OCAML MEETING 2011

PARIS, APRIL 15TH

OCAPIC

programming PIC microcontrollers using Objective Caml

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OCAPIC

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OCAPIC

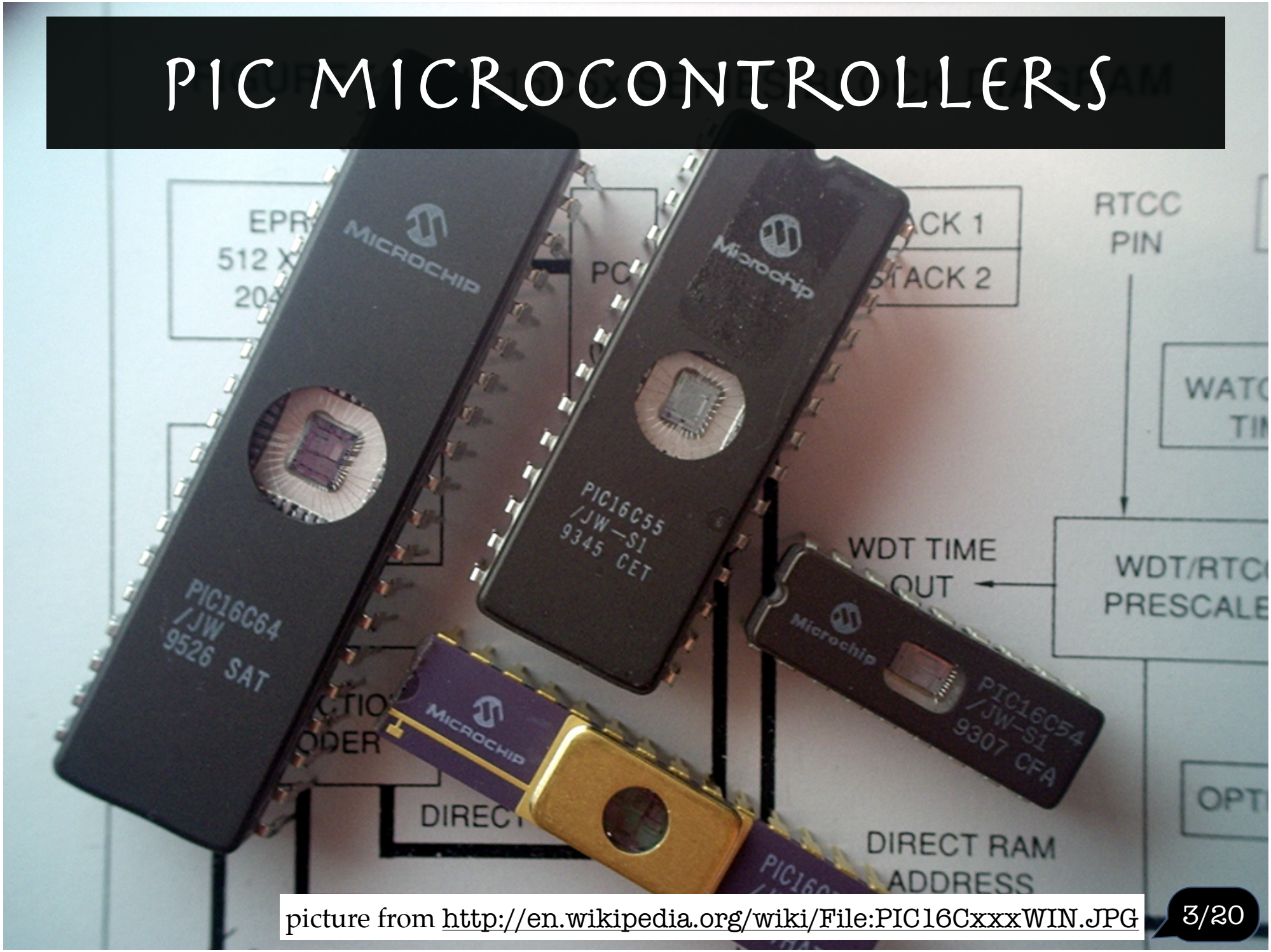
programming PIC microcontrollers
using Objective Caml

picture from http://fr.wikipedia.org/wiki/Fichier:4pics.jpg

OUTLINE

- What PIC microcontrollers (μC) are.
- What we did with a PIC18 μC.
- How we did it.
- What is OCaml in OCAPIC?
- Conclusion.

PIC MICROCONTROLLERS



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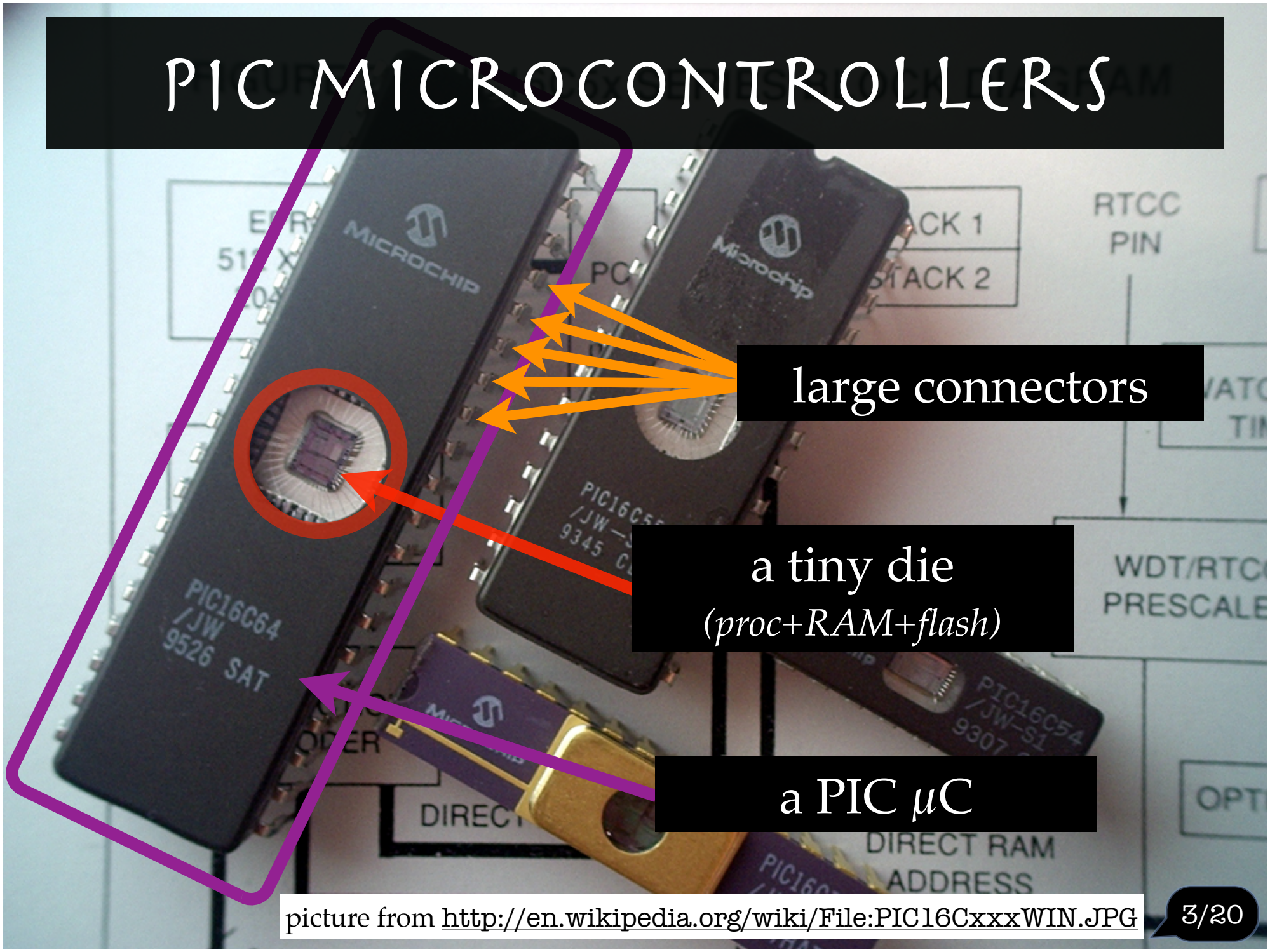

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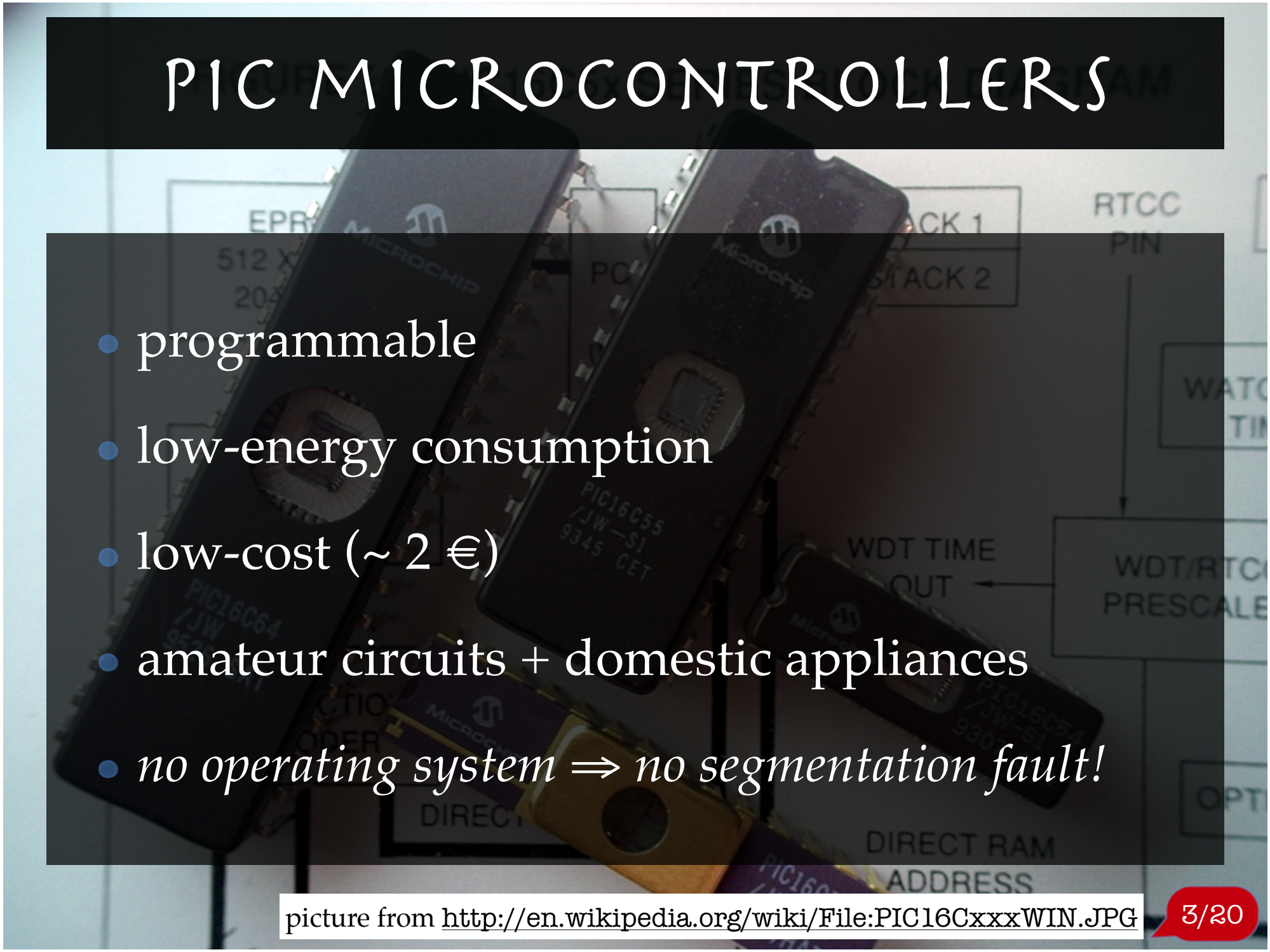
PIC MICROCONTROLLERS

- programmable
- low-energy consumption
- low-cost (~ 2 €)
- amateur circuits + domestic appliances
- *no operating system ⇒ no segmentation fault!*



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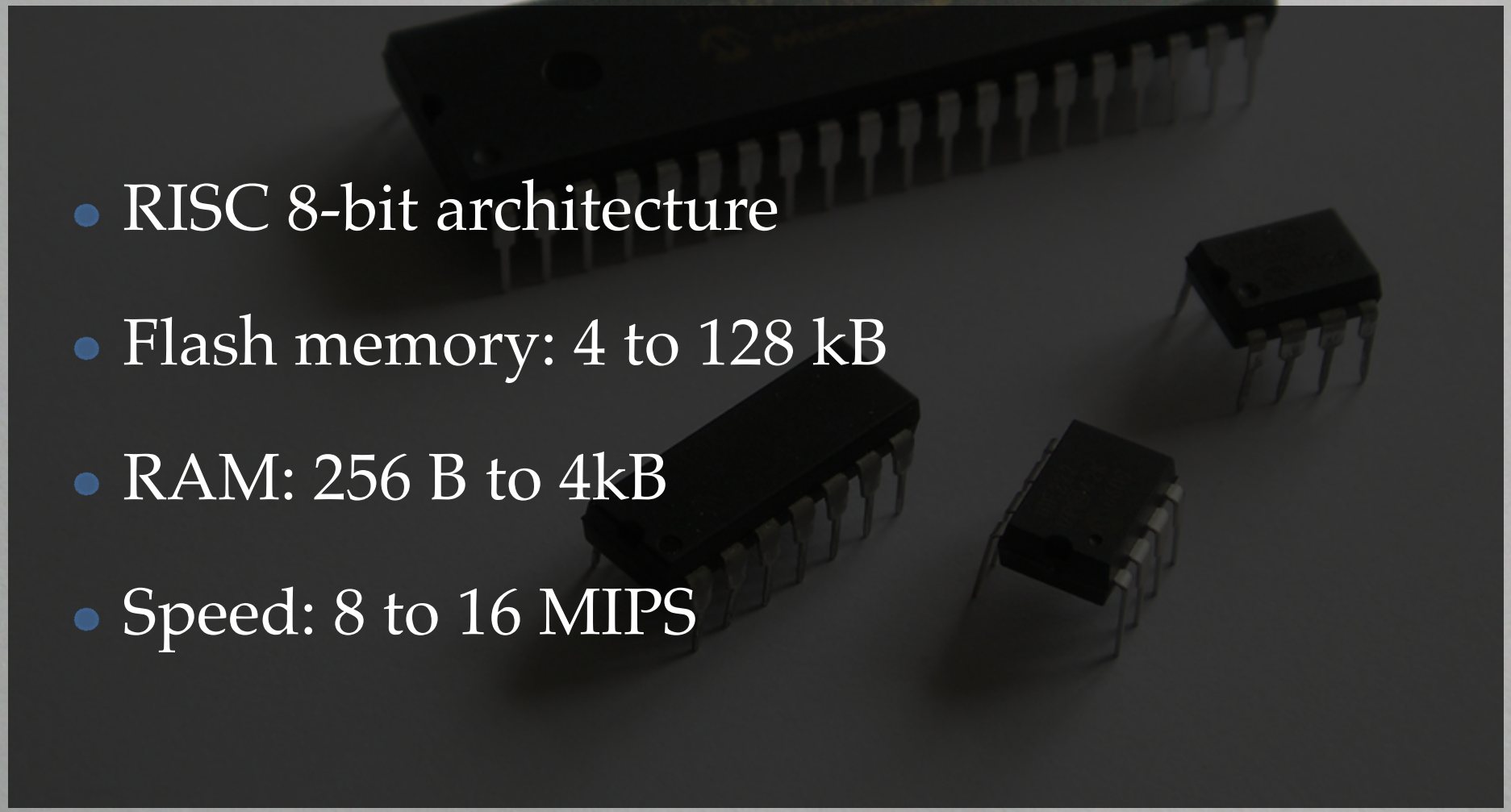
PIC18 MICROCONTROLLERS



- RISC 8-bit architecture
- Flash memory: 4 to 128 kB
- RAM: 256 B to 4kB
- Speed: 8 to 16 MIPS

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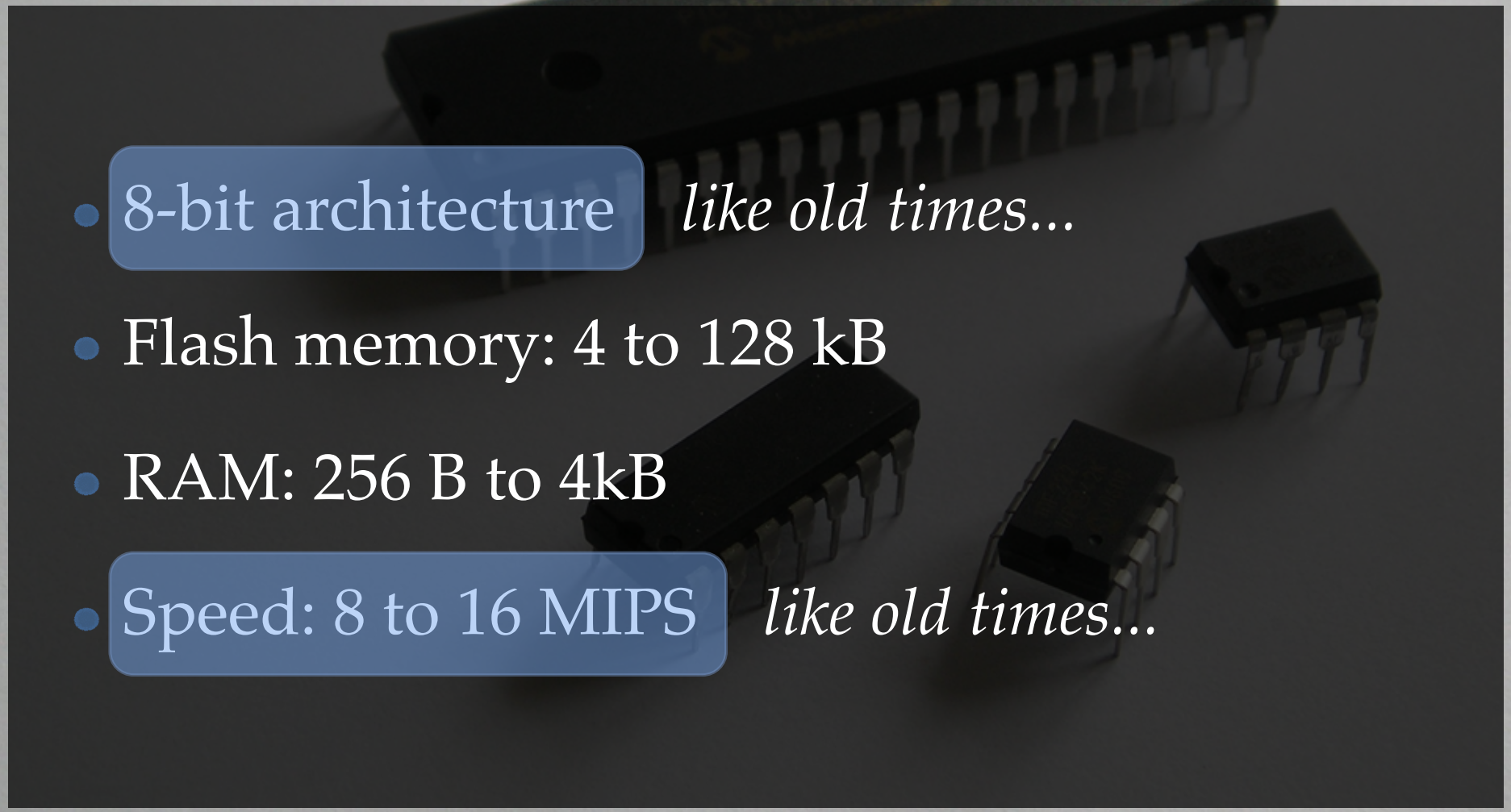
PIC18 MICROCONTROLLERS



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PIC18 MICROCONTROLLERS

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- Flash memory: 4 to 128 kB *stores the program*
- RAM: 256 B to 4kB ***wow... that's tight !***
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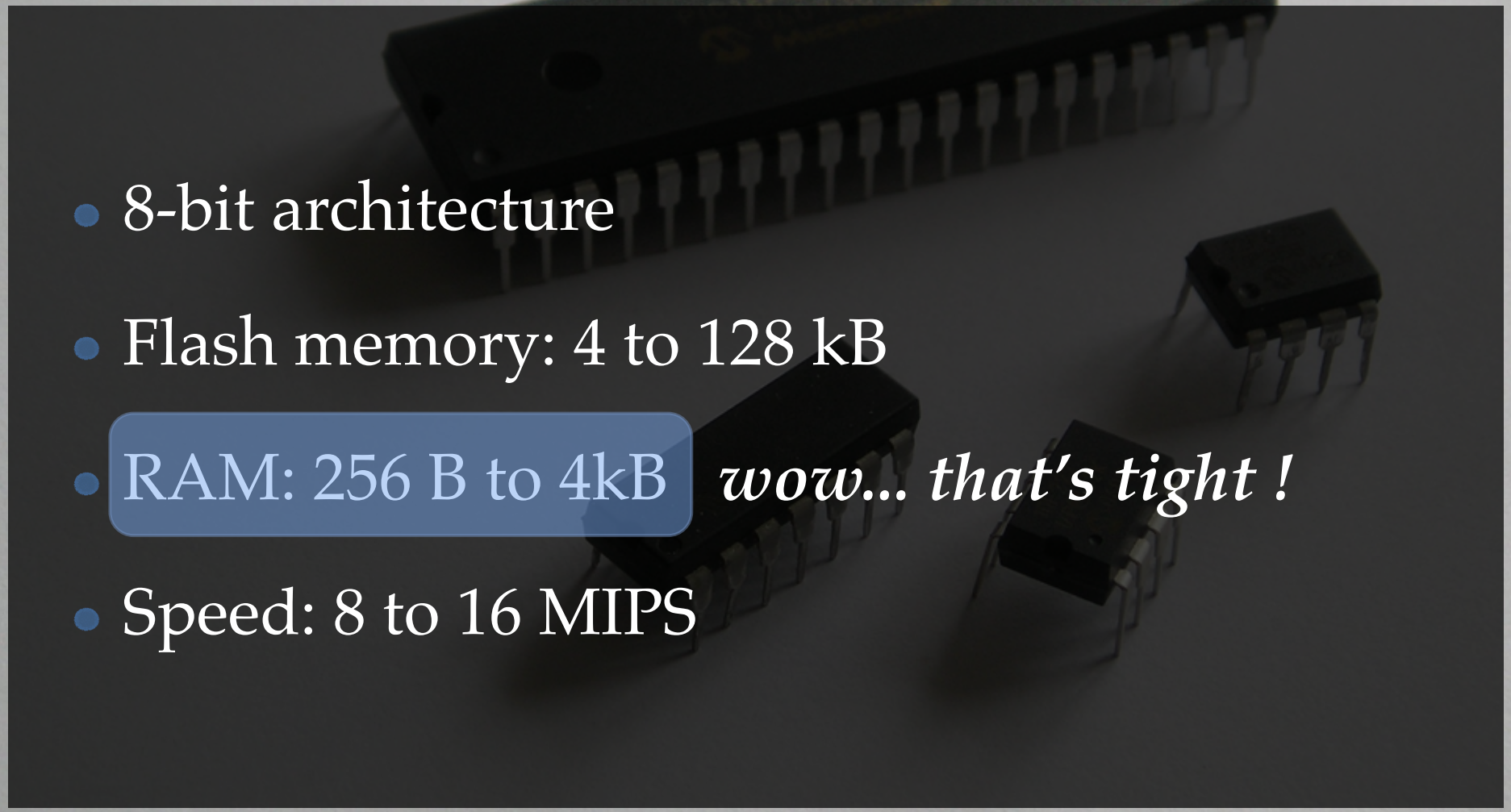
PIC18 MICROCONTROLLERS



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APP EXAMPLE

picture taken at JFLA 2011

APP EXAMPLE

- a 2-player strategy game
- human *versus* computer

- a board with 24 push-buttons + wiring
- an LCD display + a PIC18 μC + a battery

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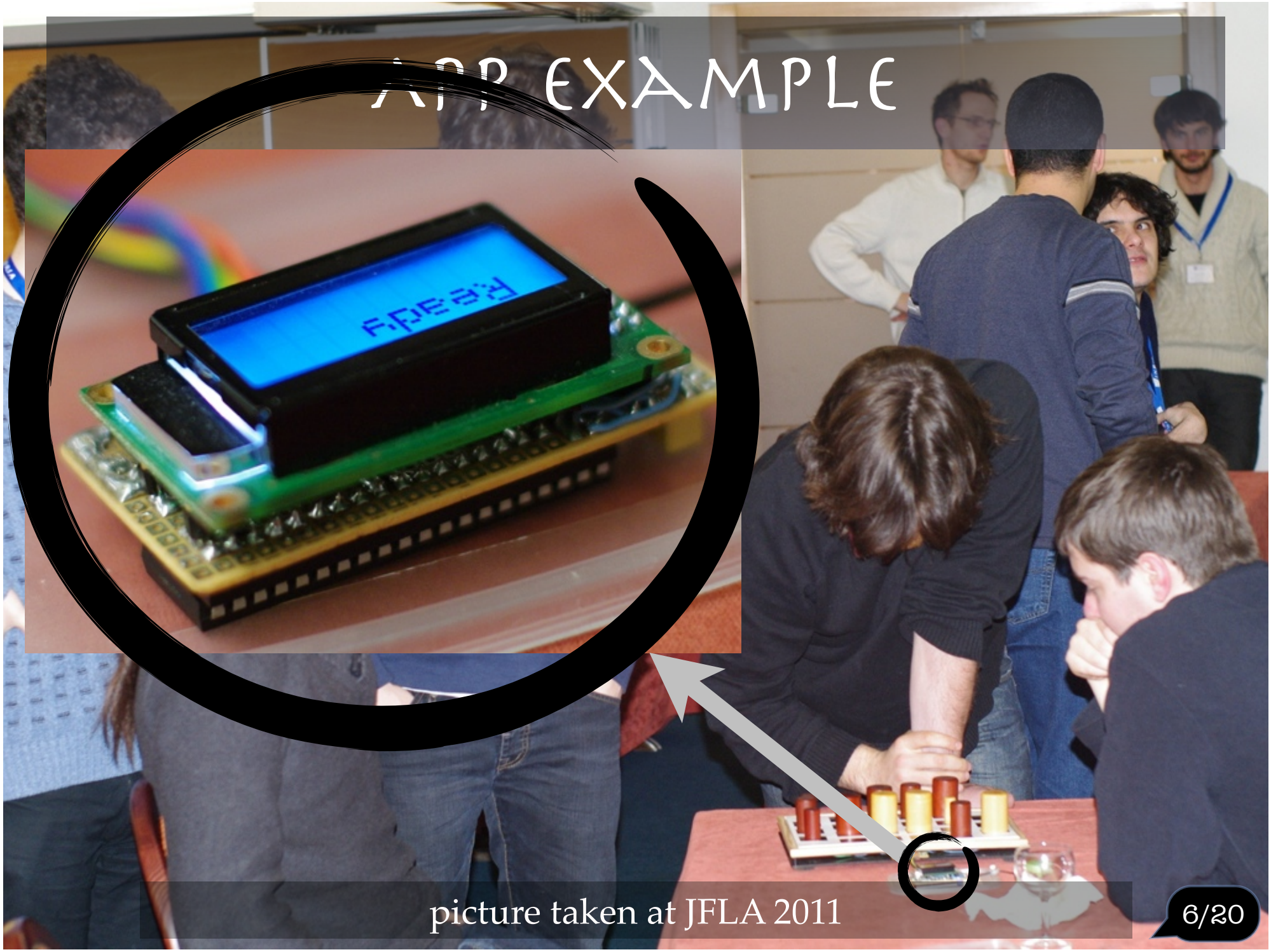

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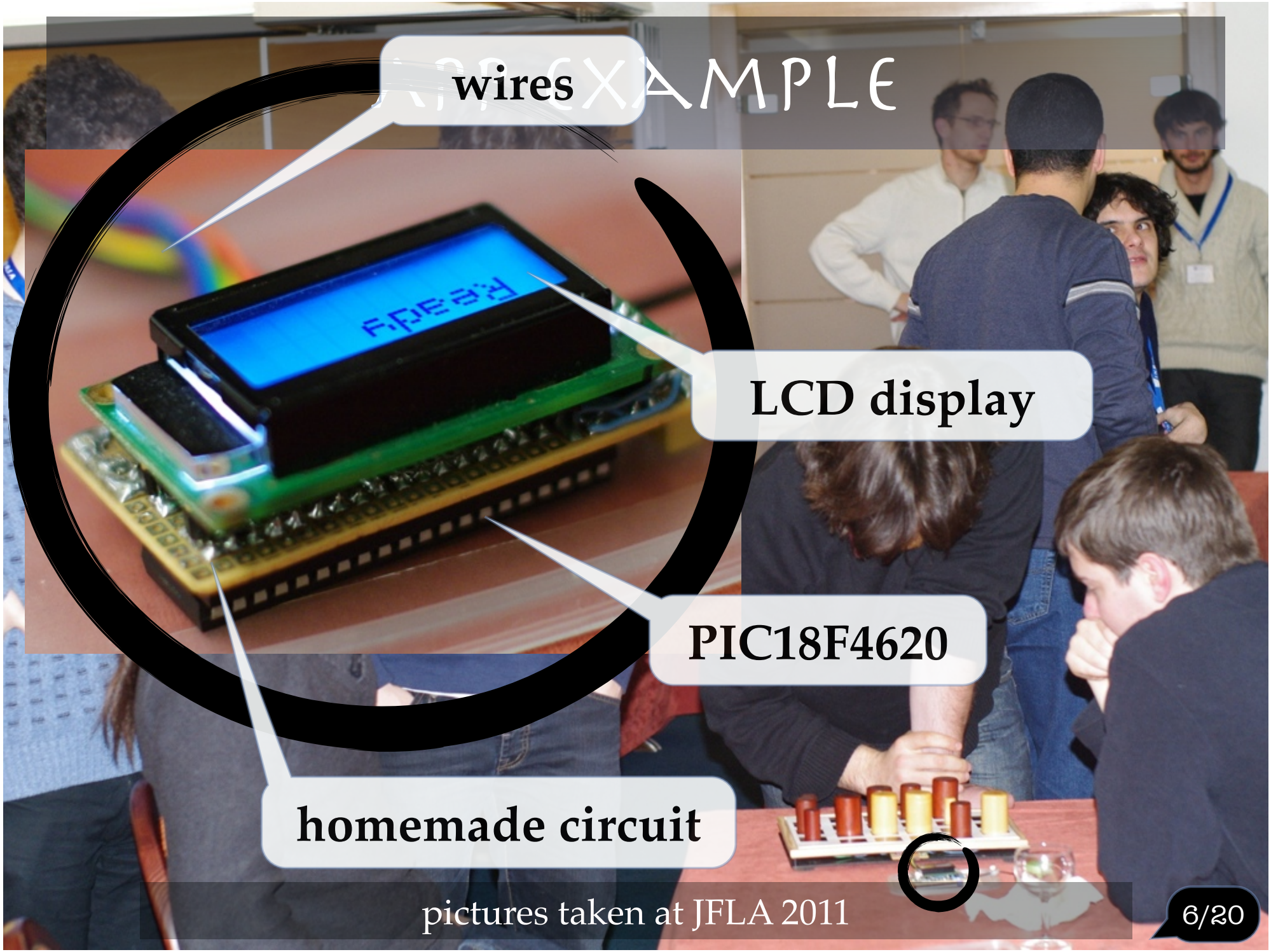
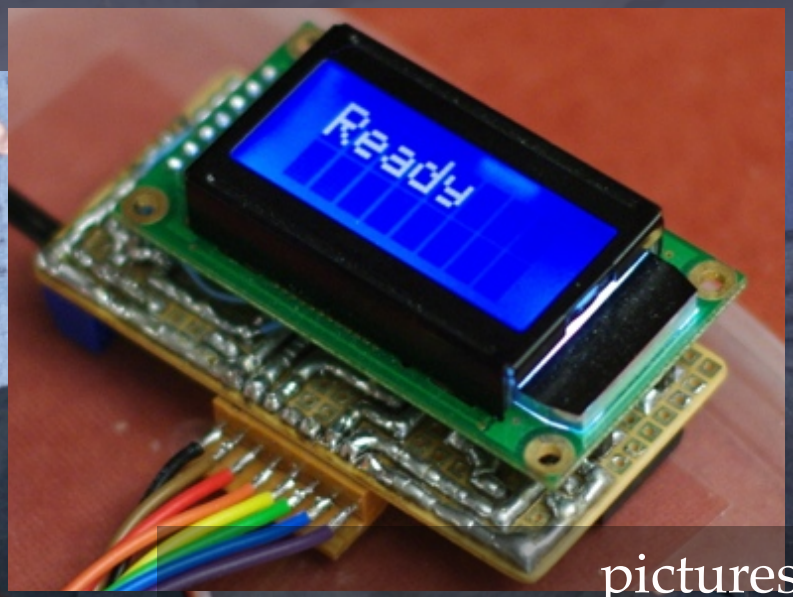
EXAMPLE



pictures taken at JFLA 2011

APP EXAMPLE

humans tend to lose...



pictures taken at JFLA 2011

APP EXAMPLE

implementation in OCaml

```
$ wc -l *.ml*
   78 display.ml
  156 goblet.ml
  256 grid.ml
  117 ia.ml
   60 stacks.ml
   14 types.mli
  681 total
```

but how to program PIC μCs in OCaml?

picture taken at JFLA 2011

A NEW BACKEND FOR OCAML FOR PROGRAMMING PIC18 µC

let's keep in mind what PIC18 µC are

- 8-bit architecture
- Flash memory: 4 to 128 kB
- RAM: 256 B to 4kB *wow... that's tight !*
- Speed: 8 to 16 MIPS
- no operating system

OCAPIC provides (among other things)
an OCaml VM on a PIC, to run them all

PIC & OCaml

- PIC18F4620
  - 3968 registers of 1 byte (→ RAM)
  - 8-bit RISC architecture
  - 64 kB of flash memory

- OCaml
  - multiparadigm, high-level features
  - automatic safe memory management
  - complex RT lib (*e.g.*, `Pervasives.compare`)

PIC & OCAML

- PIC18F4620
  - 3968 registers of 1 byte (→ RAM)
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tight resources

- OCaml
  - multiparadigm, high-level features
  - automatic safe memory management
  - complex RT lib (*e.g.*, `Pervasives.compare`)

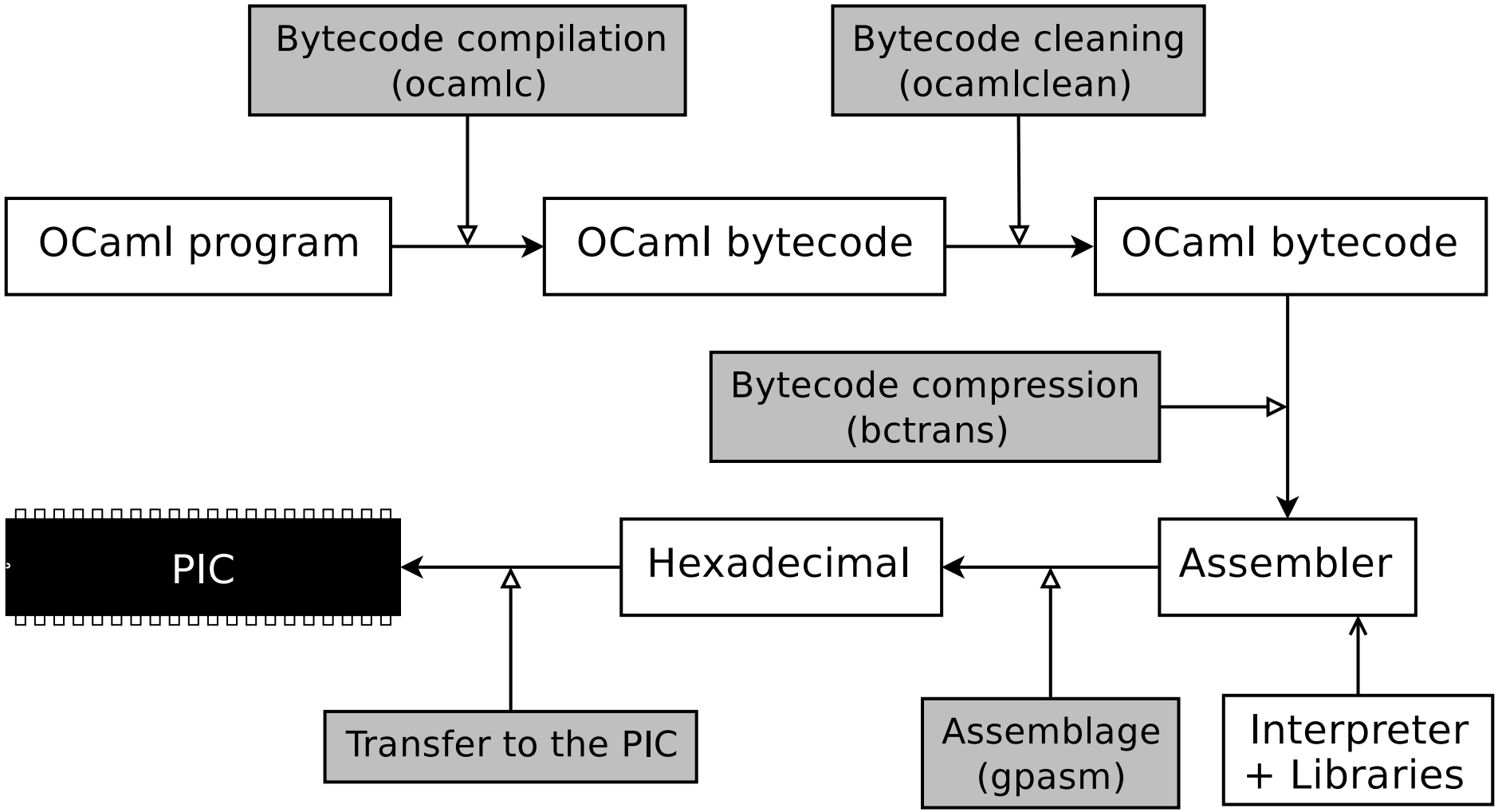
rich language

PROGRAMMING PIC MICROCONTROLLERS WITHOUT OCAML

- Assembly language
- Compiled languages
  - Basic (BASIC84plus)
  - C (sdcc, SIXPIC, MCC18, ...)
  - Forth (PicForth)
- Interpreted languages
  - Basic (BasicStamps), Forth (FlashForth)
- Virtual Machine
  - PICOBIT (a Scheme VM for PIC)

```
SAMPLE:
    tblrd*+
    addwf FSR0L, W
    rcall SUB_PRGM
    btfsc STATUS, C
    incf  FSR0H, F
    return
```

WITH OCAML



OCAPIC usage overview

OCAPIC
A NEW BACKEND FOR OCAML & A SET OF TOOLS

- OCamlClean
  - a tool for eliminating dead code
- BCtrans
  - compress bytecode for PIC (take back zeros)
- OCaml Virtual Machine
  - implemented in PIC18 ASM
- **(+ a PIC environment simulator)**

OCAMLCLEAN
EMPTY BYTECODE FOR EMPTY PROGRAMS

- takes a binary, gives back a lighter binary

- reduce heap occupation
  & remove unused closures (a lot from libraries)
  - reduce bytecode size & faster initialization
- reduce indirections (closures globalization)
  - better performance

(can be used in casual programming)

COMPRESSION WITH BCTRANS
(OCAML BYTECODE → .HEX)

- converts an OCaml binary into PIC data

- take back zeros (divides size by 3.5)
  OCaml bytecode binaries have a lot of zeros for good reasons, but it's a huge waste for PIC µC
- change heap initialization technique
  replace computations by a simple copy
- external (ASM) functions link resolution

OCAMLVM IN PIC ASM

OCAMLRUN ON A PIC

```
wc -l interp.asm runtime.asm
 2556 interp.asm
  368 runtime.asm
 2924 total
```

- memory garbage collector
  - *a simple Stop&Copy (150 lines of ASM)*
  - *a full cycle runs in less that 1.5ms (RAM is small)*
- uniform data representation, using **16 bits**
  - *15-bit integers, repr. as in orig. OCaml (tag on 1 bit)*
  - *block repr. ~ as in original OCaml: tag & size & data*

OCAPIC LIBRARY

STANDARD LIBRARY

```
wc -l stdlib.asm
 6757 stdlib.asm (+ ~180 lines of OCaml)
```

- part that can't be in OCaml: `stdlib.asm`

  Arithmetic operators, Pervasives.compare, ...

- some OCaml modules are copied

  Array, ArrayLabels, CamlinternalLazy, CamlinternalMod, Char, Hashtbl, Int32, Int64, Lazy, List, ListLabels, MoreLabels, OO, Queue, Set, Sort, Stack, StdLabels, String, StringLabels

- some OCaml modules are modified

  Buffer+ , CamlinternalOO+ , Gc+, Map+, Obj+, Pervasives , Random, Printf*, Std_exit, Stream, Sys*,*

- some OCaml modules are left behind

  Arg, Complex, Callback, Digest, Filename, Format, Genlex, Marshal, Nativeint, Parsing, Printexc, Scanf, Weak

OCAPIC LIBRARY

PIC SPECIFIC LIBRARIES

```
external read_reg : reg -> int = "caml_pic_read_reg";;
(** [read_reg reg] reads value of
    a Special Function Register [reg].
    Return value between 0 and 255. *)

external write_reg : reg -> int -> unit = "caml_pic_write_reg";;
(** [write_reg reg value] writes value in
    the Special Function Register [reg].
    [value] should be between 0 and 255. *)
```

PIC I/O

```
external set_interruption_handler : (bit -> unit) -> unit =
  "caml_set_interruption_handler";;
(** Register an interruption handler. *)

external clear_interruption_handler : unit -> unit =
  "caml_set_interruption_handler";;
(** Remove the interruption handler. *)
```

interruptions

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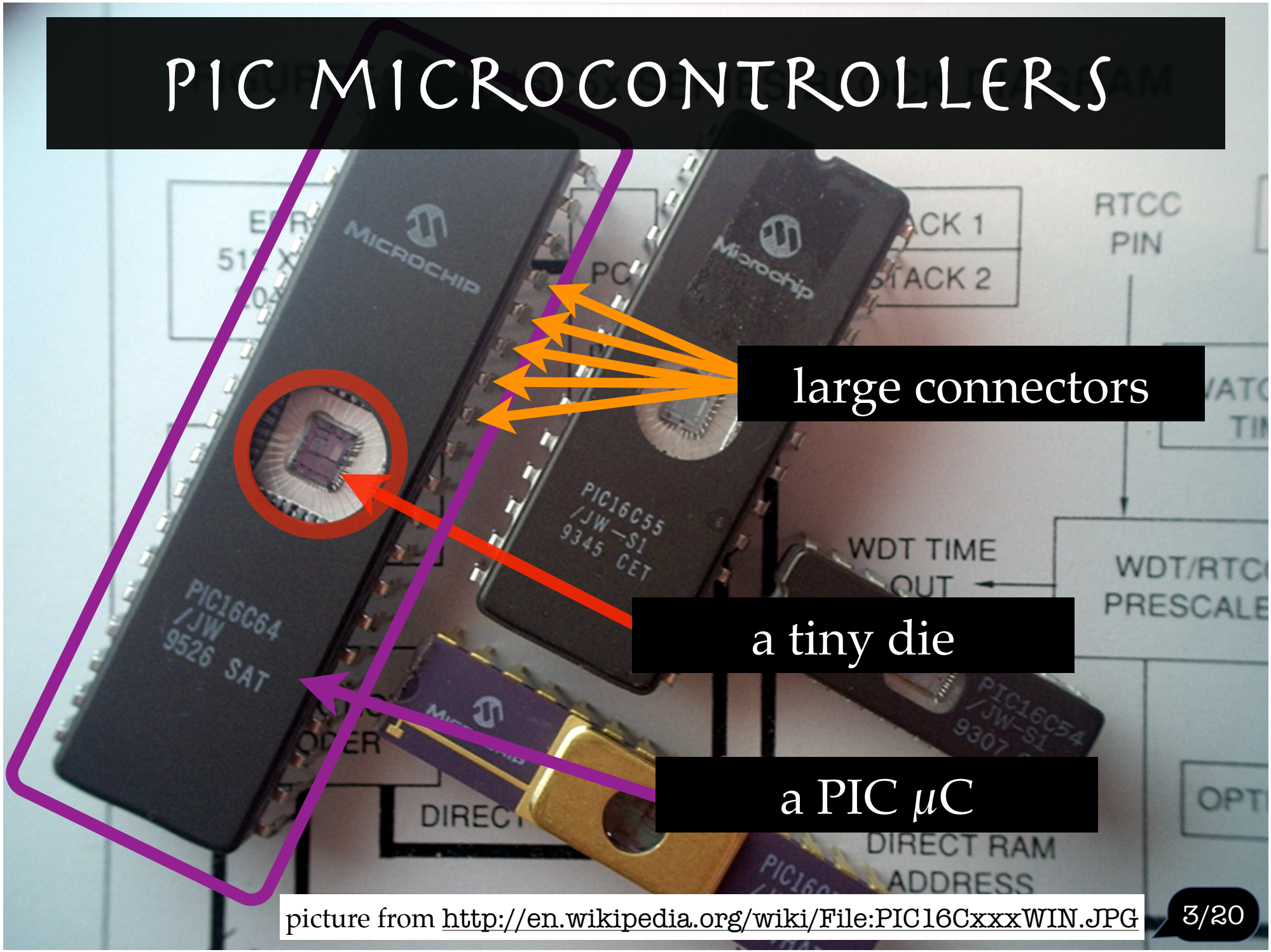

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OCAPIC LIBRARY

PIC SPECIFIC LIBRARIES

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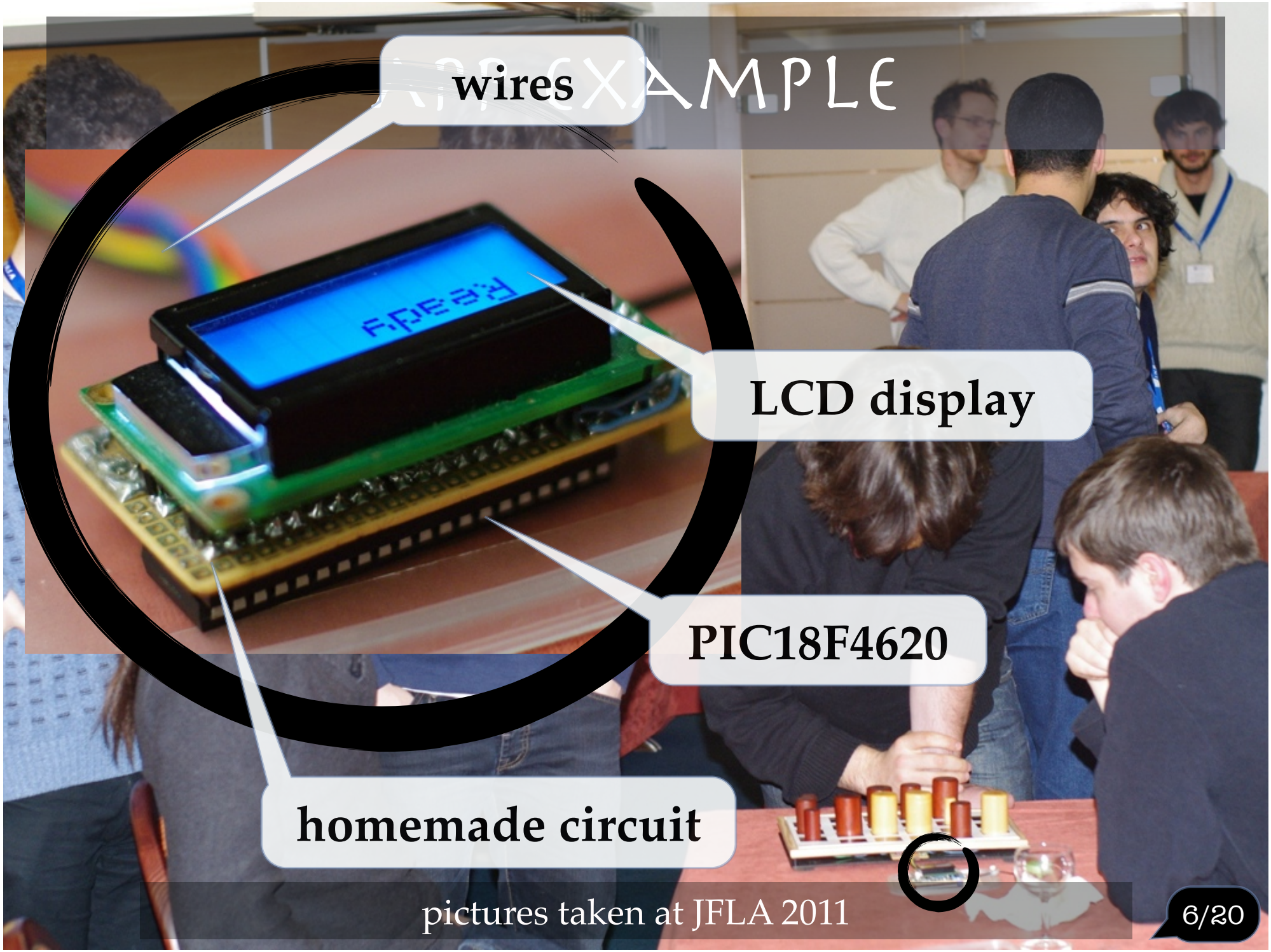
module MyDisplay = Lcd.Connect (
struct
  let bus_size = Lcd.Four (* databus mode *)
  let e  = Pic.LATD0      (* command connector *)
  let rs = Pic.LATD2
  let rw = Pic.LATD1
  let bus = Pic.PORTC     (* databus port *)
end);;
MyDisplay.init ();;
MyDisplay.config ();;
MyDisplay.print_string "Hello world";;
```

LCD display

```
let (ic : t in_channel) = Serial.open_in () in
  while true do
   match Serial.receive ic with
    | Clear -> clear ()
    | Moveto (l, c) -> moveto l c
    | Int i -> print_int i
    | Text t -> print_string t
done
```

serial conn.

EXAMPLE



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OCAPIC + PIC18F4620 BENCHMARKS

execution speed

- ~400,000 VM instructions / second
- ~25 machine cycles / VM instruction
  (~18 for a standard processor)
- PICOBIT runs 37,000 VM instructions / second
  - less by 11 times, but for a **different** bytecode

flash memory occupation

- 64 kB of flash memory on PIC18F4620
- Interpreter: 4954 B (7.6%)
- Runtime library: ≤ 4254 B (≤ 6,5%)
- Bytecode: **up to** 55kB (86%)

CONCLUSION

- Full OCaml frontend & Good performance
  thanks to a virtual machine! (+ a set of tools)
- OCAPIC works with any PIC18 *(but check the memory size)*
- OCamlClean was necessary to allow the use of OOP
  (but not necessary for small programs without OOP)
- Other ideas
  - make other languages target OCaml VM
  - port OCaml VM on other architectures
  - try other garbage collection algorithms
  - try external RAM

http://www.algo-prog.info/ocaml_for_pic/

THANKS!

don't miss the demo session

this afternoon ;-)

ANY QUESTIONS?

picture taken at JFLA 2011