Tutorial T24

Assembly Language Programming: Street Smarts from OOP

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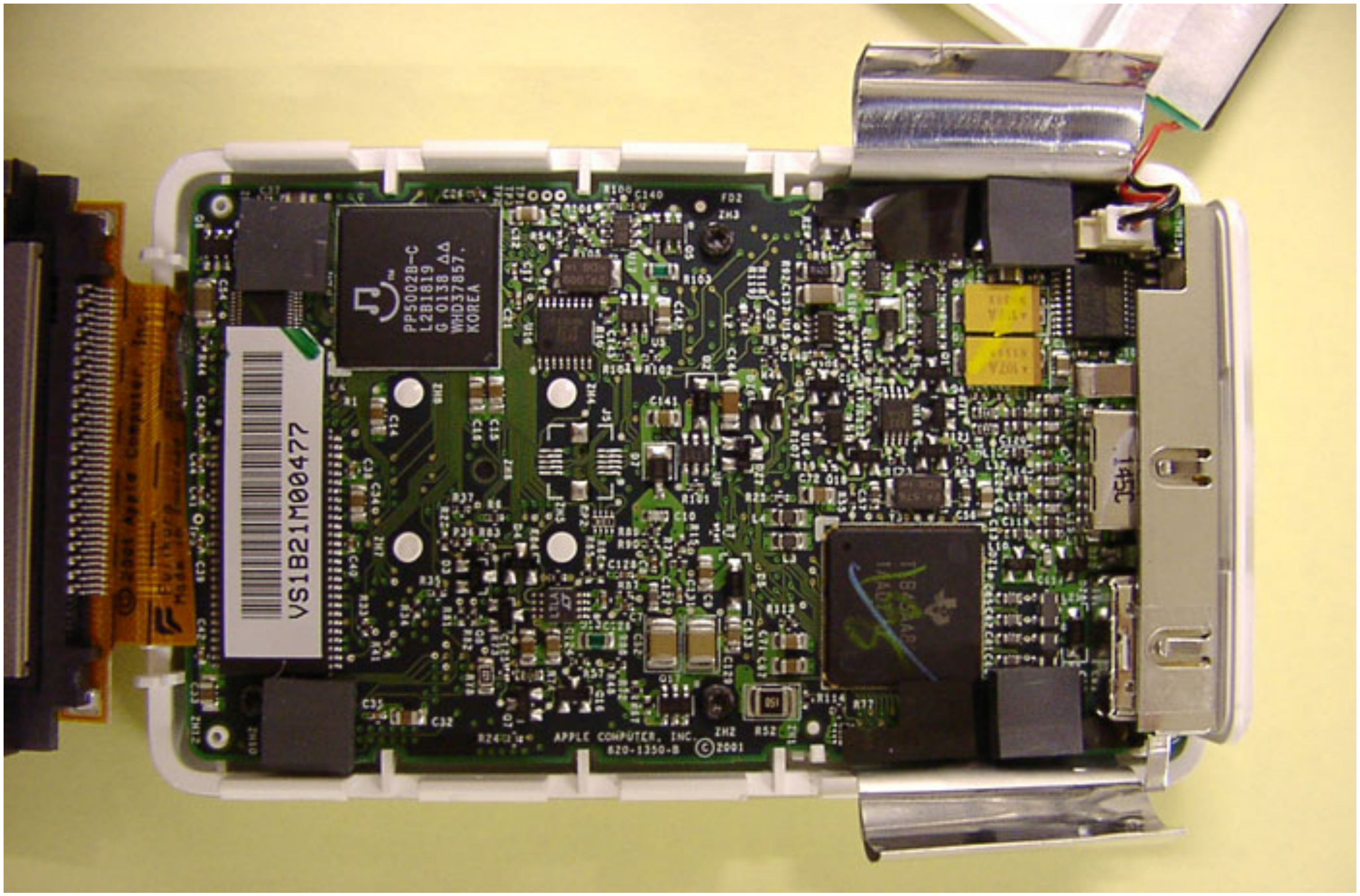
What we will cover

- Real-world case study: Inside an MP3 player
- OOP Principles for Embedded
  - Object
  - Encapsulation
  - Inheritance
- Summary: Benefits of OOP for Embedded

iPOD



http://www.chipmunk.nl/iPod/ipodChipmunk1.jpg

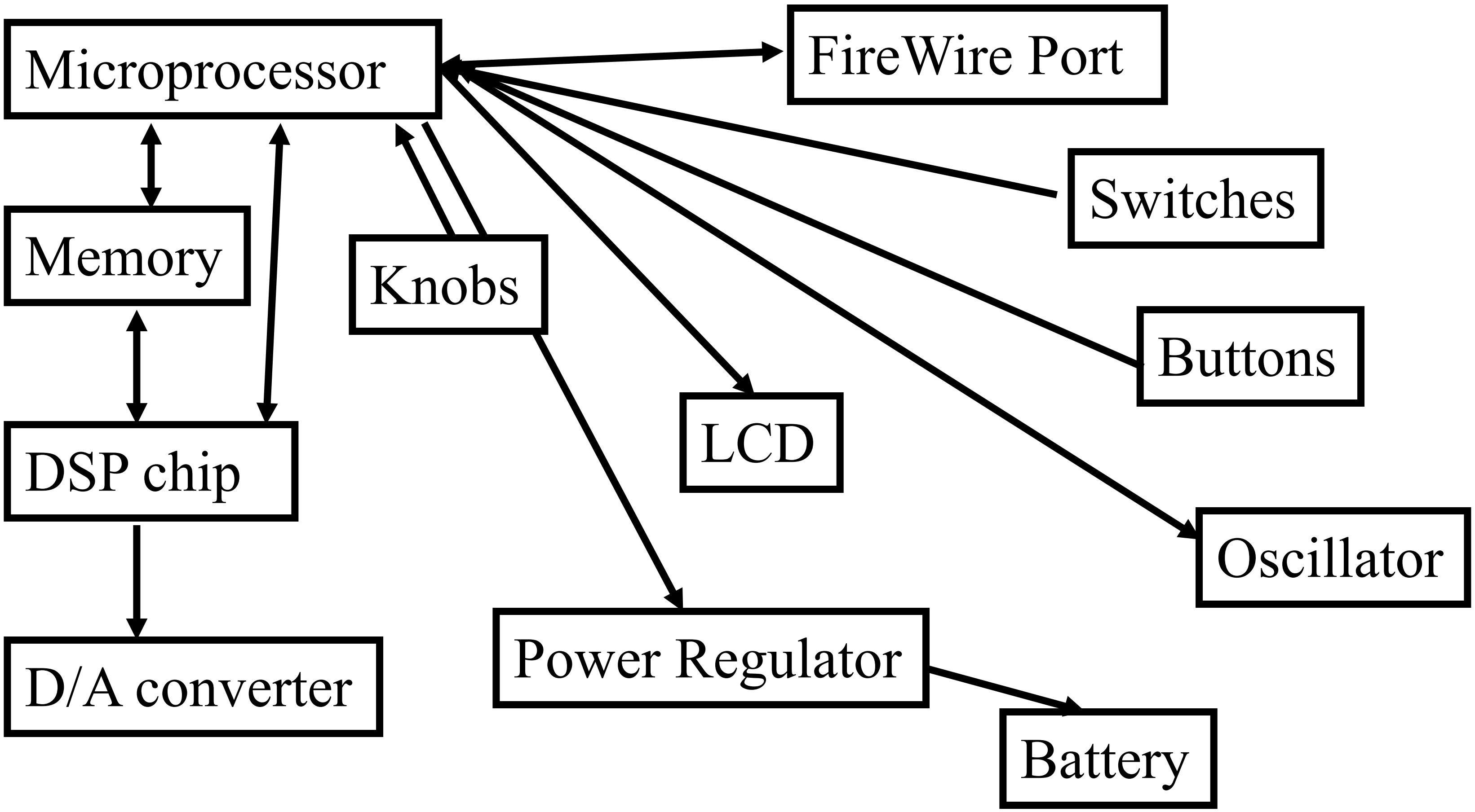
What’s in a typical DSP-based consumer audio device?

What’s in a typical DSP-based consumer audio device?

"Typical" MP3 Player

- μP
- DSP chip
  - D/A converter
- FireWire port
- Memory
- Disk Drive
- User Interface
  - Buttons
  - LCD
  - Knobs
- On-chip clock
- Power
  - Battery
  - Regulator

MP3 Player


Microprocessor
FireWire Port
Switches
Memory
Knobs
Buttons
LCD
DSP chip
Oscillator
D/A converter
Power Regulator
Battery

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Object

- A set of software
- Corresponds to something: (physical object, person, peripheral, algorithm, ...)
- Cleanly defined boundaries

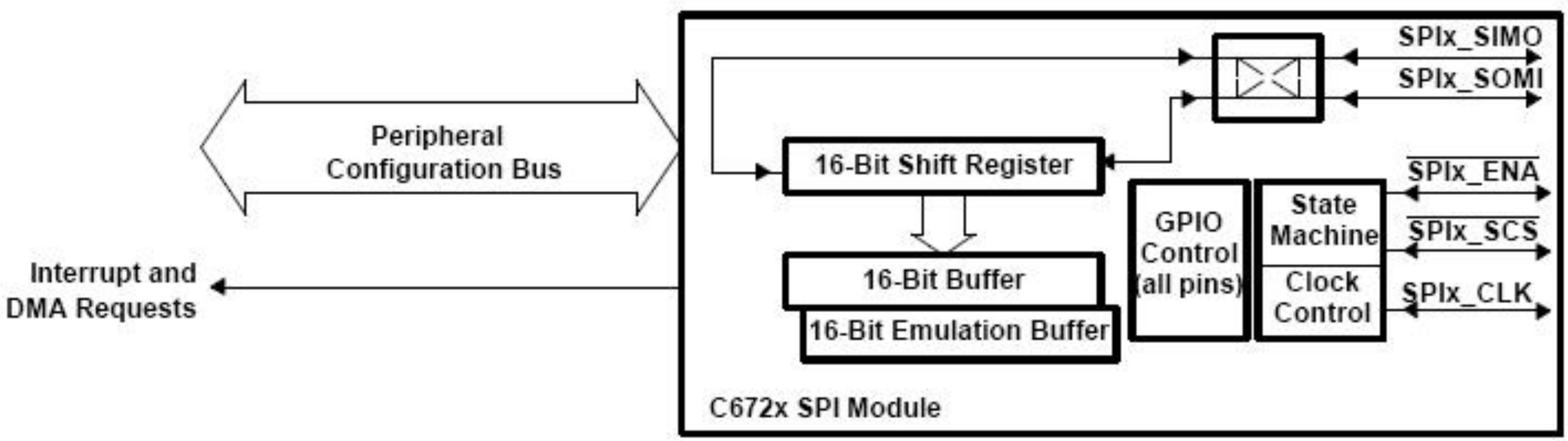
Sample Objects

- μP
- Serial Port
- External Memory
- FFT routine
- Filter routine
- One interrupt service routine
- All the interrupt service routines
- …

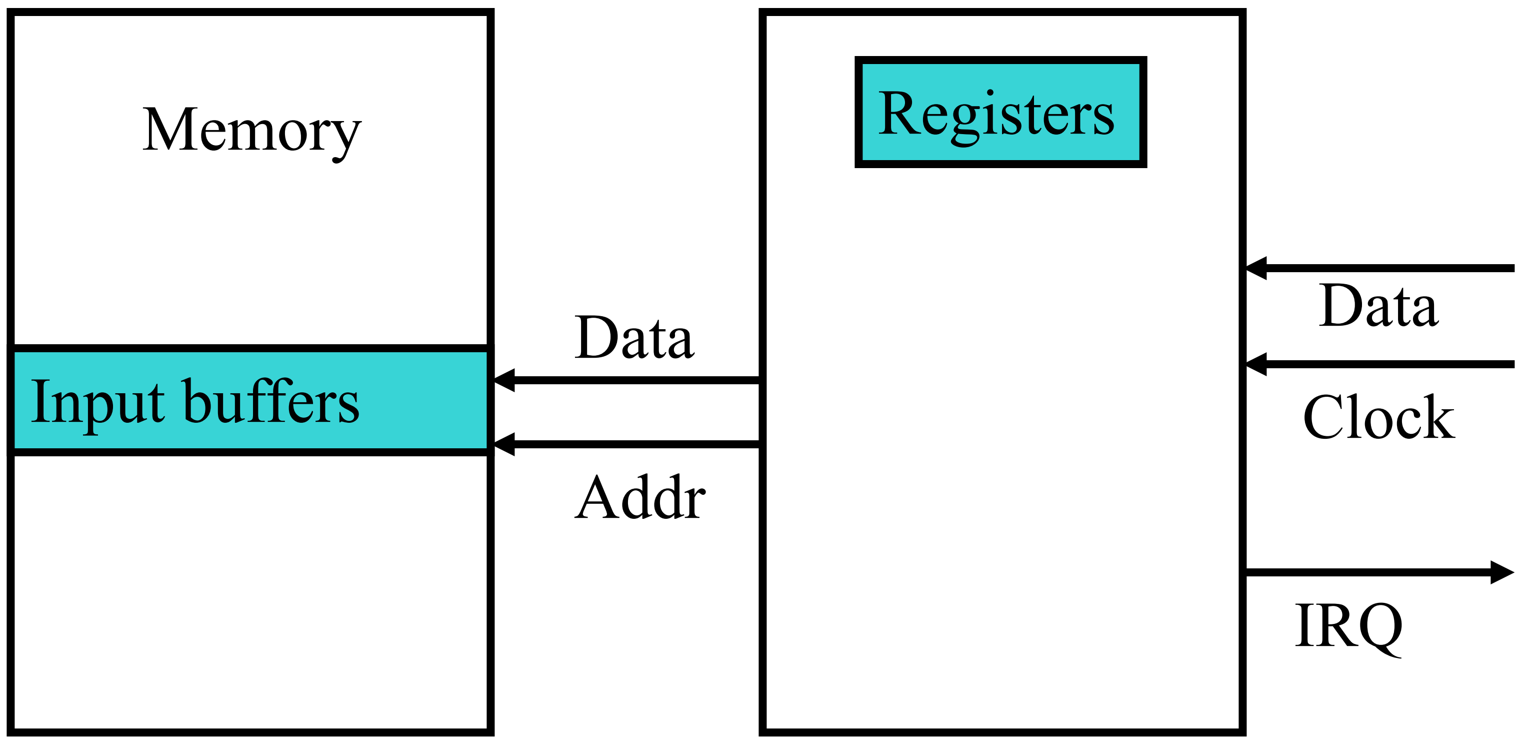
Sample Object: Serial Port ---

What' s in one?

TI C672x Serial Port



Prototypical Serial Port



Prototypical serial port: Hardware

- Memory buffer
  - Base address
  - Length ("mod")
  - Current read, write pointers
  - Storage for other pointers for double-buffer
- Registers

Prototypical serial port: Software

- Interrupt service routine: handle one sample
- Initialization
- Start/Stop
- Routine to deal with full buffer
  - Swap buffer pointers
  - Tell DSP that the buffer is full

Serial Port Elements

Registers

Input buffer(s)

Interrupt service routine

Initialization/reset

Allocate buffers

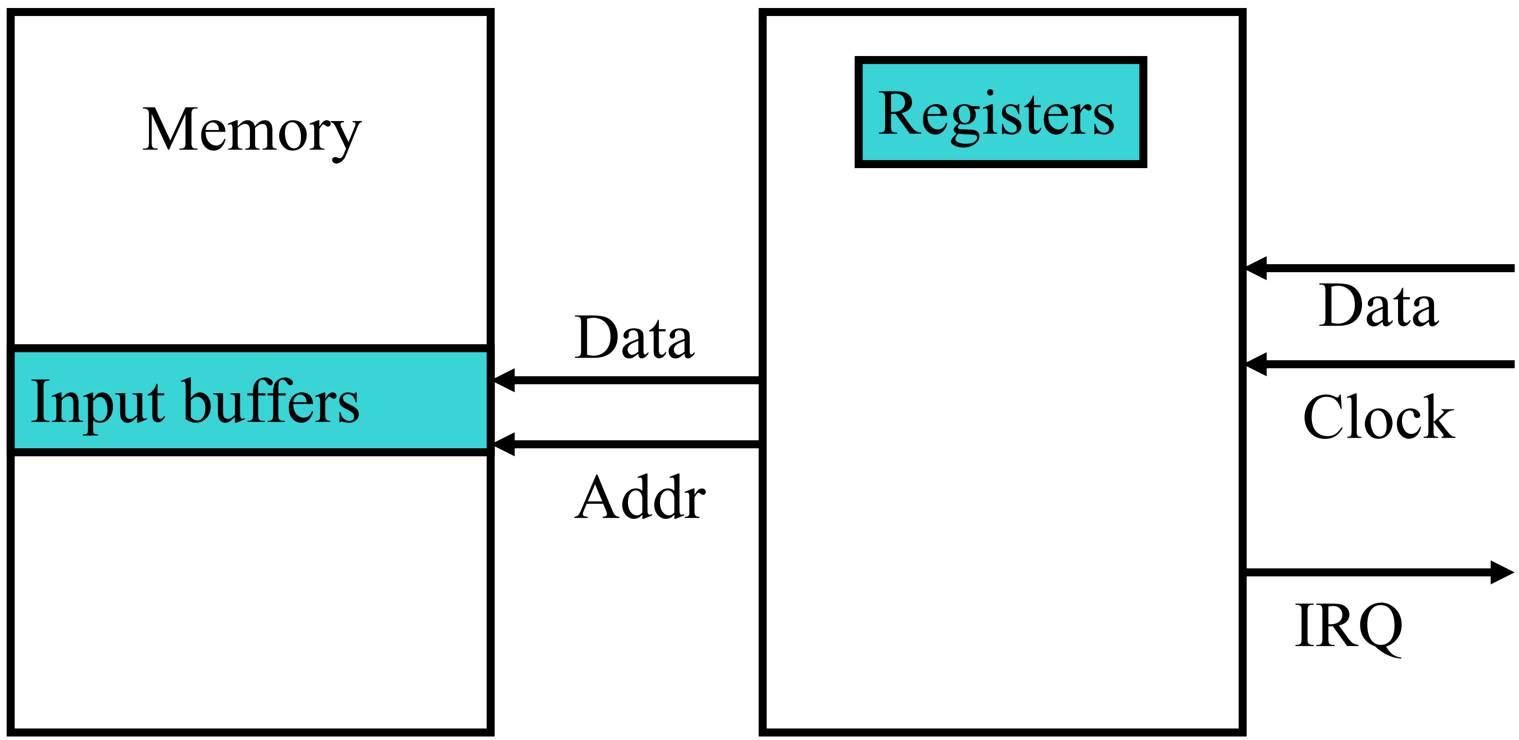
Setup transfer

Start transfer

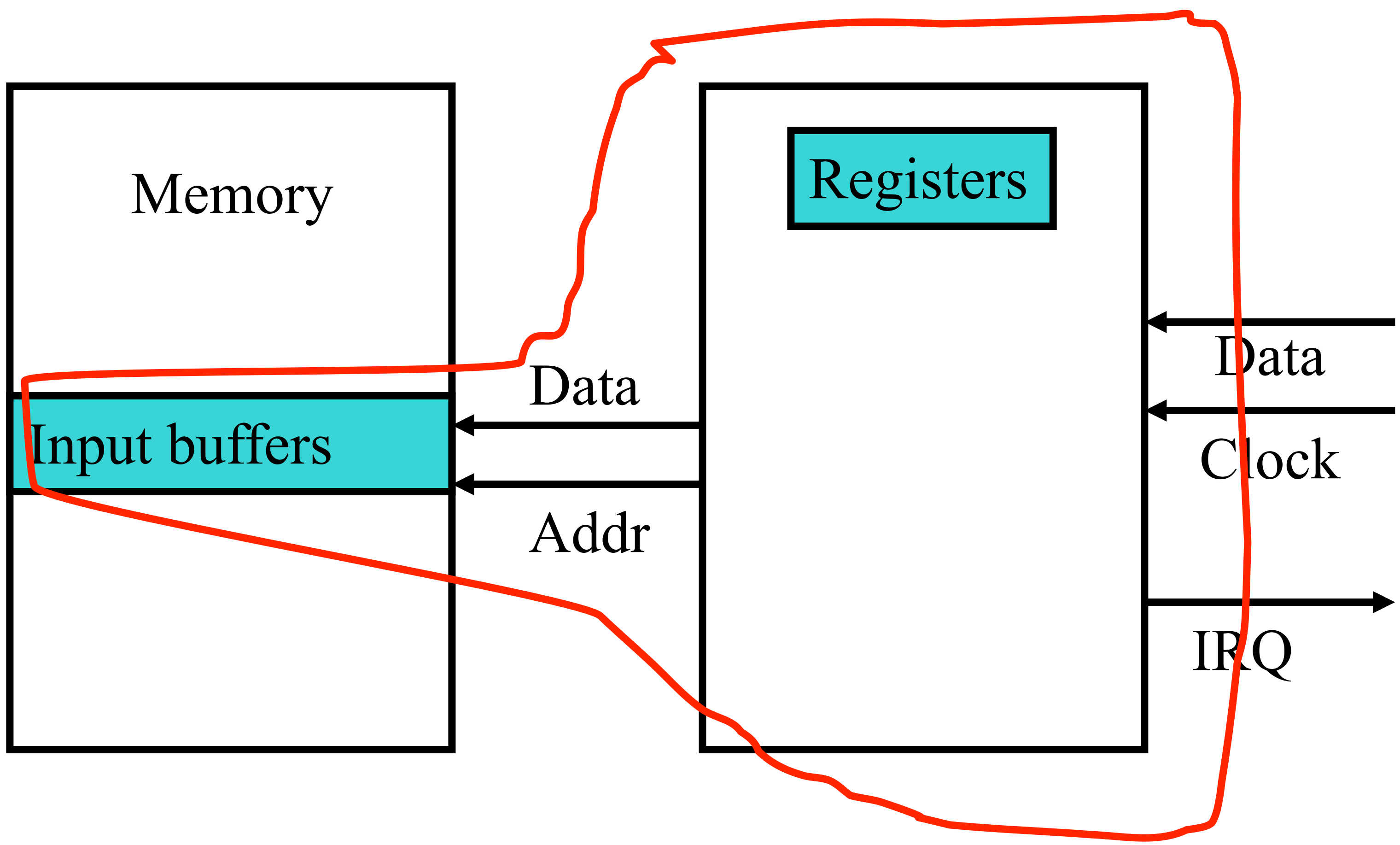
Check buffer full

Stop transfer

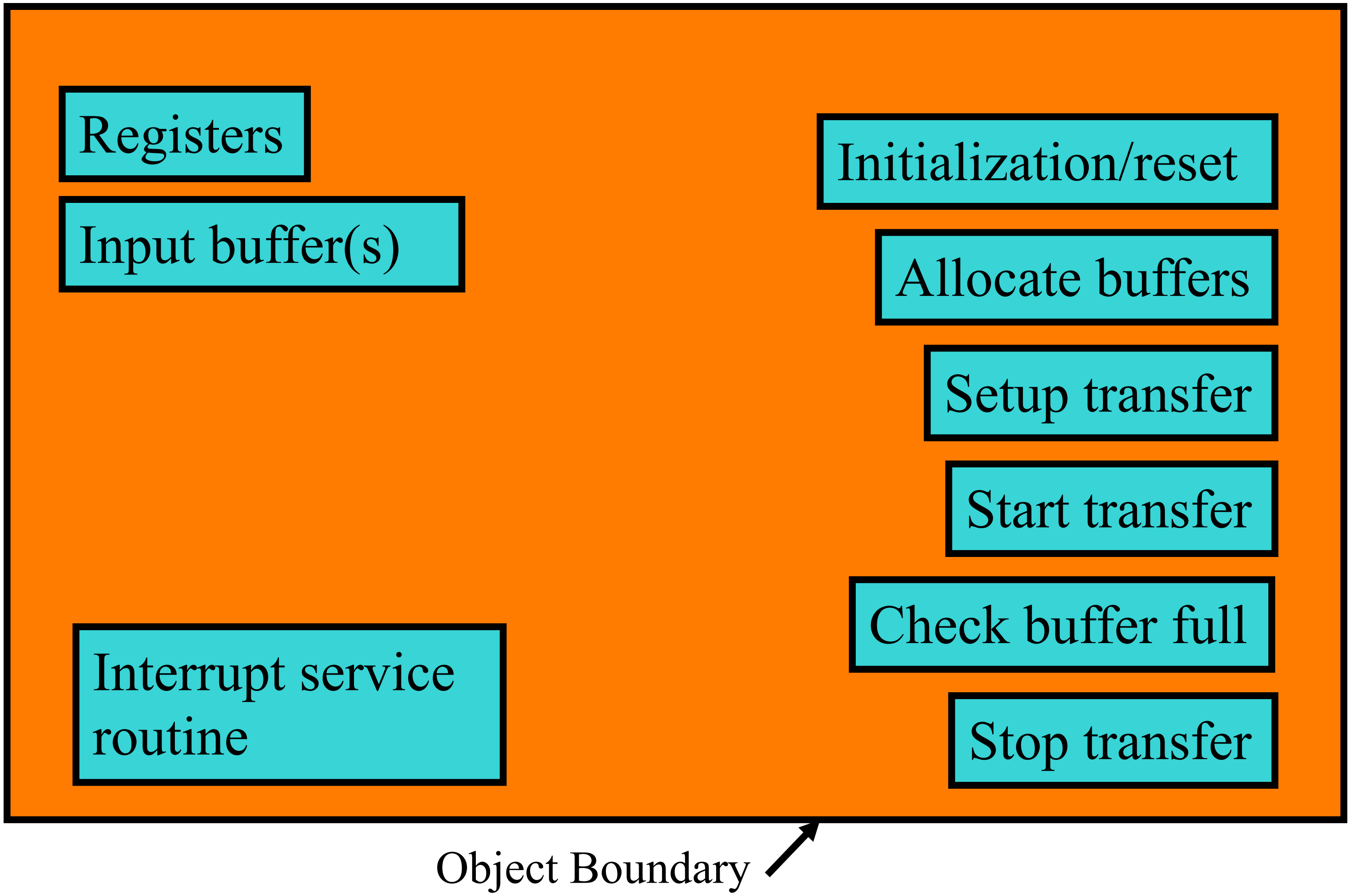
µP Serial Port: where are the object boundaries?



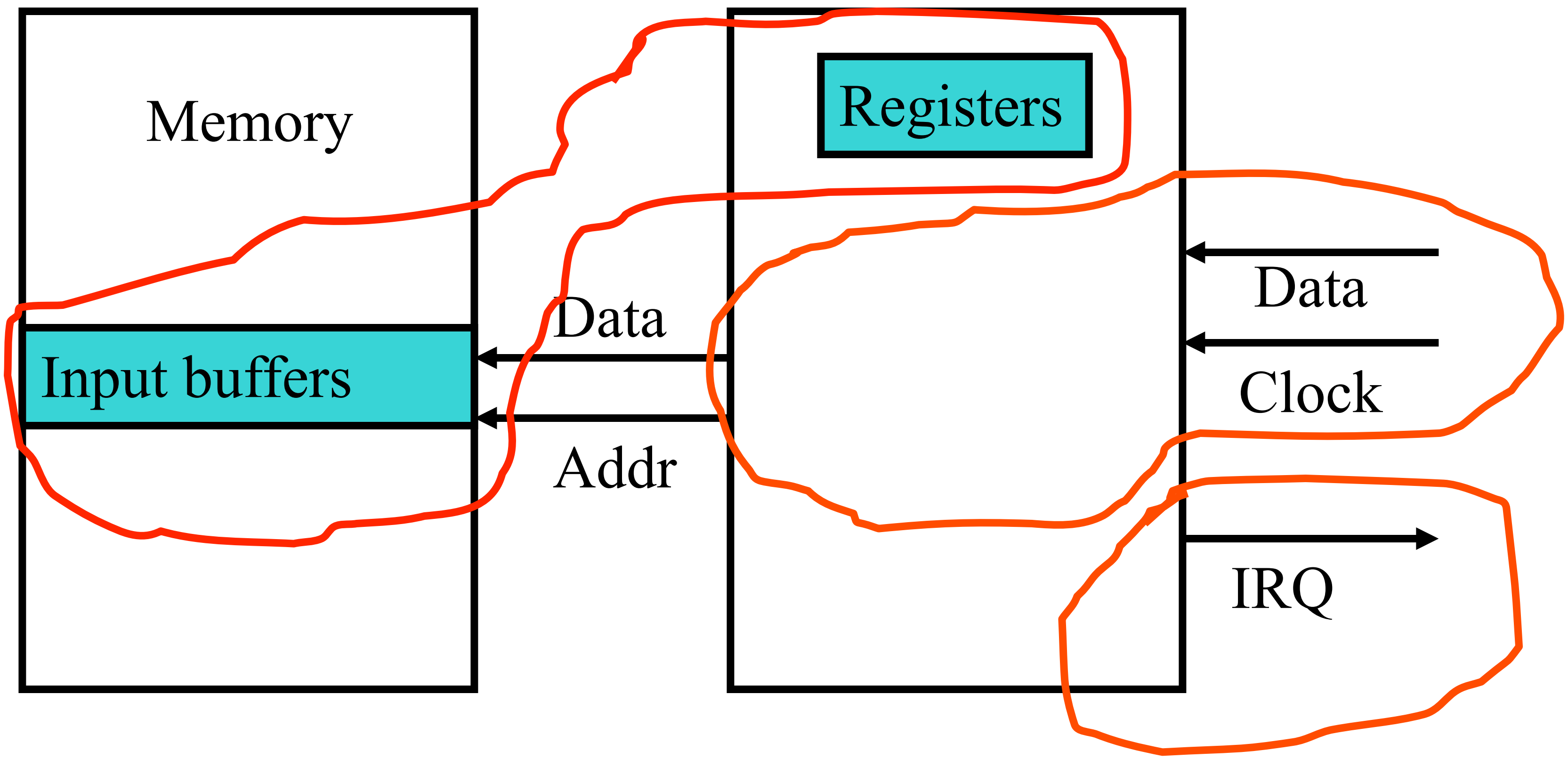
µP Serial Port Object: Boundaries Version 1



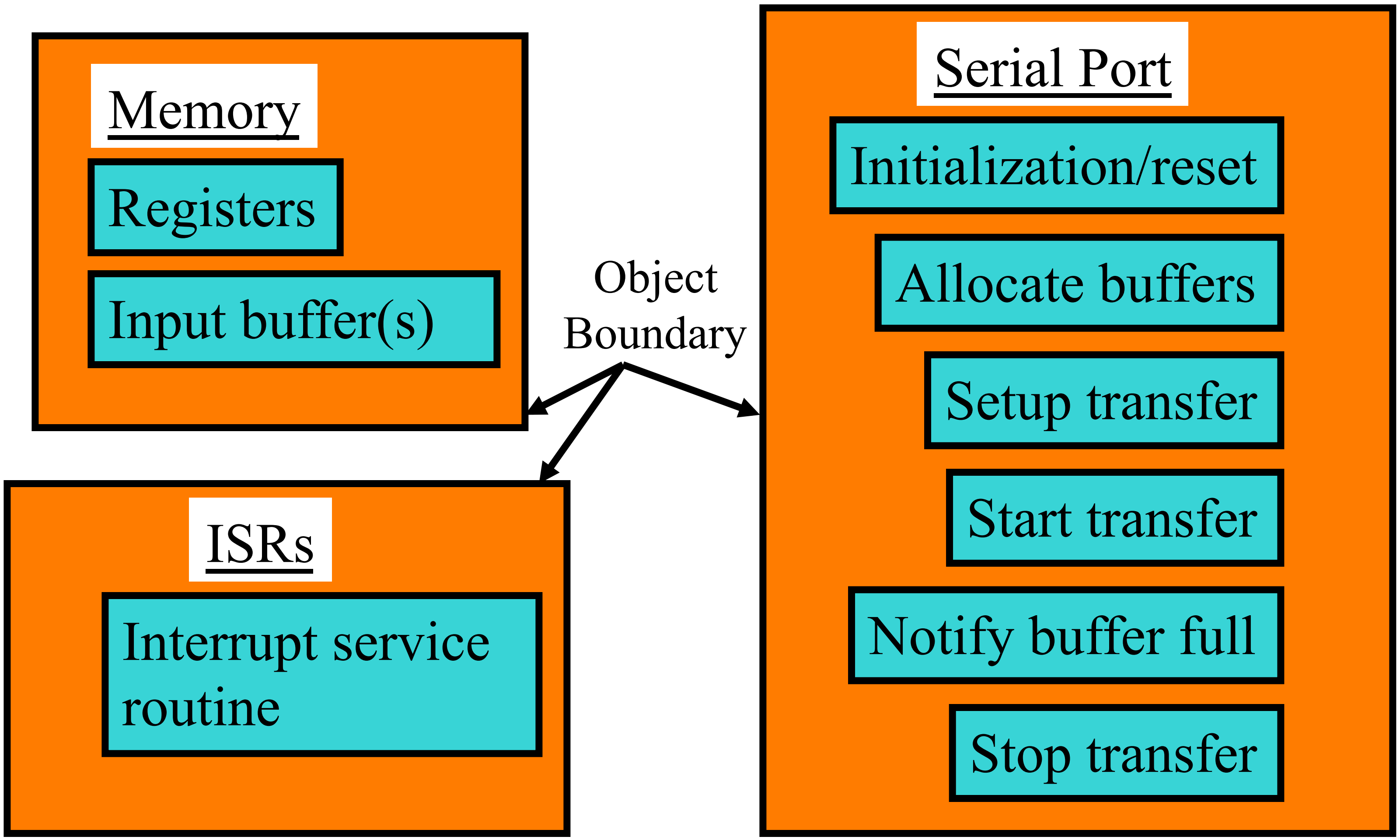
One Object: Serial Port



µP Serial Port Object: Boundaries Version 2



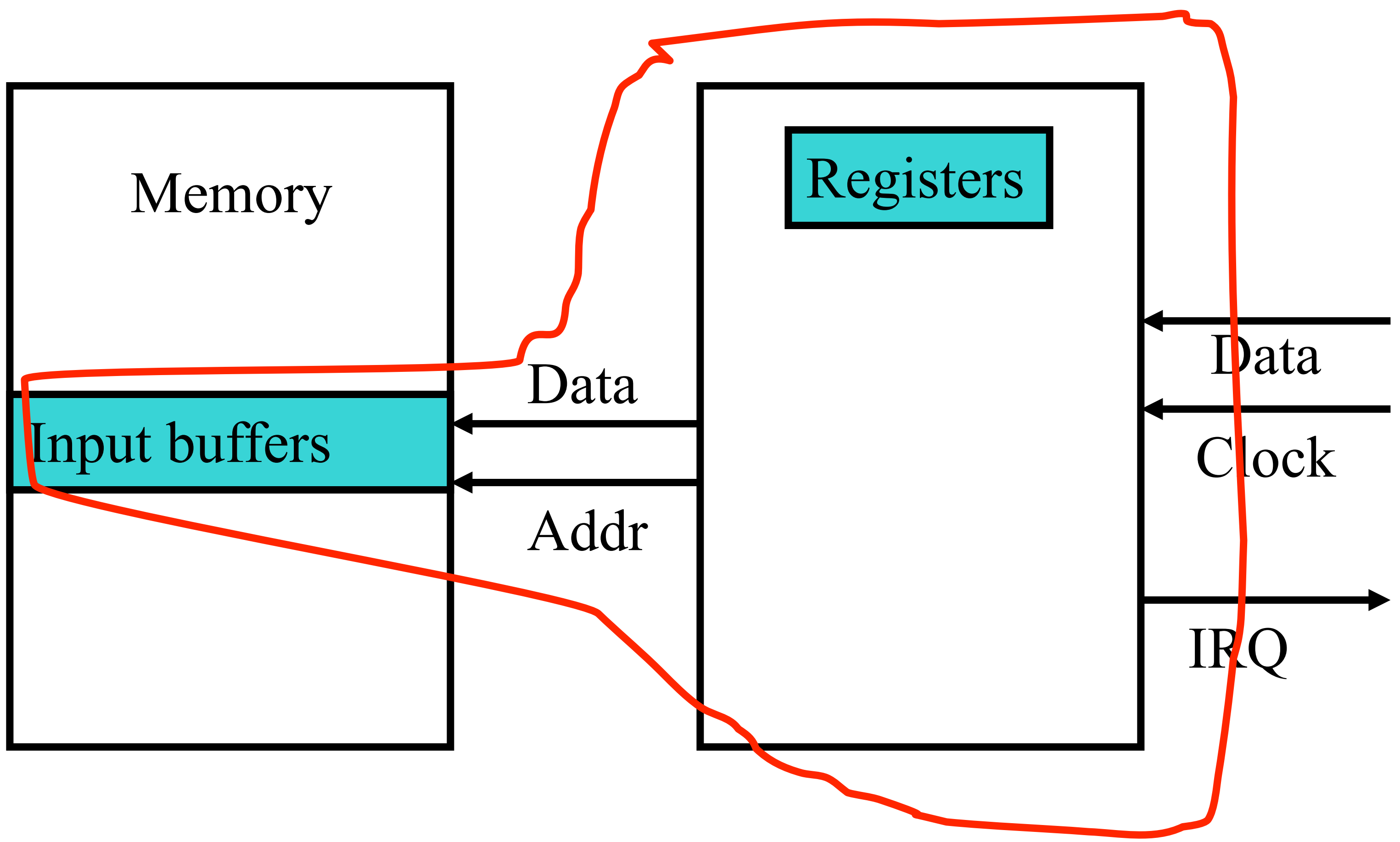
3 Objects:
Serial Port, Memory, ISRs



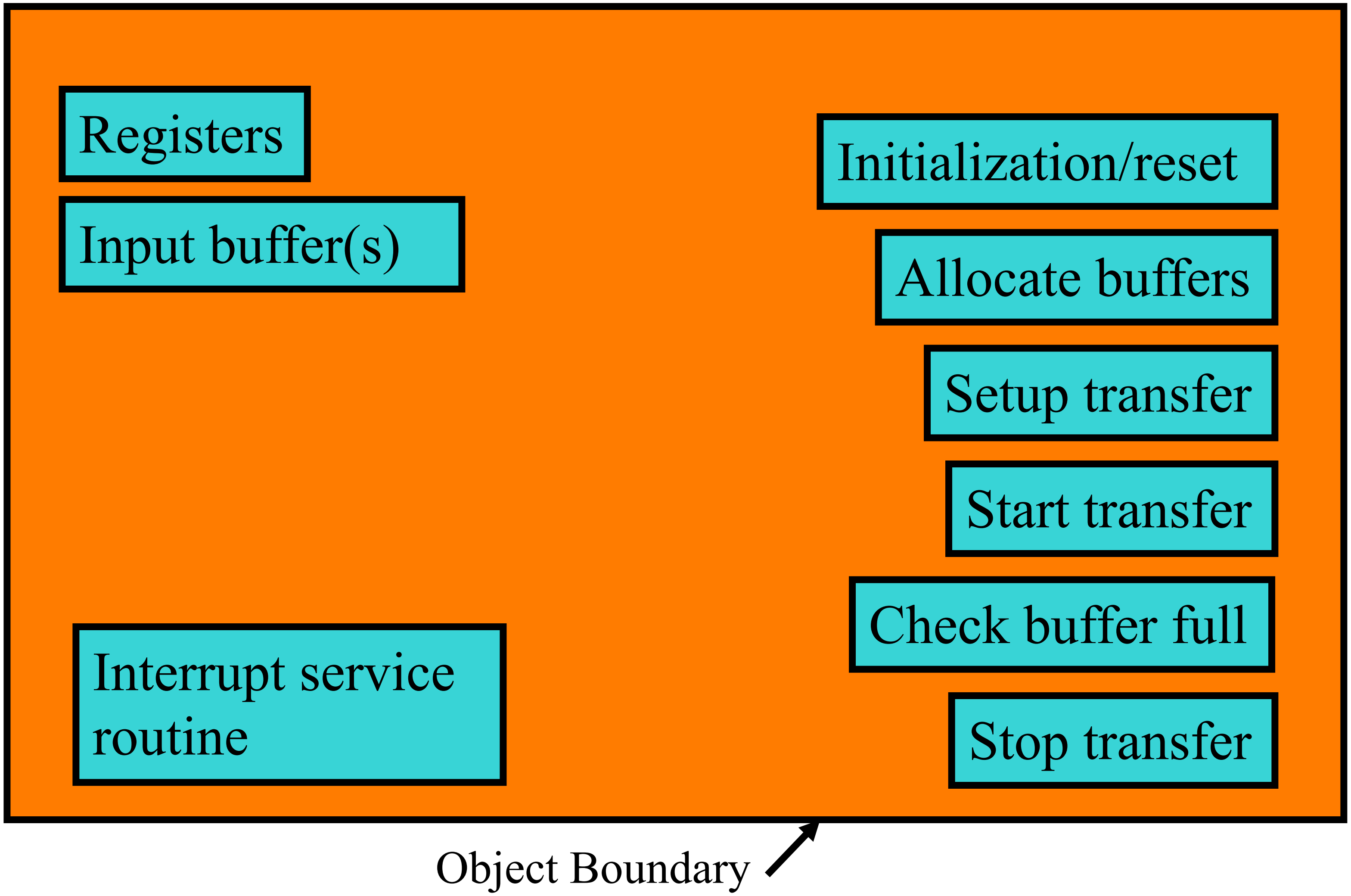
How to make an "object"

- Group similar things
- Decide the boundaries
- Header
  - file, or section of file
  - "#define"
  - interface for other objects --- more later
- Code file (or section of file)
  - details inside
- Test file

Review: Boundaries Version 1



Review, One Object: Serial Port



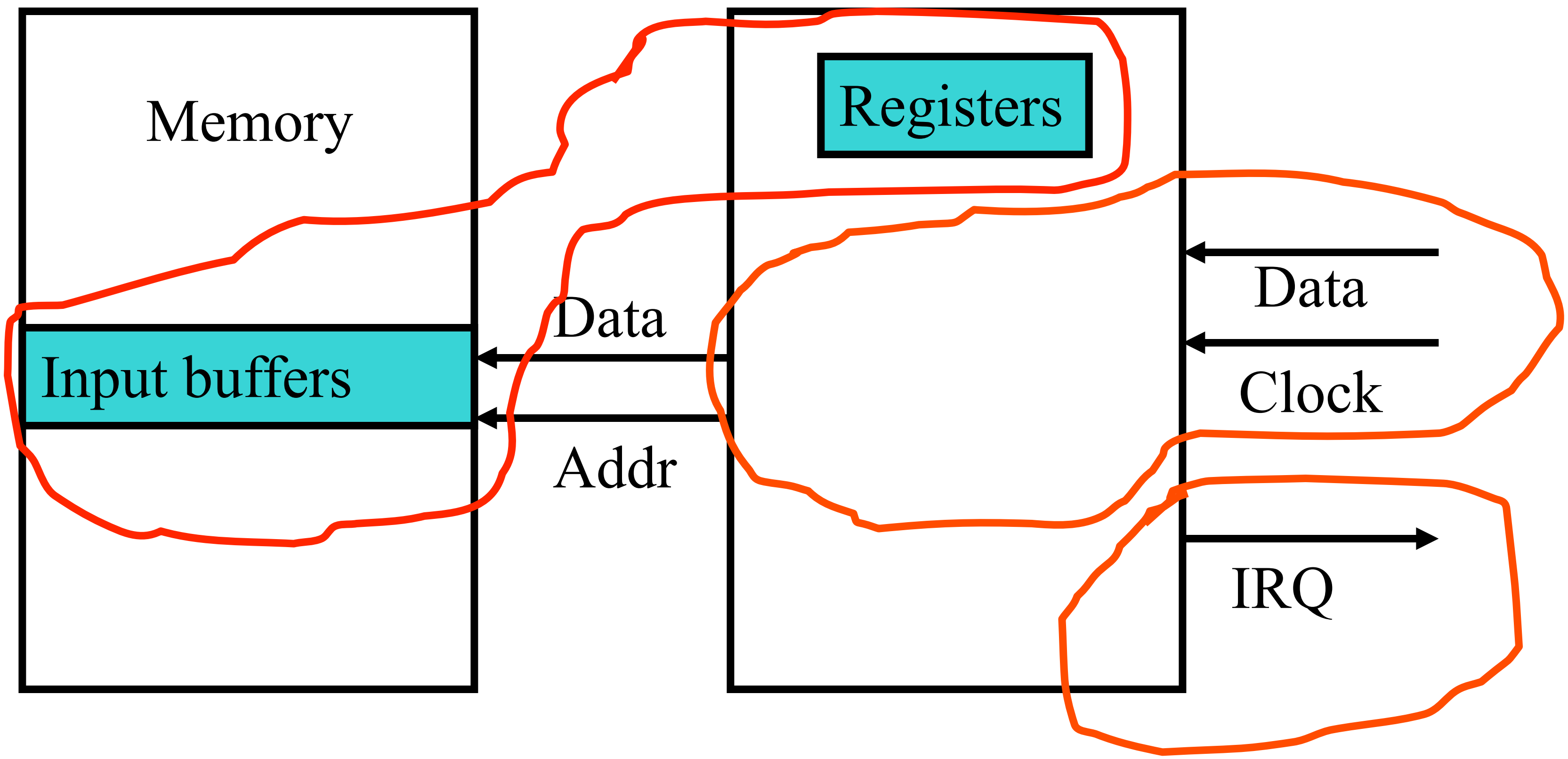
Files, 1 Object

Memory.inc

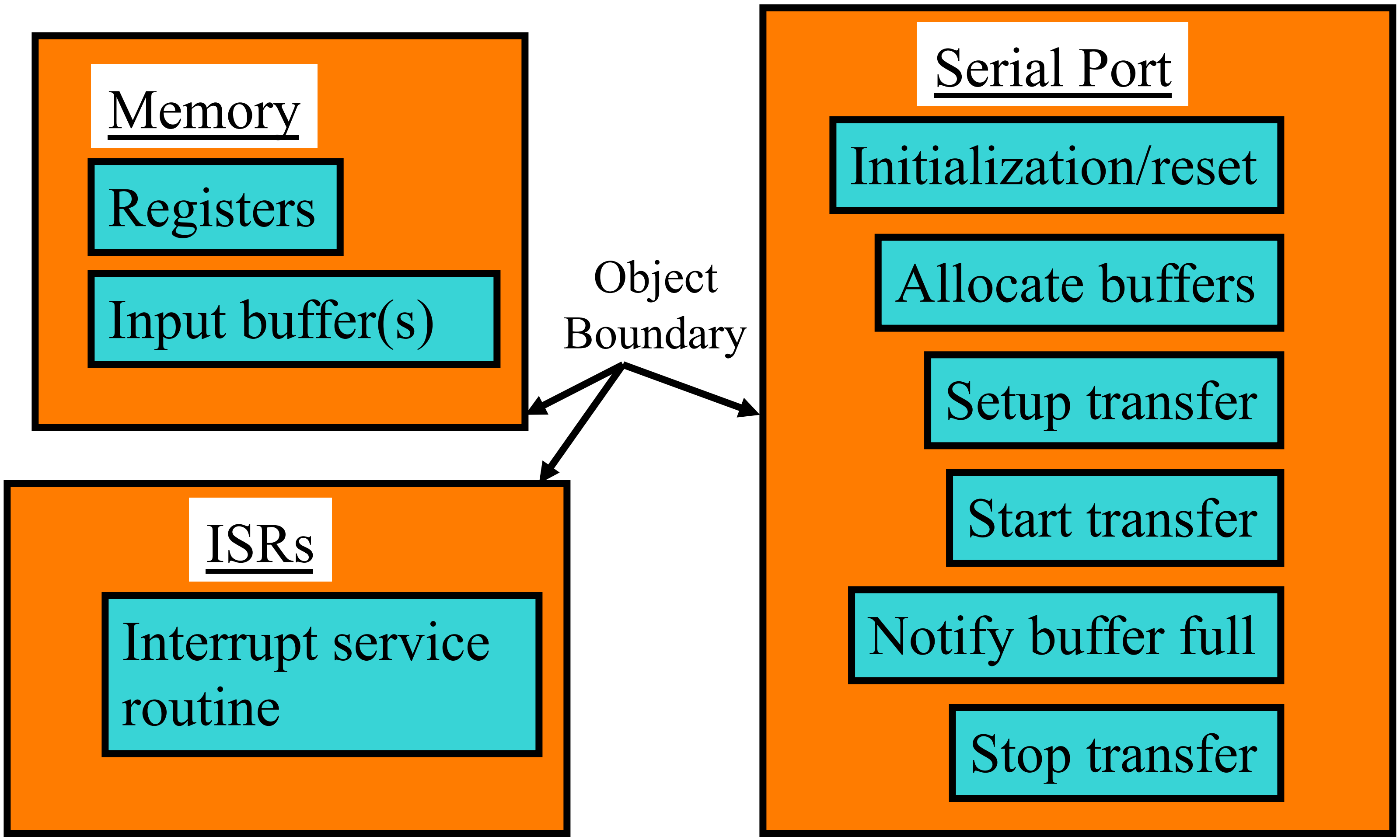
ISR.inc

Serial_port.inc
Serial_port.asm
- **includes memory.inc, ISR.inc, Serial_port.inc**
- **contains implementation for registers, buffers, ISR**
- **contains implementation of rest of serial port**

µP Serial Port Object: Boundaries Version 2



Review, 3 Objects: Serial Port, Memory, ISRs



Files, 3 Objects

```
Memory.inc
Memory.asm
  includes memory.inc
  contains implementation for registers, buffers

ISR.inc
ISR.asm
  includes ISR.inc
  contains implementation for ISR

Serial_port.inc
Serial_port.asm
  includes Memory.inc, ISR.inc, Serial_port.inc
  calls on implementation in Memory.asm, ISR.asm
  contains implementation of rest of serial port
```

Real-world example: objects

```
NR.inc
NR.asm
NR_init.asm
 test_NR.asm

NR_mem.asm
  NR_mem.inc

NR_io.asm
  NR_io.inc
```

```
NR_fft_hann.inc
NR_fft_sincos.inc
NR_atan2.asm
  test_atan2
NR_sqrt.asm
  test_sqrt.asm
NR_fft.asm
  NR_fft.inc
  test_fft.asm
```

What we will cover

- Real-world case study: Inside an Ipod
- OOP Principles for Embedded
  - Object
  - Encapsulation
  - Inheritance
- Summary: Benefits of OOP for Embedded

Encapsulation

- (from Object): Cleanly defined boundaries
- Gather the details inside those boundaries
- Hide the details from the outside world
- Provide an interface to the outside world

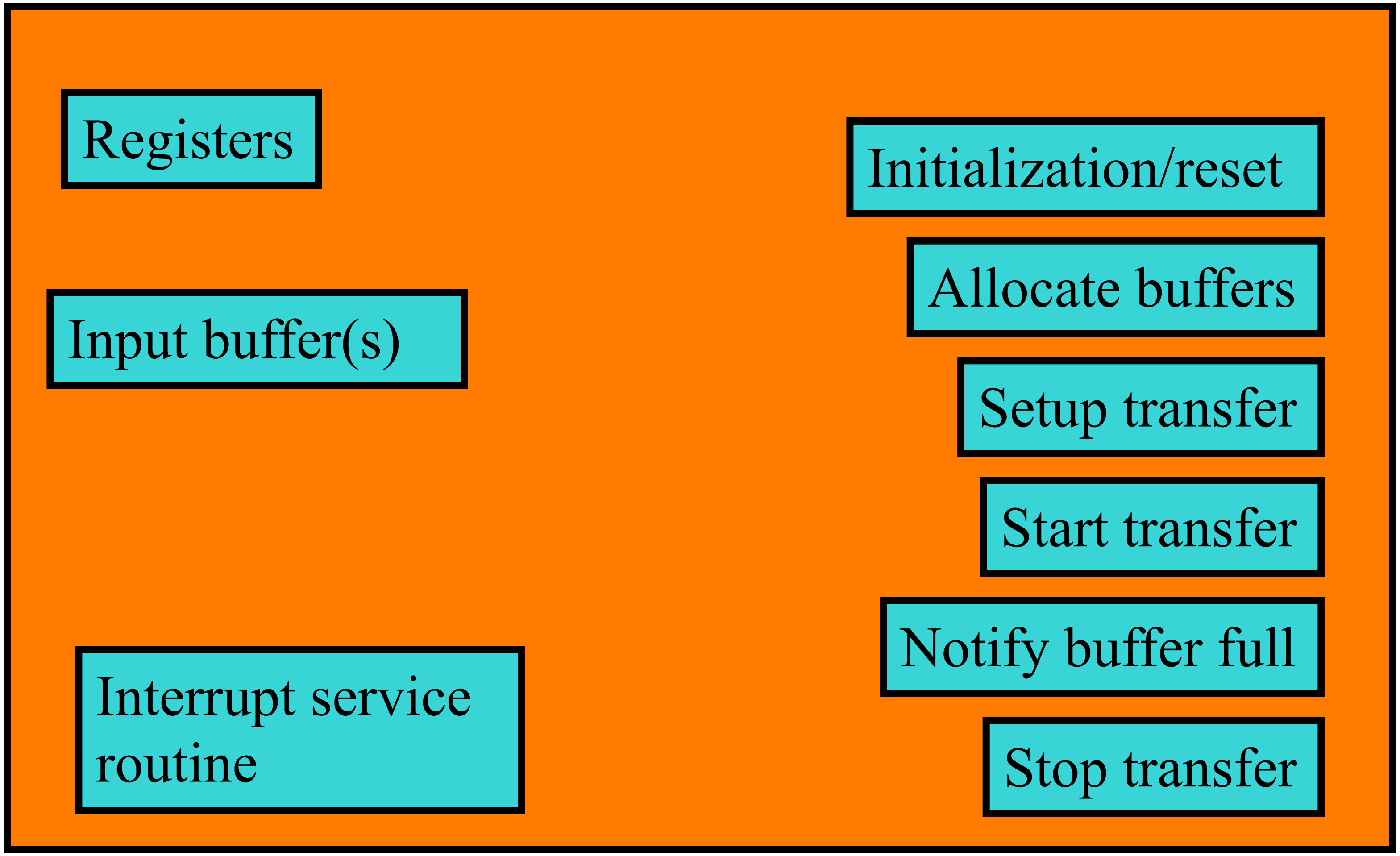
Encapsulation: levels of access (inspired by C++)

- "Public":
- "Private":
- "Protected":

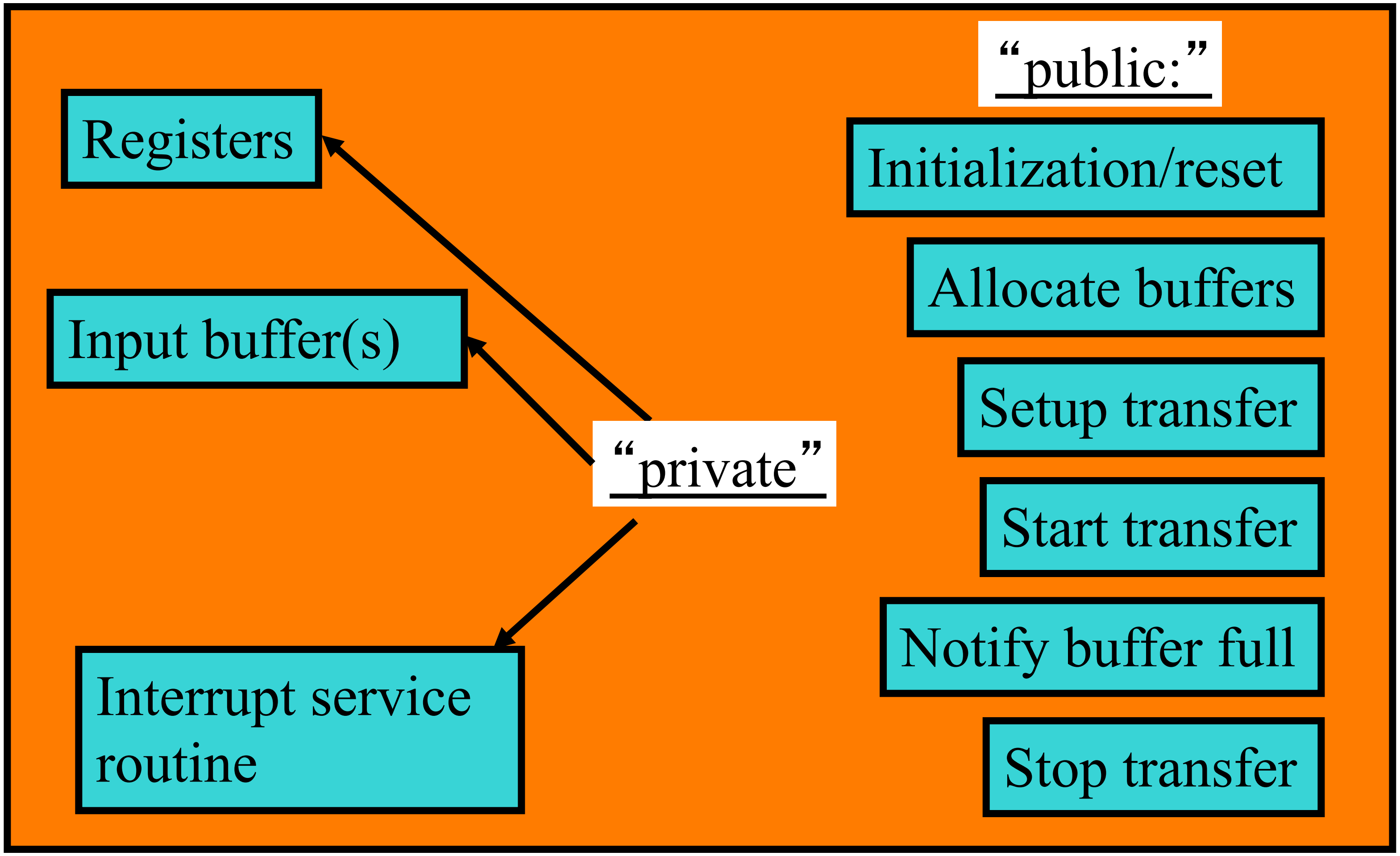
Encapsulation: levels of access (inspired by C++)

- “Public”: anybody can modify/see
- “Private”: nobody else can modify/see directly
- (“Protected”: only trusted entities can modify/see)

Serial Port Object: What is public/private?



Serial Port Object: What is public/private?



Private: C++ code

```
class Serial_Port
{
  private:
    int * buf_read_ptr;
    int * buf_write_ptr;
    int   buf_len;
    void  IRQ();
    int   buf[SP_MAX_NUM_BUF][SP_MAX_BUF_LEN];
    int   control_reg;
```

Interface: Public in C++ code

```
 public:
    ...
    void  SP_Reset();
    void  SP_Allocate_Buffers(
      int Num_Buffers,
      int Num_Points_Per_Buffer);
    void  SP_Setup_Xfer();
    void  SP_Start_Xfer();
    int   SP_Buffer_Ready();
    void  SP_Stop_Xfer();
    int * SP_getReadPtr();
};
```

Interface: C++ Main Loop

```
#include "serial_port.h"

void main()
{

  Serial_Port s;

  s.SP_Reset();

  s.SP_Allocate_Buffers(2, 256);
  s.SP_Setup_Xfer();
  s.SP_Start_Xfer();
```

Interface: C++ Main Loop

```
  while (...)
  {
    iReady = s.SP_Buffer_Ready();
    if (iReady == ...)
    {
      ...
    }
  }

  s.SP_Stop_Xfer();

}
```

Private: Motorola 56K example

```
MAX_BUF_LEN EQU 512
MAX_NUM_BUF EQU 4

  org x:0

  ; private:
buf_base  dsm MAX_BUF_LEN*MAX_NUM_BUF
buf_read  ds MAX_NUM_BUF
buf_write ds MAX_NUM_BUF
```

Public Interface: 56K example

```
 ; public:
  org p:

SP_Allocate_Buffers
  ; ...
  rts

SP_Setup_Xfer
  ; ...
  rts

SP_Start_Xfer
  ; ...
  rts
```

Interface: Typical main loop (56K)

```
    move #2,r0                  ; 2 buffers
    move #256,r1                ; 256 points per buffer
    jsr  SP_Allocate_Buffers
    ; ...
    jsr  SP_Setup_Xfer
    ; ...
    jsr  SP_Start_Xfer
main_loop:
    ; ...
    jsr  SP_Buffer_Ready        ; a = flag
    tst  a                      ; if a = 0
    jne  main_loop
    ; ...                       ; process buffer
    jmp main_loop
```

Interface Useage: Typical startup (56K)

```
reset:
    ; ...
    jsr  Stack_Reset
    jsr  SP_Reset
    jsr  DAC_Reset
    jsr  GUI_Reset
    jsr  Mem_Reset
    jsr  Clock_Reset
    ; ...
```

How to make “encapsulation”

- Plan “private,” “public”, (“protected”).
- Make objects (see above).
- Keep the details inside the object.
- Provide an interface for the outside world.
- Don’t let the outside world muck with what’s inside the object (except through the interface).

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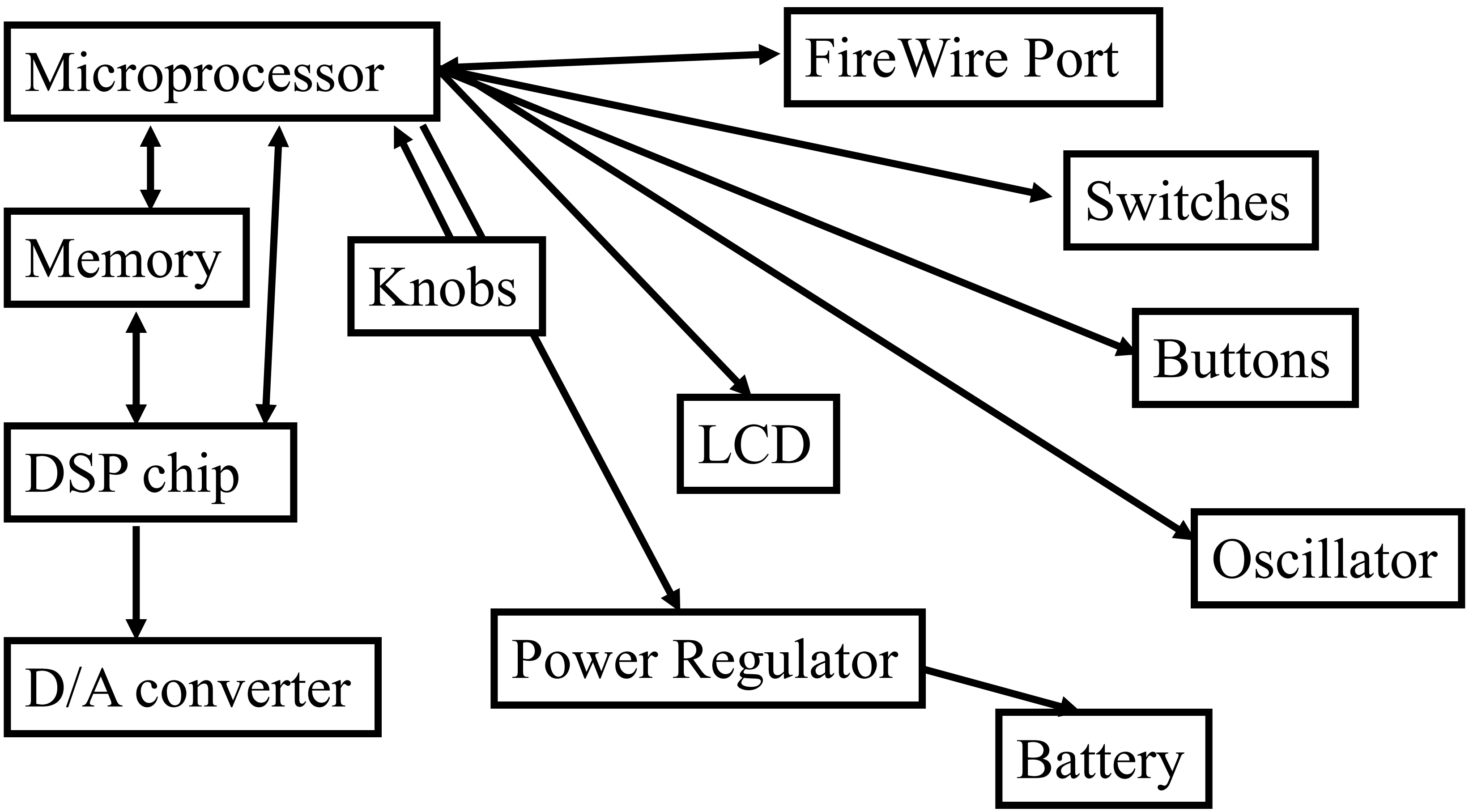
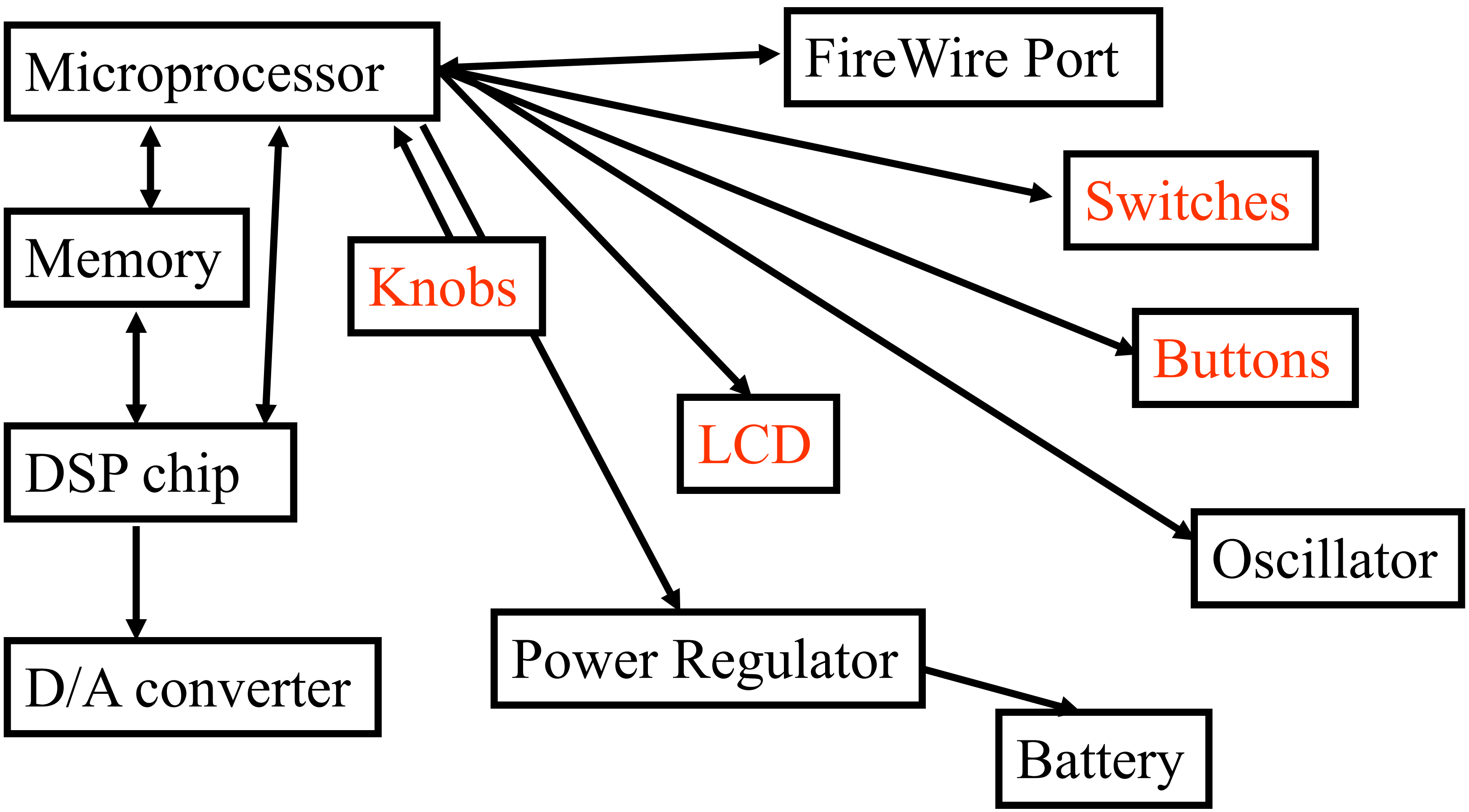
Inheritance

- OOP: child class can inherit from the parent class
- Embedded: Find what is common, create a parent, inherit from it (abstraction)

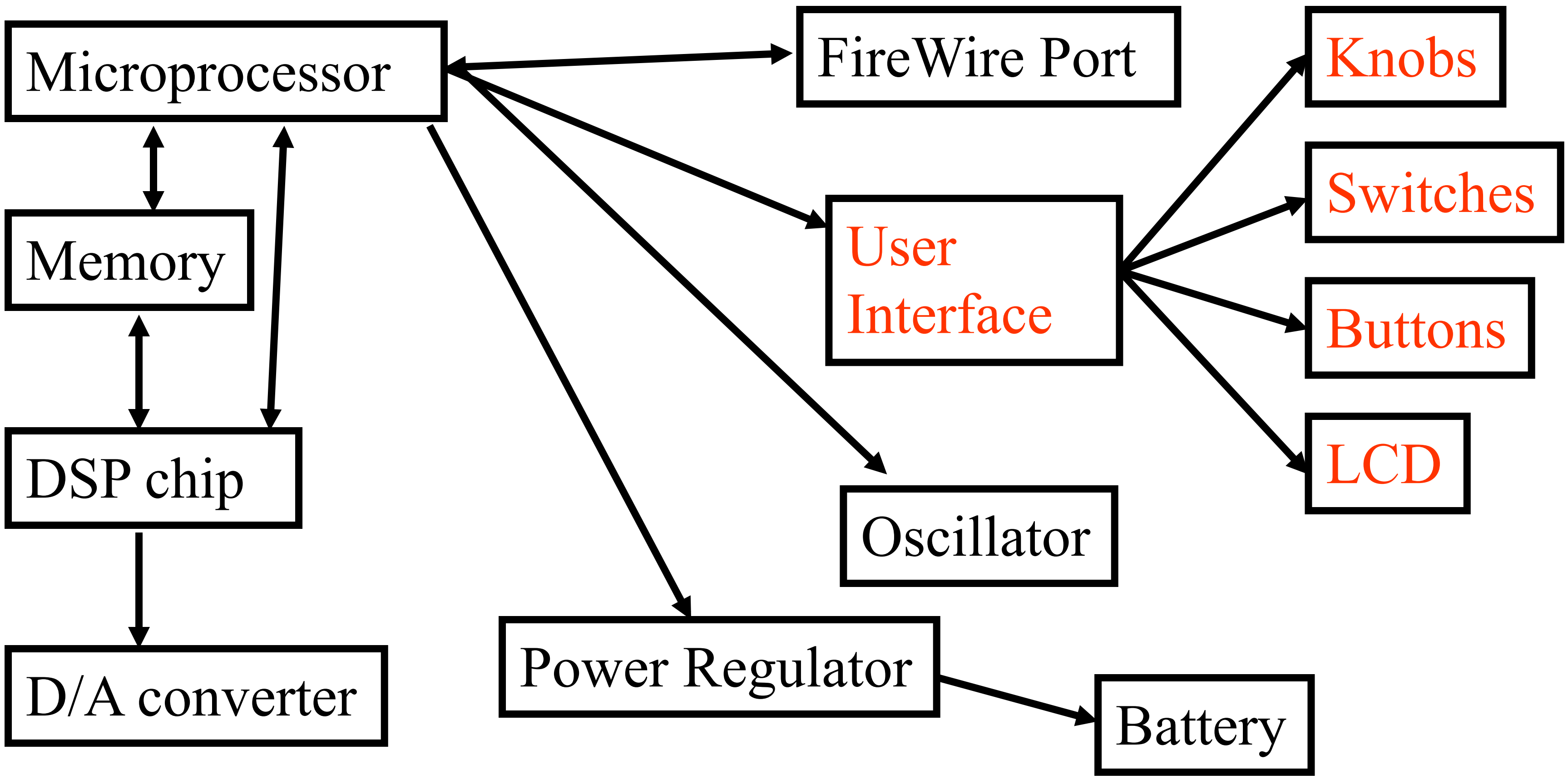
MP3 Player: what is common?



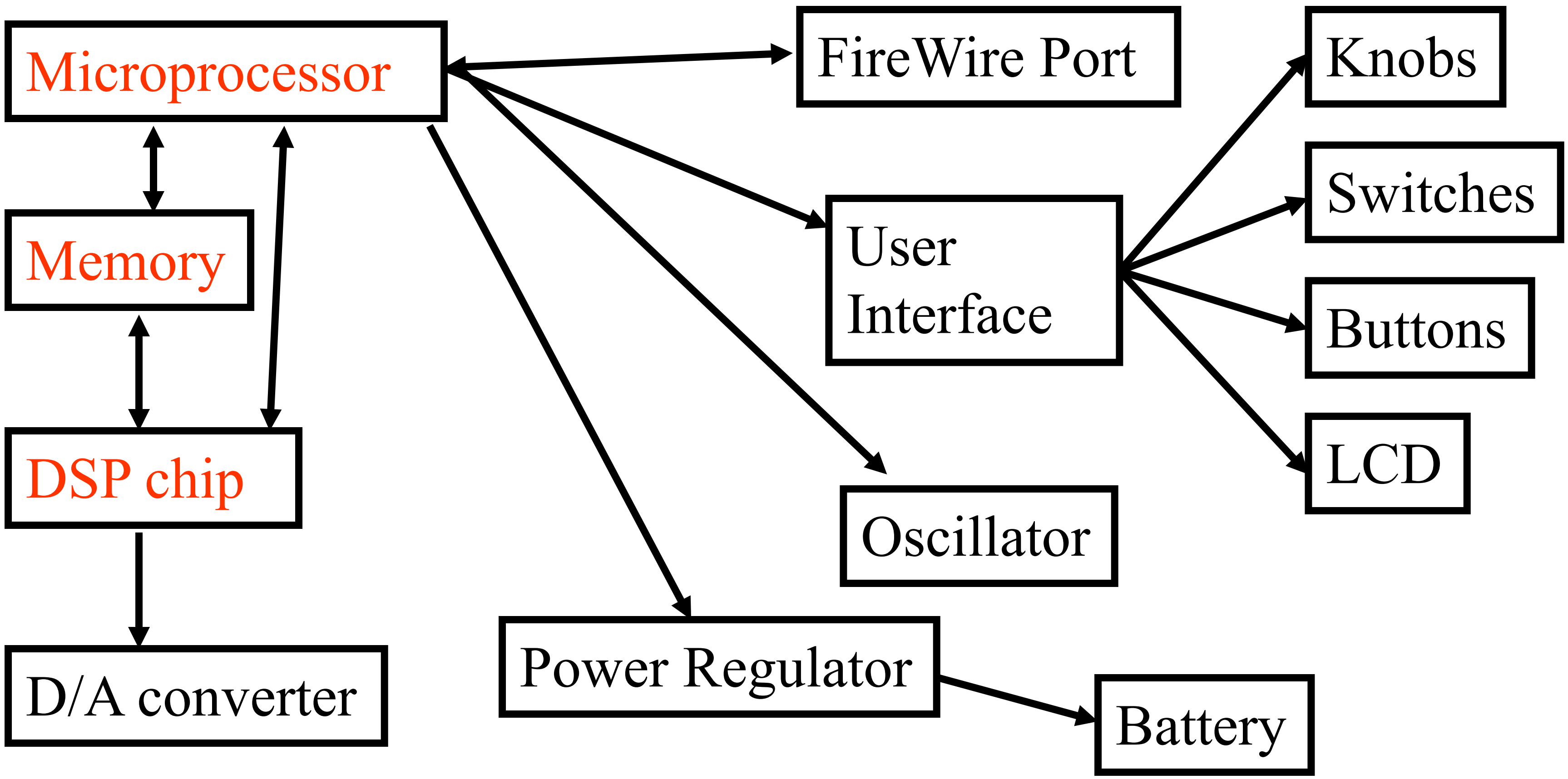
MP3 Player: what is common?



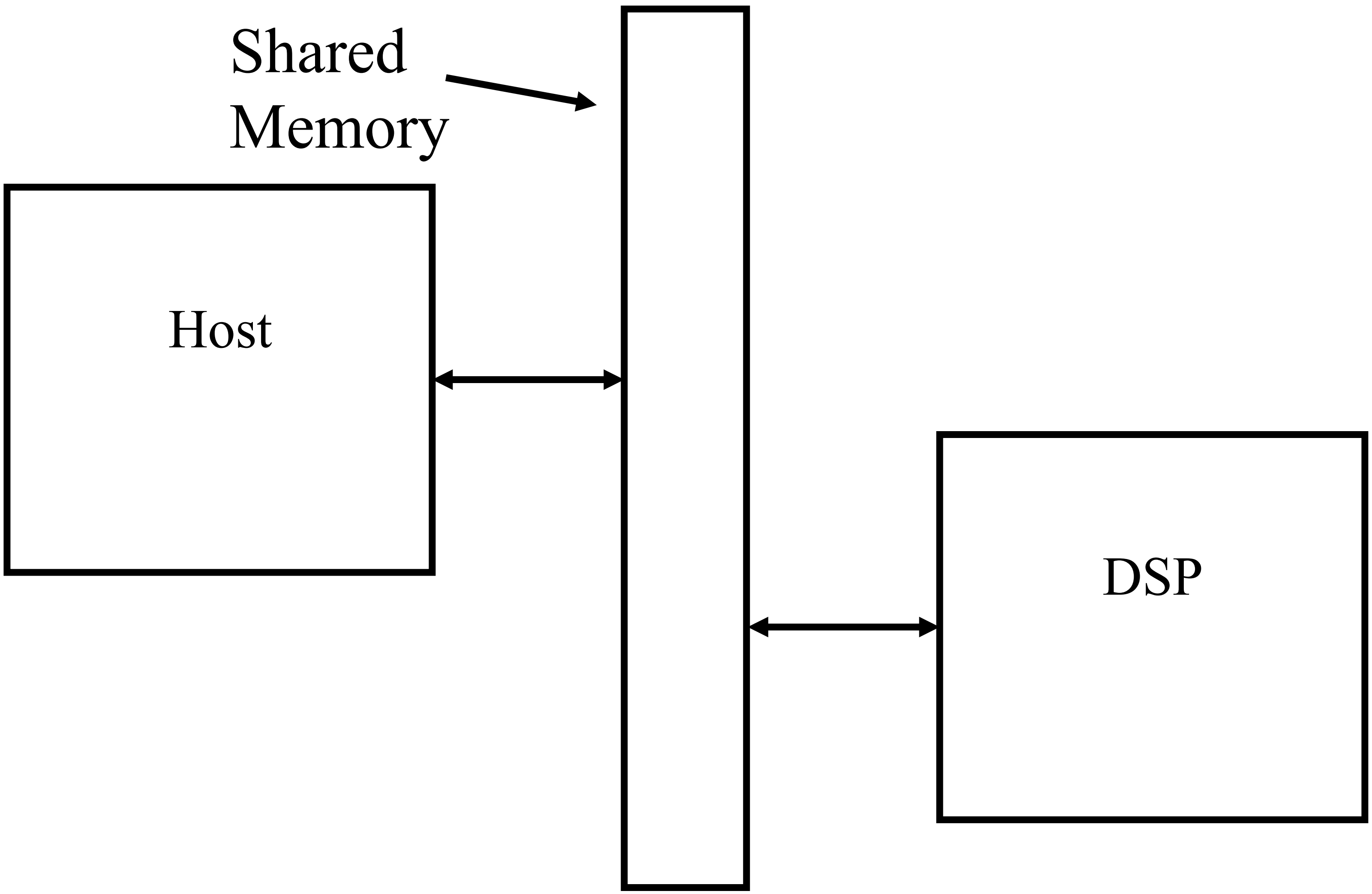
Inheritance: Relationship of Objects (Abstraction)



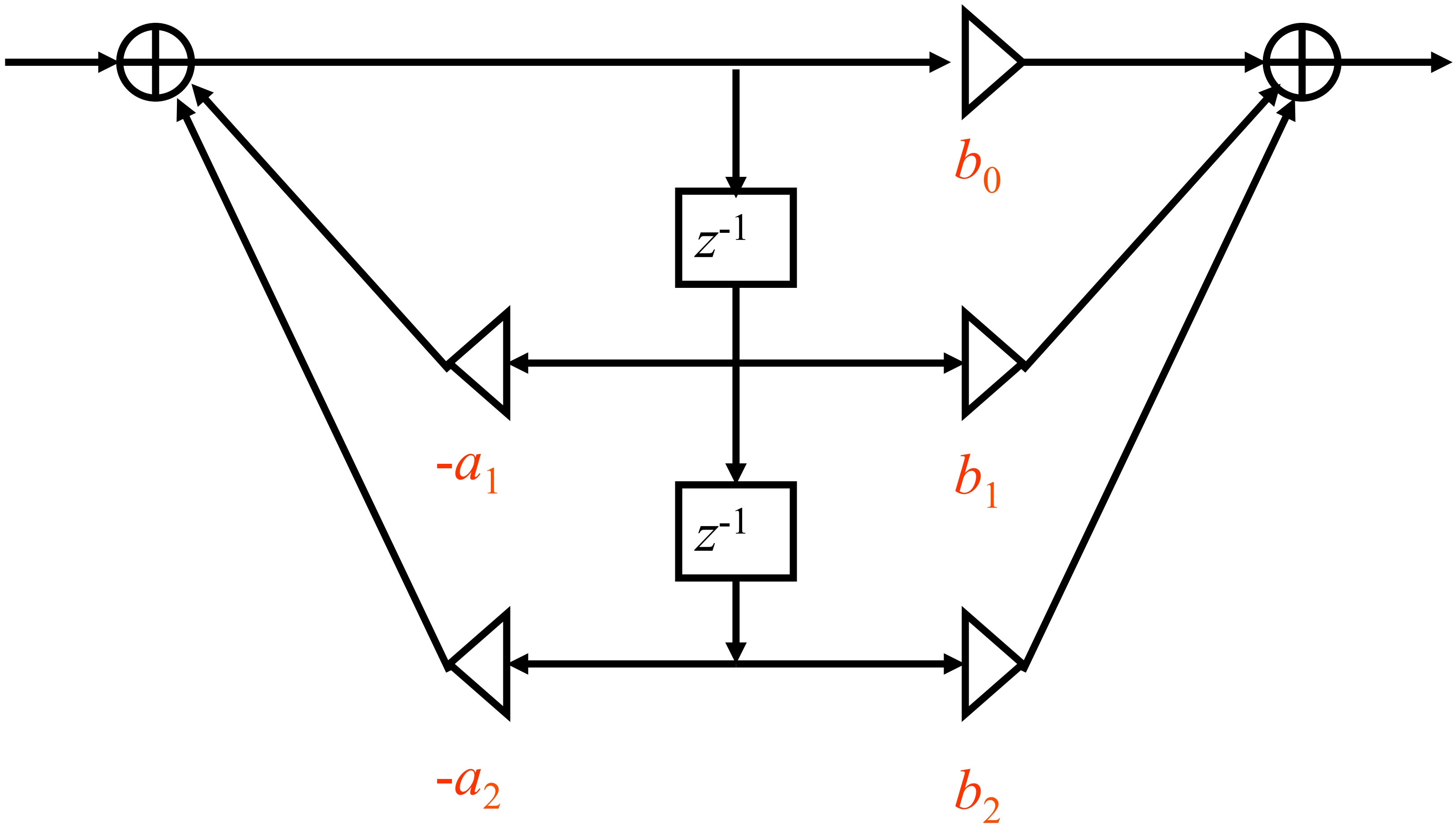
Inheritance: Shared Memory



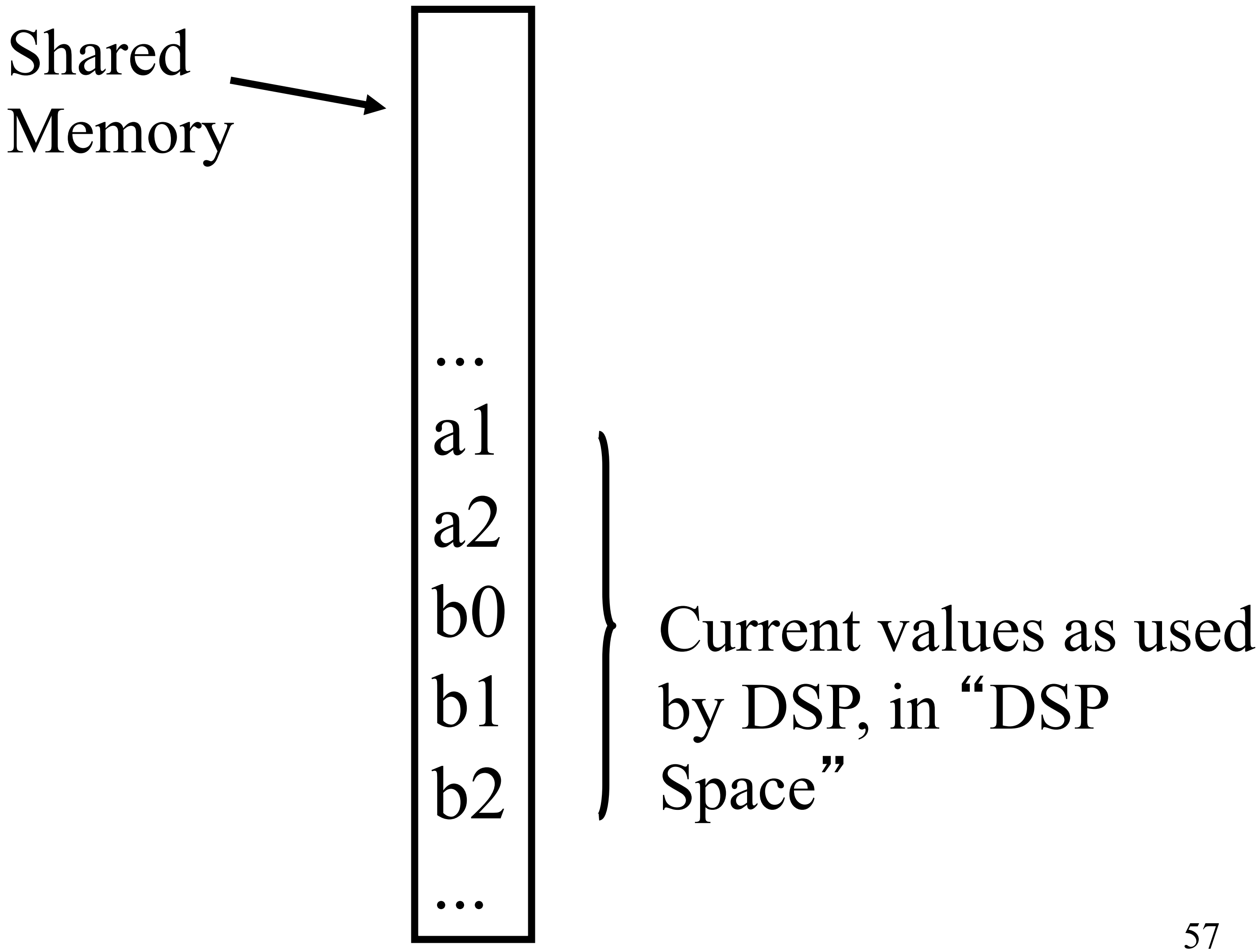
Prototypical Plugin Architecture



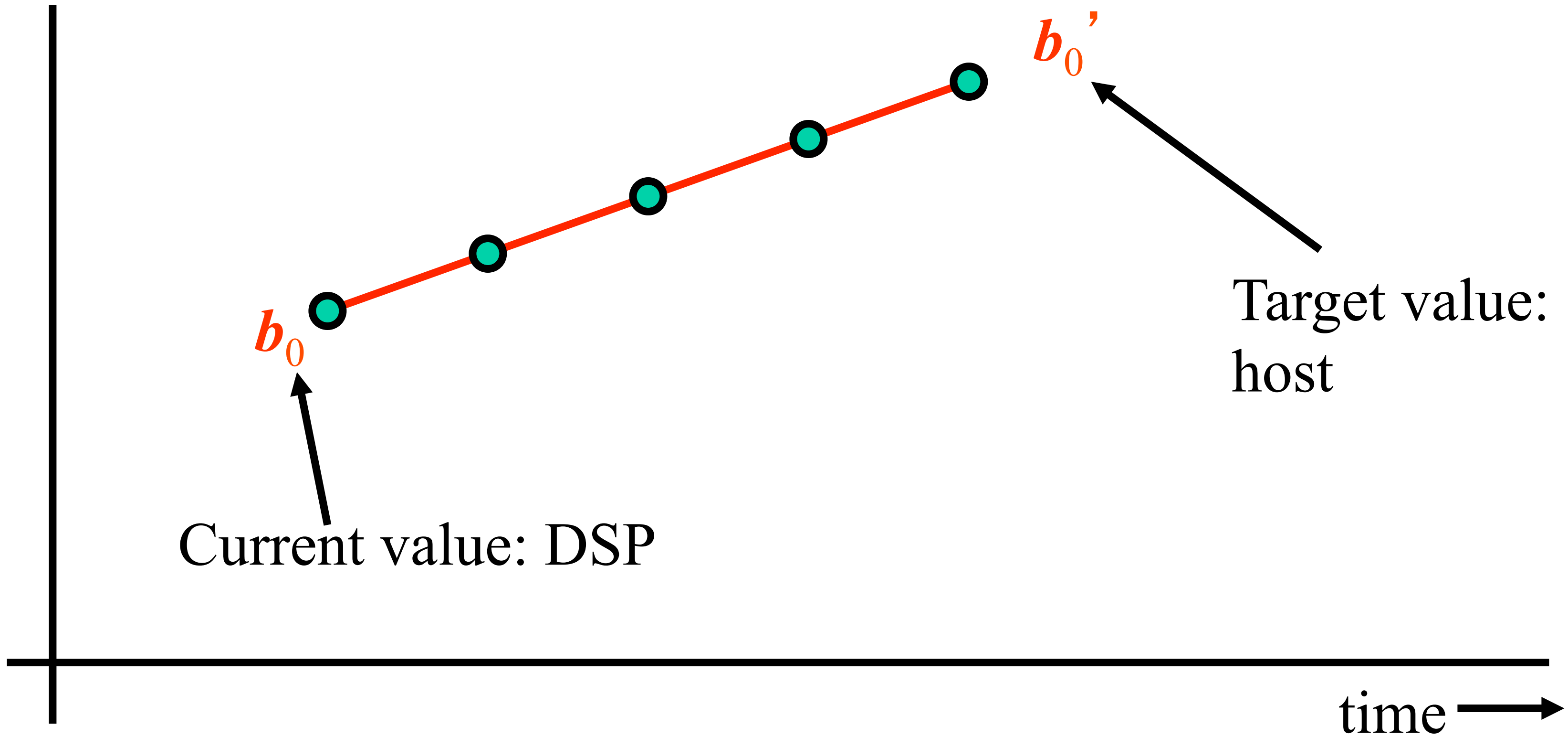
Inheritance: Biquad structure



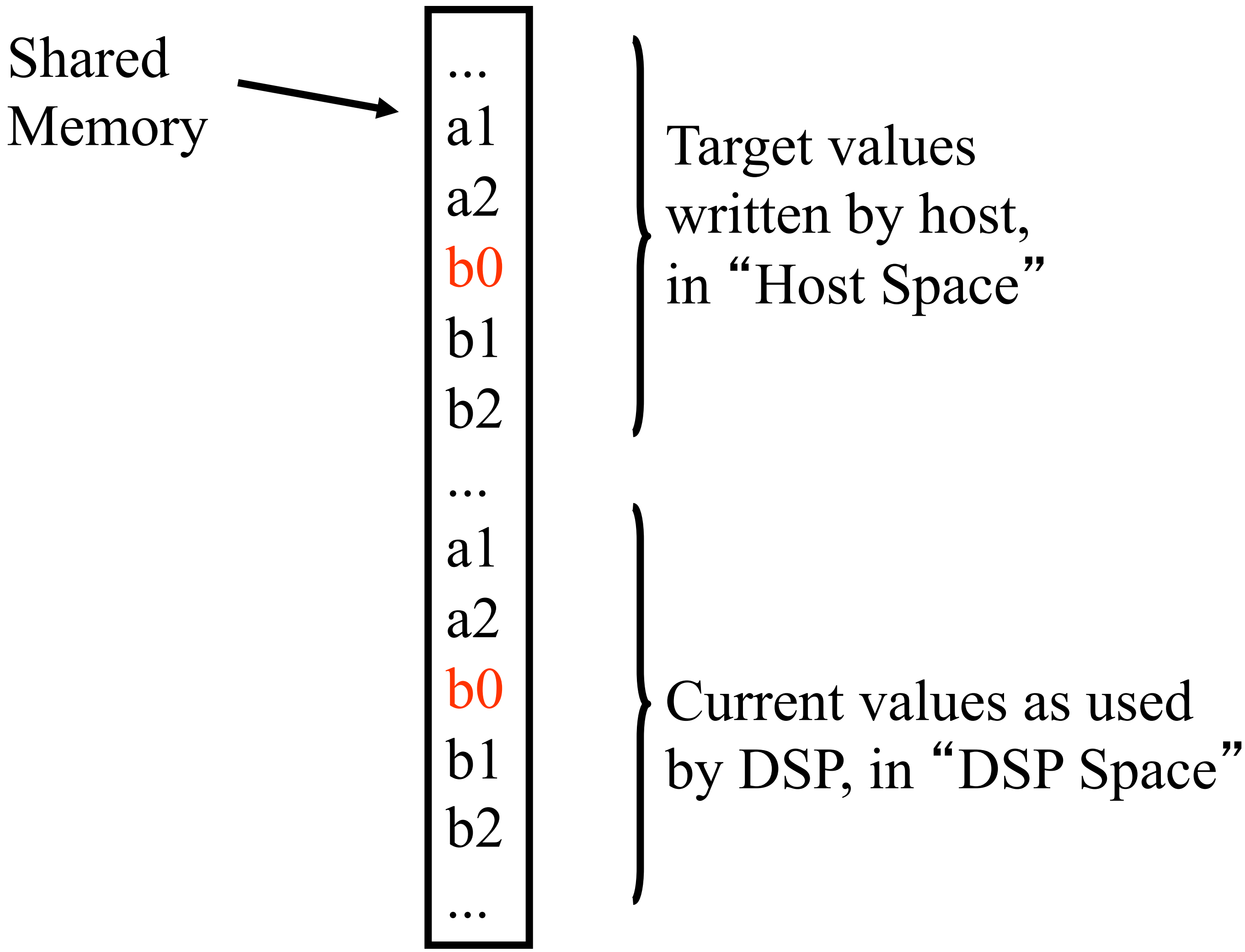
Inheritance: DSP



Interpolate Biquad Coefficients



Inheritance: µP + DSP



Inheritance:Macro define, call

```
Biquad    MACRO name
name + _a1:    allocate one memory location
name + _a2:    allocate one memory location
name + _b0:    allocate one memory location
name + _b1:    allocate one memory location
name + _b2:    allocate one memory location
MACRO END
#define BIQUAD_LEN 5

     ...
     Biquad HostSpace
     ...
     Biquad DSPSpace
     ...
```

Inheritance: Macro results

Shared Memory →

```
   ...
HostSpace_a1
HostSpace_a2
HostSpace_b0
HostSpace_b1
HostSpace_b2
   ...
DSPSpace_a1
DSPSpace_a2
DSPSpace_b0
DSPSpace_b1
DSPSpace_b2
   ...
```

HostSpace_a1 … HostSpace_b2: Target values written by host, in "Host Space"

DSPSpace_a1 … DSPSpace_b2: Current values as used by DSP, in "DSP Space"

Inheritance: interp using memory

```
pHost  = &HostSpace_a1;
pDSP =  &DSPSpace_a1;

for (i=0; i< BIQUAD_LEN; i++) {

    *pDsp = *pHost ... *pDSP ...;

    pHost++;
    pDSP++;
}
```

Inheritance: Using memory

```
  move #HostSpace_a1,r0 ; init pHost
  move #DSPSpace_a1,r1  ; init pDSP
  move #BIQUAD_LEN,y0   ; do 0<=i<n {
  do y0,p_interp
  move x:(r0),x0        ;   *pHost
  move x:(r4),x1        ;   *pDSP
  ; ...                 ;   *pDSP = ...
  move (r0)+            ;   pHost++;
  move (r1)+            ;   pDSP++
p_interp:               ; }
```

Inheritance: Modify the Biquad

```
Biquad     MACRO name
name + _a1:     allocate one memory location
name + _a2:     allocate one memory location
name + _b0:     allocate one memory location
name + _b1:     allocate one memory location
name + _b2:     allocate one memory location
name + _gain:  allocate one memory location
MACRO END

#define BIQUAD_LEN 6
```

Inheritance: Macro results

Shared Memory →

```
HostSpace_a1
HostSpace_a2
HostSpace_b0
HostSpace_b1
HostSpace_b2
HostSpace_gain
      ...
DSPSpace_a1
DSPSpace_a2
DSPSpace_b0
DSPSpace_b1
DSPSpace_b2
DSPSpace_gain
      ...
```

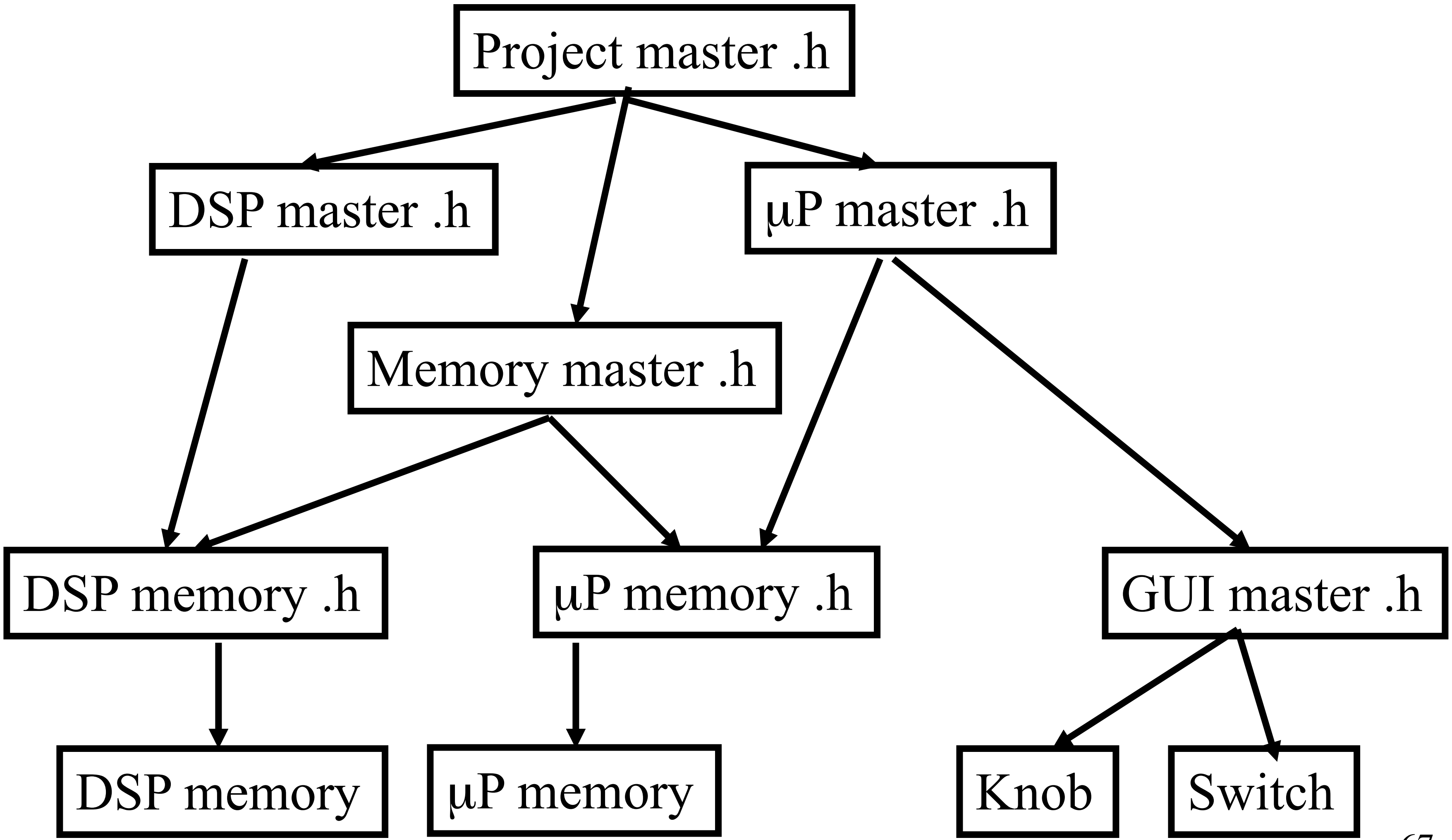
Target values written by host, in "Host Space" (HostSpace_a1 … HostSpace_gain)

Current values as used by DSP, in "DSP Space" (DSPSpace_a1 … DSPSpace_gain)

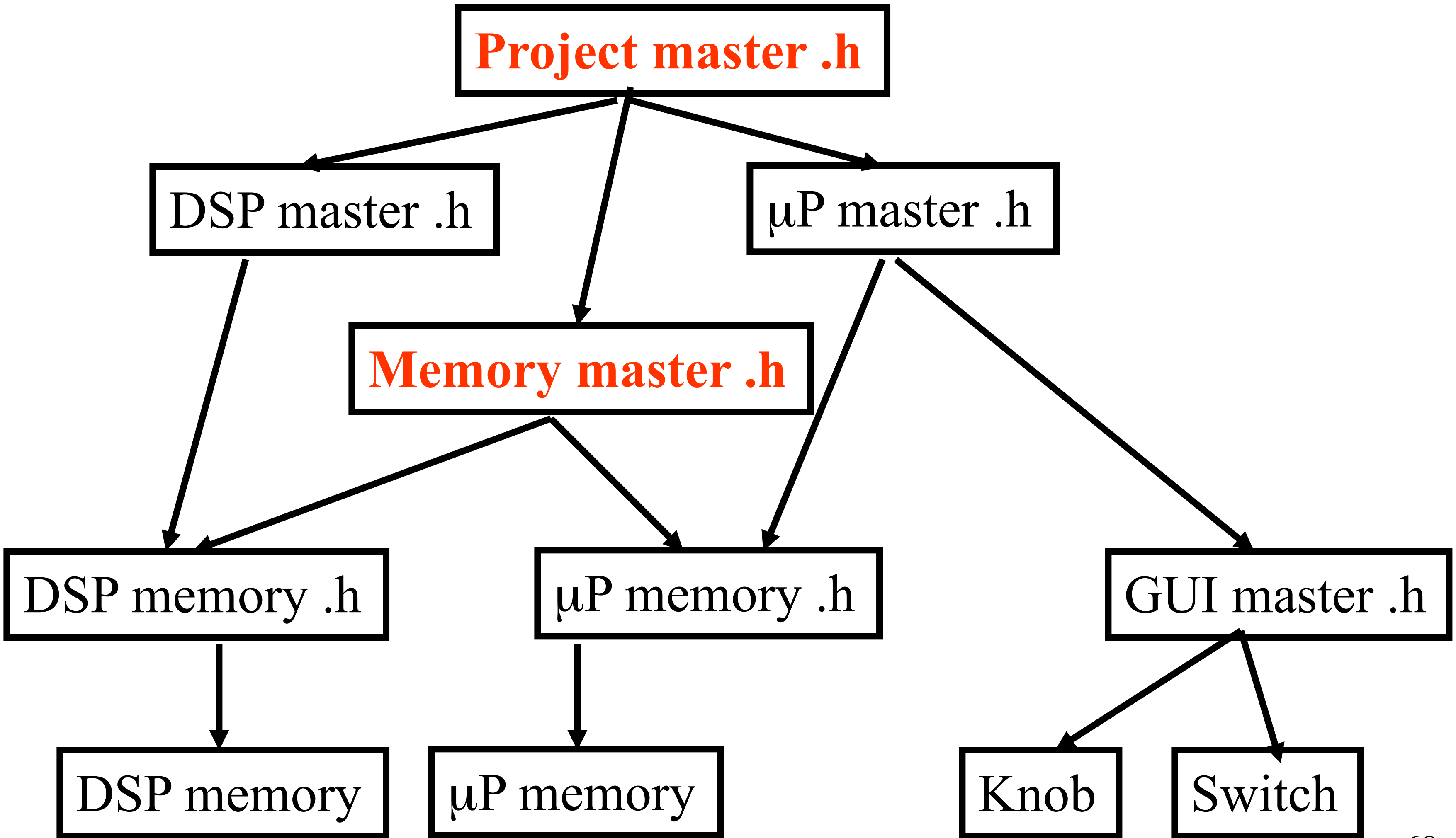
How to make "abstraction" and "inheritance"

- Look for objects that have similar properties.
- Abstract those properties into a common header file and source file.
- Include the header file.
- Invoke the common properties.

Inheritance: header files



Abstraction: header files



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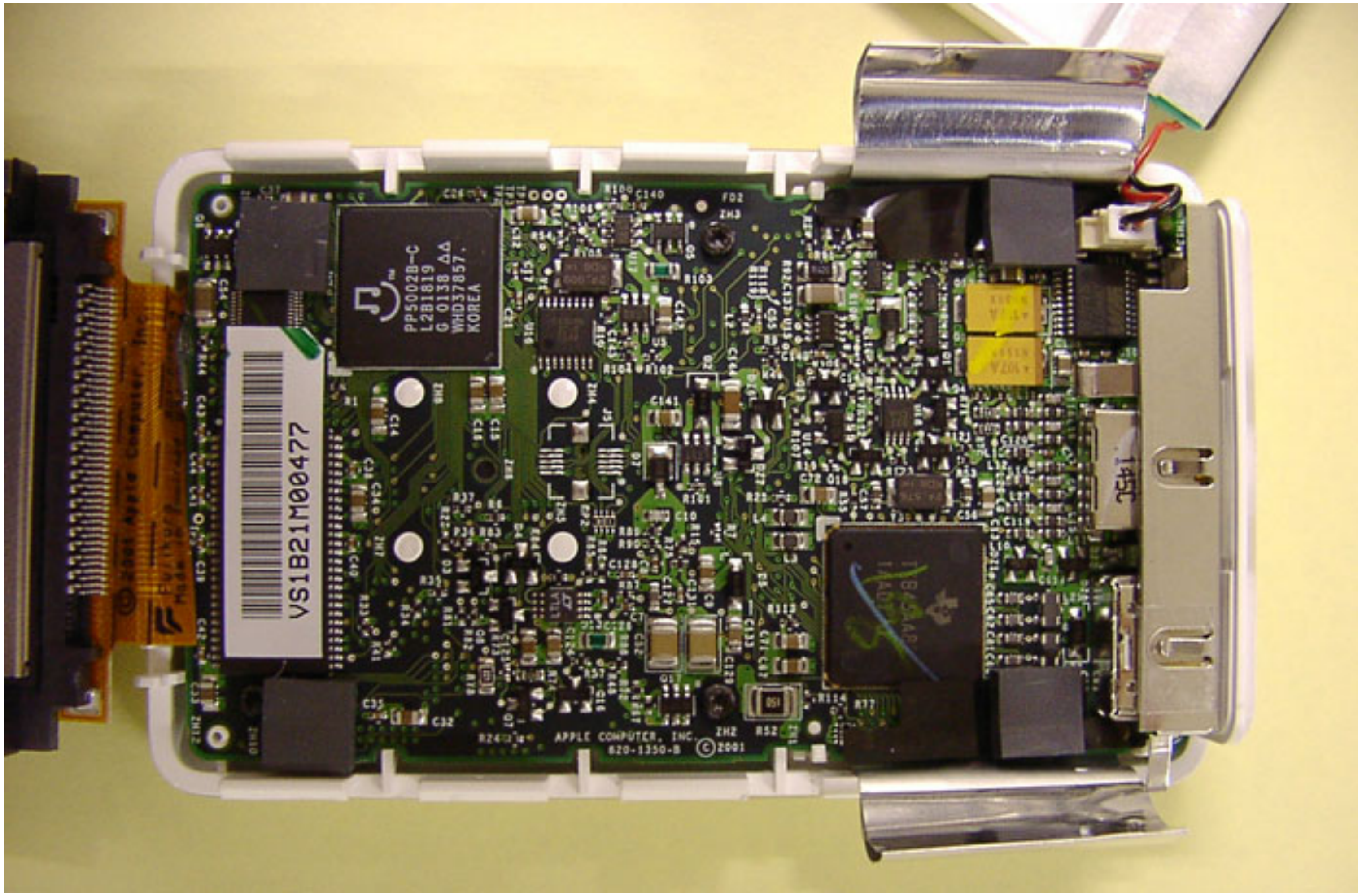
Benefits of OOP for Embedded

- Speed up my development time.
- Improve reliability of my code.
- Easier to isolate my bugs.
- Easier for me to modify my own code now.
- Easier for me to modify my own code later.
- Easier for others to modify my code.
- Easier to re-use code for new projects (maybe)

Street Smarts to apply

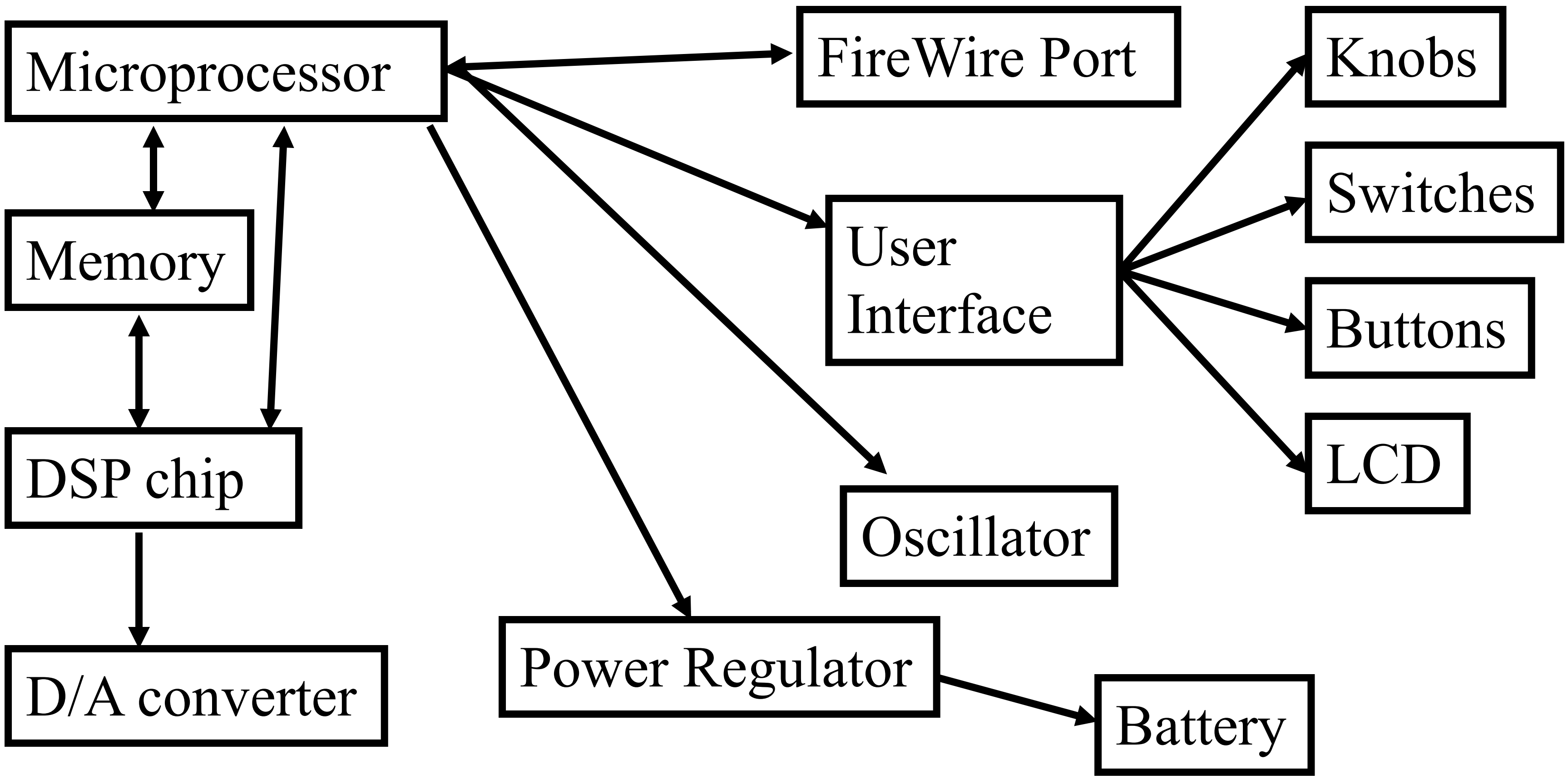
- Object
- Encapsulation
- Inheritance

iPOD



http://www.chipmunk.nl/iPod/ipodChipmunk1.jpg

MP3 Player


Microprocessor
FireWire Port
Knobs
Switches
Memory
User
Interface
Buttons
DSP chip
LCD
Oscillator
Power Regulator
D/A converter
Battery

OOP Resources

- http://www.objectfaq.com/oofaq2/
- Grady Booch, *Object-Oriented Analysis and Design with Applications*
- Grady Booch, *The Unified Modeling Language User Guide*

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