Introduction to Design (2)

Microcontrollers and Interfacing

Week 07

Managing multiple outputs

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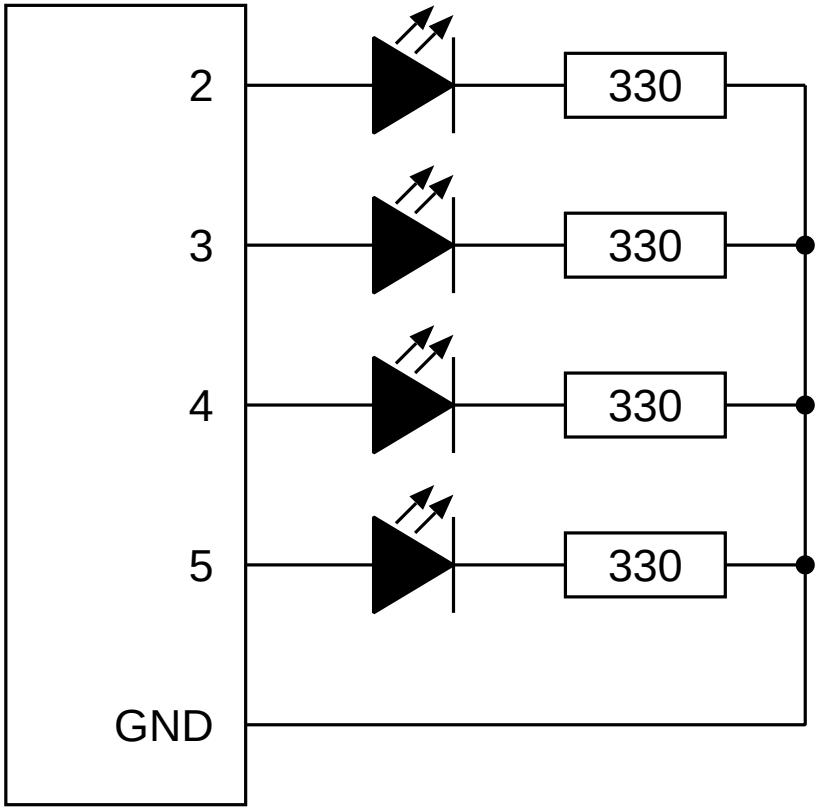
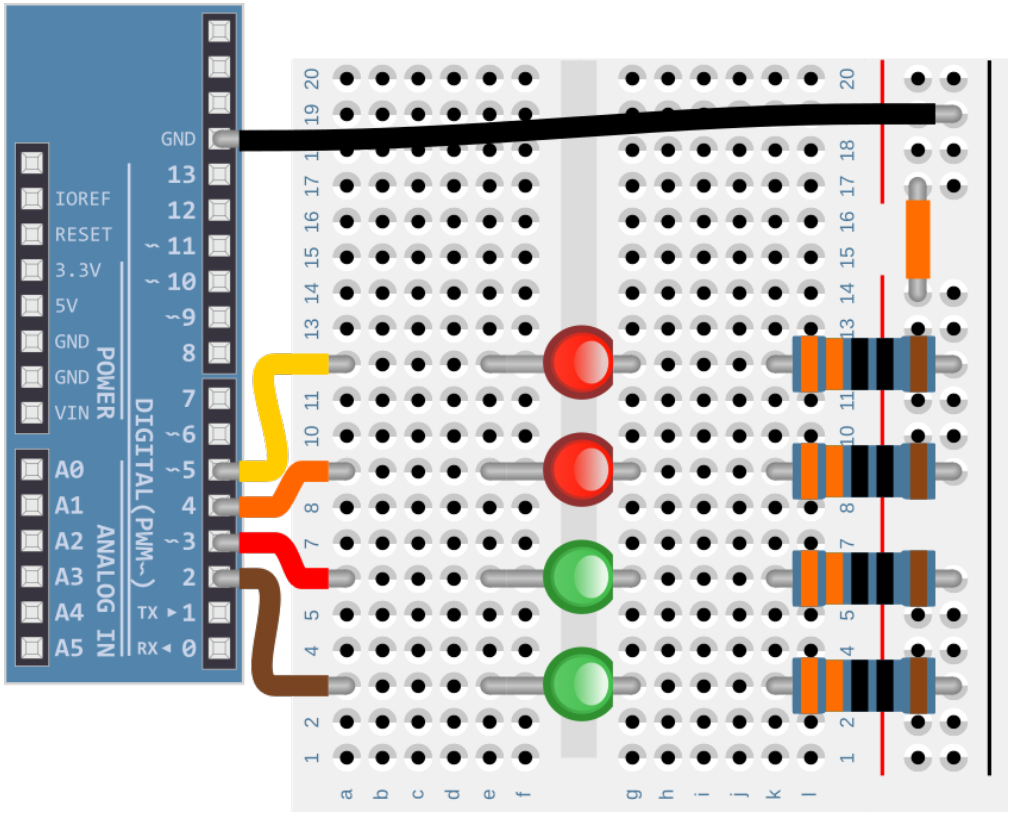
connecting several leds





connect up to 20 LEDs (or other digital devices)

- pins 0 to 13 give 14 outputs, plus six analogue pins can be digital outputs too
- beware of pins 0 and 1, which are used for serial communication
- pins 2–13 are therefore recommended for digital outputs

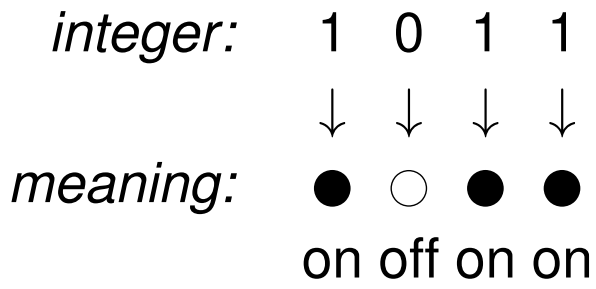
represent all LED states as a single integer

writing one output at a time is tedious

- desired effect is buried inside lots of `digitalWite()`s

why not use an `int` to represent many LED states?

- one integer is made of many digits
- use each digit to store the state of one LED



each LED only has two states: on or off

- only need two digits, e.g., `0` and `1`
- can use binary (base 2) instead of decimal (base 10)
- binary is how the computer stores integers internally

decimal and binary numbers

decimal numbers (base 10)

- the rightmost column has weight $10^0 = 1$ (‘units’ column)
- weight increases $10\times$ per column towards the left

	10^3		10^2		10^1		10^0	
	1000		100		10		1	
	$\times$		$\times$		$\times$		$\times$	
1011_{10} =	1	+	0	+	10	+	1	
↑ ↑	1000	+	0	+	10	+	1	= 1011

digits *base*

binary numbers (base 2)

- the rightmost column has weight $2^0 = 1$ (‘units’ column)
- weight increases $2\times$ per column towards the left

	2^3		2^2		2^1		2^0	
	8		4		2		1	
	$\times$		$\times$		$\times$		$\times$	
1101_2 =	1	+	1	+	0	+	1	
	8	+	4	+	0	+	1	= 13

binary	*decimal*
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	10
1011	11
1100	12
1101	13
1110	14
1111	15

testing the bits in an integer

on our microcontroller, an `int`eger contains 16 binary digits (bits)

- an `int` can represent the state of up to 16 digital outputs

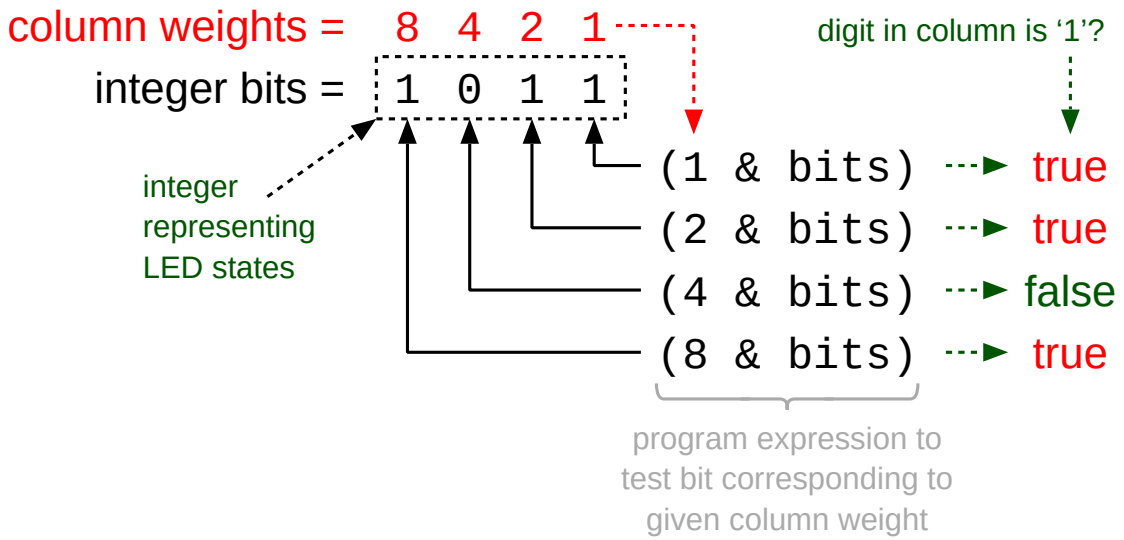
each bit in the integer corresponds to one output pin

- its value is either `0` or `1`

the bits (digit columns) in the integer have power-of-two weights

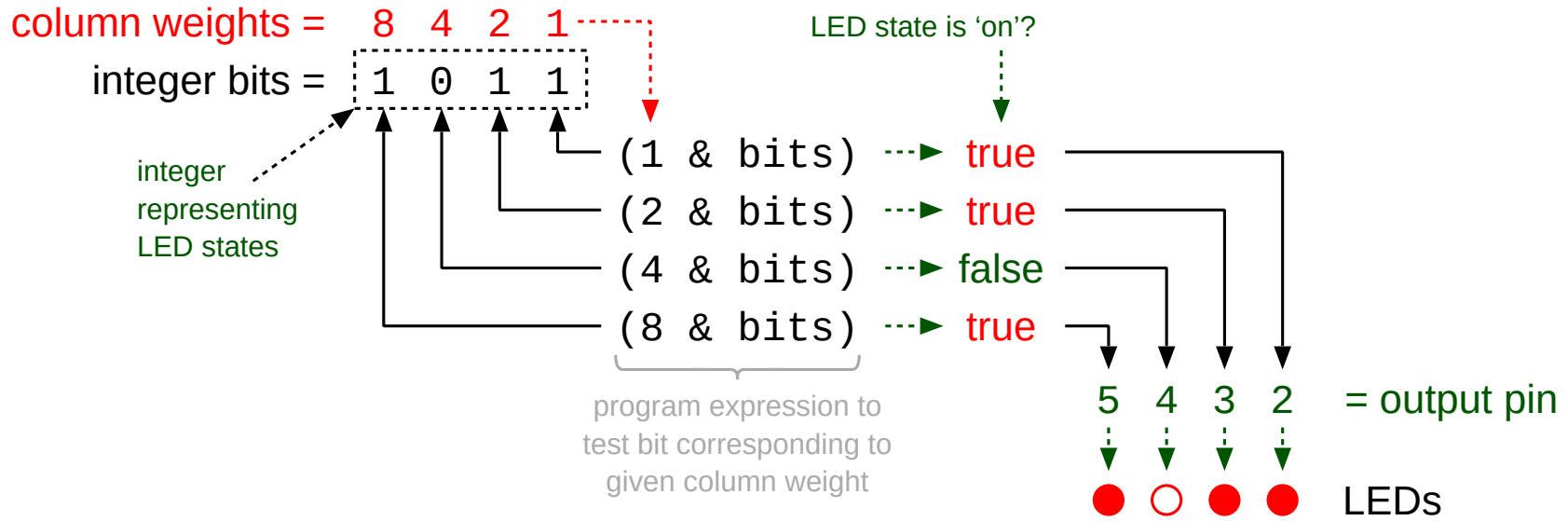
- 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768

use the `&` (‘and’) operator with a column weight to test if the corresponding bit is `1`



setting LEDs according to the bits in an integer

test each bit in an integer, set LED pin to HIGH or LOW accordingly




```
void setLEDs(int bits) {
  //          ⌜ bit weight     ⌜ corresponding output pin ⌝
  if (bits & 1) digitalWrite(2, HIGH); else digitalWrite(2, LOW);
  if (bits & 2) digitalWrite(3, HIGH); else digitalWrite(3, LOW);
  if (bits & 4) digitalWrite(4, HIGH); else digitalWrite(4, LOW);
  if (bits & 8) digitalWrite(5, HIGH); else digitalWrite(5, LOW);
  // similarly for column weights 16, 32, 64, 128, etc.
}
```

e.g: $12_{10} = 1100_2$ represents pins 5 and 4 being `HIGH`, and pins 3 and 2 being `LOW`