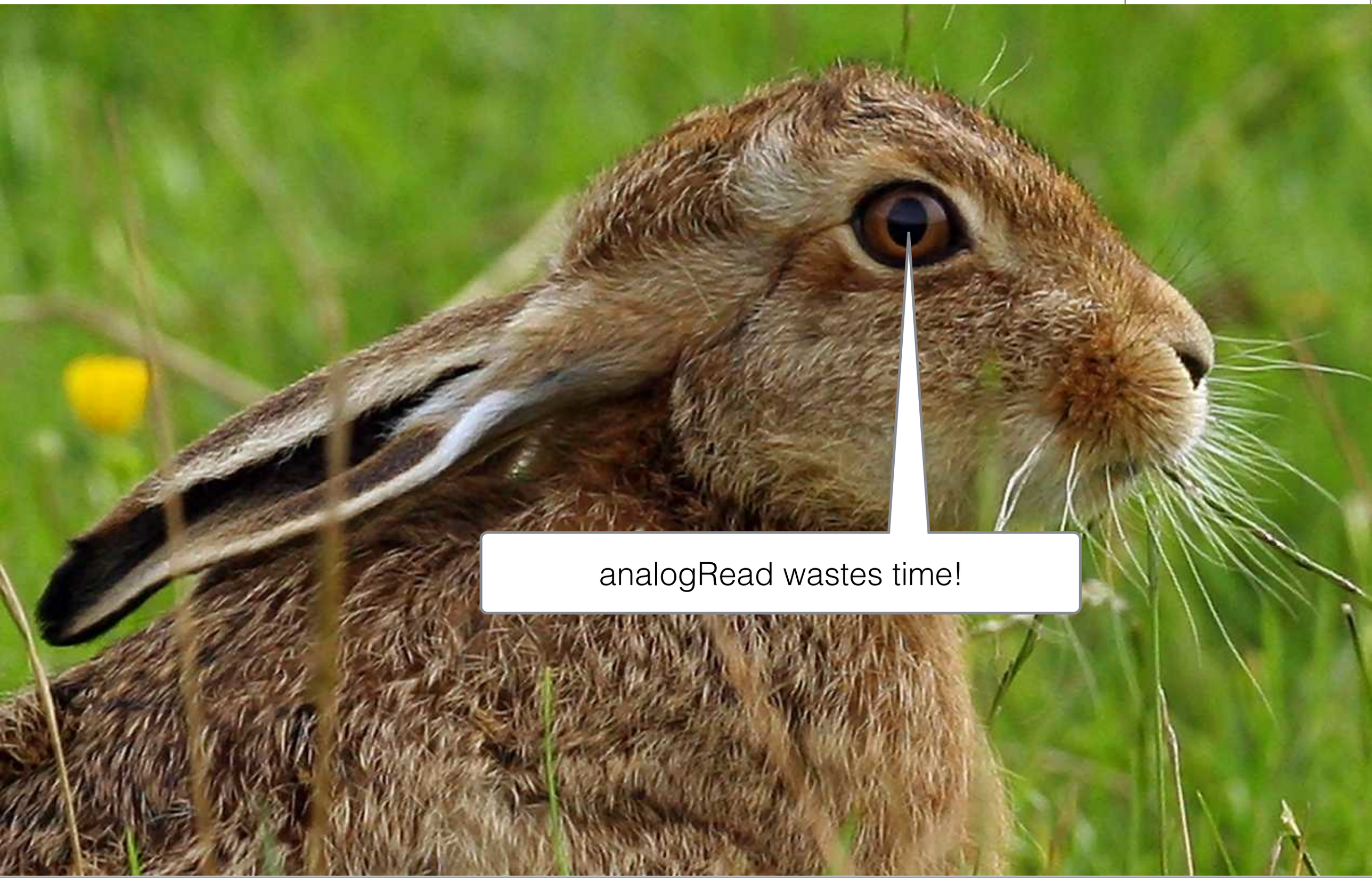
full resolution, ADC < 200kHz

ADC sampling is 16MHz / 64 ~ 250kHz

			Division Factor
0	0	0	2
0	0	1	2
0	1	0	4
0	1	1	8
1	0	0	16
1	0	1	32
1	1	0	64
1	1	1	128

ADCSRA – ADC Control and Status Register A

Bit	7	6	5	4	3	2	1	0	
(0x7A)	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0	ADCSRA
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	


analogRead wastes time!

ADC

reference slide

- fastest ADC possible
  - do not use the arduino library

```
// set up the ADC
ADCSRA &= ~PS_128;  // remove bits set by Arduino library

// you can choose a prescaler from above.
// PS_16, PS_32, PS_64 or PS_128
ADCSRA |= PS_64;    // set our own prescaler to 64
```

```
/* Enable the ADC */
ADCSRA |= _BV(ADEN);

/* Set the PIN pin as an output. */
pinMode(A0, INPUT);
```

then use the registers directly to read ADC

ADC

reference slide

```
int adc_read(byte adcx) {
    /* adcx is the analog pin we want to use.  ADMUX's first few bits are
     * the binary representations of the numbers of the pins so we can
     * just 'OR' the pin's number with ADMUX to select that
     * We first zero the four bits by setting ADMUX equal t
     * four bits. */
    ADMUX   &=      0xf0;
    ADMUX   |=      adcx;

    /* This starts the conversion. */
    ADCSRA |= _BV(ADSC);

    /*  wait around until the conversion is finished. */
    while ( (ADCSRA & _BV(ADSC)) );

    /* return the converted value */
    return ADC;
}
```

set reference

select analog pin

ADMUX – ADC Multiplexer Selection Register

Bit	7	6	5	4	3	2	1	0	
(0x7C)	REFS1	REFS0	ADLAR	–	MUX3	MUX2	MUX1	MUX0	ADMUX
Read/Write	R/W	R/W	R/W	R	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

- **Bit 7:6 – REFS[1:0]: Reference Selection Bits**

These bits select the voltage reference for the ADC, as shown in Table 24-3. If these bits are changed during a conversion, the change will not go in effect until this conversion is complete (ADIF in ADCSRA is set). The internal voltage reference options may not be used if an external reference voltage is being applied to the AREF pin.

- **Bits 3:0 – MUX[3:0]: Analog Channel Selection Bits**

The value of these bits selects which analog inputs are connected to the ADC. See Table 24-4 for details. If these bits are changed during a conversion, the change will not go in effect until this conversion is complete (ADIF in ADCSRA is set).

ADC

reference slide

```
int adc_read(byte adcx) {
    /* adcx is the analog pin we want to use.  ADMUX's first few bits are
     * the binary representations of the numbers of the pins so we can
     * just 'OR' the pin's number with ADMUX to select that pin.
     * We first zero the four bits by setting ADMUX equal to its higher
     * four bits. */
    ADMUX   &=      0xf0;
    ADMUX   |=      adcx;

    /* This starts the conversion. */
    ADCSRA |= _BV(ADSC);

    /*  wait around until the conversion is finished. */
    while ( (ADCSRA & _BV(ADSC)) );

    /* return the converted value */
    return ADC;
}
```

start conversion

wait to be done

ADCSRA – ADC Control

Bit	7	6	5	4	3	2	1	0	
(0x7A)	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0	ADCSRA
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

- **Bit 7 – ADEN: ADC Enable**

Writing this bit to one enables the ADC. By writing it to zero, the ADC is turned off. Turning the ADC off while a conversion is in progress, will terminate this conversion.

- **Bit 6 – ADSC: ADC Start Conversion**

In Single Conversion mode, write this bit to one to start each conversion. In Free Running mode, write this bit to one to start the first conversion. The first conversion after ADSC has been written after the ADC has been enabled, or if ADSC is written at the same time as the ADC is enabled, will take 25 ADC clock cycles instead of the normal 13. This first conversion performs initialization of the ADC.

ADSC will read as one as long as a conversion is in progress. When the conversion is complete, it returns to zero. Writing zero to this bit has no effect.

ADC summary

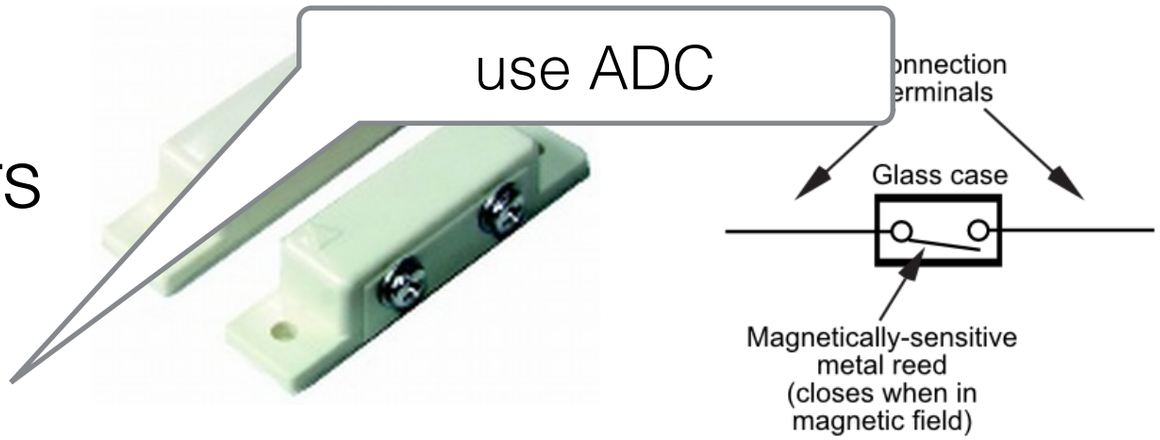
- try using analogRead without adjustments
- if not fast enough, use the prescaler
- if you still need to shave time,
  - write your own adc_read using the registers
  - look at reference slides if you want

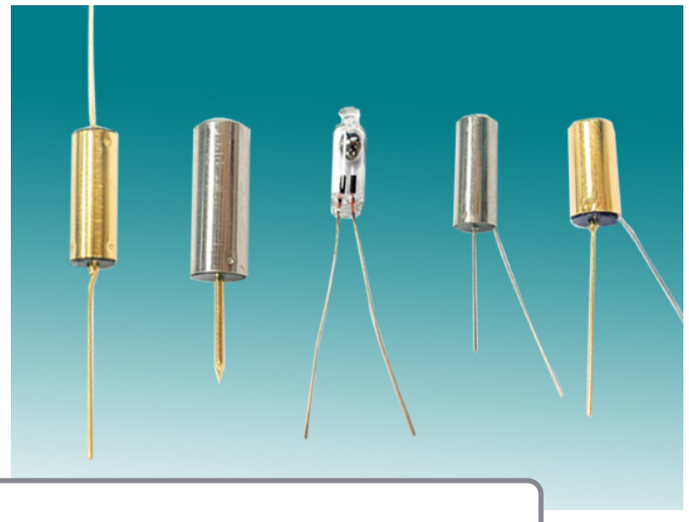
device one: potentiometers

- controls voltage, divided by to resistors
- three leads
  - V+
  - GND
  - analog out

other devices and sensors

- analog
  - hall effect sensors
  - capacitive touch
  - accelerometers
- binary
  - reed switches
  - buttons
  - ball switches

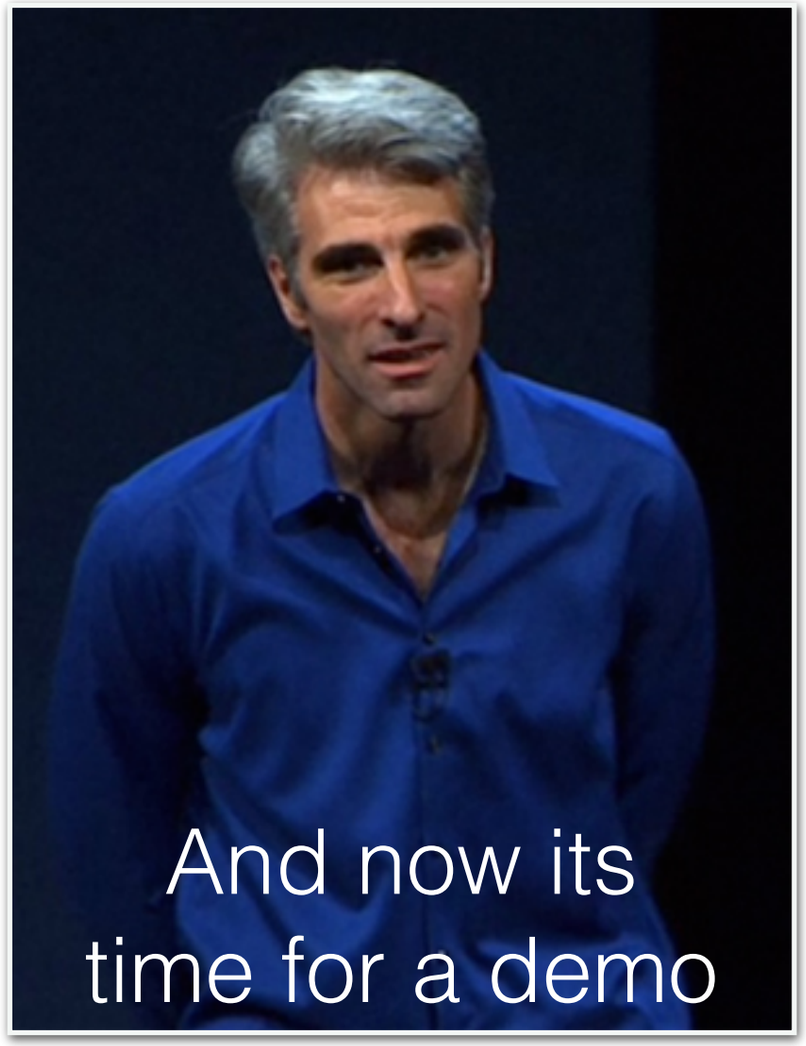




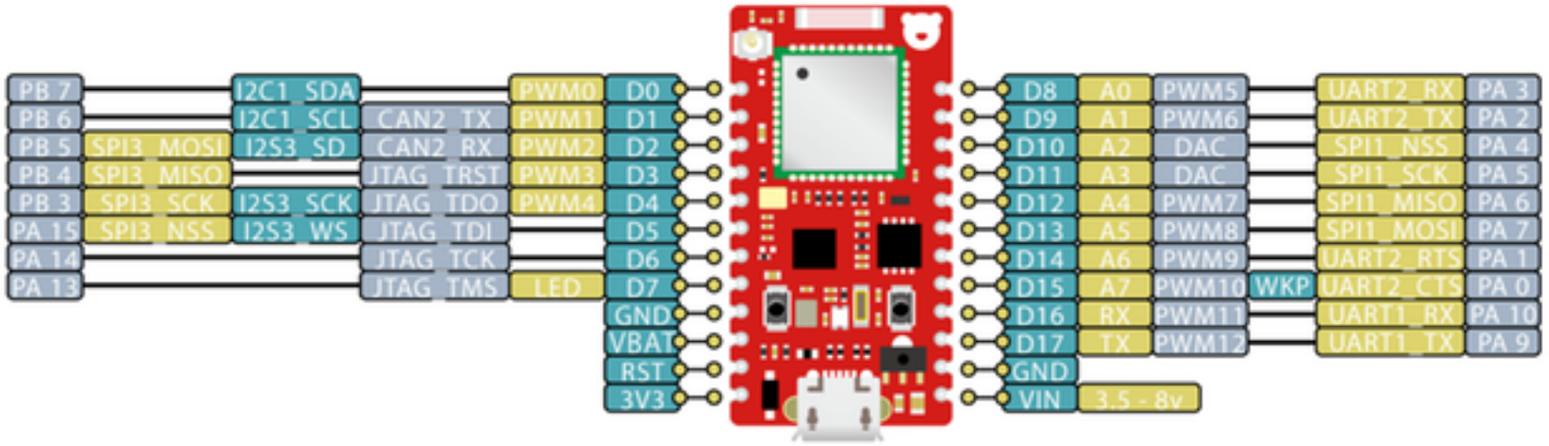
no need to use ADC

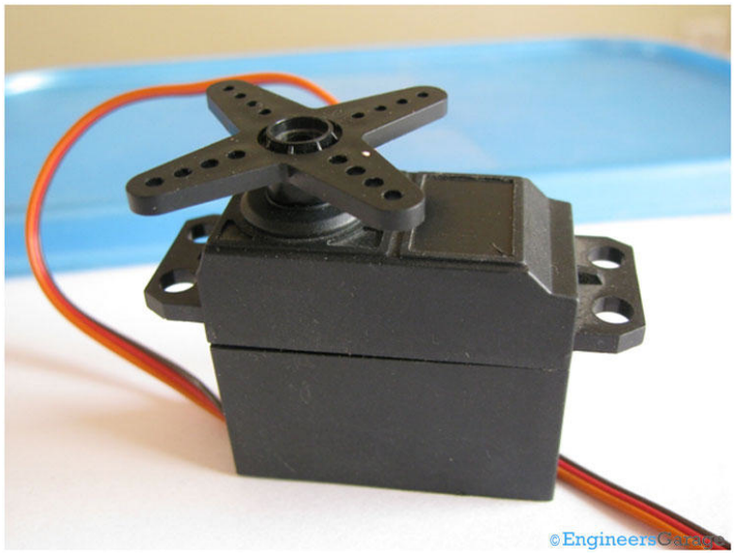
- http://playground.arduino.cc/Main/InterfacingWithHardware#arstat

Servo +ADC demo



- **REVIEW**: map ADC to motor position
  - what else can we make this do?





Arduino

GPIO

GPIO

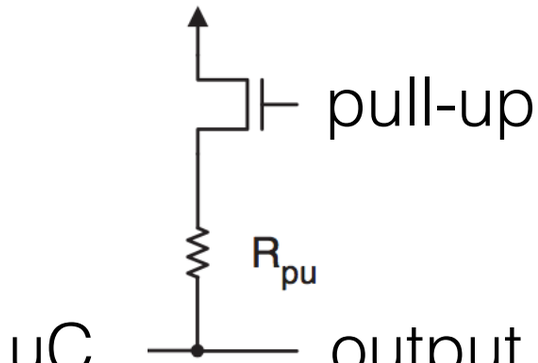
- digital inputs and outputs
  - buffered to drive ~40mA loads max
    - about the current needed to drive an LED, max brightness
- multiplexed for different functions
- internal pull-up resistors (20k)
  - can enable or disable
  - arduino auto enables pull-ups for input
  - disables for output
- edge detection (as interrupts)

GPIO

```
//configure pin2 as an input and enable the internal pull-up resistor
pinMode(2, INPUT_PULLUP);
pinMode(3, INPUT);
pinMode(13, OUTPUT);
```

input driven
high if floating

input unstable if floating
(called high-Z)



arduino read or write

```
int sensorVal = digitalRead(2);
 digitalWrite(13, LOW);
```

GPIO

reference slide

- fast access

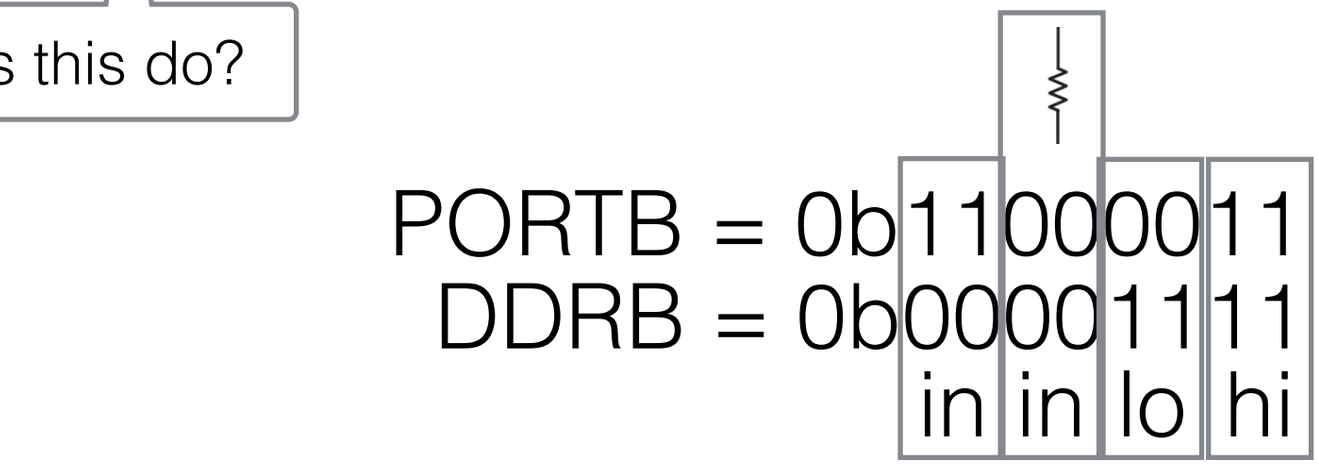
Table 14-1. Port Pin Configurations

DDxn	PORTxn	PUD in MCUCR)	I/O	Pull-up	Comment
0	0	X	Input	No	Tri-state (Hi-Z)
0	1	0	Input	Yes	Pxn will source current if ext. pulled low.
0	1	1	Input	No	Tri-state (Hi-Z)
1	0	X	Output	No	Output Low (Sink)
1	1	X	Output	No	Output High (Source)

```
PORTB = (1<<PORTB7)|(1<<PORTB6)|(1<<PORTB1)|(1<<PORTB0);
DDRB = (1<<DDB3)|(1<<DDB2)|(1<<DDB1)|(1<<DDB0);

byte pinValues = PINB;
```

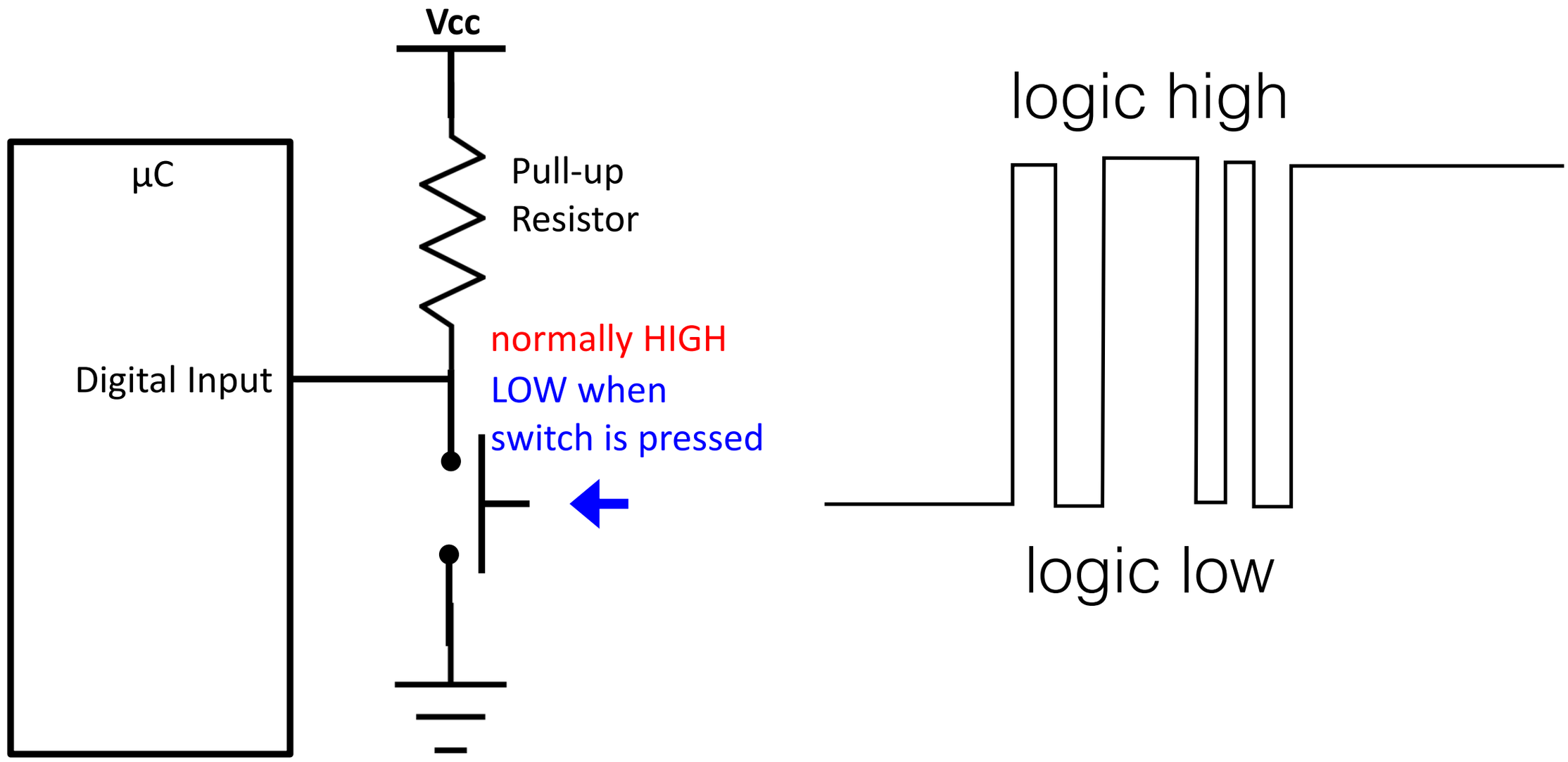
read register

what does this do?



GPIO: bounce

- connecting to mechanical devices
  - like a switch



GPIO: bounce

- connecting to mechanical devices
  - like a switch

```
// If the switch changed, due to noise or pressing:
if (reading != lastButtonState) {
  // reset the debouncing timer
  lastDebounceTime = millis();
}
```

```
if ((millis() - lastDebounceTime) > debounceDelay) {
  // whatever the reading is at, it's been there for longer
  // than the debounce delay, so take it as the actual current state:

  // if the button state has changed:
  if (reading != buttonState) {
    buttonState = reading;

    // only toggle the LED if the new button state is HIGH
    if (buttonState == HIGH) {
      ledState = !ledState;
    }
  }
```

Arduino

Interrupts

arduino interrupts

- how to handle input from a user?
- **interrupts** are from **external** or **internal** triggers
  - dedicated hardware “looks” for a trigger
    - main loop stops execution
    - local variables and instruction location copied to stack
    - **other interrupts turned off**
    - interrupt service routine called (**you write this!**)
    - after execution, stack reloaded, main loop continues

arduino interrupts

```
volatile boolean blinkLED;

// configure interrupts when switch is pressed
attachInterrupt(0, SW_ISR, FALLING);
```

select pin 2

call this routine (not function)

Uno: pin2=0, pin3=1

could be rising, falling, change, low

```
/* switch press interrupt service routine */
void SW_ISR() {
    blinkLED = !blinkLED;           // toggle blink state
}
```

switch off/on interrupts

```
noInterrupts();

// code that needs continuous execution

interrupts();
```

Timer interrupts

- arduino does not give full access to interrupts
- “ble.h” module has some nice function to access internal ISR

```
static btstack_timer_source_t characteristic2;
```

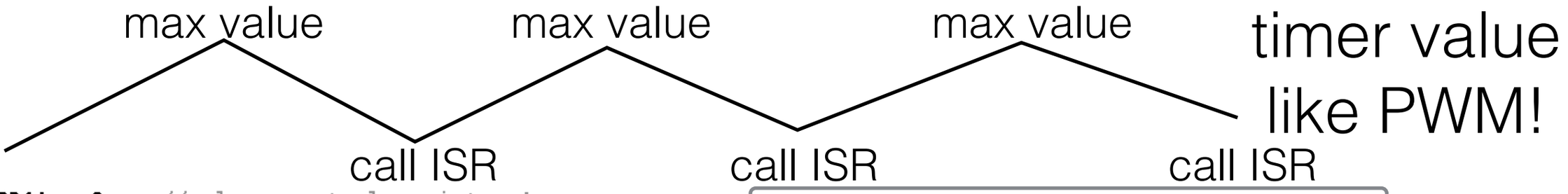
```
static void  characteristic2_notify(btstack_timer_source_t *ts) {
  // reset
  ble.setTimer(ts, 200);
  ble.addTimer(ts);
}
```

```
// set one-shot timer
characteristic2.process = &characteristic2_notify;
ble.setTimer(&characteristic2, 500);//100ms
ble.addTimer(&characteristic2);
```

AVR interrupts

reference slide

- arduino does not give full access to interrupts
- so timer interrupts must use the AVR c-code




```
TCCR1A = 0;   // clear control register A
TCCR1B = _BV(WGM13); // set PWM phase correct mode
```

count up and then down

```
// get the prescaler amount
long cycles = (F_CPU / 2000000) * MICROSECONDS;
// the counter runs backwards after TOP, interrupt is at bottom so divide microseconds by 2
if(cycles < RESOLUTION)              clockSelectBits = _BV(CS10);              // no prescale, full xtal
else if((cycles >>= 3) < RESOLUTION) clockSelectBits = _BV(CS11);              // prescale by /8
else if((cycles >>= 3) < RESOLUTION) clockSelectBits = _BV(CS11) | _BV(CS10);  // prescale by /64
else if((cycles >>= 2) < RESOLUTION) clockSelectBits = _BV(CS12);              // prescale by /256
else if((cycles >>= 2) < RESOLUTION) clockSelectBits = _BV(CS12) | _BV(CS10);  // prescale by /1024
else        cycles = RESOLUTION - 1, clockSelectBits = _BV(CS12) | _BV(CS10);  // request was out of bounds, set as max

// set the timer period
ICR1 = cycles;  // number of cycles before overflow (when ICR = 0)

// set the prescaler
TCCR1B &= ~(_BV(CS10) | _BV(CS11) | _BV(CS12)); // clear bits
TCCR1B |= clockSelectBits; // set scaler bits
// enable the interrupt
TIMSK1 = _BV(TOIE1); // sets the timer overflow interrupt
```

convert u-seconds to cycles

max value of counter

set pre-scale

enable interrupt from PWM

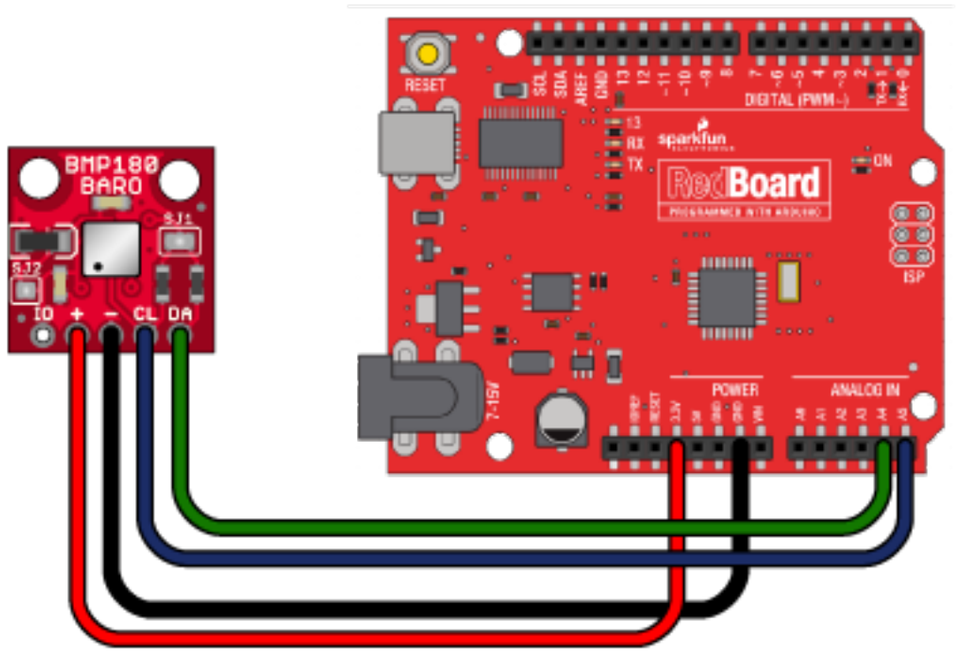
Arduino

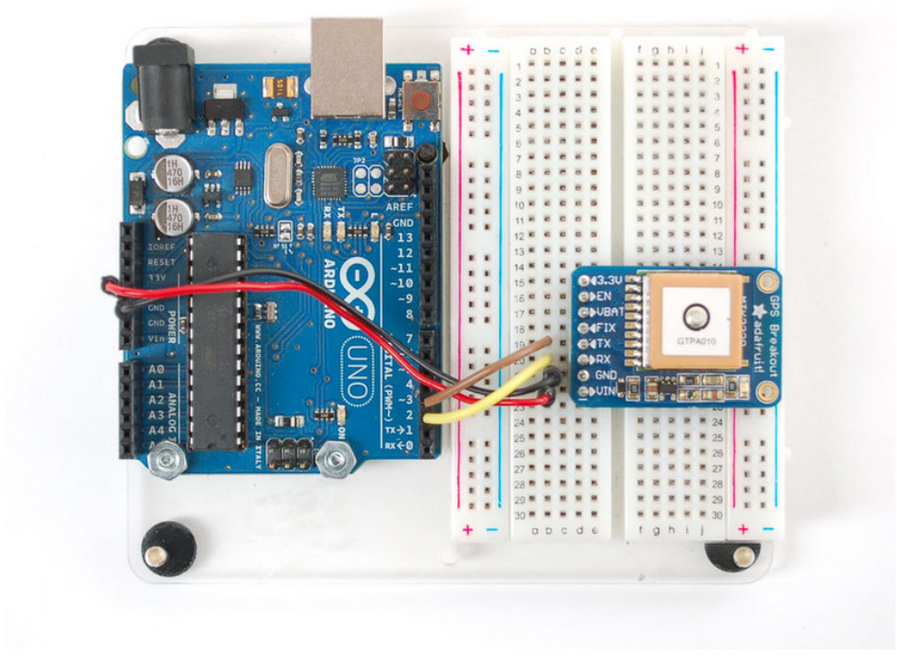
Other Sensors

other sensors

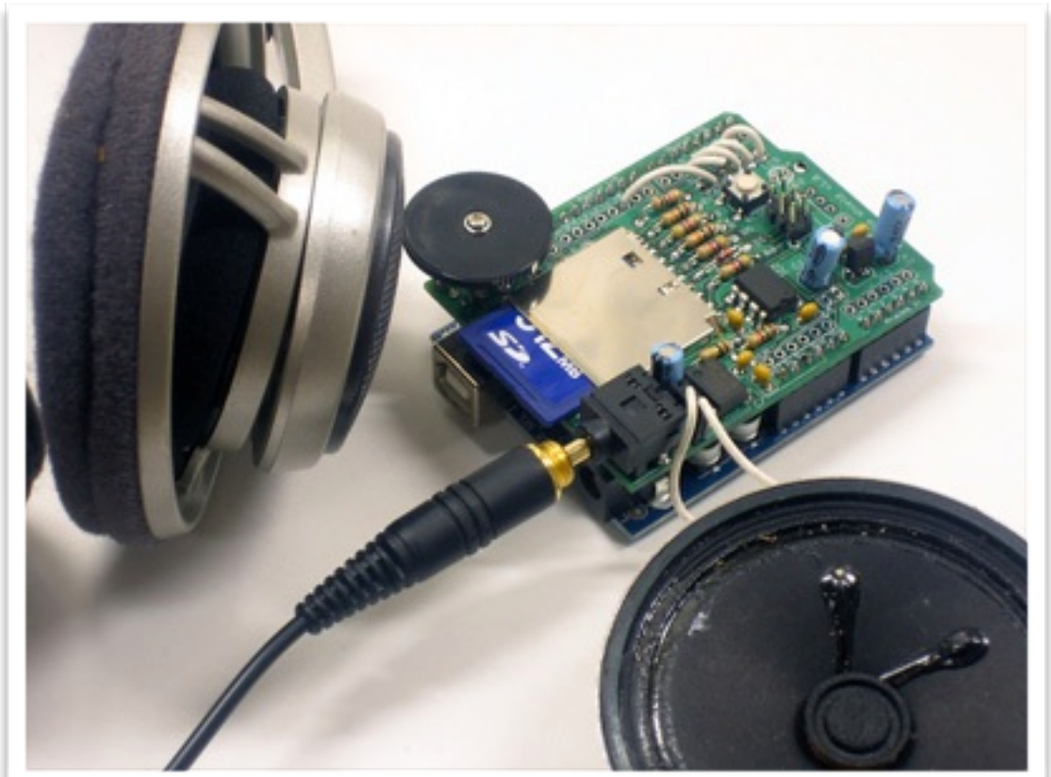
- digital sensors: serial communication

TMP04FS: Serial Digital Output Thermometer

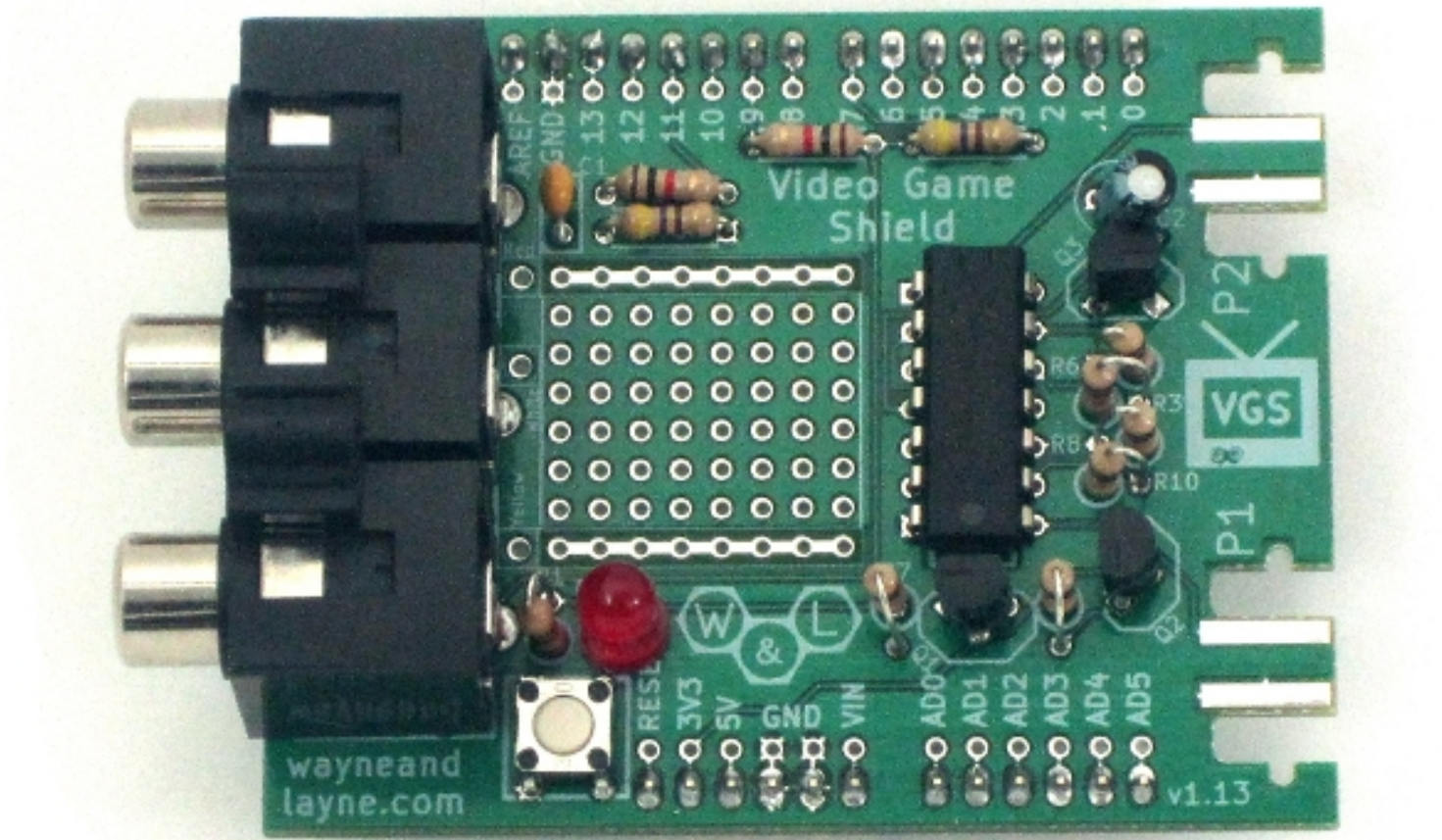




arduino shields

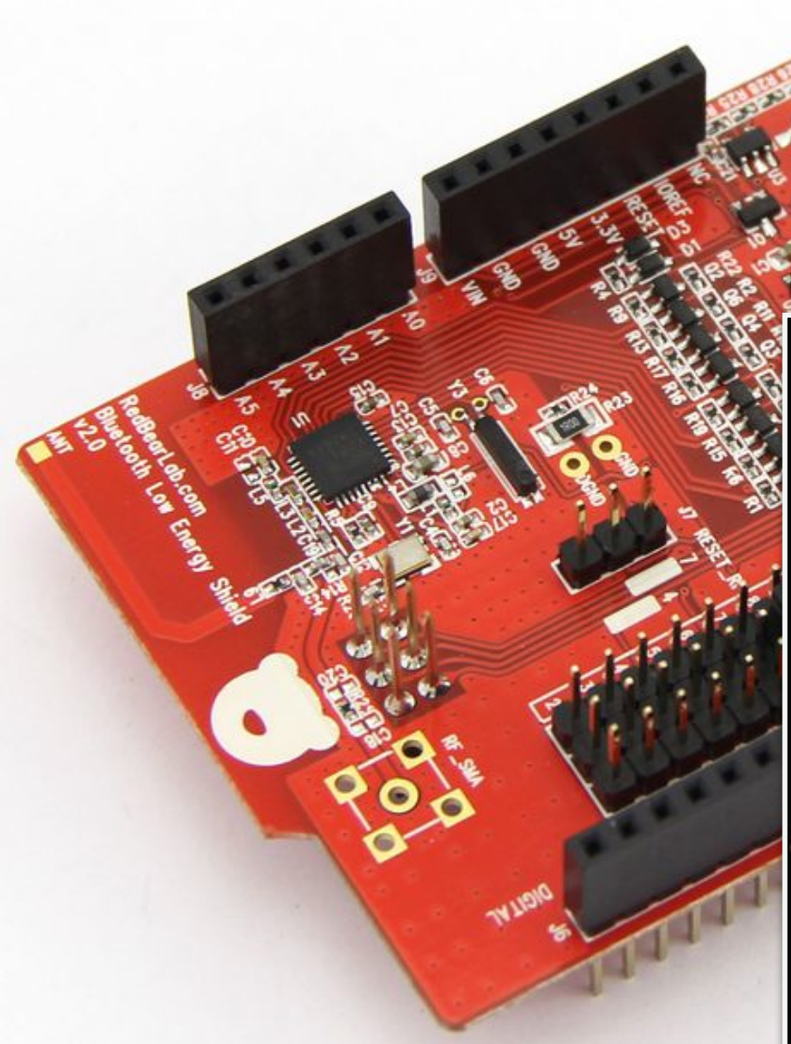


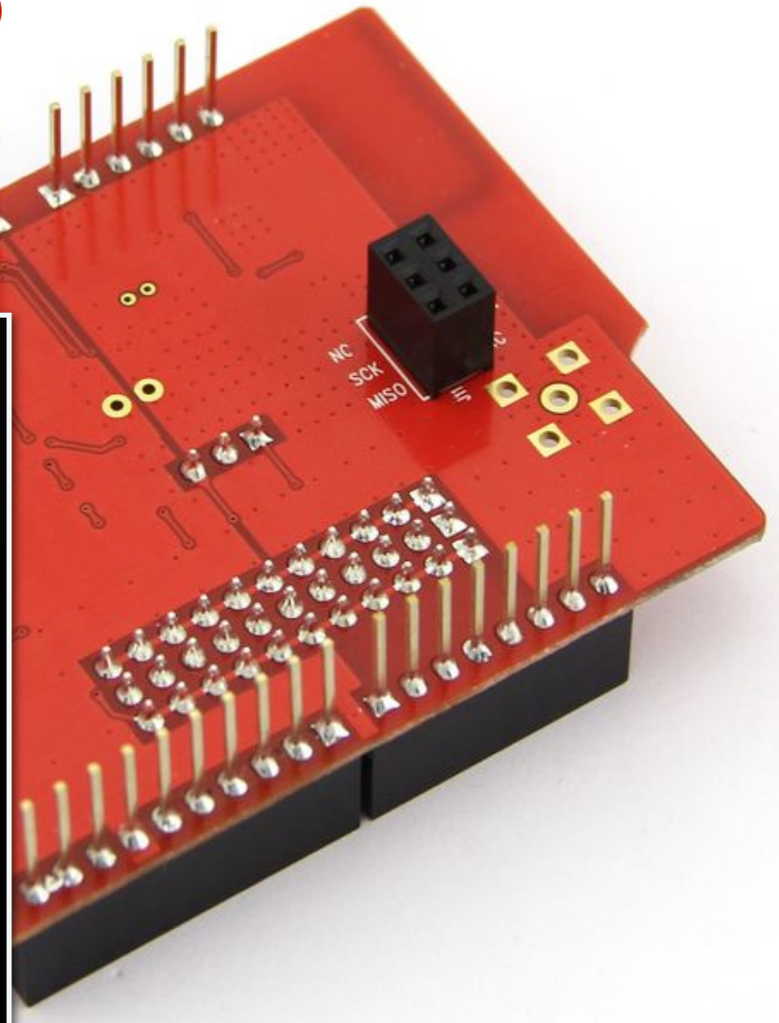
arduino shields



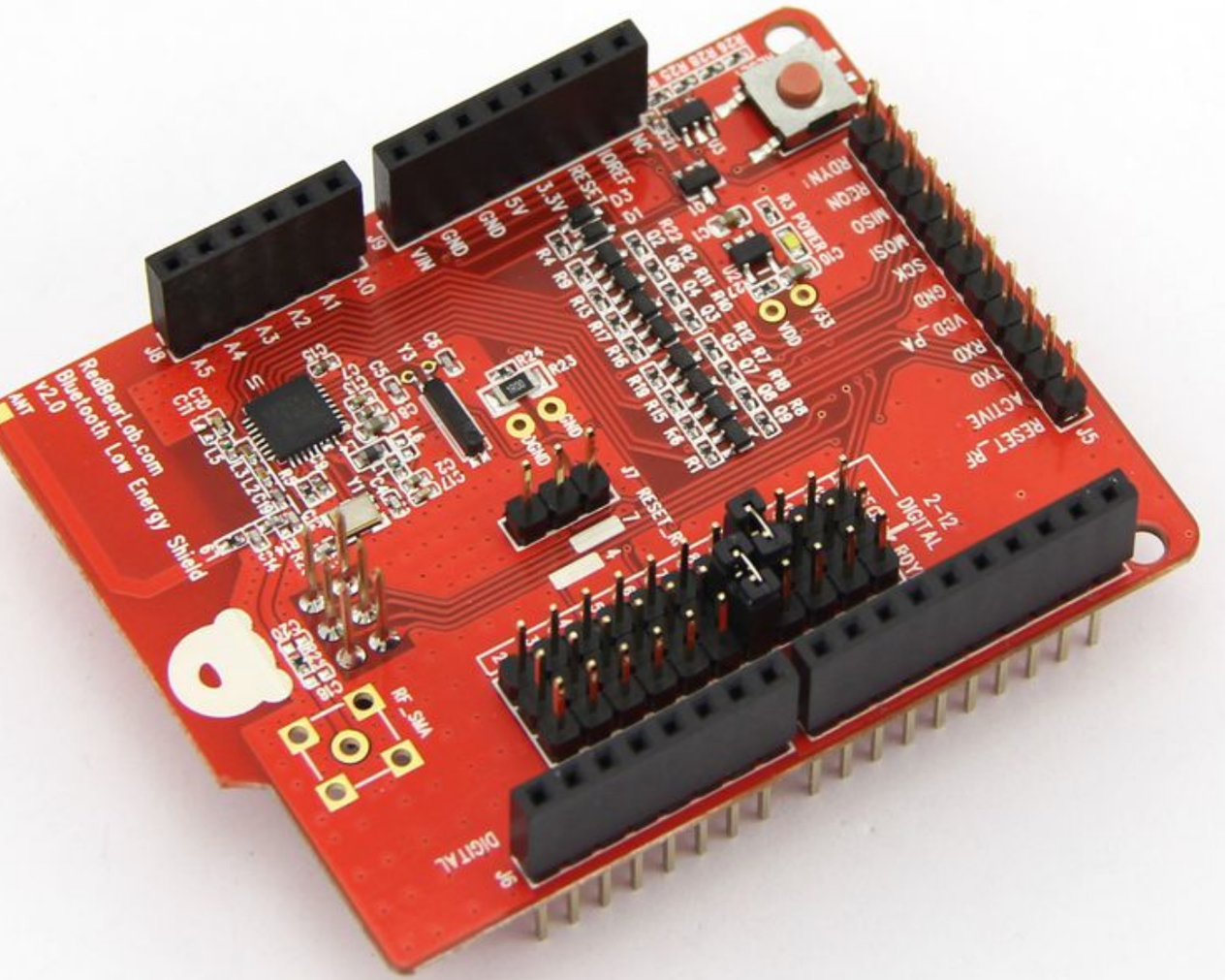
arduino shields

what is ESD?



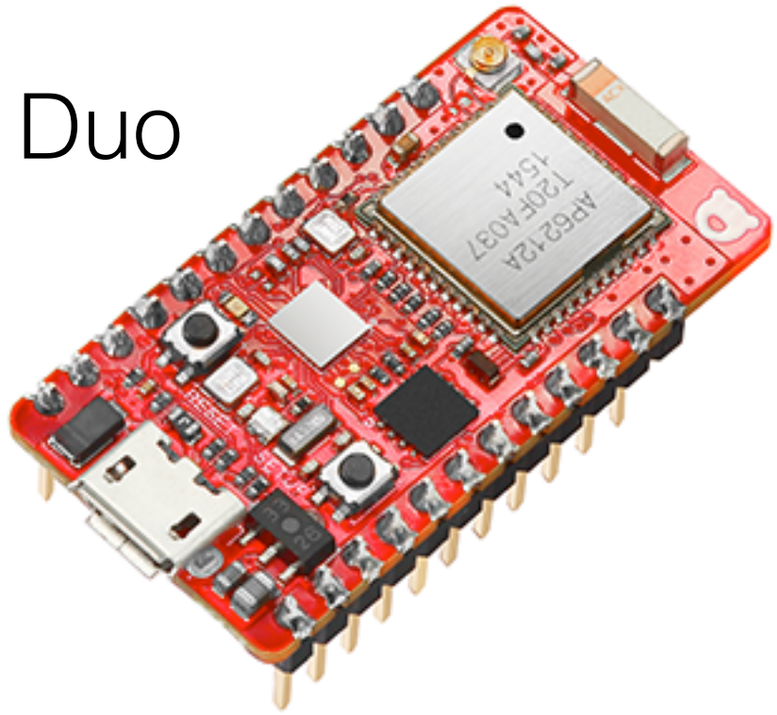


https://docs.particle.io/reference/firmware/photon/



BLEShield

Duo

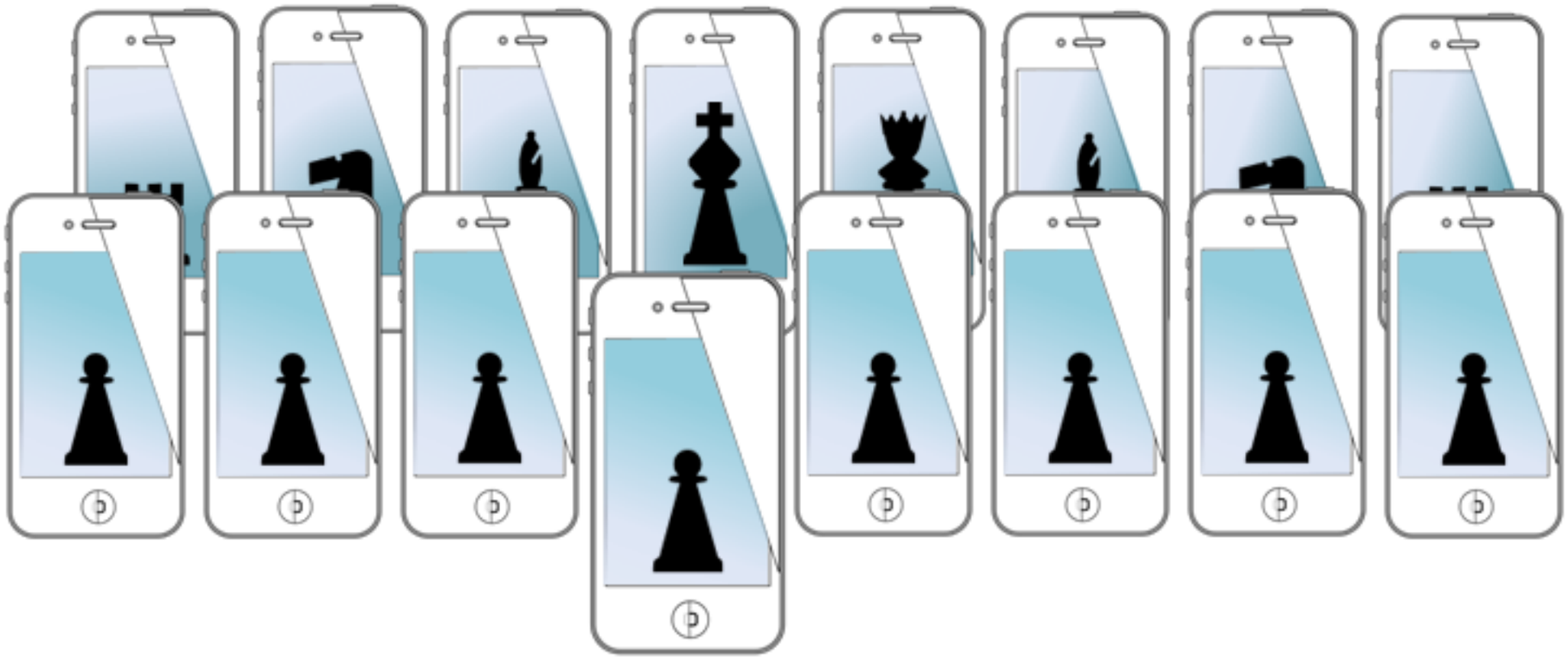


- STMicroelectronics ARM Cortex-M3 @120MHz, 128 KB SRAM and 1MB Flash
- Broadcom BCM43438 Wi-Fi 802.11n (2.4GHz only) + Bluetooth 4.1 (Dual Mode) combo chip
- On-board 16 Mbit (2 MB) SPI Flash
- Integrated chip antenna with the option to connect external antenna
- 18 I/O pins
- RGB status LED
- Small single-sided PCB for easy mounting on other PCB boards

for next time…

- all about bluetooth (flipped module)
  - overview of specs
  - using the API and libraries to transmit data between iPhone and arduino

MOBILE SENSING LEARNING



CSE5323 & 7323

Mobile Sensing and Learning

week 7 and 8: microcontroller basics

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