memory map

A table or diagram containing the name and address range of each peripheral and memory device within a processor's memory space. Memory maps are a helpful aid in getting to know one's target.

memory-mapped I/O

A common hardware design methodology in which peripheral control and status registers are mapped into the memory space rather than the I/O space. From the software developer's point of view, memory-mapped I/O devices look very much like memory devices. Their registers can even be accessed via ordinary pointers and data structures, greatly simplifying device driver implementation.

microcontroller

A highly integrated microprocessor designed specifically for use in embedded systems. Microcontrollers typically include an integrated CPU, memory (a small amount of RAM, ROM, or both), and other peripherals on the same chip. Common examples are Microchip's PIC, the 8051, Intel's 80196, and Motorola's 68HCxx series.

microprocessor

A piece of silicon containing a general-purpose CPU. The most common examples are Intel's 80x86 and Motorola's 680x0 families.

A/D converter

A hardware device that reads an analog signal—typically a voltage—compares it to a reference signal, and converts the resulting percentage to a digital value. Short for analog-to-digital converter. Abbreviated ADC. The reference signal represents 100%. An n-bit A/D converter has a maximum value of 2n - 1 and a resolution of $Vref/2^n$

address bus

A set of wires connected to a processor and all of the peripherals with which it communicates, for the purpose of selecting a specific memory location or register within a particular peripheral. If the address bus contains n electrical lines, the processor can address up to 2n unique locations. Address decoding logic between the processor and the devices connected to the bus select the proper device, typically based on the uppermost bits.

assembler

A software development tool that translates human-readable assembly language programs into machine-readable code that the target processor can understand and execute.

assembly language

A human-writable form of a processor's native instruction set. In its typical form, each line of assembly code represents a single CPU instruction. The human-readable representation of each opcode is called a mnemonic.

bidirectional

Describes a type of device or bus that supports two-way data transfers. To reduce wiring, connectors, and pin counts, it's common to share data on one bus. Data can move from device A to B or from B to A, though not at the same time.

big-endian

A data representation for a multibyte value that has the most significant byte stored at the lowest memory address. Note that only the bytes are reordered, never the nibbles or bits that comprise them. Every processor stores its data in either big-endian or little-endian format. Sun's SPARC, Motorola's 68k, and the PowerPC families are all big-endian. The Java virtual machine is big-endian as well. Similarly, every communications protocol must define the byte order of its multibyte values. TCP/IP uses big-endian representation.

EXAMPLE: If the 32-bit value 0x12345678 is located at address 1000d in memory, its most significant byte, 0x12, would be found at location 1000d. Location 1001d would contain the next most significant byte, 0x34; location 1002d would contain 0x56; and location 1003d would contain the least significant byte, 0x78.

central processing unit

The part of a processor that executes instructions.

compiler

A software-development tool that translates high-level language programs into the machine-language instructions that a particular processor can understand and execute. However, the object code that results is not yet ready to be run; at least a linker or link-step must follow.

complex instruction set computer

Describes the architecture of a processor family. Abbreviated CISC. So-called CISC processors generally feature variable-length instructions and multiple addressing formats and have a small number of general-purpose registers. Intel's 80x86 family is the quintessential example of CISC.

counter/timer

A common peripheral that counts either external events (counter mode) or processor cycles (timer mode). Virtually every microcontroller has one or more on-board counter/timers. Most operate in a vast number of modes; some have dozens of control registers (Motorola's TPU has more than 50).

Counter/timer hardware has more uses than can be imagined, including as input devices to count events, as outputs to drive pulse-width modulation

devices, and as internal units to create regular interrupts for RTOS context switching.

cross-compiler

A compiler that runs on a different platform from the one for which it produces object code. Often even the processor architecture/family of the host and target platforms differ.

D/A converter

A hardware device that takes a set of bits, typically from a processor, as input and produces an analog signal proportional to the digital input as output. Short for digital-to-analog converter. Abbreviated DAC. D/A converters might be as simple as an array of resistors configured in the typical "R-2R" fashion or a hybrid module that generates very precise results with many bits of resolution. A simple use is to vary the intensity of a lamp (another approach that avoids the messy analog world is a pulse-width modulator that uses different switching rates and pulse lengths to control intensity).

data bus

A set of electrical signals connected to the processor and all of the memory and peripheral devices with which it communicates for the purpose of transferring data between them. When the processor wants to read (write) the contents of a memory location or register within a particular peripheral, it sets the address bus pins appropriately and receives (transmits) the contents on the data bus. One unit of data is transferred in each memory cycle.

debugger

A tool used to test and debug software. A typical remote debugger runs on a host computer and connects to the target through a serial port or over a network. Using the debugger, you can download software to the target for immediate execution. You can also set breakpoints in the code and examine the contents of specific memory locations and registers.

digital signal processing

Whether involving a DSP or not, the work of digital signal processing experts is to communicate and compress audio and video data.

EEPROM

A type of ROM that can be erased electronically and reprogrammed in-circuit (or with a device programmer). Short for Electrically Erasable Programmable Read Only Memory. From the programmer's perspective, EEPROM is very similar to flash memory. The biggest difference is that the bytes (words) of an EEPROM can be erased individually.

embedded system

A combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a dedicated function. In some cases, embedded systems are part of a larger system or product, as in the case of an antilock braking system in a car.

EPROM

A type of ROM that can be erased by exposing it to ultraviolet light. Once erased, an EPROM can be reprogrammed with a device programmer. Short for Erasable Programmable Read Only Memory. A window in the device allows ultraviolet radiation to enter the device and reset the ROM circuitry to its initial state.

executable

A file containing object code that is ready for execution on the target. All that remains is to place the object code into a ROM or download it via a debugging tool.

flash

To download new firmware into a flash memory. A bootloader typically facilitates this process by communicating with a program on the host, erasing the flash memory, and writing the new code. The sector of the flash memory that contains the bootloader's code must not be overwritten in the process.

flash memory

A RAM-ROM hybrid that can be erased and rewritten under software control. Abbreviated flash. Flash is an in-circuit programmable nonvolatile memory segmented into blocks called sectors. Each sector can be individually erased, then the data within it rewritten. Flash memory is common in systems that require nonvolatile data storage at very low cost. In some cases, a large flash device can be used instead of a disk drive. Although there is a theoretical limit to the number of times a flash memory can be erased and rewritten successfully, this limit is seldom reached in practice.

general-purpose I/O

Customizable input/output pins on a microcontroller. Abbreviated GPIO. By wiring the hardware appropriately and configuring the GPIO port in software, one pin can be used as input to read a switch, another as an output to control a status LED, and a pair to serve as clock and data for a serial EEPROM.

I/O

Short for input/output.

The interface between a processor and the world around it. The simplest examples are switches (inputs) and LEDs (outputs).

I/O device

A piece of hardware that interfaces between the processor and the outside world. Common examples are switches, LEDs, serial ports, and network controllers.

I2C

An inexpensive chip interconnection popular on circuit boards. Short for Inter-Integrated Circuit bus. Featuring a two-wire synchronous (data and clock)

connection, I2C can run at speeds up to 100 kHz ("standard") or 400 kHz ("high speed") and is multidrop.

in-circuit emulator

A debugging tool that takes the place of (emulates) the processor on the target board. Abbreviated ICE and often called an emulator for short. The ICE is a bridge between the target system and a software debugger running on the host. It provides the resources needed to access the target microprocessor. An emulator connects to or completely replaces the target CPU via a large cable, which routes all signals to the ICE unit. In-circuit emulators frequently incorporate a special bond-out version of the target processor that brings normally buried signals out of the chip to the ICE's logic circuits.

interrupt

An asynchronous electrical signal from a peripheral to the processor. When the peripheral asserts this signal, an interrupt is said to occur. When an interrupt occurs, the current context is saved and an interrupt service routine is executed. When the interrupt service routine exits, control of the processor is returned to whatever part of the software was previously running.

interrupt service routine

A small piece of software executed in response to a particular interrupt. Abbreviated ISR

interrupt type

A unique number associated with each interrupt. The interrupt type is typically the processor's index into the interrupt vector table.

interrupt vector

The address of an interrupt service routine.

USAGE: This term is sometimes used incorrectly to refer to either the interrupt type or the address of the interrupt vector.

interrupt vector table

A table containing interrupt vectors, indexed by interrupt type, that maps interrupts and interrupt service routines. The interrupt vector table must be initialized before interrupts are enabled.

JTAG

A standard for providing external test access to integrated circuits serially, via a four- or five-pin external interface. Short for Joint Test Action Group, which developed the standard. The JTAG standard has been adopted as an IEEE standard (IEEE 1149 Standard Test Access Port and Boundary-Scan Architecture). JTAG ports have been widely embraced by processor manufacturers. Debug monitors and in-circuit emulators increasingly leverage the capabilities inherent in JTAG.

linker

A software development tool that accepts one or more object files as input and outputs a relocatable program. The linker is thus run after all of the source files have been compiled and assembled into object files.

nonmaskable interrupt

An interrupt that cannot be disabled. Abbreviated NMI. Known as a trap (on some Intel processors), as a level 7 interrupt (Motorola), or by other names.

object code

A set of processor-readable opcodes and data. The output of compilers and assemblers and the input and output of a linker are files containing object

code. However, there are a variety of standardized and proprietary object file formats, meaning that development tools from one vendor can only rarely read the object code produced by those of another.

object file

A file containing object code; in particular, the output of a compiler or assembler. Most object files begin with a symbol table, which is followed by intermixed segments of code and data.

on-chip debug

A technology-agnostic name for the variety of techniques (like BDM) that include software debug capability within the processor hardware. Sometimes abbreviated OCD. The connection to the host-based debugger is generally over a standard JTAG port or a proprietary header.

one-time programmable

Describes any programmable device, like a PROM or a PLD, that can be programmed just once by the end user. Abbreviated OTP. [more]

peripheral

A piece of hardware other than the processor, usually an I/O device. A peripheral can reside within the same chip as the processor; in which case, it can be called an integrated or on-chip peripheral.

processor

A generic term that does not distinguish between microprocessor, microcontroller, network processor, or digital signal processor.

processor family

A set of related processors, usually successive generations from the same manufacturer. For example, Intel(link is external)'s 80x86 family began with the 8086 and now includes the 80186, 286, 386, 486, Pentium, and many others. The later models in a family are typically backward-compatible with the ones that came before.

pulse width modulation

A digital control technique wherein the processor adjusts the duty cycle of a sequence of fixed-width pulses. Abbreviated PWM. Unlike other modulation techniques, PWM is used more to control external analog signals or mechanical devices than to transmit data.

Consider driving a motor: a simple analog approach is to bias a transistor by varying amounts to control the motor's speed. This is very inefficient because the transistor dissipates considerable amounts of heat. PWM offers an alternative: connect the same transistor to a digital output pin and control the duty cycle of a train of pulses. Now the transistor is either on or off, so there's little power ($P = I2 \times R$) loss.

Other applications abound. Passing the digital output through a lowpass filter converts the pulses to analog—the voltage a function of duty cycle. In effect, it's a cheap D/A converter.

Many processors have built-in PWM controllers that generate the pulse stream for a programmable duty cycle.

random access memory

A broad classification of memory devices that includes all devices in which individual memory locations can be read or written in any order required by the application. Abbreviated RAM. Misused to mean memory that can be both read and written, but the term is so broadly (mis)used in this fashion that nearly everyone assumes random access is the same as read-write.

read-only memory

A broad classification of memory devices that includes all devices in which memory locations cannot be modified. Abbreviated ROM. Misused to mean any nonvolatile memory, including flash and EEPROM, that can be modified in-system.

register

A memory-like location that is part of a processor or an I/O device. The reference to the register is encoded as part of the instruction, not as a discrete address. A processor register is much faster to read or write than a location in memory. Generally, each bit or set of bits within a peripheral register controls or tracks some behavior of the larger device.

simulator

A debugging tool that runs on the host and pretends to be the target processor. A simulator can be used to test pieces of the embedded software before the embedded hardware is available. Unfortunately, attempts to simulate interactions with complex peripherals are often more trouble than they are worth.

SRAM

A type of RAM that retains its contents as long as the system is powered on. Short for Static Random Access Memory. Data stored in SRAM is lost when the system is powered down or reset

stack

A list in which elements are always added and removed from the (conceptual) end. A last-in, first-out queue. Stacks are one of the four basic kinds of queues or lists. They are used most frequently to keep track of hierarchically nested processes. They are common in both application- and system-level software. Any processor that implements a call instruction must also support some kind

of hardware stack (the run-time stack). Compilers rely on the run-time stack to support function calls and argument passing.

timer

A peripheral that measures elapsed time, typically by counting processor cycles or clocks. Compare to counter. See also input capture timer, counter/timer.

Universal Serial Bus

A serial protocol and physical link that transmits all data differentially on a single pair of wires. Abbreviated USB. USB is an increasingly popular replacement for slower serial and parallel ports, especially for connecting to general-purpose computers. In addition to higher throughput, USB also offers the ability to power downstream devices and to connect a much larger number of devices.

The USB 1.0 standard specifies two kinds of cables and two variations of connectors. High-speed cables, for 12 Mbps communication, are better shielded than their less expensive 1.5 Mbps counterparts. Each cable has an "A" connector on one end and a "B" on the other. Since the two types are physically different it's impossible to install a cable incorrectly.

watchdog timer

A fail-safe mechanism that intervenes if a system stops functioning. Abbreviated WDT. A hardware timer that is periodically reset by software. If the software crashes or hangs, the watchdog timer will expire, and the entire system will be reset automatically.