Lab 3: Sensing

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How does sensing work?

Sensor

analog

digital

Microcontroller and out

Physical process generates variation in

- Voltage
- Current
- Resistance

Process digital values, send over radio, output over serial or other interfaces

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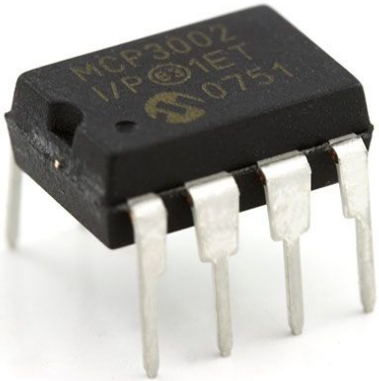
Sensor

analog

Analog to Digital converter (ADC)



digital

Microcontroller and out

Physical process generates variation in

- Voltage
- Current
- Resistance

Convert analog inputs to digital values

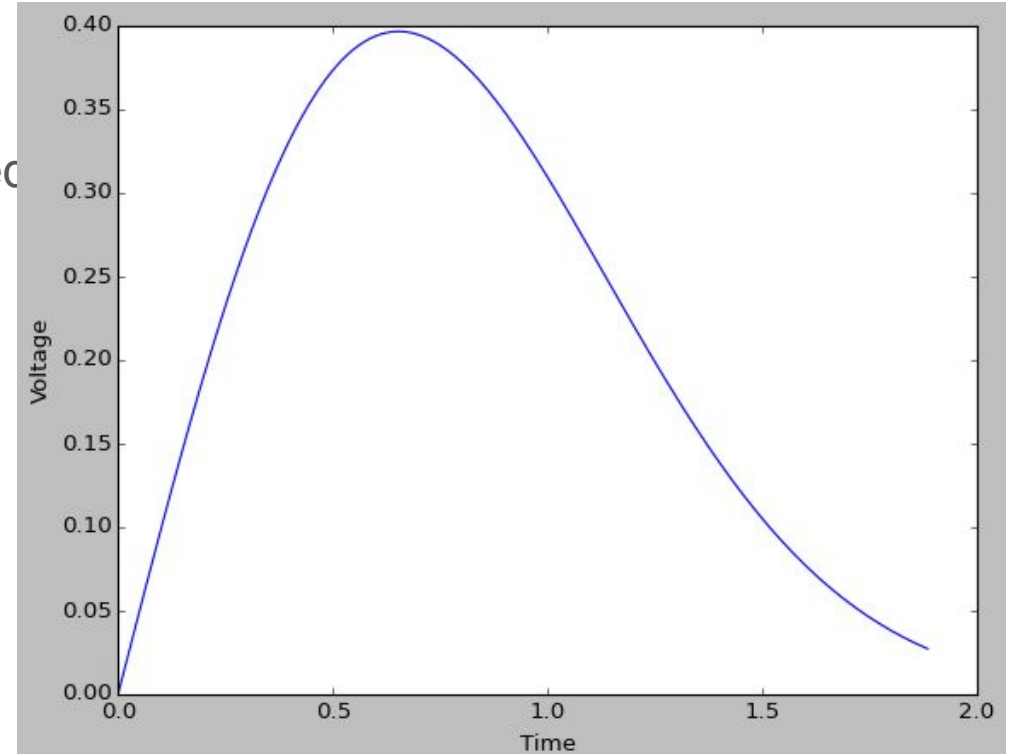
Process digital values, send over radio, output over serial or other interfaces

Usually part of the same package

A bit on ADCs

Sampling rate

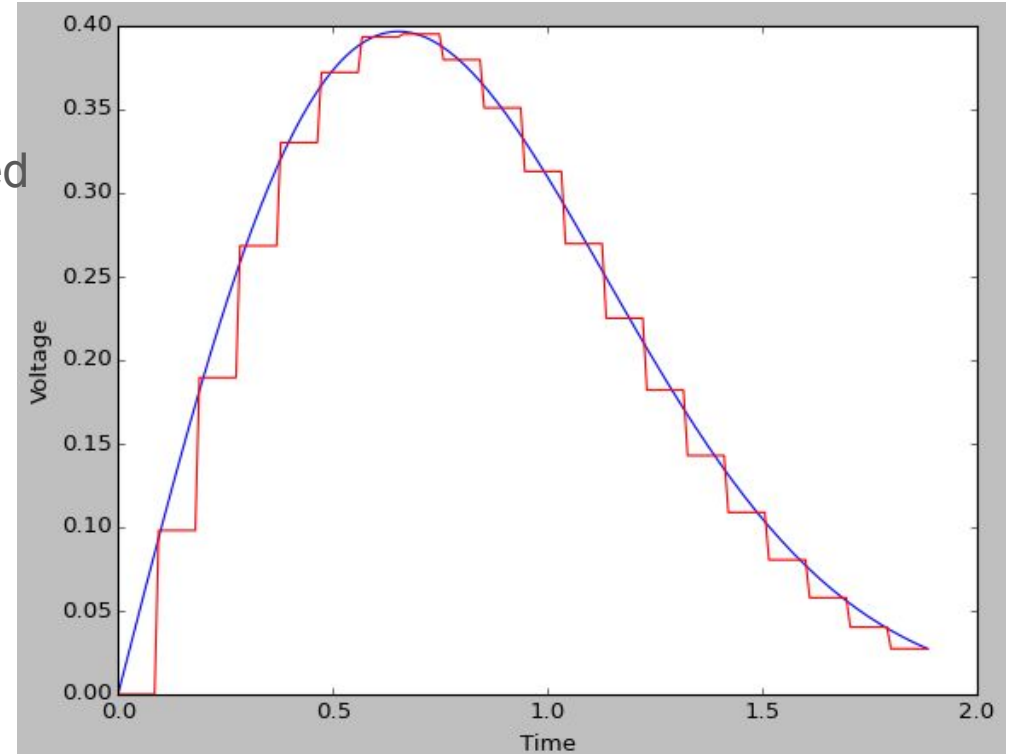
- How much information is captured



A bit on ADCs

Sampling rate

- How much information is captured
- Nyquist's theorem
  - Sample at 2x desired frequency



A bit on ADCs

Resolution

- Number of bits used for output
- Max input - reference voltage

Input max ----------> 11...11 (Output max)

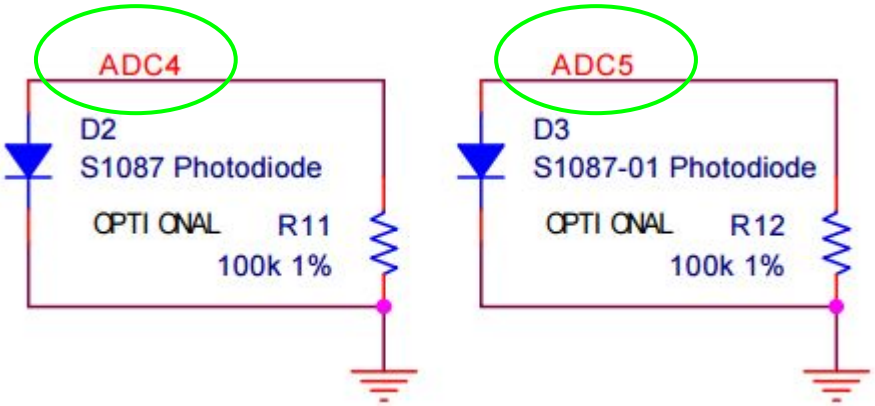
Input crt ----------> Output crt

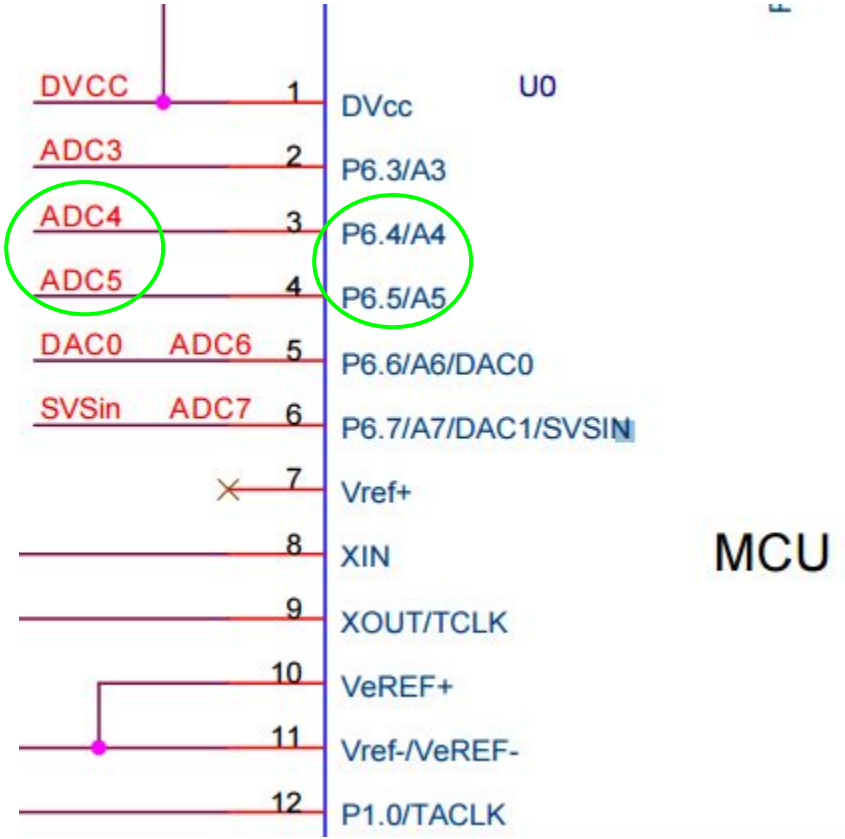
So: $\frac{In_{crt}}{In_{max}} = \frac{Out_{crt}}{Out_{max}}$, resolution is $\frac{Out_{max}}{In_{max}}$

So for every unit variation in input we have out_max/in_max change in output.

A bit on ADCs

- ADCs also have multiple input channels
- Can read things in parallel
- Must know to which channel the sensor is connected
  - Based on hardware design



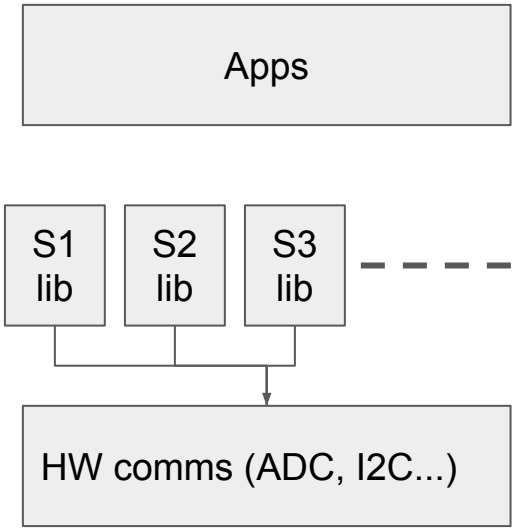


Sensing support from the OS

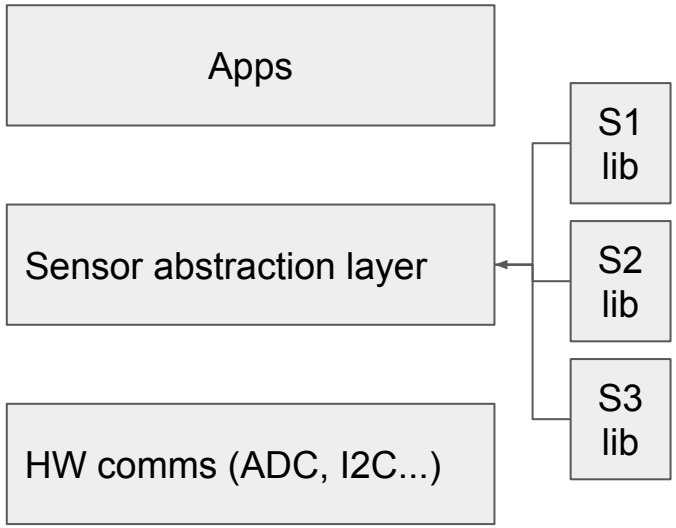
- Driver for the ADC
- Driver for the sensor
  - Which ADC channels it’s using
  - Access and timing information
  - Registers/commands to switch on/off state machines, etc
- Please note - there are sensors that don’t need ADC
  - Communicate over serial, I2C, SPI, etc

Sensing support from the OS

Option 1



Option 2



Contiki sensors

Contiki sensing infrastructure

Contiki sensing infrastructure

- core/lib/sensors.[ch]
- Sensors for tmote:
  - Light sensor: platform/sky/dev/light-sensor.[ch]
  - Temp-hum sensor: dev/sht11/
- Macros:
  - SENSORS_ACTIVATE(<sensor>)
  - SENSORS_DEACTIVATE(<sensor>)
- Functions:
  - <sensor>.value(<sub-sensor>)

Problem 1

- Periodically sample temperature (every 1s)
  - Remember the **etimer** and **ctimer** from last week
  - Temperature is provided by the SHT11 sensor - you need to find the name of that sensor
  - Sensor names are defined as “const struct sensors_sensor <name>”
    - Handy command line for searching for text in files:
    - grep <text> <path> will search for <text> in all the files in <path> NOT RECURSIVE
    - grep <text> -R <path> does the same but recursively
    - So, “grep <text> -R .” will search recursively in the current folder
- Average every 5 samples
  - If you want to use an array, use a static one, embedded development doesn’t like malloc
  - So, “int samples[5]; int crt_sample;” one variable to hold the current sample index
- If average is greater than a threshold, print “It sure is nice today!”

Processes and events

Contiki processes

- Declared with PROCESS(<handle>, <description string>)
- Start on boot by including in AUTOSTART_PROCESSES(<p1>, <p2>, …)
- Defined with PROCESS_THREAD(<handle>, <event>, <event_data>)

Contiki process management

```
PROCESS_BEGIN();
while (1) {
  ……
  PROCESS_YIELD();
  … …
}
PROCESS_END();
```

```
PROCESS_BEGIN();
while (1) {
  ……
  PROCESS_WAIT_EVENT();
  … …
}
PROCESS_END();
```

```
PROCESS_BEGIN();
while (1) {
  ……
PROCESS_WAIT_EVENT_UNTIL(...);
  … …
}
PROCESS_END();
```

process functions (PROCESS_THREAD…)

Contiki process management

Exit function for now,
until event happens

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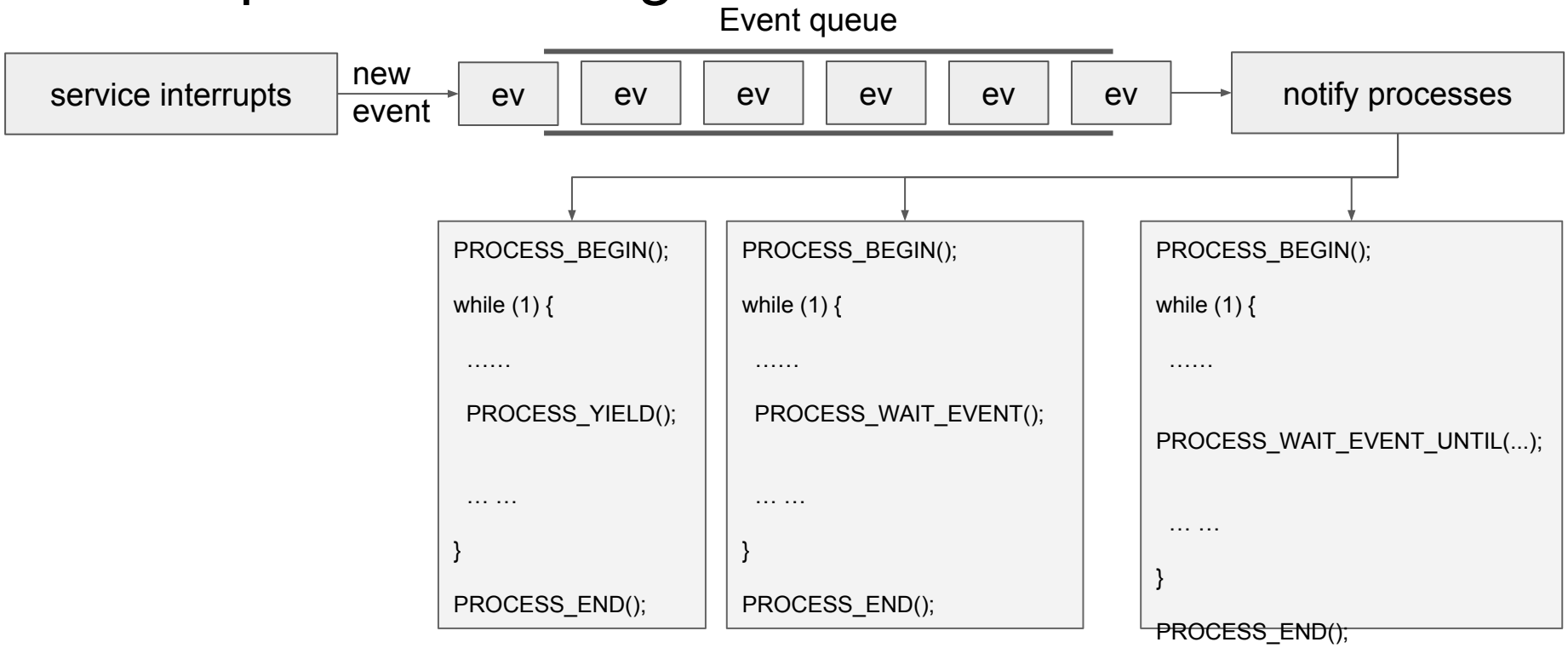

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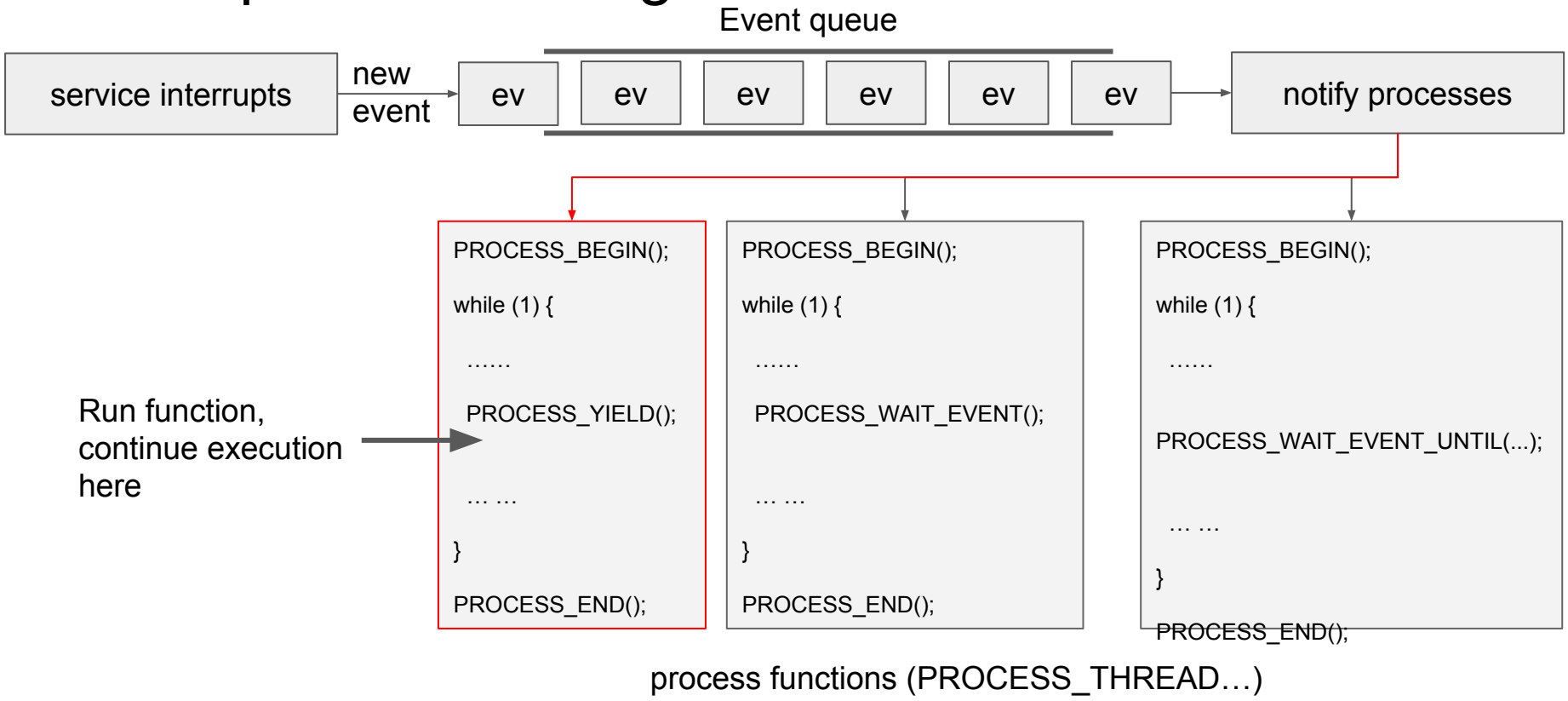

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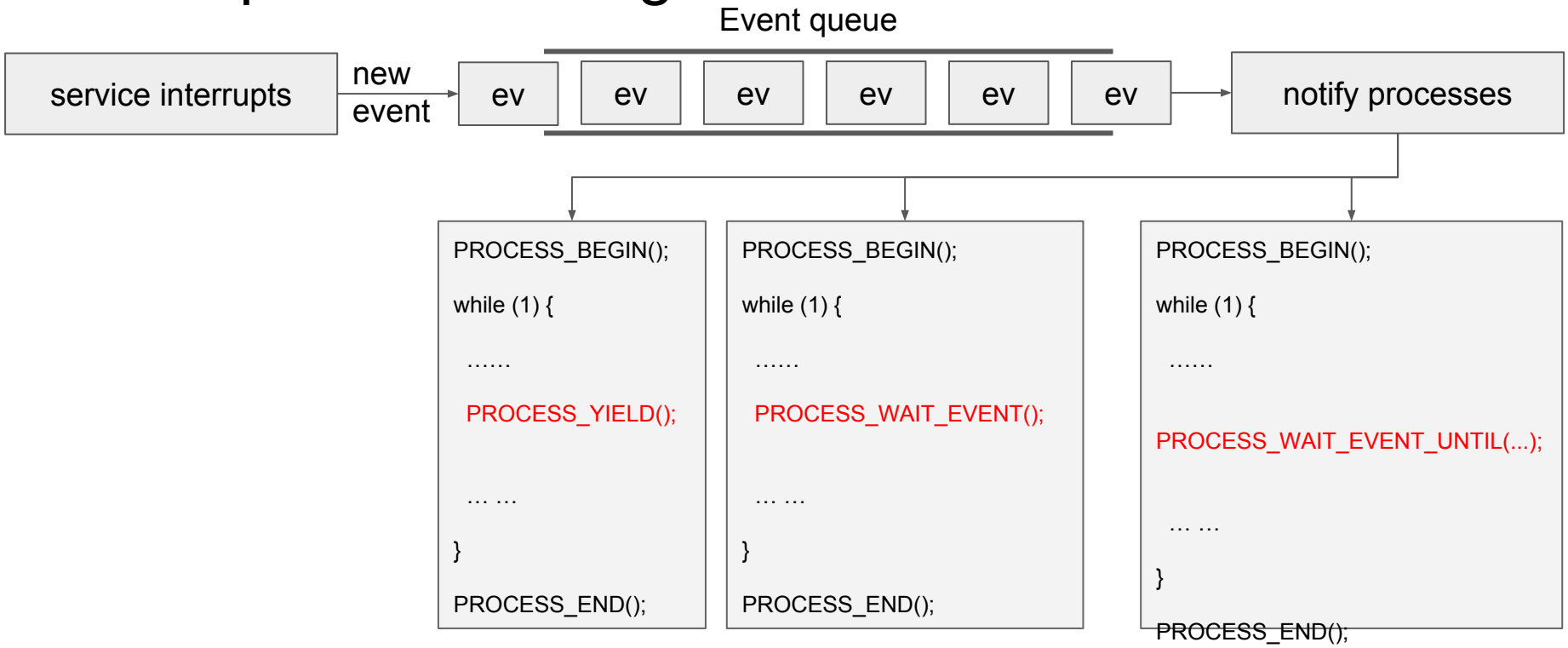

process functions (PROCESS_THREAD…)

Contiki process function (PROCESS_THREAD)

```
PROCESS_THREAD(handle, ev, data)
{
        // pre-begin work

        PROCESS_BEGIN();

        // pre-loop setup work

        while (1) { // or any other loop

                // in-loop setup

                PROCESS_YIELD(); // or similar

                // processing
        }
        PROCESS_END();
}
```

- Regular C function
- Initially called at boot time with null ev and data

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        PROCESS_BEGIN(); // switch(flag)

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  - Side-effect - can’t use switch inside while!
- pre-begin work is executed for every event received
  - Variables declared here: static, uninitialised

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- pre-loop setup is only executed on first run
  - Commonly used for initialisation
- execution continues here on new event

Creating and raising events

- We’ve seen: PROCESS_EVENT_TIMER, sensors_event
- Anyone can declare an event:
  - process_event_t <name of event>;
  - Then after PROCESS_BEGIN(), and before the while loop,
    - <name of event> = process_alloc_event();
- Why?
  - Custom events for inter-process communication
  - Example:
    - one process for churning data, one process for reporting it
    - Data process notifies reporting process when data is ready
- Event posting (sending events)
  - process_post(PROCESS_BROADCAST, <name of event>, <event data>)

Handling events

First of all - need to know about the event

- Usually define event (process_event_t…) in a header file that can be included by anyone interested

The PROCESS_THREAD function takes as parameters:

- event and event data (pointer to!)

After a PROCESS_YIELD, PROCESS_WAIT_EVENT, etc

- Check event type: if (ev == <name of shared event>) { // great, process data}

Problem 2: multiple processes

- Process 1 prints out “hello world” repeatedly
- Process 2 prints out “this is pseudo-multi-threading” repeatedly
  - Timers are not important

Instructions:

- Can have both processes in same file, or in separate files
- AUTOSTART_PROCESSES is important
- If you use two files
  - Makefile must be updated - specify both files
  - One process must declare its process in an include file for the other to access for AUTOSTART_PROCESSES
    - In the include file, use PROCESS_NAME(<name of process>)

Problem 3: inter-process communication

Problem 1 split over two processes: one for sensing, the other for printing.

- Process 1
  - Periodically senses temperature
  - Averages every 5 samples
  - Defines an event that indicates when an average is ready
  - After averaging, sends the event to Process 2, setting the data to the average
- Process 2
  - Waits for the event from process 1
  - Reads the data and prints it out

Can be done in a single file or separately

Additional info

- Tmote Sky HW datasheet and schematic:
  - http://www2.ece.ohio-state.edu/~bibyk/ee582/telosMote.pdf
- SHT11 datasheet, including formulas for converting ADC values to temp/hum
  - https://cdn.sparkfun.com/datasheets/Sensors/Pressure/Sensirion_Humidity_SHT1x_Datasheet_V5.pdf
- MSP430 (microcontroller on Tmote Sky) user guide
  - Pins, timers, adc, etc
  - In case you want to program the motes in assembly ;)
  - http://www.ti.com/lit/ug/slau049f/slau049f.pdf