

# XO-4 Hardware Design Specification

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## **History**

v1.0 - Created from the XO-1.75 specification. Changes include system architecture improvements, better explanation of the different models is now provided, descriptions of the touchscreen and mechanical keyboard were added, and minor corrections were made.

v1.02 - Changes to the wireless networking section, minor formatting fixes

v1.03 - Corrected audio input.

# **1 Introduction**

This document introduces the system architecture and hardware design requirements for the XO-4 Touch Laptop (CL4/CL4A) and the XO-4 Laptop (CL4B/CL4C). While the functionality of the XO-4 is similar to an ordinary notebook PC, it was designed by One Laptop per Child as a laptop for elementary school children. The foremost goal of the hardware design is low-power operation. To achieve this goal, the XO-4 utilizes a very low power ARM processor and incorporates novel technologies such as a low power dual mode TFT LCD display and a low power networking interface.

The XO-4 is designed for outdoor use with a 19 cm (diagonal) 4:3 aspect ratio color/monochrome dual mode TFT LCD panel and a dust and moisture resistant keyboard and case. For ruggedness and low power, it uses NAND Flash as storage device in the system. To allow many hours of operation it supports a 20 WH battery.

The XO-4 is a system/motherboard upgrade to the original XO-1 design. No changes to the overall industrial design or tooling will be made. The addition of four raised dots (in a diamond pattern) to the hinge cover allows easy differentiation of XO-1, XO-1.5, XO-1.75 and XO-4 machines in the field.

Four basic models of the XO-4 laptop are available:

- ☒ **XO-4 Touch** - this laptop integrates a multi-touch touchscreen on the LCD display, and has a water-resistant keyboard suitable for use by small children.
- ☒ **XO-4 HS Touch** - this laptop integrates a multi-touch touchscreen on the LCD display, and has a traditional (non-membrane) keyboard.
- ☒ **XO-4** - this laptop has a water-resistant keyboard suitable for small children, but no touchscreen.
- ☒ **XO-4 HS** - this laptop has a traditional (non-membrane) keyboard, but no touchscreen.

The features of the laptop are described in section 2. Testing and certification is described in section 3.

## **1.1 General Specifications**

### **Processor & core system:**

Marvell PXA2128 System on Chip, including:

Dual core ARM PJ4 processors, running at 1 GHz or 1.2 GHz

32KiB/32KiB L1 caches, 512 KiB unified L2 cache

1024 MiByte or 2048 MiByte DDR3L SDRAM system memory

Embedded controller for system monitoring, battery charging, and solar power input

ISA Compatibility: ARM v6 and v7, with Thumb and WMMX2\* instruction set extensions

### **Storage:**

4 GiBytes or 8 GiBytes of eMMC NAND Flash memory on motherboard – other storage size options also available

1 MByte of serial Flash memory provided separately for Open Firmware

32 KByte of serial Flash memory provided separately for EC Firmware

Expandable through an externally accessible SD/MMC memory card socket, or an optional internal microSD/MMC memory card socket.

### **Audio:**

Internal stereo speakers and amplifier

Internal monoaural microphone

Jack for external stereo headphone

Jack for external mono microphone, sensor, or switch

### **Display:**

7.5in (19 cm) color/monochrome dual mode TFT LCD, 1200x900 (200dpi)

Viewing area: 152.4 mm x 114.3 mm; 6 in x 4.5 in

Sunlight readable

Solid state (LED) backlight

### **Touch Screen (only on XO-4 Touch and XO-4 HS Touch models):**

7.5in (19 cm) Infrared touchscreen, using zForce technology, developed in collaboration with Neonode.

\* WMMX2 is a trademark of Intel.

### *XO-4 Hardware Design Specification*

Supports multiple touch points.

Can be used with finger, stylus or pencils, without exerting pressure.

Does not interfere with the sunlight readable display.

Resilient and easily repairable.

#### **Camera module:**

Integrated user-facing color video camera

640 x 480 resolution

Full frame rate (30fps)

#### **Wireless Networking:**

Integrated IEEE 802.11/b/g (2.4 GHz) wireless networking interface.

Optional: IEEE 802.11a/b/g/n (2.4 GHz and 5GHz) integrated wireless networking interface.

Ad-hoc and AP mode networking supported

Capable of network operation when CPU is suspended.

#### **Expansion Ports:**

Two external USB 2.0 ports provided

#### **Video Out Port:**

MicroHDMI port mirrors the integrated display for an external monitor or projector.

#### **Input Devices:**

XO-4 and XO-4 Touch: Water and dust proof 80+ key rubber keyboard, with 1.6 mm stroke.

XO-4 HS and XO-4 HS Touch: 77 key mechanical keyboard, with 1.8 mm stroke.

Capacitive touchpad used for pointing device

Three-axis Accelerometer provides information about laptop movement.

#### **Buttons:**

Power button on the side of the display

Screen rotate button on the side of the display

Two sets of 4-direction cursor control buttons

Magnetic sensor detects laptop closure

Magnetic sensor detects use in eBook mode

#### **Indicators:**

Power on/off LED

Battery status LED (Dual color)

Wi-Fi status LED

Storage status LED

Hardware controlled internal Microphone In Use LED

Hardware controlled Camera In Use LED

#### **Power Conversion:**

DC power input, from 11V to 25V

Integrated charger for Ni-MH/ LiFePO<sub>4</sub> batteries

High efficiency LED Backlight control circuit

6 mm power input connector (1.65 mm center pin)

#### **Overall Safety:**

IEC 60950-1 qualified

EN 60950-1 qualified

CSA/UL 60950-1 qualified

ASTM F 963 – Standard Consumer Spec on Toy Safety qualified

#### **Battery Pack:**

2 cells of LiFePO<sub>4</sub> AF type or five cells of NiMH with integrated gas gauge IC

2800 mAh typical capacity

LiFePO<sub>4</sub>: 5.5V to 7.5V operating range (@0.2C discharge)

LiFePO<sub>4</sub>: 0 ~ +50°C operating temp. range

*XO-4 Hardware Design Specification*

NiMH: 5.5V to 8.5V operating range (@0.2C discharge)

NiMH: 0 ~ +35°C operating temp. range

Safety: UL 1642 and UL 2054 qualified

A minimum of 50% charge left after 2000 charge cycles

**AC adapter:**

25W external AC adapter

90v(-10%) ~ 240v(+25%), 35-60Hz, AC input

13.5V DC output

Safety: IEC 60950-1, EN 60950-1 & CSA/UL 60950-1 qualified

Extra Transient and Burst Immunity: IEC 61000-4-4 passed

Extra Surge Immunity: IEC 61000-4-5 passed

**Weight:** <1.6Kg **Size:** 245mm (9.65") × 230mm (9") × 30.5mm (1.2")

## 2 XO-4 System Architecture

This chapter provides an overview of the architecture and the overall hardware design principles for the XO-4. The architecture of the XO-4 differs from more conventional laptop designs in that large parts of the laptop (including the CPU) may be suspended quickly, without affecting the operation of other parts. The XO-4 is designed to run the Linux open source operating system. Standard Fedora and Ubuntu distributions and other operating systems may be available from the OLPC developer community.

### 2.1 System Block Diagram

Figure 2.1 is the block diagram of the XO-4 system. Unlike most laptops, all components except the keyboard and touchpad are located behind the LCD panel. This assembly is called the **Core Module**. The keyboard matrix, keyboard encoder, touch pad module, and battery are combined together in a separate **Input Module**, connected to the core module through two small cables in the laptop hinge.

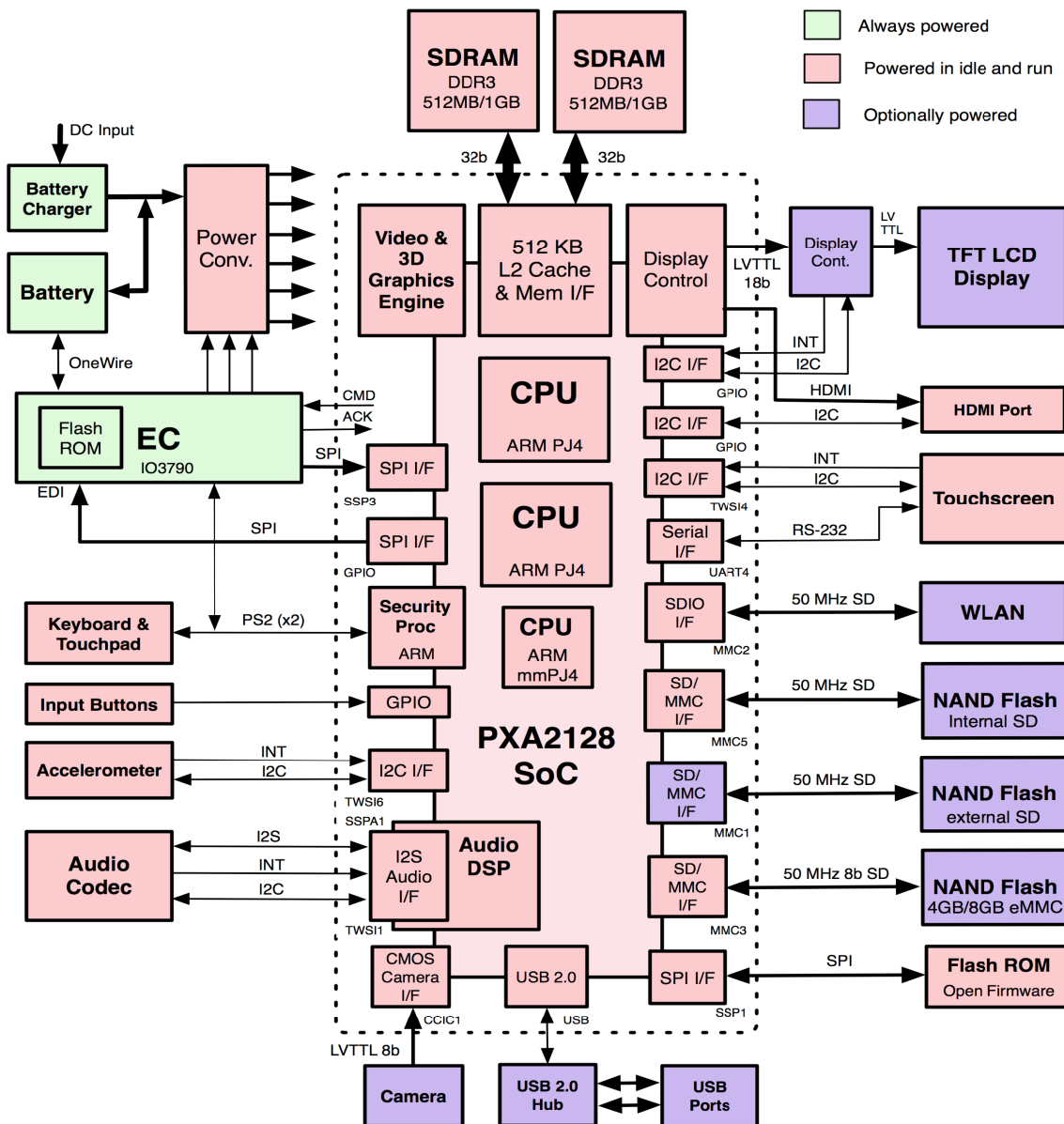


Figure 2.1: XO-4 Touch Hardware System Diagram



## 2.2 CPU & Companion Chip

The core processing system used in XO-4 is the Marvell PXA2128, which integrates multiple ARM processor cores and multi-level coherent caches. The PXA2128 also includes a graphics processing unit, two integrated memory controllers providing an interleaved unified memory, a “security processor” and integrated display controllers. Also included are I2S interfaces to the sound system, a USB 2.0 controller, power management logic, and system components such as real time clock (RTC), memory transfer engines (DMA), and programmable interrupt controllers.

### 2.2.1 Interrupts

Dedicated system interrupts are provided for system timer, keyboard, Audio codec, SDIO (used for SD cards and networking), Camera, Accelerometer, system control, USB, display control, touchpad, and DMA.

### 2.2.2 Firmware

In XO-4, Open Firmware resides in a dedicated SPI Flash ROM. The Embedded Controller firmware is stored separately, in a Flash ROM internal to the EC. Both Firmware ROMs have hardware protection to prevent overwriting by malicious application or system software.

The Open Firmware Flash ROM is also used to store manufacturing information about the laptop (up to 64 KiBytes).

### 2.2.3 Graphics Processing Unit

A 3D graphics-processing unit (GPU) is provided in XO-4 to accelerate common graphics and video operations. This GPU shares the main memory with the main processors, using a unified memory architecture. It provides separate processing pipelines for video and graphics, with a hardware blend before display. Separate color-space conversion and rescaling is provided for each pipeline.

### 2.2.4 Security Processor

The SoC integrates a small ARM processor, identified as the “security processor”, which controls early boot stages and handles keyboard and mouse input streams. It interacts with the embedded controller to manage power states of the system, allowing fast wakeup on keyboard input.

### 2.2.5 Memory

The XO-4 processor supports two integral 32 bit wide DDR3L SDRAM interfaces. No external buffering is used. Four 16-bit wide DDR3L SDRAM ICs are directly mounted on the motherboard, supporting 1 GByte of main memory. Alternatively, parts can be installed for 2 GByte main memory configuration. The speed of this memory bus is currently 400 MHz.

As the memory is mounted on the motherboard, and not expandable, there is no SPD interface supported for detecting the speed or size of memory.

## 2.3 Power Conversion

The power subsystem design in the XO-4 is complex relative to a normal laptop. In order to minimize the power consumption, the power supplied to a number of subsystems may be sequenced on or off as needed.

### 2.3.1 Battery Charger

The XO-4 provides a DC power input jack. A DC voltage source between 11 and 25 volts is suitable for powering the laptop. The DC input jack will safely withstand an input voltage between -32V and 40V. Exceeding these input parameters should not cause permanent harm to the laptop, but will destroy an internal fuse, requiring repair.

An integrated battery charger is provided, which converts power input to the laptop into voltages suitable for charging and controls the charge current.

The battery charger supports both constant voltage and constant current charging algorithms, under control of firmware running on the Embedded Controller.

The battery charger is designed to limit in hardware the power drained from an external input. The total input wattage is limited to 25W. If the laptop components are drawing less than this amount, any remaining power is used to charge the battery. The charging voltages supported are 7.5V for LiFePO<sub>4</sub>, and 8.5V for NiMH.

### 2.3.2 Battery Pack

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XO-4 is designed to support a variety of battery technologies. Currently, the laptops are available with battery packs comprised of two LiFePO<sub>4</sub> cells in series, or five NiMH cells in series. Each battery pack contains an integral gas gauge IC.

The battery packs can be recharged 2000 times (to 50% capacity – as repeated charge and discharge slowly decreases how much power can be stored in the battery). Nonetheless, these batteries last approximately four times longer than the standard laptop batteries that are typically specified as rechargeable 500 times (to 50% capacity).

Communications between the laptop and the gas gauge chip are carried over a single wire, using the Dallas Semiconductor One-Wire protocol and specifications. This single wire interface allows the laptop's Embedded Controller to read information about a battery pack's technology, status, and history. It even allows the laptop to power the gas gauge chip in batteries that have been discharged completely. A three-pin connector is used between the battery pack and XO-4.

#### **2.3.3 Backlight control**

The XO-4 LCD backlight is provided by white LEDs. Multiple LEDs are connected in series into three chains in order to equalize their brightness. These chains are powered in parallel. LEDs from all three chains should be interleaved, to minimize the impact of a single chain burning out. Up to 60 mA of current (at 17.6V) is provided to drive the backlight.

Two signals are used to control the backlight operation. One enables/disables the backlight, and a second one is pulse-width modulated at 200Hz to generate a voltage that varies the brightness of the backlight.

#### **2.3.4 Power Timing Sequence**

Whenever a battery is inserted into a XO-4, or power is supplied to the DC power input, the system Embedded Controller (EC) is powered and operating.

##### **2.3.4.1 Power Off to On**

If the laptop power button is pressed, the EC supplies power to the power management logic in the companion chip, and communicates the power button press to it. The companion chip will enable power to the main memory, processor, and most other components of the system. The EC notices this action, and powers up the display controller in response. The display controller then powers up the LCD display and backlight.

##### **2.3.4.2 On to Suspend**

If the operating system determines that the CPU should be suspended in order to conserve power, it takes the needed steps to disable the operation of any co-processors which might access main memory, notifies the networking interface, places the main memory in a low power self-refresh mode, then notifies the power management logic in the companion chip. This logic will disable power from the processor and most other components of the system. Parts of the companion chip, the main memory, the display and display controller, the backlight, the keyboard, and the networking interface remain powered and operational.

##### **2.3.4.3 Suspend to On**

When any button press is detected, either from the keyboard or the buttons around the display (power, rotate, and game keys/pad), the EC notifies both the display controller and the power management logic in the SoC. The display controller immediately unblanks the display (if blanked due to inactivity). The power management logic enables power to the processor and most other components.

##### **2.3.4.4 On to Off**

When the operating system determines that the laptop should be turned off (usually in response to the power button being pressed), it sends a command to the EC. The EC disables power to all subsystems, including the keyboard, display controller and networking interface. If powered by the DC Power input, the EC remains awake to handle battery charging. If operating from a battery, the EC enters a deep sleep state and awaits a press of the power button (or the arrival of DC Power input).

## **2.4 Embedded Controller**

The Embedded Controller (EC) is a microprocessor providing a number of critical system monitoring and management functions. These include system power management and battery management. It is powered whenever there is a battery with sufficient charge or the laptop has DC power input, although it enters a sleep mode when possible.

The EC communicates with the main processor through an SPI interface. A second SPI interface is used to upgrade the firmware internal to the EC from the main processor.

#### **2.4.1 Programming Interface**

The functions supported by the EC are best described by the programming interface provided for use by the XO-4 firmware and operating system. This interface defines the laptop hardware that the EC must monitor and control.

Firmware and operating system running on the XO-4 laptop may read the following hardware status through the Embedded Controller, using I/O ports (in the x86 input/output address space) 0x6C and 0x68:

- Battery Voltage
- Battery Current
- Battery Accumulated Current Register (ACR)
- Battery Temperature
- Ambient Temperature
- Battery Status (Exists, Fully Charged, Low, Destroyed, DC Power input present)
- Battery State of Charge
- Battery Gas Gauge Serial Number
- Laptop motherboard ID
- System Control Interrupt (SCI) Source
  - Game Button
  - Battery Status Change
    - DC Power input provided or removed
    - Battery inserted or removed
    - Battery low
    - Battery full
    - Battery destroyed
  - Battery SOC change
  - Battery subsystem error
  - eBook mode change
  - Lid status change
- System Control Interrupt Mask
- Display Panel Button Status (eight directional game keys and display rotate)
- Battery subsystem error
  - Pack info fail (LiFePO<sub>4</sub> & NiMH)
  - Over voltage checking fail (LiFePO<sub>4</sub>)
  - Over temperature (58C) (LiFePO<sub>4</sub>)
  - Gauge stop or sensor break (LiFePO<sub>4</sub>& NiMH)
  - Sensor out of control (NiMH)
  - Battery ID fail & temperature > 52C
  - Accumulated Charge Register fail (NiMH)
- Laptop power status (Display Controller, Wireless mesh networking interface)

Firmware and operating system running on the XO-4 laptop may control the following hardware functions through the Embedded Controller:

- Set System Control Interrupt (SCI) Mask
- Initialize NiMH and LiFePO<sub>4</sub>Battery
- Enable/Disable Wireless mesh networking interface (WLAN) power
- Wake up WLAN
- Reset WLAN
- Enable/Disable Display Controller power

#### **2.4.2 Embedded Controller Firmware**

The firmware for the Embedded Controller is stored in a separate 32 KiByte serial Flash memory internal to the EC IC.

##### **2.4.2.1 Write Protect Function**

In order to prevent malicious software from rewriting crucial firmware and manufacturing information stored in the

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Embedded Controller and Open Firmware Boot ROM, XO-4 provides a firmware write protect mechanism. This mechanism is only disabled by a full system reset. It is enabled by the main processor. Once enabled, the write protect may not be disabled except by another system reset.

After a system reset, firmware from the serial Flash will be loaded and executed by the main processor. If the firmware determines that a trusted update to the firmware is available, it may perform the update at that time (followed by a reboot of both the EC and the main processor). If no update is available, the main processor write protects the serial Flash, before execution of the operating system begins. This prevents malicious applications or modifications of the OS from modifying the basic firmware and boot process.

## **2.5 Display**

The TFT LCD display used is a unique design, developed specifically for the XO-4, and produced by Chi Mei Innolux. It is a dual mode 19cm display, providing a color display when used in transparent mode, and a very low power monochrome display when used in reflective mode. It can be used in bright sunlight.

In reflective (monochrome) mode, it supports a display of 1200 x 900 pixels (200 dots per inch), each capable of 64 gray levels. The frame buffer stores a full 24 bits for each pixel. In transmissive (color) mode, the perceived resolution is 1024x768 or higher, depending on the ambient illumination.

As a transfective display, the luminance depends on the ambient lighting. In a dimly lit room (140 cd/m<sup>2</sup>), the display luminance is 100 luxcd/m<sup>2</sup>, minimum, and typically 120 luxcd/m<sup>2</sup>. In office lighting (350 luxcd/m<sup>2</sup>), the luminance is typically 170 luxcd/m<sup>2</sup>, and in daylight, the luminance is roughly 25% of the ambient illumination. The contrast ratio of the display is 85:1 in low ambient illumination.

The LCD backlight for transmissive mode is provided by white LEDs. Multiple LEDs are connected in series into three chains in order to equalize their brightness. These chains are then powered in parallel. LEDs from all three chains are interleaved, to minimize the impact of a single chain burning out. The exact spectrum (white point) of the LEDs used in the backlight is not specified, but the LEDs used in any single backlight are closely matched to provide a uniform backlight spectrum.

The dimensions of the LCD are 17.0cm x 14.0cm x 0.62cm (thick). The active display area is 15.2cm by 11.4cm, and the bezel area is 15.5cm by 11.7cm. Its weight is only 172g.

As the XO-4 design minimizes the length of the cabling between the display controller and the display, a dual-edge TTL signaling protocol is used for interfacing. One 55-pin flexible cable provides data connections, with a separate 4-pin flex cable connecting the integral LED backlight to the laptop motherboard.

## **2.6 Display Controller**

Display controllers in conventional integrated processors and laptops do not meet the low power design requirements of the XO-4. Until suitable display controllers become available, a separate display control (DCON) application-specific integrated circuit developed for XO-4 will be used. The DCON provides the following features:

- Autonomous display refresh, independent of the CPU or GPU's power state
- Support for "color swizzling", allowing a conventional graphics engine to drive the dual-mode color/monochrome LCD display
- Monochrome mode support provides for a pixel-addressable automatic color-to-gray-scale conversion mode
- Optional anti-aliasing improves text display in color mode
- A dual-edge TTL output for interfacing to the XO-4 LCD display.

The DCON is designed to work with a conventional display controller. It provides an input interface emulating a TTL-compatible LCD display, allowing direct connection to a conventional display controller. In normal operation, when the conventional display controller is powered and operating, the DCON simply passes the video directly through, performing any required transformations (color swizzling with anti-aliasing or monochrome mode) but not buffering any of the video.

Before the operating system places the laptop into suspend power mode, it notifies the DCON and the DCON buffers the frame of video being displayed in its own memory. The DCON will then continue to display this frame until notified by the operating system that it has exited suspend mode and is generating valid video again.

## 2.7 Audio

The XO-4 provides both internal and external audio input and output. Internally, stereo speakers are provided on each side of the display, along with a single channel microphone mounted on one side of the display. Jacks are provided for use of headphones, external speakers, or an external microphone.

The audio subsystem is built around an I2S Audio Codec, which provides conversion between digital and analog audio signals, as well as mixing capabilities. This codec supports input or output sampling at rates up to 48 KHz, using analog/digital converters with a dynamic range of 80 dB and digital/analog converters with a dynamic range of over 90 dB. The audio codecs support operation with either 16 bit or 24 bit audio data.

### 2.7.1 Internal Speakers

There are two internal speakers in the XO-4 laptop, each driven by a separate audio channel. These are driven by a dedicated audio amplifier capable of providing 1.4 W continuously into each speaker, with a total harmonic distortion of 1%. The frequency response of the internal speakers is roughly from 480 Hz to 40 KHz.

### 2.7.2 Internal Microphone

An internal microphone is included with XO-4, located on the left side of the display. This provides a single channel of audio input. The microphone is an electret condenser microphone, with a minimum S/N of 56 dB, and a minimum sensitivity of  $-46$  dB (0 dB at 1Pa, freq. of 1 KHz).

An indicator light is provided near the microphone on the left side of the display that indicates if the microphone is currently being used (turned on). This light is directly controlled by hardware whenever it is possible for the internal microphone to be in use. It may not be disabled by software.

### 2.7.3 External Headphones or Speakers

A stereo jack is provided on the laptop for connecting headphones or an external amplifier and speakers. When a plug is inserted into this jack, the internal speakers are automatically disconnected and their amplifier is powered down. The state of this jack may be determined by software.

The headphone is driven by an amplifier integrated with the audio codec, capable of providing 30mW continuously into a  $32\Omega$  impedance.

### 2.7.4 External Microphone Input

A mono jack is provided on the laptop for connecting an external microphone, switch, or other sensor. This jack is connected to the audio codec's microphone input, with provides a programmable gain preamplifier. The input impedance is 10 K $\Omega$ .

A DC blocking capacitor may be inserted into the input signal path, under software control. This is used when the input is an audio signal. When used, the frequency response of the input is flat down to 10 Hz.

A bias voltage (2.0 or 2.5V, with a 3 K $\Omega$  source impedance) may also be driven onto this external microphone input, under software control. This may be used to power external electret condenser microphones, or external passive sensors (such an external switch or thermistor). Due to the high impedance of the bias source, this input may safely be shorted to ground.

An external voltage applied to this input is limited to the range of  $-9V$  to  $+9V$ . Inputs exceeding this range may cause excessive current to flow through a protective diode.

When the external microphone jack is in use, the internal microphone is disconnected, and the indicator light indicating microphone use is disabled. The state of this jack may be queried by software.

## 2.8 Storage System

XO-4 has no spinning media storage devices, such as hard disk drives or optical drives. It relies on NAND Flash memory for non-volatile storage. 4 or 8 GBytes of NAND Flash are provided using a single internal eMMC device mounted on the motherboard. Alternative SKUs which provide other size internal Flash storage may be provided. The interface between the processor and the NAND is critical to system performance. It is high-speed (guaranteed to be at least 2MBytes/s with regular performance above 10 MBytes/s) and provides error-correction and wear-

The endurance of the NAND device is five thousand erase cycles, with a data retention lifetime of at least ten years. Wear-leveling of the device to avoid premature failure is provided in hardware.

The XO-4 also provides an internal microMMC/SD card slot for replacing a failed eMMC device. The actual card socket is not provided, but may easily be added in a repair facility.

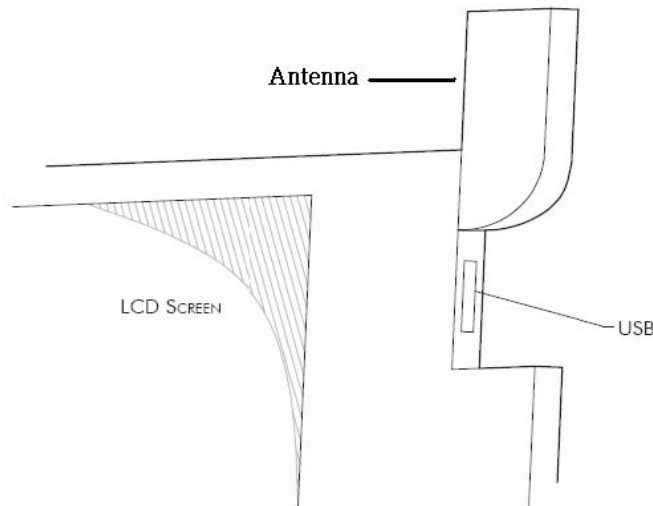
The XO-4 also provides a single external full size MMC/SD card slot for extending the laptop's storage.

## 2.9 Wireless Networking Interface

The XO-4 laptops provide a wireless network interface for communication with other laptops and the Internet. Two wireless networking options are available: one providing 802.11b/g (2.4 GHz only), and the other providing 802.11a/b/g/n (5 and 2.4 GHz). Both networking options provide a separate ARM processor, offloading networking functions from the main processor.

The wireless interfaces are custom to the XO laptop, in order to minimize power consumption. They use a +1.8V 4-bit SDIO running at 50 MHz, both to reduce signaling power and support fast suspend/resume. They obtain multiple supply voltages from the more efficient power conversion system on the motherboard.

The 802.11b/g wireless interface also supports the draft 802.11s mesh networking protocol through the use of the Open 802.11s software stack.



**Figure 2.9: External Antenna**

### 2.9.1 Antenna Design

The antennas for wireless networking on XO-4 are designed to provide the best performance possible. Two rotatable external antennas are provided, located at the top right and left corners of the display, frequently referred to as *rabbit ears*. The ability to rotate the antennas up, away from the body of the laptop, provides optimum antenna performance. When the rabbit ears are down, they cover the laptop's I/O ports (USB and audio), and provide a latching mechanism.

## 2.10 Camera Module

The XO-4 provides a video camera with a fixed lens, located on the right side of the display. This camera has a resolution of 640 x 480 pixels, and may operate at up to thirty frames per second. It provides a signal/noise ratio of at least 46 dB, and has a sensor array size of 2.36mm x 1.76mm. The F-number of the optical system is 2.8 (+/- 5%), effective focal length is 2.45mm, and the field of view is 60 degrees.

Parameters of the video camera (such as automatic gain control, automatic exposure control, automatic white balance, lens correction, manual color balance, or black level control) are adjustable under software control.

An indicator light is provided near the camera on the right side of the laptop display which indicates whether the

camera is currently being used (turned on). This light is directly controlled by hardware whenever it is possible that the camera might be in use. It may not be disabled by software.

## 2.11 User Input Devices

In addition to the microphone, and camera described separately, the user input devices provided on XO-4 are a keyboard, a touchpad, a directional gamepad and *display rotation* button on the left side of the display, and four game keys and a power button on the right side.

### 2.11.1 Touch Screen

The XO-4 Touch and XO-4 HS Touch models are equipped with a infrared multi-touch capable touchscreen on the LCD display. This allows a more natural and intuitive user interface than the touchpad. The XO-4 Touch uses zForce technology from Neonode technology, as it doesn't interfere with the sunlight readable display integrated into the XO laptops.

At least two simultaneous touch points are supported, with additional simultaneous touches supported in some interface layouts. The touchscreen detects fingers or a soft-tipped stylus, as long as the stylus has a diameter of 8 mm or larger (measured within a mm of the end.)

The touchscreen interface is integrated into a removable bezel around the LCD panel. While it is quite resilient, it may easily be replaced in case of damage.

### 2.11.2 Keyboard

Two styles of keyboard are supported, the water and dust resistant membrane keyboard available on all XO laptops, and a new mechanical keyboard which has larger keys (90% of "full size"). The XO-4 and XO-4 Touch models have the membrane keyboard, and the XO-4 HS and XO-4 HS Touch models have the mechanical keyboard. Both styles of keyboard are available in a number of languages.

The XO-4 keyboard is a 72-key silicon rubber membrane keyboard, with a 1.6 mm stroke. It is sealed against water and dust ingress.

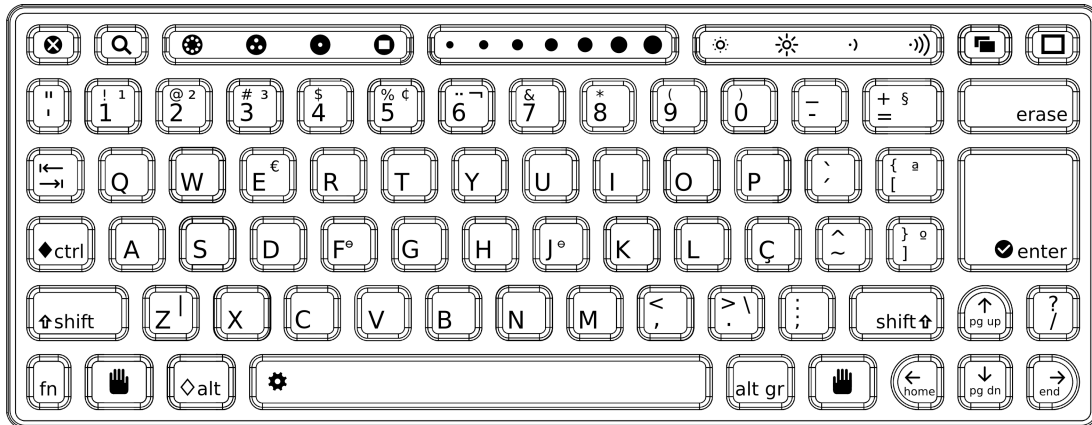
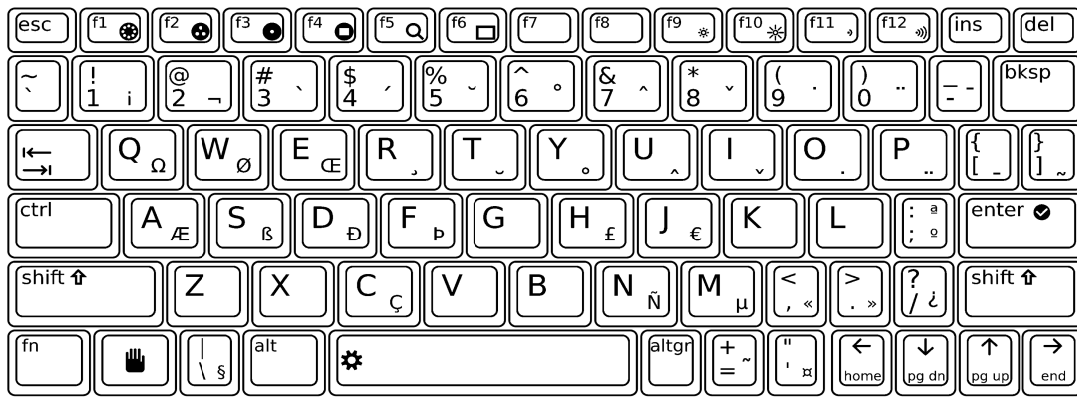


Figure 2.11: Membrane Keyboard Layout (Portuguese version shown)

The XO-4 HS keyboard is a 77-key traditional (mechanical) keyboard, with a 1.8 mm stroke. The mechanical keyboard is not as resistant to water and dust intrusion, and also carries a safety concern with younger children (choking on a removed key cap). It was designed for easy replacement without disassembling the laptop.



**Figure 2.12: Mechanical Keyboard Layout (English/International version shown)**

The keyboard and the touchpad share a single cable connection to the Core Module, using the standard PS/2 signaling protocol.

### 2.11.3 Touch Pad

The XO-4 is equipped with a touchpad for use as a pointing device, requiring just a bare finger. This touchpad has a resolution of 1000dpi, and an active area of 6.0 cm by 4.4 cm. It is located underneath the plastic in front of the keyboard, maximizing the resistance to moisture, dirt, and electrostatic discharge.

### 2.11.4 Core Module Buttons

The XO-4 includes two sets of directional input buttons, one on each side of the display. On the left side, these are combined into a single large directional button. On the right side of the display, these are marked with distinctive icons (square, circle, check and X) as well as having a directional grouping. Both sets are oriented to provide up, down, left, and right input relative to the display.

In addition, a single user input button is provided on the left side of the display (mirroring the power button). This button is dedicated to rotating the display orientation (to better support eBook mode).

The Embedded Controller provides the interface for these buttons, inserting them into the character stream received from the keyboard.

### 2.11.5 Lid and eBook Switches

There are two magnetic sensors in the Core Module that determine its proximity and orientation relative to the Input Module. One of these is used to detect if the laptop is closed, with the display unviewable and keyboard unreachable. The operating system will use it to either suspend or power off the laptop. The other is used to detect if the laptop is being used in eBook mode, where the display is rotated before the laptop is “closed”. In this mode, the keyboard is unusable but the display and Core Module buttons are still usable.

These sensors are connected to the Embedded Controller, and changes in their state are communicated to the operating system via System Control Interrupts.

## 2.12 I/O Ports

In addition to the headphone (audio out) and microphone (audio/sensor in) jacks described above, the XO-4 provides USB ports for connecting to external peripheral devices.

### 2.12.1 USB

The XO-4 supports two USB 2.0 ports, one on each side of the display. These are both USB type A connectors, for connecting to peripheral and storage devices.

Unlike a regular laptop, which provides up to 2.5 W of power per USB port, the XO-4 provides a total power consumption of 5 W for all two USB ports. This may be shared equally among all the ports or drawn through a single one, but cannot be exceeded.

### 2.12.2 Debugging Support

The XO-4 motherboard in the Core Module includes a number of connectors to aid in repair and firmware or operating system debugging. Only one, a main processor RS-232 serial port proven useful in repair, is populated in Rev. 1.03, 2/14/13



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production machines, but the remainder may be easily added to aid in software development. They are not accessible unless the laptop is partially disassembled. These connectors include:

- Two RS-232 protocol serial connections (3.3V) to the main processor
- A main processor JTAG connector
- An RS-232 protocol serial connection (3.3V) to the Embedded Controller
- An SPI interface for reprogramming the OFW boot ROM.
- An SPI interface for reprogramming the EC firmware ROM.

## **3 Testing**

The XO-4 meets a wide range of environmental, mechanical, and electrical tests.

### **3.1 Safety**

XO-4 meets UL and EC safety certification. The laptop meets IEC 60950-1, EN 60950-1, and CSA/UL 60950-1 (Safety of Information Technology Equipment) specifications. It also complies with UL 1310 and UL 498. In order to guarantee the safety of children using the laptop, it also passes ASTM F 963 (Standard Consumer Safety Specification on Toy Safety, 2003 edition).

The external power adapter complies with IEC, EN, and CSA/UL 60950-1. The removable battery pack complies with IEC, EN, and CSA/UL 60950-1 and UL 2054 (Household and Commercial Batteries).

### **3.2 Environmental Conditions**

XO-4 is designed for operation over an extended range of environmental conditions:

- Ambient Temperature: 0C to 50C
- Operational Altitude: 0m to 5500 m
- Non-operational Ambient Temperature: -20C to 60C

### **3.3 Durability**

The XO-4 was designed for durability and easy repair.

#### **3.3.1 Input Devices**

The game buttons and gamepad are tested to 500,000 cycles.

The membrane keyboard is tested to 5,000,000 cycles. The mechanical keyboard is tested to 1,000,000 cycles.

All I/O connectors (Power, USB, Headphone, and Microphone) are tested to 5,000 insertion/removal cycles.

#### **3.3.2 Drop Tests**

The XO-4 passes a 10 point free-drop test from a height of 80 cm onto a carpet, and a 10 point free-drop test from a height of 45 cm onto wood.

### **3.4 Concern for the Environment**

The XO is the most energy-efficient and environmentally friendly laptop ever made, based on independent evaluations and data. XO consumes the least power, minimizes toxic materials, is extraordinarily rugged, has a long lifetime, works with renewable power sources, and is itself recyclable. XO has earned the highest environmental certifications: it is in full compliance with the European Union's rigorous Reduction of Harmful Substances (RoHS) standards; it is designed for Energy Star Version 4.0 Category A Tier 2 performance, the most stringent level..

According to ENERGY STAR®, an average idle desktop computer uses 70 watts of power and an average idling laptop computer consumes 20 watts of power. When idle, the XO laptop uses as little as one watt of electricity.

Among the XO's other environmentally friendly attributes and innovations:

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XO is more rugged — it will last longer, thus staying out of landfills longer. The XO has been designed for a **five-year lifetime** even in extreme environments like the outdoors, the jungle, and the desert. The average laptop has a two-year lifetime when used in an office and far less when brought outside or to the desert. Doubling the lifetime of the laptop halves its environmental impact.

XO is about **half the size and weight** of typical laptops. Less material halves the environmental impact.

XO is designed for use with **renewable energy sources**. It's the first laptop designed to harvest energy directly from solar cells and other power-limited energy sources.

XO uses a new battery using LiFePO<sub>4</sub> (Lithium Ferro Phosphate) chemistry that lasts **four times longer** than standard laptop batteries, and is vastly safer than the current dominant technology of Lithium Ion.