Introduction to Design (2)

Microcontrollers and Interfacing

Week 09

RGB LED arrays
Concurrency and timer interrupts

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this week

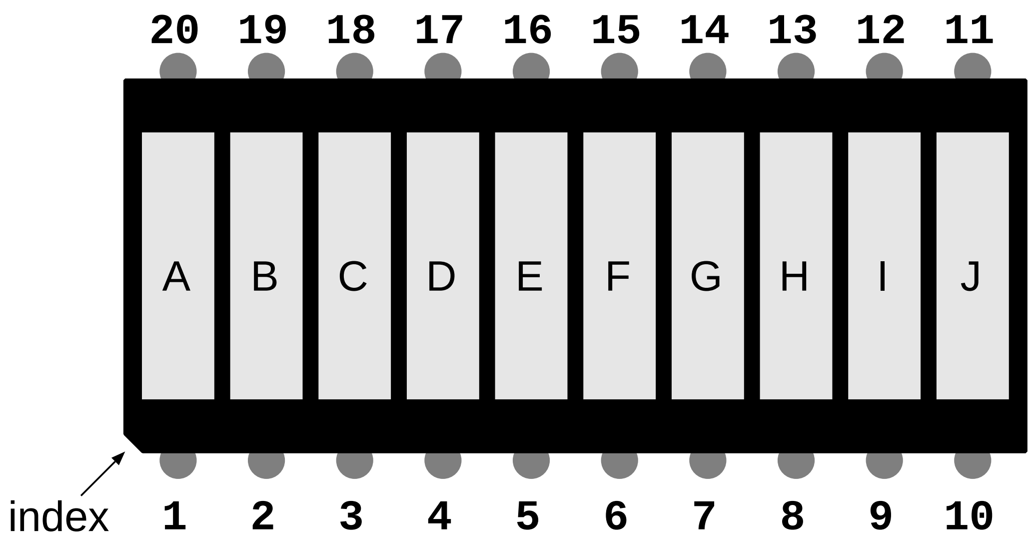
RGB LED arrays

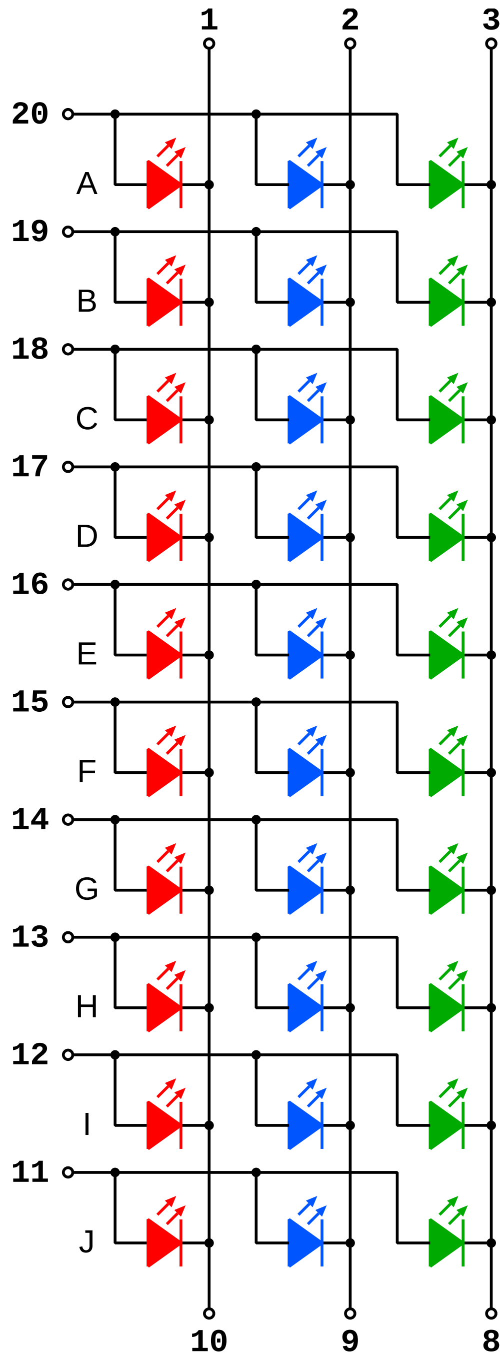
- connecting 30 LEDs using 13 pins
- software techniques
- time-division multiplexing

concurrency

- background tasks
- timer interrupts

RGB LED arrays





LED array with multiple colours

- each segment has red, green, and blue LEDs

anode and cathode pins create X-Y coordinate system

to switch on blue LED of segment F:

- make pin 15 2 V more +ve than pin 9

to ensure no other LEDs on:

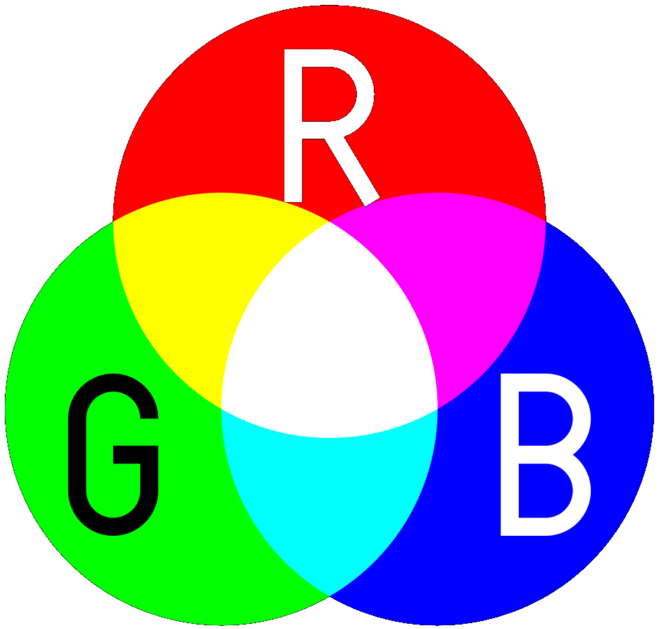
- make other anode pins 0 V (pins 11–14, 16–20)
- make other cathode pins 5 V (pins 8, 10)

why RGB?

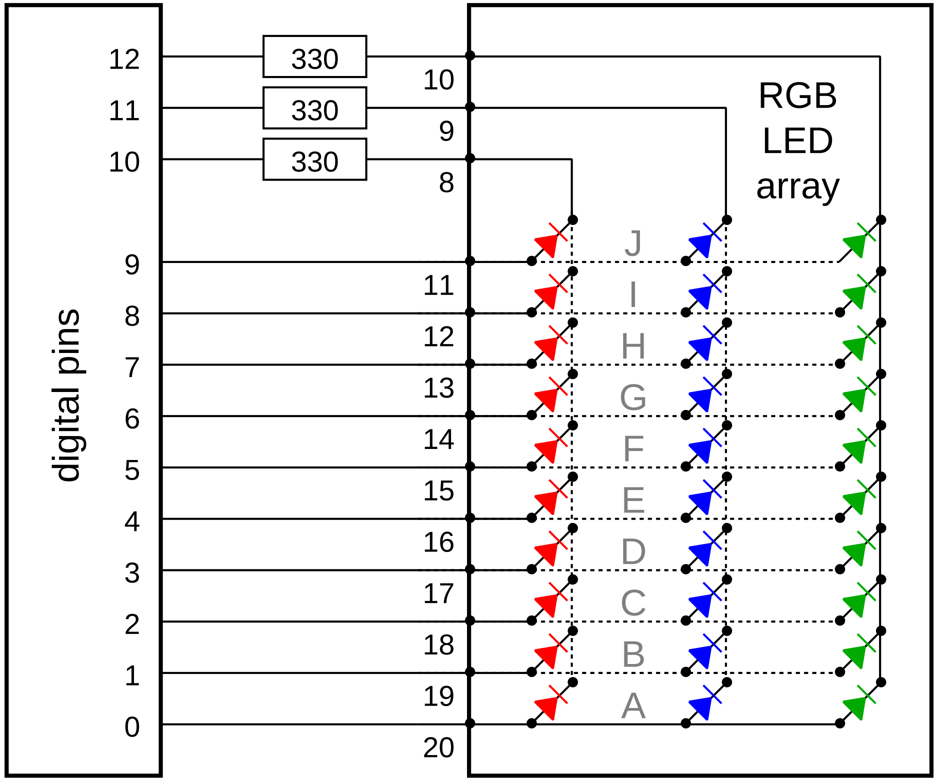
turning on different combinations of R, G, and B yields different colours

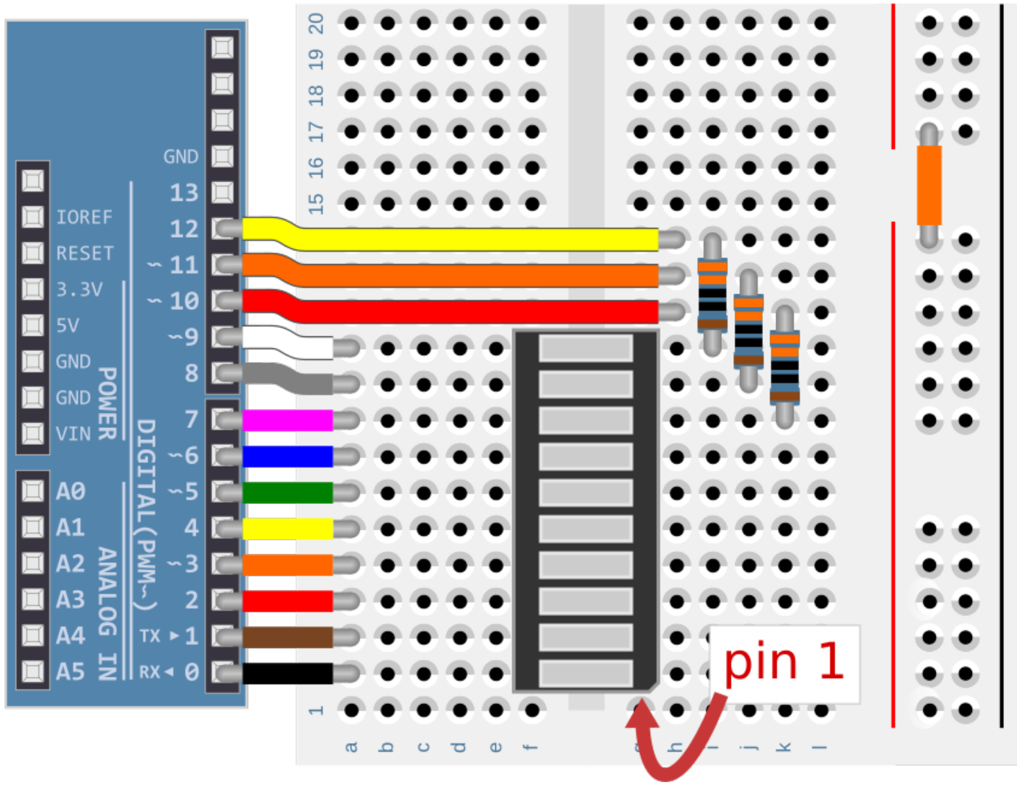
colour:	black	red	green	yellow	blue	magenta	cyan	white
red:	off	on	off	on	off	on	off	on
green:	off	off	on	on	off	off	on	on
blue:	off	off	off	off	on	on	on	on

additive colour synthesis:



interfacing with the RGB array





pins 0 to 9 drive anodes of each segment

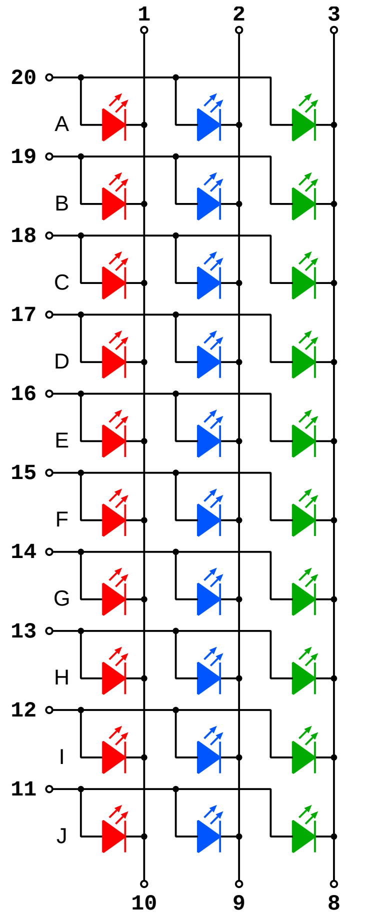
pins 10 to 12 drive cathodes of each colour

3 $\times$ series resistors limit current

- $\approx$ 10 mA per colour
- $\approx$ 30 mA total current with all LEDs lit

configuring LED pins

```
void setup() {
  // SEGMENTS                          disable
  pinMode( 0, OUTPUT);  digitalWrite( 0,  LOW);   // A
  pinMode( 1, OUTPUT);  digitalWrite( 1,  LOW);   // B
  pinMode( 2, OUTPUT);  digitalWrite( 2,  LOW);   // C
  pinMode( 3, OUTPUT);  digitalWrite( 3,  LOW);   // D
  pinMode( 4, OUTPUT);  digitalWrite( 4,  LOW);   // E
  pinMode( 5, OUTPUT);  digitalWrite( 5,  LOW);   // F
  pinMode( 6, OUTPUT);  digitalWrite( 6,  LOW);   // G
  pinMode( 7, OUTPUT);  digitalWrite( 7,  LOW);   // H
  pinMode( 8, OUTPUT);  digitalWrite( 8,  LOW);   // I
  pinMode( 9, OUTPUT);  digitalWrite( 9,  LOW);   // J
  // R/G/B                             disable
  pinMode(10, OUTPUT);  digitalWrite(10, HIGH);   // R
  pinMode(11, OUTPUT);  digitalWrite(11, HIGH);   // B
  pinMode(12, OUTPUT);  digitalWrite(12, HIGH);   // G
}
```



all LEDs are initially *reverse biased*

to turn on a given LED both its anode *and* cathode voltages must be reversed

selecting individual LEDs

```
//                    0...9  0bxxxxxBGR
void setLED(int segment, int colour)
{
  // SEGMENT enabled when pin is HIGH
  if (0 == colour)                      // black
    digitalWrite(segment, LOW);   // => completely disable segment
  else
    digitalWrite(segment, HIGH); // enable segment

  // R/G/B enabled when pin is LOW
  if (0 == (colour & 0b001)) digitalWrite(10, HIGH);   // red off
  else                       digitalWrite(10,  LOW);   // red on

  if (0 == (colour & 0b010)) digitalWrite(12, HIGH);   // green off
  else                       digitalWrite(12,  LOW);   // green on

  if (0 == (colour & 0b100)) digitalWrite(11, HIGH);   // blue off
  else                       digitalWrite(11,  LOW);   // blue on
}
```

displaying different colours on different segments

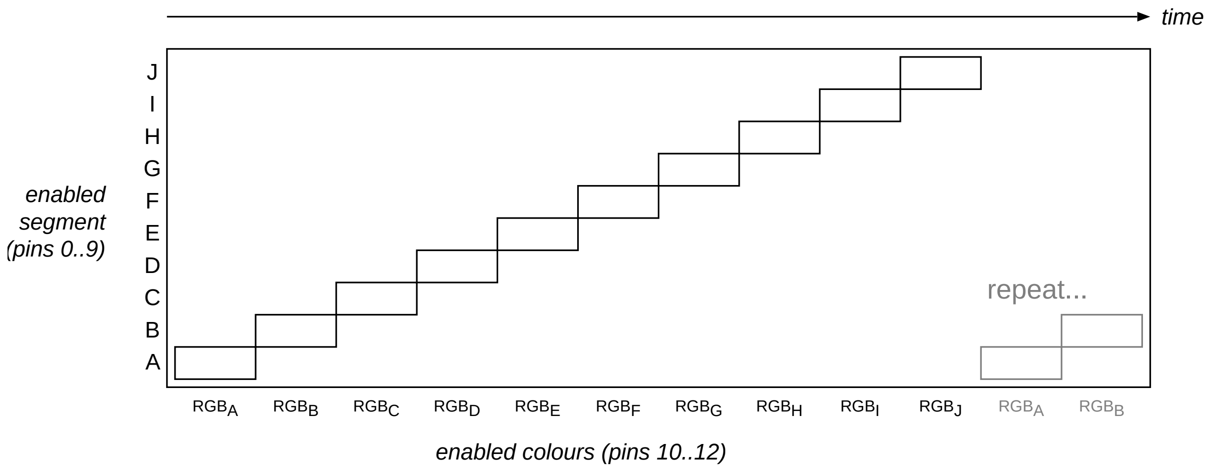
segments and colours ‘interfere’ with each other

- all colours that are enabled will affect all segments that are enabled

to display different colours on different segments

- enable one segment and enable just its colours
- repeat for all segments

allowing for all ten segments to have ten different colours leads to this pattern



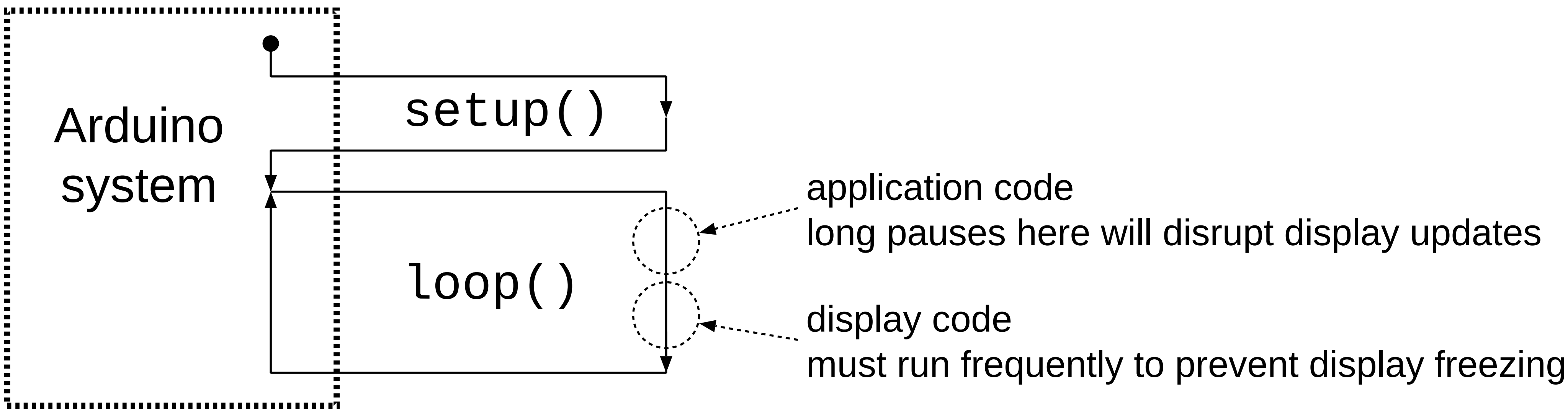
this is a very powerful technique in communication called *time-division multiplexing*

- 10 $\times$ different RGB_x values sent over one connection using 10 divisions of time
- the segment pins (0..9) are a kind of ‘clock’ saying which division is being sent

interrupts

updating segments using time-division multiplexing relies on persistence of vision

- a long pause in the updates will ‘freeze’ the LEDs with one or zero segments lit
- the application code can introduce pauses unpredictably
  - by using `delay()`
  - by waiting for serial communication
  - etc.
- putting application code and LED updates in the same `loop()` is not reliable



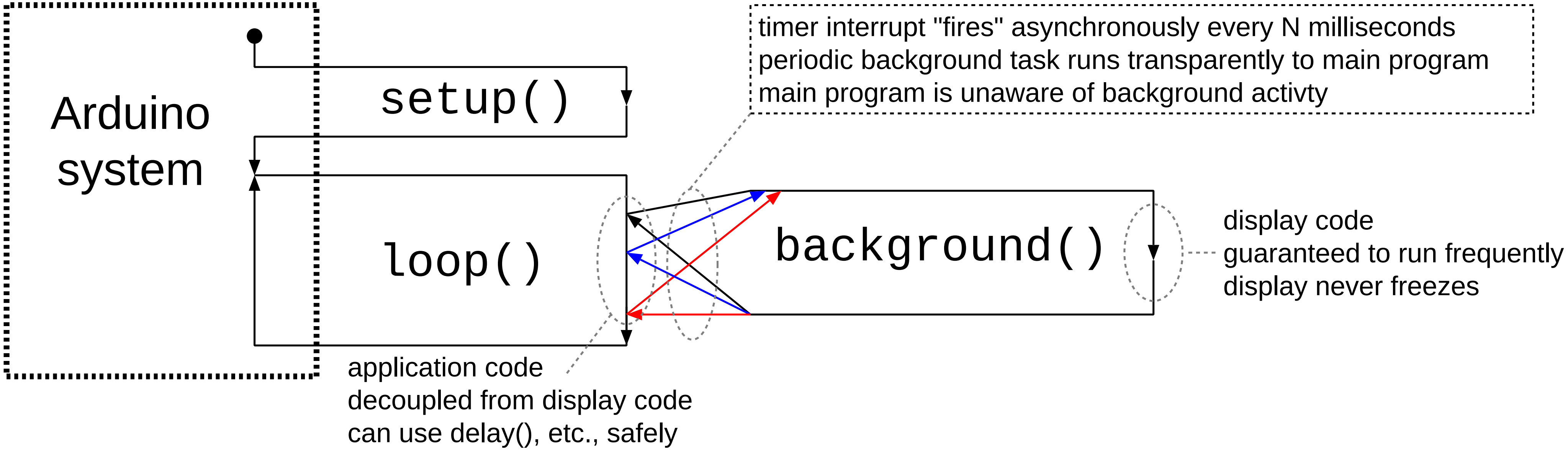
interrupts

an interrupt

- temporarily diverts the microcontroller from its normal task
- a 'background' task can then be performed
- when finished, the main task resumes as if nothing had happened

if the interrupt is attached to a regular timer

- the background task is performed regularly, decoupled from the normal task
- almost as if there were two `loop()`s running concurrently



using timer interrupts

```
#include <TimerOne.h>

void setup(void) {
  Timer1.initialize(period);            // in microseconds
  Timer1.attachInterrupt(handler);     // the name of a function
}

void handler(void) {
  // this function is executed asynchronously
  // every period microseconds
  // to perform background tasks
  // e.g., updating a multiplexed display
}

void loop(void) {
  // application code performs a foreground task
  // and can be written as if
  // the background task did not exist
}
```