Arduino Programming Part 7: Flow charts and Top-down design

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Goals

Introduce flow charts

- A tool for developing algorithms
- A tool for documenting algorithms
- A visual method of communicating about any sequential or iterative process
- Great for visual learners!

Top-down design

- One technique for creating a plan for large, multi-step problems
- Not tied to flow charts, but can be used effectively with flow charts

Flow chart symbols

Terminator

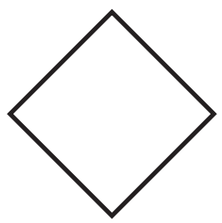
Start or stop a sequence.
May contain module name.

Process

A step in the process or
computational algorithm

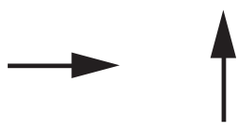
Data input

Information from outside of
the algorithm or process



Decision

Choose a flow path for continuing
the algorithm or process



Flow indicators

Connect other elements

Connector or Junction

Optional joint where flow
indicators merge

Exercise 1

Draw the flow chart to read and display the salinity value on the LCD monitor

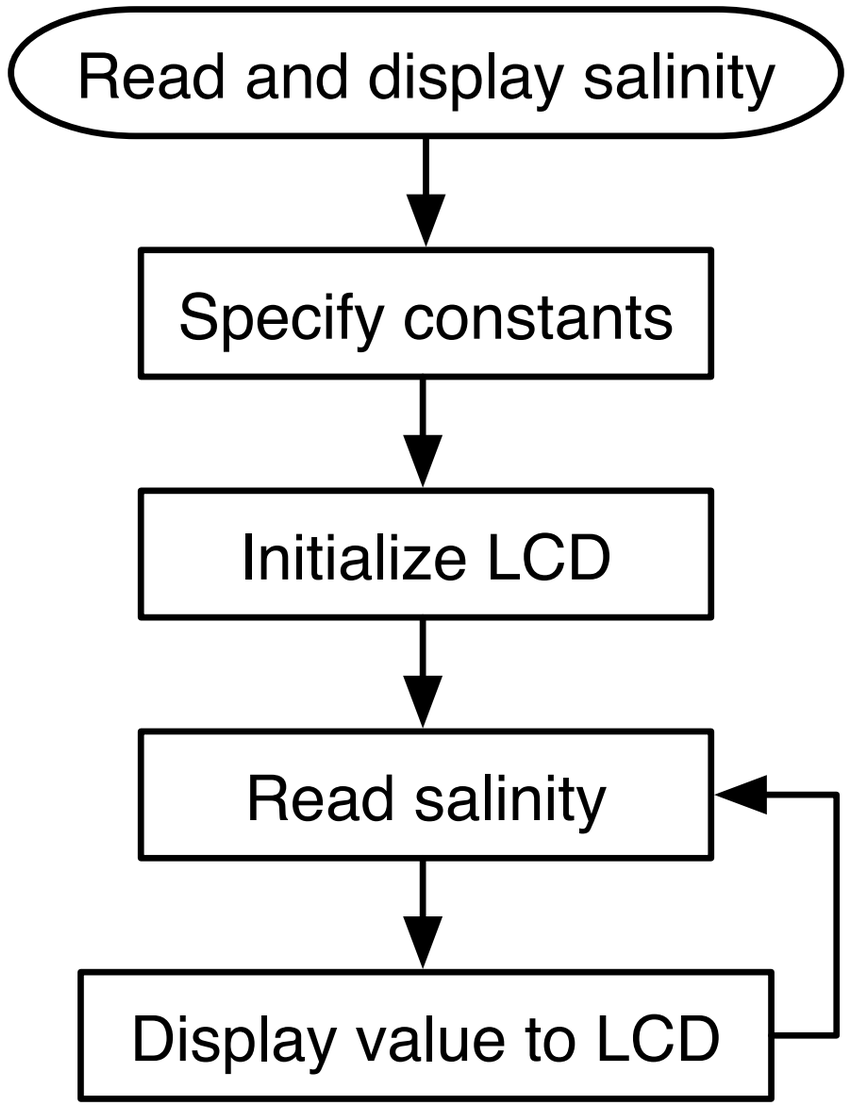
Keep it simple

- 5 or so symbols (not counting arrows)
- Describe only the high level actions

Exercise 1

Your answer goes here.

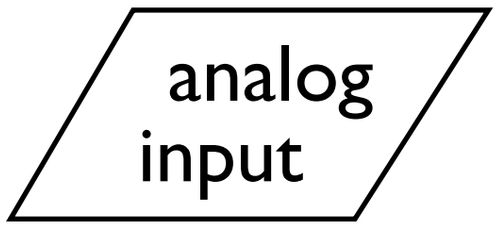
Exercise 1

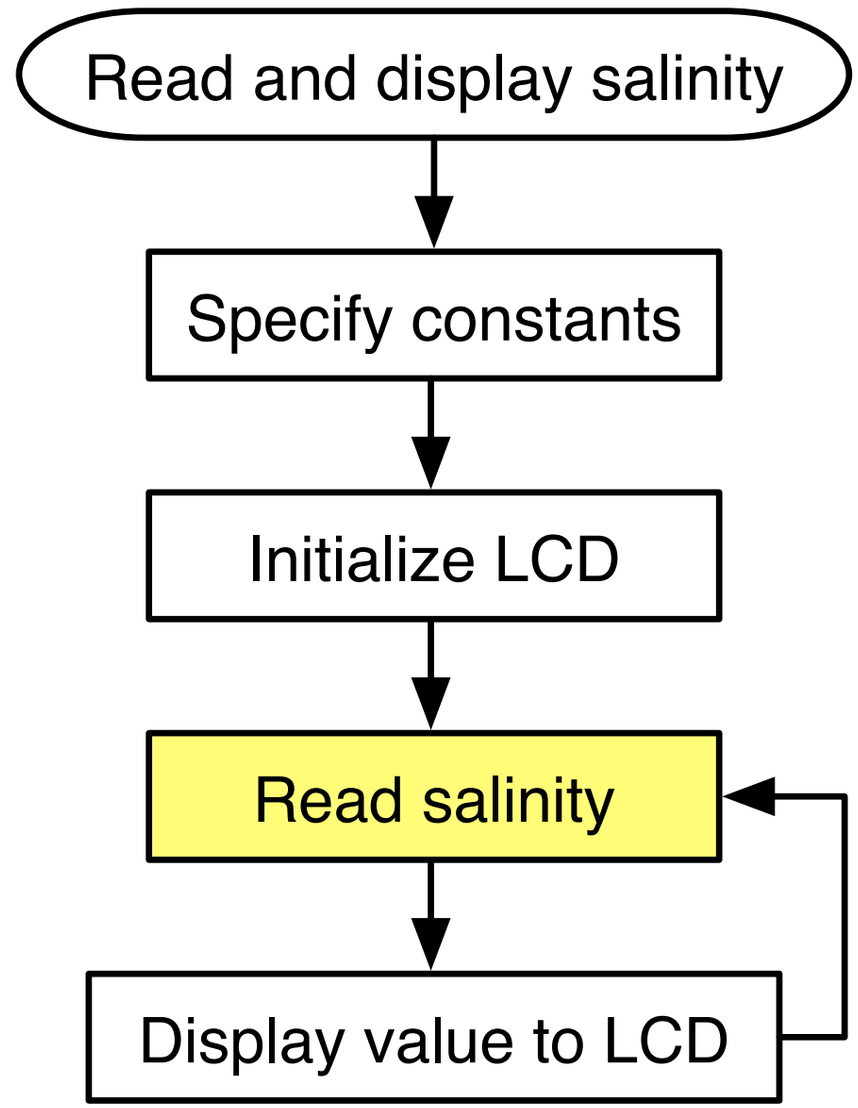

Read and display salinity
Specify constants
Initialize LCD
Read salinity
Display value to LCD

Exercise 2

Expand the "Read salinity" step in another flow chart

- Keep it simple
- "analog data" is an external input

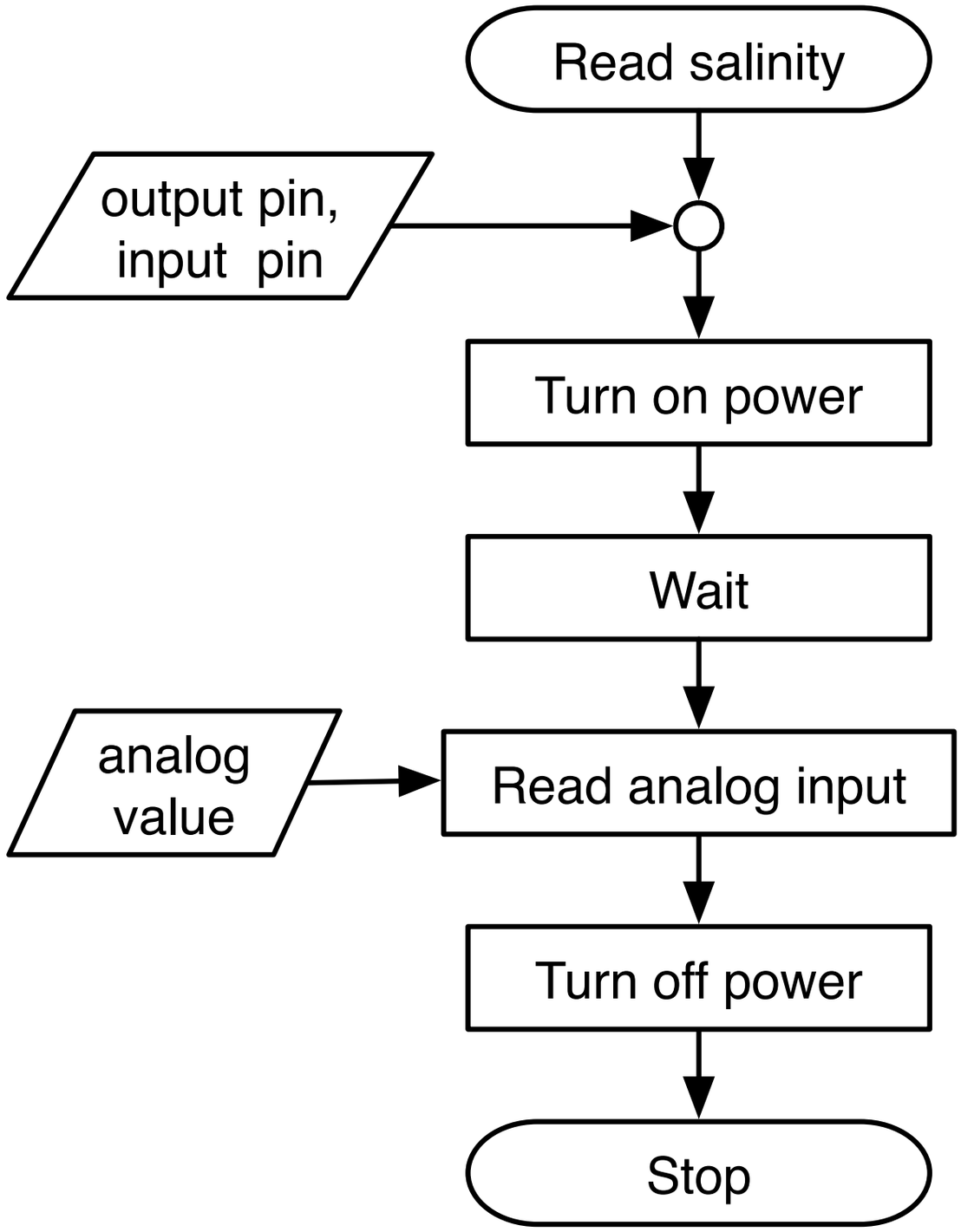




Exercise 2

Your answer goes here.

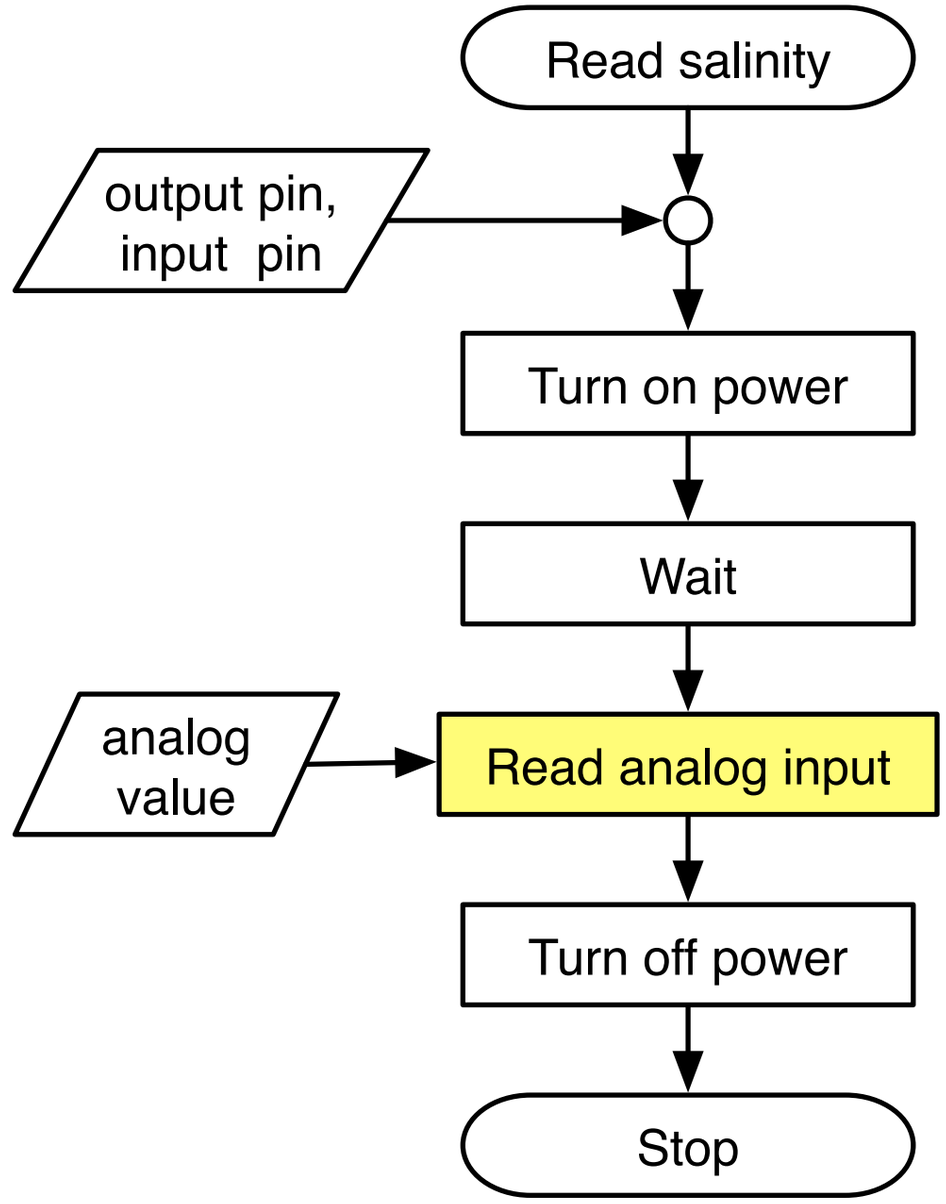
Exercise 2


Read salinity
output pin,
input pin
Turn on power
Wait
analog
value
Read analog input
Turn off power
Stop

Exercise 3

Expand the "Read analog input" step in another flow chart

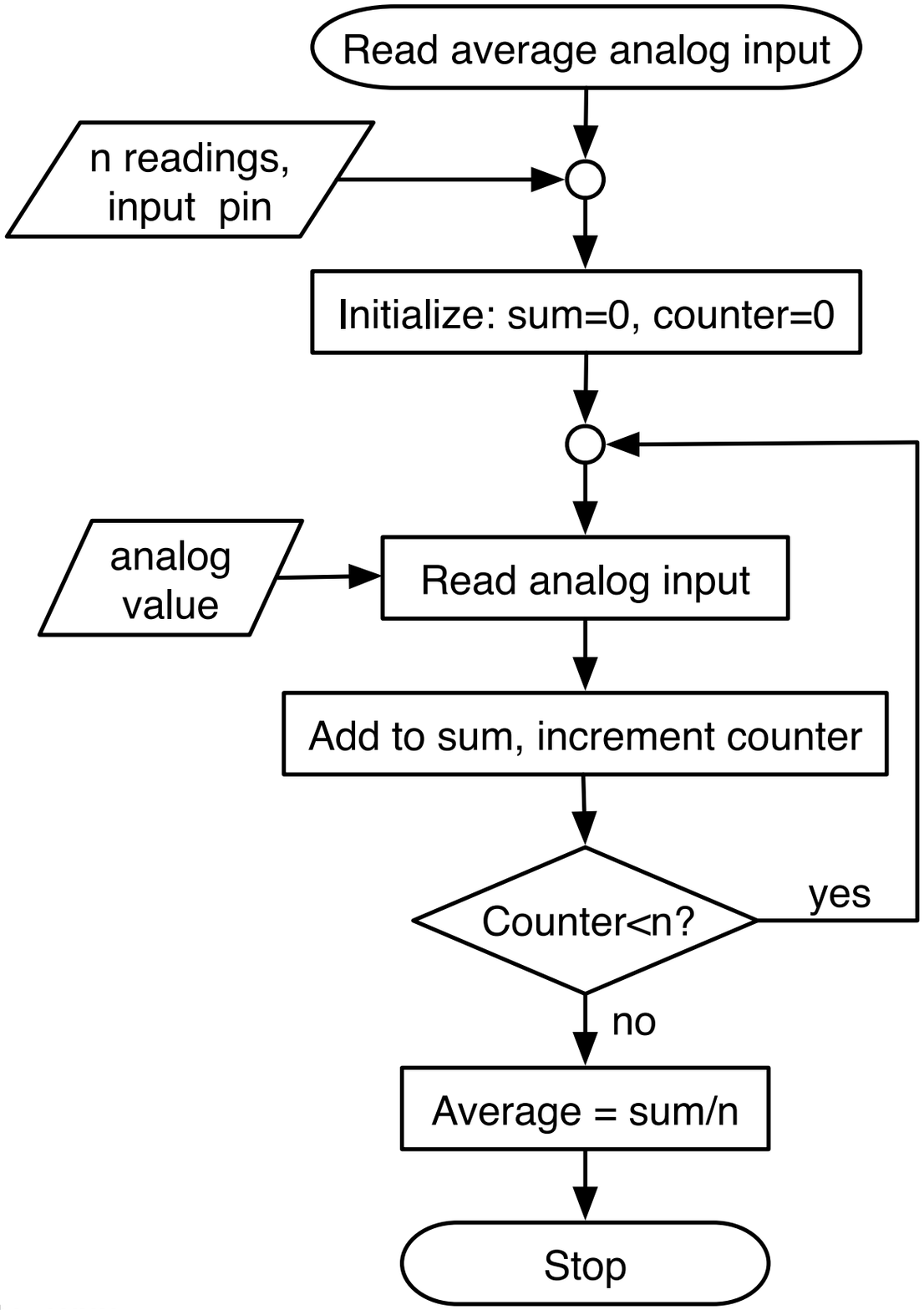
- Compute the average of n readings
- "analog data" is an external input



Exercise 3

Your answer goes here.

Exercise 3

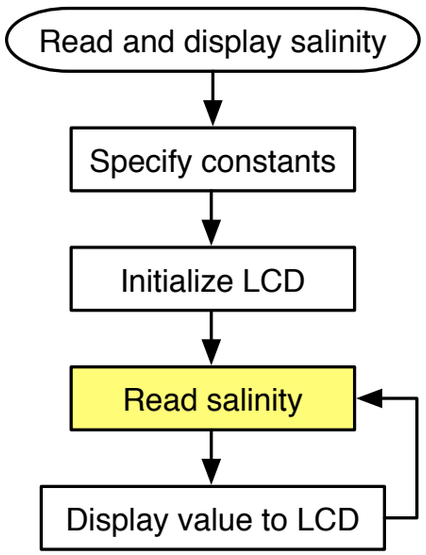

Read average analog input
n readings,
input pin
Initialize: sum=0, counter=0
analog
value
Read analog input
Add to sum, increment counter
Counter<n?
yes
no
Average = sum/n
Stop

Top-down design

1. Start with a general statement of the solution
   a. List the main steps
   b. Don't worry yet about details
2. Pick one of the steps
   a. Break this step into a manageable number of sub-steps
   b. Don't worry about too many of the details
   c. Apply step 2 to one of steps just generated

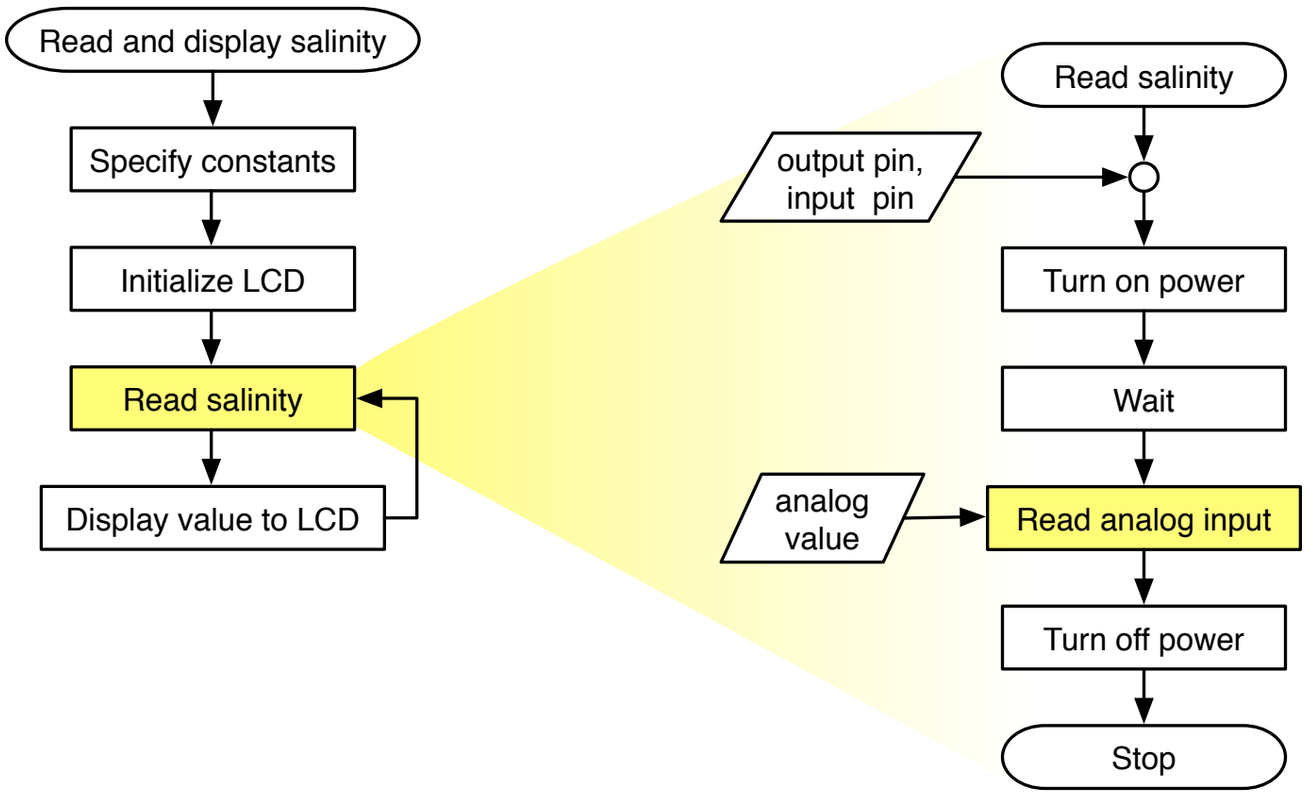
Top-down design

Recursive refinement: from general to specific



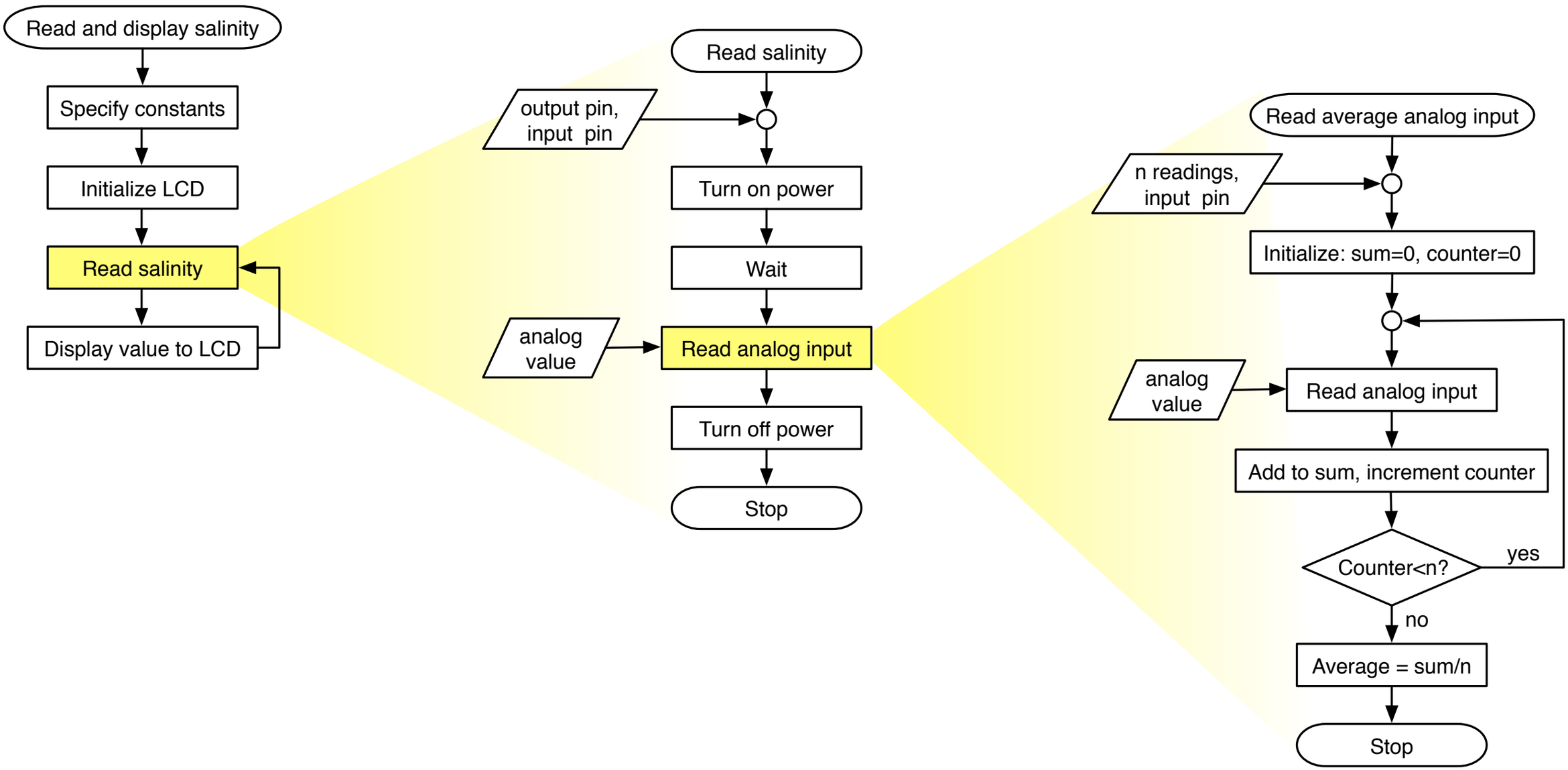
Top-down design

Recursive refinement: from general to specific



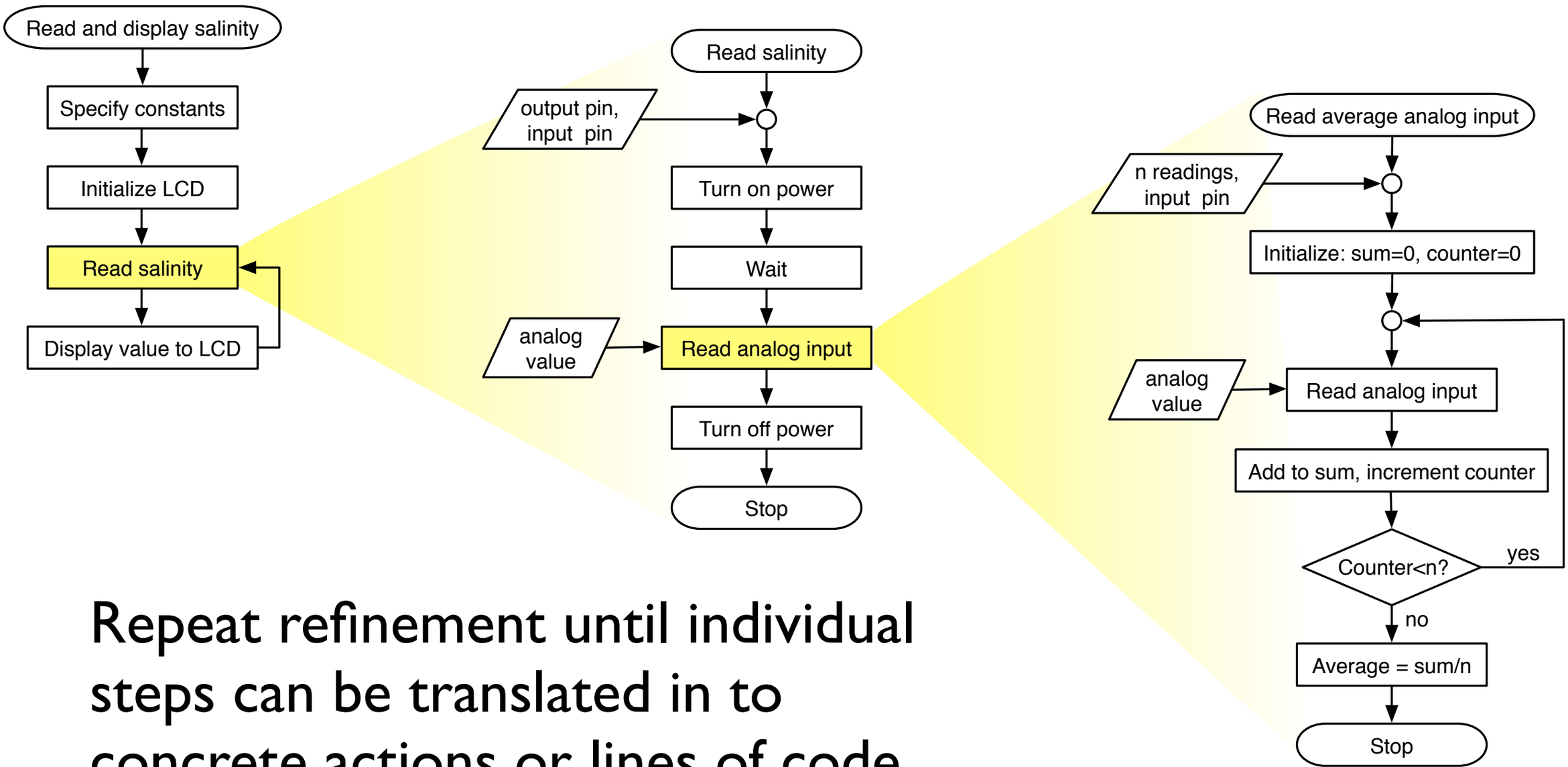
Top-down design

Recursive refinement: from general to specific



Top-down design

Recursive refinement: from general to specific



Repeat refinement until individual steps can be translated in to concrete actions or lines of code

Extending top-down design to salinity control of the fish tank

Main tasks

- Measure salinity
- Display salinity on the LCD panel
- Check: Are we in the deadtime?
  - If yes, skip to next loop iteration
  - If no, check for out of deadband condition
    - If salinity is above UCL, add fresh water
    - If salinity is below LCL, add salty water

Each of the tasks could (should!) be decomposed into smaller steps with a top-down design process

Core control algorithm

```
//  File:  wait_for_deadtime.ino
//
//  Structure of salinity control code to implement a deadtime during which
//  no salinity correction is made.  This code is incomplete and will not compile.

unsigned long last_salinity_update;  //  Time of last correction

void setup() {
  Serial.begin(9600);
  last_salinity_update = millis();   //  Initial value; change later
}

void loop() {
  float LCL, UCL, salinity;
  int deadtime = ... ;

  salinity = salinity_reading( ... );
  update_LCD( ... );

  // -- Check for deadtime
  if ( ( millis() - last_salinity_update ) > deadtime ) {

    if ( salinity>UCL ) {
      //  add DI water:  several missing steps
      last_salinity_update = millis();
    }

    if ( salinity<LCL ) {
      //  add salty water:  several missing steps
      last_salinity_update = millis();
    }
  }
}
```

Core control algorithm: managing deadtime

```
//  File:  wait_for_deadtime.ino
//
//  Structure of salinity control code to implement a deadtime during which
//  no salinity correction is made.  This code is incomplete and will not compile.

unsigned long last_salinity_update;

void setup() {
  Serial.begin(9600);
  last_salinity_update = millis();
}

void loop() {
  float LCL, UCL, salinity;
  int deadtime = ... ;

  salinity = salinity_reading( ... );
  update_LCD( ... );

  // -- Check for deadtime
  if ( ( millis() - last_salinity_update ) > deadtime ) {

    if ( salinity>UCL ) {
      //  add DI water:  several missing steps
      last_salinity_update = millis();
    }

    if ( salinity<LCL ) {
      //  add salty water:  several missing steps
      last_salinity_update = millis();
    }
  }
}
```

Global (and persistent) value to remember time of last change to the system

Set initial value. Update again later

Don't even consider making changes while we are in the deadtime. "In the deadtime" means "current time minus time of last system change" is greater than deadtime

Update the "time of last system change" every time the salinity is changed

Core control algorithm: task decomposition

```
//  File:  wait_for_deadtime.ino
//
//  Structure of salinity control code to implement a deadtime during which
//  no salinity correction is made.  This code is incomplete and will not compile.

unsigned long last_salinity_update;

void setup() {
  Serial.begin(9600);
  last_salinity_update = millis();
}

void loop() {
  float LCL, UCL, salinity;
  int deadtime = ... ;

  salinity = salinity_reading( ... );
  update_LCD( ... );

  // -- Check for deadtime
  if ( ( millis() - last_salinity_update ) > deadtime ) {

    if ( salinity>UCL ) {
      //  add DI water:  several missing steps
      last_salinity_update = millis();
    }

    if ( salinity<LCL ) {
      //  add salty water:  several missing steps
      last_salinity_update = millis();
    }
  }
}
```

1. Function to read salinity sensor and convert reading to mass fraction.

2. Function to update LCD

3. Function to determine size of the correction and open the valve. One function could handle both corrections if you design it to use the right input arguments

Recommendations

- Work in small increments
  - Identify a task, build the code to test that task independently of the entire control algorithm
- Write functions to do specific tasks
  - Read salinity sensor and convert to mass fraction
  - Update display
  - Determine size duration of valve opening, and open it
- Document your code as you write it
- Save backups of working code and testing codes
- Use Auto Format to clean up code