Eobody3: a ready-to-use pre-mapped & multi-protocol sensor interface

Emmanuelle Gallin
Creation Department
Eowave
La Cure - 58110 Tintury - France
+33/(0)661 702 050
info@eowave.com

Marc Sirguy
Scientific Director
Eowave
La Cure - 58110 Tintury - France
+33/(0)661 702 050
info@eowave.com

ABSTRACT
Away from the DIY world of Arduino programmers, Eowave has been developing Eobody interfaces, a range of ready-to-use sensor interfaces designed for meta-instruments, music control, and interactive installations… With Eobody3, we wanted to create this missing link between the analogue and digital worlds, make it possible to control analogue devices with a digital device and vice versa: for example, to control a modular synthesizer with an IPad with no computer and vice versa. With its compatibility with USB, MIDI, OSC, CV and DMX protocols, Eobody3 is a two-way bridge between the analogue and digital worlds… This paper describes the challenge of designing a ready-to-use, pre-mapped, multi-protocol interface for all types of applications.

Keywords
Controller, Sensor, MIDI, USB, Computer Music, USB, OSC, CV, MIDI, DMX, A/D Converter, Interface.

1. INTRODUCTION
Developing a ready-to-use pre-mapped multi-protocol sensor interface is quite challenging. With Eobody2, we developed a range of sensor to USB interfaces commonly used for interactive installations, museography, live music and video performances, dance, but also for industrial and medical applications. With Eobody3, we wanted to go further. The popularized use of sensors in the communication and game industries has deeply influenced our control gestures, creating new reflex gestures and new control needs. Many would like to transpose these new control gestures to control music, synths or softwares, but there is no existing ready-to-use and multi-protocol bridge to create such interactions. Creating an interface that is dedicated to one particular application would be easy, but making the interface compatible with different protocols and existing products (different OS, softwares like Ableton Live, iPads or analogue synthesizers) and adaptable to many applications involves many other parameters.

2. DESIGNING A MULTI-PURPOSE PRE-MAPPED INTERFACE
2.1 Eobody philosophy
Since the creation of the first Eobody interface in 2002[1], Eowave has followed the same idea of making sensor control accessible for all. This means that anyone, with or without technical skills, would be able to use Eobody sensor systems. With the growing number of sensor controlled installations, performances, we've seen a lot of interest for these ready-to-use systems that enable artists to realize interactive creations without the assistance (and costs) of an engineer, or learning to program a microcontroller themselves.
On the other hand, engineers found that using these systems saved a significant amount of time, as they just had to set their own parameters to fit their needs. This specific 'plug & play for all" approach has a particular impact on the design process of our interface: 1) the technical side must be transparent to the user; 2) the design is focused on the way the interface will be used; 3) the accessible parameters are only "visible" setting parameters; 4) it imposes a wide compatibility with existing OS, softwares, MIDI devices and other hardware interfaces; 5) it requires different level of use: ready-to-use; internal parameter access via the editor; and Max programming; 6) it requires compatibility with other communication protocols.

2.2 From Eobody2 to Eobody3
Eobody2 was a USB MIDI sensor interface with 8 inputs, internal memory, and internal signal process[2]. After three years of existence, the customer response is still quite good, but we thought it was time to move towards Eobody3. We noted a recurring need among users to add different kinds of inputs and for a system that would be more open to protocols like OSC.
We used the Microchip PIC-32 MX microcontroller with a frequency of 80 MHz for 1,56 DMIPS/MHz. We also wanted the Eobody3 to be "evolutive", totally adaptable to future protocols and formats, with extensive number of inputs.

2.3 Question of times
Technologies evolve with time. iPhones and iPads with all sorts of musical Apps are now commonly used as control surfaces and create new needs. The idea of using an iPhone's surface like a "sensor" that would offer the potential to control the signal process of a CV or MIDI instrument needed to be explored.

3. EOBODY3 INTERNAL MODULAR ARCHITECTURE

The new Eobody3 project specifications involved the design of an internal modular architecture with a separated master motherboard, interchangeable daughter boards to host protocol format DSP, and a third board with inputs types (0-5V sensors, triggers, pedals and logic I/O) and outputs types (CV, PWM and digital I/O).

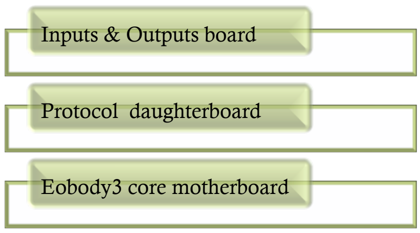

Figure 1 : Eobody3 modular architecture

3.1 Eobody3 core motherboard

Signal processes and mappings are made inside the Eobody3 core, so it requires no cpu from the computer. Different mappings are stored in the Eobody3 internal non-volatile memory, so it can be used without any computer when needed. The motherboard of Eobody3 is the brain of the system with a Microchip PIC32 programmed with pre-mappings for the different daughter boards. It hosts an updated version of the processing library Eobody2 Sensor Systems (ESS DSP) used in Eowave interactive devices. The role of the Eobody3 core motherboard is to process the raw data coming from daughter boards and to send them to the computer via USB or another chosen protocol. This modular architecture offers different advantages such as the ability to re-program the core for specific applications or to update the core with new mappings.

3.2. A core compatible with other communication protocols and I/O formats

The core is capable of interfacing through other communication protocols embedded on daughter boards, including OSC, MIDI, and DMX. On each daughter board, a Microchip 16 bit dsPIC receives data from the sensors, samples them at 30 kHz and transmits them to the core in high speed SPI. The choice of the compatible protocols was made considering the most commonly used protocols: MIDI is still widely used by musicians; OSC enables to use LAN cables on longer distance for live applications. Concerning DMX, there are many affordable DMX to USB converters on the market. Eobody3 is not just a DMX to USB converter but enables to connect a sensor directly to a DMX enabled device without a computer. The modular architecture also enables compatibility with new future protocols like Copperlan for example.

3.3 Input types

Inputs types can be chosen between 0-5V sensors (can be switched to 3,3V), triggers, pedals and logic I/O. Eobody3 can host from 8 to 32 inputs (in blocks of 8 inputs each).

The 0-5V input boards have a 1 pole low-pass filter and a buffer to accept different signals and filter data before the A/D conversion. Sensor input board dsPIC performs an average measure of incoming signal. Unlike the sensor input board, which measures continuous variations of the signal, trigger inputs enable to track impulses and attacks of the signal. A decoupling capacitor and rectifier diode at the input of the signal enable filtering of continuous components of the signal. The dsPIC tracks and keeps the highest values of the signal at each communication between the core and the input board. The connector does not have a 5V power on the tip of the TRS jack connector.

Pedals inputs have a similar architecture to the sensor input board, and allow switching automatically between Roland or Yamaha pedal format or footswitches.

Digital inputs/outputs provide logic 0/1 levels (0-5V).

3.4 Output types

Outputs types include CV, PWM and digital I/O.

Control voltage Output (CV) commonly used with analogue synthesizers, provides up to 8 x 0-10V outputs and 8 x gate (ON/OFF). These allow direct control over a synthesizer parameter with a sensor or by sending information from a computer. They also enable control of dimmers, light and any other voltage-controlled device. For modular synthesizers, Eobody3 core and Eobody3 compatible modules offer the possibility to patch directly outputs from a modular system to a computer or other digital devices. PWM enables to control motors and LED controllers. Sensors control the pulse width.

Digital inputs/outputs provide logic 0/1 levels (0-5V) that can be used to control relays.

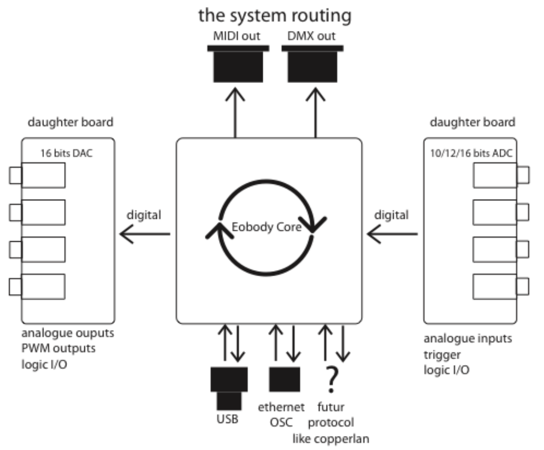

Figure 2: Eobody3 routing

4. PRE-ROUTING: FORMATTING MESSAGES TO HOST

This is one of the most important configuration parameters, since it determines which type of MIDI message the device is going to send in response to variations in a particular analogue input.

Eobody3 can generate 5 different message types:

CC: Control number change (control change) 7 bits or 12 bits (the 5 LSB bits are mapped on CC number + 64), PB: Pitch bend (variation in pitch) real 12 bits or mapped 14 bits, Monophonic aftertouch, Note on Trigger and Program change.

The analogue signal must correspond to an envelope changing with time and which has a maximum value. Users specify three parameters: program change sent, higher threshold, and lower threshold. Eobody3 analyses this envelope: once the envelope has reached the higher threshold, a MIDI program change or note message is generated. As long as the envelope remains above a threshold, named lower threshold, the program change is maintained (no new MIDI message is sent). When the level falls beneath the lower threshold, Eobody3 is ready to receive a new message.

5. PRE-PROCESSING TOOLS

Data from sensors can be processed using the on-board pre-processing tools to get the best exploitable signal for a specific use. The Microchip PIC32 allows to have different processes according to the type of data, standard sensors (continuous controller), triggers (peak detection), simple logic or more complex algorithms for certain sensors like gyroscopes for example.

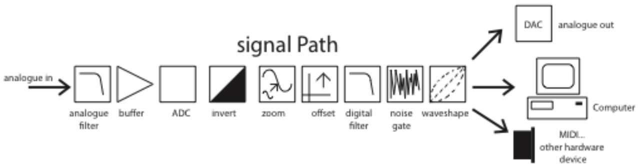

Figure 3: Signal path

Signal from analogue inputs goes thru analogue filters and buffers before A/D conversion. Then, pre-processing tools enable to reshape the signal with features like invert, zoom, offset, digital filter, noise gate, wave shaper. Pre-mapping settings per sensors are included.

5.1 Buffering the data flow

Common music softwares like Ableton Live or NI Reaktor, are only compatible with MIDI or OSC on Mac/PC OS. To have Eobody3 compatible with these, we were restrained to these protocols and their limitations in terms of update rate. With the Microchip PIC32, the update rate for all sensors has been reduced to less than 1ms, only delayed by the power of the computer to process the data flow. Real-time sensor interactions cannot accept the buffering techniques used with audio signal. Buffers need to be as low as possible to create an immediate perceptual sensation when a sensor is touched. To make this immediate perceptual interaction happen, the whole process needs to last less than 10ms (preferable 5). These 10ms include the audio process in the computer and the delay generated by the outgoing process of the soundcard. Tests made with USB show certain limitations with Windows7 as well as with OSX[3]: below 2ms, the midiin object in Max/MSP cannot process all incoming data and will “freeze” after a couple of seconds. Ethernet allows a larger data flow at once but the update rate is not faster. To limit the flow of incoming data, data from sensors are packed in Eobody3 and updated after a complete scanning cycle has been realized. This can be done with Ethernet as well as with USB.

5.2 Denoising data with gate and filters

Active sensors often generate noise. Eobody3 offers different types of processes to reduce noise. With Eobody2, an “analogue zoom” controlled the internal PGA (Programmable Gain Amplifier). With Eobody3, a pre-amp with analogue filters has replaced the PGA. Before the A/D conversion is done, the signal goes thru a low-pass filter and a unity gain buffer. This eliminates high frequency noises and allows sensors with high impedance outputs. After the conversion, sensors are processed as a 16-bit value, with the possibility of inversion, zoom and offset settings. Digital noise filtering is done by a 32-bit low-pass filter and a noise gate, which smoothes the signal. The noise gate threshold does not reduce the bit depth of the signal. If the signal moves in the range of the noise gate, no message is sent. This field enables to set the width of the range. A large range will be very effective against strong noise but will make the values less sensitive to a relevant change of the analogue signal. A threshold of 5 corresponds to 127 different possible values (i.e., the analogue has to change at least of 32 (from 4095 above or below its current position to be detected as a variation). A threshold of 11 corresponds to 2 bits, useful for switches or all on/off sensors.

5.3 Zoom: focusing on a part of the data

The digital zoom & offset parameters specify how the real range of an analogue input can be mapped on a 7-bit MIDI value. As a matter of fact, a sensor does not necessarily have a range equal to the reference voltage of the Analogue to Digital Converter (ADC). A custom-scaled zoom has been implemented on the digital value to take advantage of the 12-bit resolution of the A/D converter. First, the voltage reference has to be set to the largest range among the sensors connected to the unit. Then, specifying a window size and an offset can set a sensor’s range within the 12-bit dynamic. The selected range can then be converted into 7-bit MIDI data without greatly increasing the quantification step. Another application of the digital zoom & offset parameters might be to reduce or adapt the range of the sensor to control a specific range of a filter parameter in a plug-in, for example.

5.4 Transfer curves new tool

Eobody3 has a new pre-processing tool called curve (for transfer curve). This new wave shaping feature allows for changing the curve of a signal. For example, the linear response of a volume pedal can be changed to a logarithmic or exponential response.

5.5 Pre-mapping per sensor type

Pre-mapping is the art to translate the raw data coming from the stimulated sensor into a signal that will be immediately perceived as a cause to effect. « Making these mapping choices, it turns out, is anything but trivial. Indeed, designing an interactive system is somewhat of a paradox. The system should have components (dance input, musical output) that are obviously autonomous, but which, at the same time, must show a degree of cause and effect that creates a *perceptual interaction*[4]. » To create this perceptual interaction, each sensor needs a dedicated mapping depending on its affectation. With the design of a multi-purpose interface such as Eobody3, the challenge consisted in the pre-mapping of all sensor types for all applications. For this, all types of sensors have been studied to get the most versatile pre-mapping, which usually differs from (but includes) the most frequent pre-mapping. We integrated on-board calculation of complex pre-mapping with algorithms for accelerometers and gyroscopes as well as a Kalman filter. While such mappings were only possible with a Max patch or through coding an Arduino, Eobody3 gyroscopes or accelerometers are now ready-to-use and are fully compatible with MIDI applications like Ableton Live. Depending on the treatment they receive, accelerometers can provide two kinds of information: force and gravity. To measure acceleration, the DC component of the signal is filtered whilst the AC component is filtered to get gravity information. The gyroscope can track angular movement calculated from the rotation information. This calculation

requires an accurate timing, though outsourced treatments generate timing errors due to USB and computer variable delays. The generated drift needs a constant initialisation of the sensors when it returns at its zero position. Information from accelerometer and gyroscope together will provide more precision.
In the editor, selecting the sensor type will automatically call the pre-mapping for this sensor-type. Pre-maped values can be re-shaped using the pre-possessing tools to get even more customized data.

5.6 Pre-mapping for triggers

With Eobody2, we had a lot of demands for using triggers as well as sensors. This was not possible, as velocity processing would have required a more powerful microcontroller. With the Microchip PIC32, we have integrated this velocity process. Trigger input level can be adjusted with a sensibility parameter. Threshold sets the beginning of the trigger analysis and peak detection. Release time sets the time before a new detection is processed. Cross talk enables Eobody3 to cancel unwanted messages when two trigger pads are very closed one another for example. In this case, input 1 can cancel a message coming from input 2 if those are simultaneously triggered. The velocity response curve can be modified with a wave shaper. With triggers, USB connectivity allows response with less than 2ms delay.

6. EOBODY3 EDITOR

Like Eobody2, Eobody3 offers three levels of use, from ready-to-use to the opened max file[5]. In most cases, users only need the ready-to-use level. With applications like Ableton Live or other MIDI softwares, Eobody3 will be automatically recognized as an audio device and can control any available MIDI parameters of the software.
At a second level, when more parameters edition is needed, Eobody3 editor gives access to editable pre-mapping configuration and other pre-processing tools. All settings can be stored in Eobody3 non-volatile memory. The third level offers the Max5 editable file of the editor.

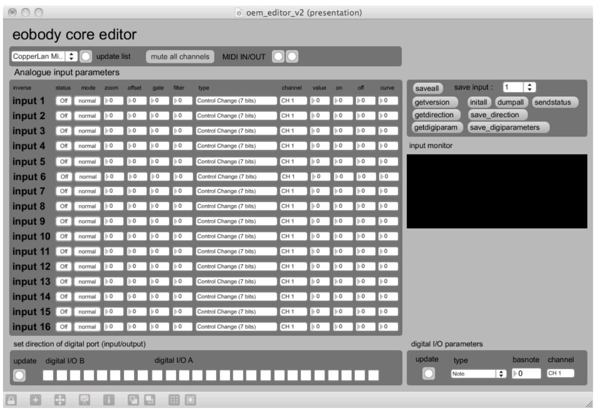

Figure 4: Eobody3 core editor

7. A New bridge

7.1 Control your modular system and other CV synths with your iPhone or iPad

While communication and game industries are releasing new powerful control tools, the world of musical interfaces seems far beyond. While many musical Apps appear on the market[6], many would like to use iPad or iPhone control technology as new controllers. But Apps are specific to their own environment and cannot be used as generic controllers. With Eobody3, we propose to make a real bridge between these worlds and offer musicians the possibility to use their iPads or iPhones to control any CV or MIDI gears without a computer thru the CV ouputs connected to a USB cable or via a LAN network with a wireless router.

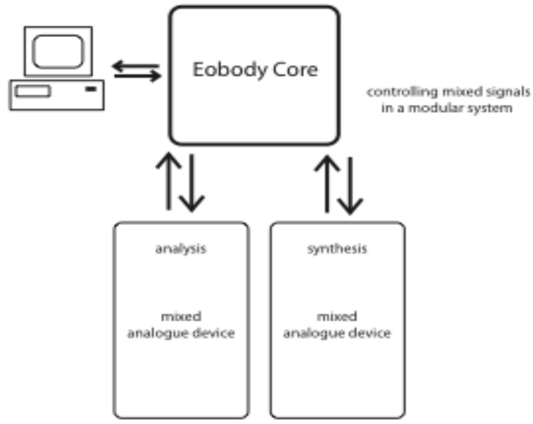

Figure 5: Controlling mixed signals in a modular system

7.2 Eobody3 compatible modules for modular systems

We've extended this idea with the development of dedicated analogue modules that comply with Eobody3 standard. With these, it will be possible to use multiple analogue filters controlled by a Max application. This opens the door to complex computer analysis and analogue re-synthesis, which give the users a unique possibility to get the best result from both analogue and digital worlds.

8. CONCLUSION

The idea of Eobody3 is to offer a new ready-to-use sensor interface that can be used for controlling music, video, but also lights, analogue synthesizers, relays, motors… It offers anyone the possibility to design his own interactive installations, meta-instruments or sensor-based control surface without any background in programming and electronics.

[1] E. Fléty, M. Sirguy : Eobody : a Follow-up to AtoMIC Pro's Technology, Proceedings of the 2003 Conference on New Interfaces for Musical Expression (NIME-03), Montreal, Canada. NIME03-225.
[2]Eobody2 specifications
http://www.eowave.com/downloads/pdf/eobody2_usb8sensorbox_manual.pdf
[3] Tests made with intel core duo.
[4] Joseph Butch Rovan, Robert Wechsler and Frieder Weiß : *Seine hohle Form: Artistic Collaboration in an Interactive Dance and Music Performance Environment*, Crossings.
[5] For other Eowave interfaces, EoMessage V 1.0, is a dedicated Max object developed by Eowave to control any ESS DSP based interfaces, EoMessage can be used with Eobody2 OEM board, Eobody2 HF, Eomono. It will easily enable to use ESS DSP based systems within a Max/MSP environment.
[6] NAMM 2011, January 13-16, Anaheim CA, USA.