

theremino
•the•real•modular•in-out•

System *theremino*

MasterDIL-V5

**The V5 Master is identical to the V4
but now all the distances between the PINs
are multiples of the 2.54 mm pitch.**

The Master module

The "Master" is the main module of the system Theremino. It puts in communication the software with the outside world via the USB.



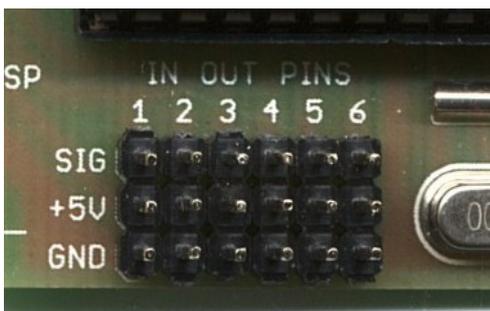
The Master module has to be connected to a USB port (usb1, usb2 or usb3), and provides twelve Generic InOut Pins. Earlier Master versions had 6 Pin (versions 1 and 2), or 10 Pin (Version 3).

So to know the Master version, just observe how many Pins are listed.

The "USB" connector can be connected to one or two USB ports to draw a current of 500mA or 1000mA, or 900mA and 1800mA with the new usb3.

The "Serial Line" is a serial line to eventually connect slave modules. Serial line has 3-poles (GND / +5 V / data). In the earlier versions the fourth pole was used for the device "Master_ISO", to isolate the transmission line, but in the last Master versions is used to provide access to the Pin 7.

It is also possible to connect more than one Master with USB and serial transmission lines separated to increase the connection possibilities. It can, for example, use a high-speed serial line for devices that require a rapid refreshment and a second serial line, slower, for all the others.



Sensors and actuators are connected to the "IN OUT PINS" with standard cables (male to female extensions)



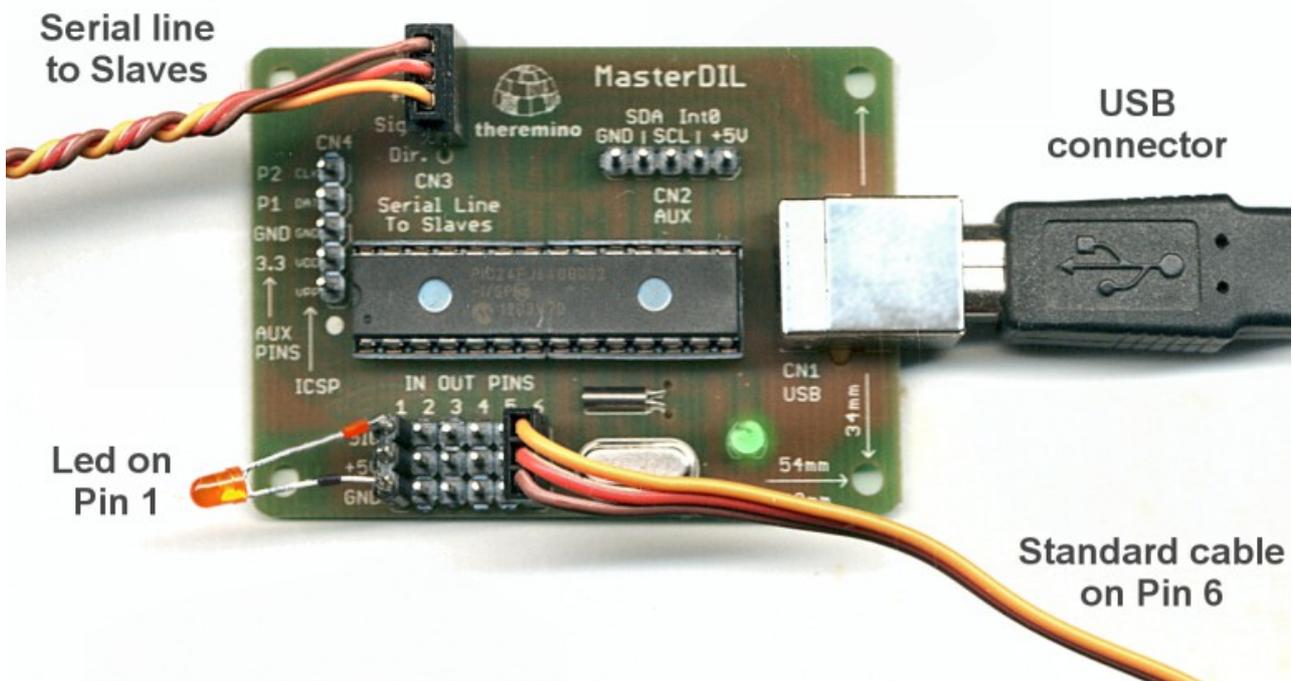
Connect the Master

Just connected to the USB, the master will automatically install its driver and, within a few seconds, the green LED starts to flash quickly. Each flash of the LED are 20 communication cycles, so the more you see it glowing nicely, the better.

Whenever possible, it is best to use more Master (possibly with a HUB) rather than one master and many Slaves. The pin of the Master can be configured with all possible types, while only some kinds of Slaves. Besides increasing the number of Master frequency trading it does not decrease, while the slow slave, in proportion to the number of Pin to transmit. Finally, the serial line is more delicate than the USB and can produce errors of communication, in the presence of electrical noise.

If you use only the Master, do not connect the serial line to the Slaves

Connection to USB is always necessary



Here you can see an LED connected to "Pin 1" ...

and a standard extension connected to "Pin 6"

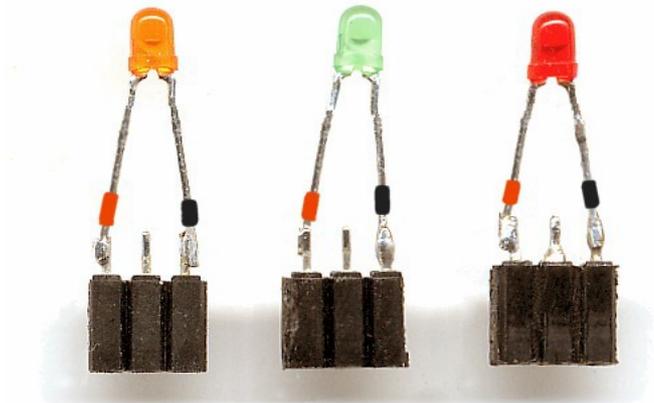
First experiments

Prepare some leds, as in this picture.

The insulating tubes are used to distinguish the sides positive (red) and negative (black), but are not important. If you connect a LED on the contrary, it do not break and it is enough to turn it to make it work.

For further information on the preparation of these handy indicators, read here:

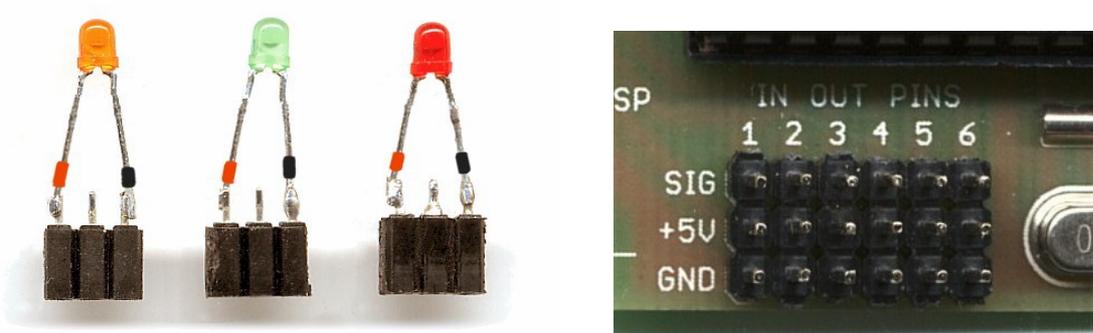
www.theremino.com/hardware/outputs/actuators



Turn on the test LEDS

Suppose we connect three LED indicators to Pin 1, 2 and 3

Check that the positive of each led (red) is connected to the "SIG" side and that the negative (black) is connected to the "GND" side

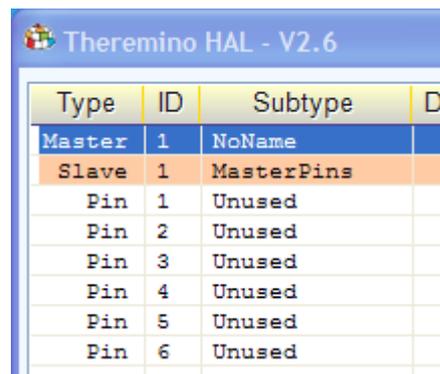


Check that the Master is connected to a USB port and its green LED is flashing fast.

Start Theremino_HAL, that must immediately **recognize the Master** and list it as "Master 1".

If the Master has not been recognized, for example, because it is connected after opening the HAL, then you must press the button "Recognize"

The second line indicates that there is a "Slave 1" (not a real slave but a virtual slave that is inside the master) **the following lines indicate** that are **six "Pins"** available, named **from "Pin 1" to "Pin 6"**

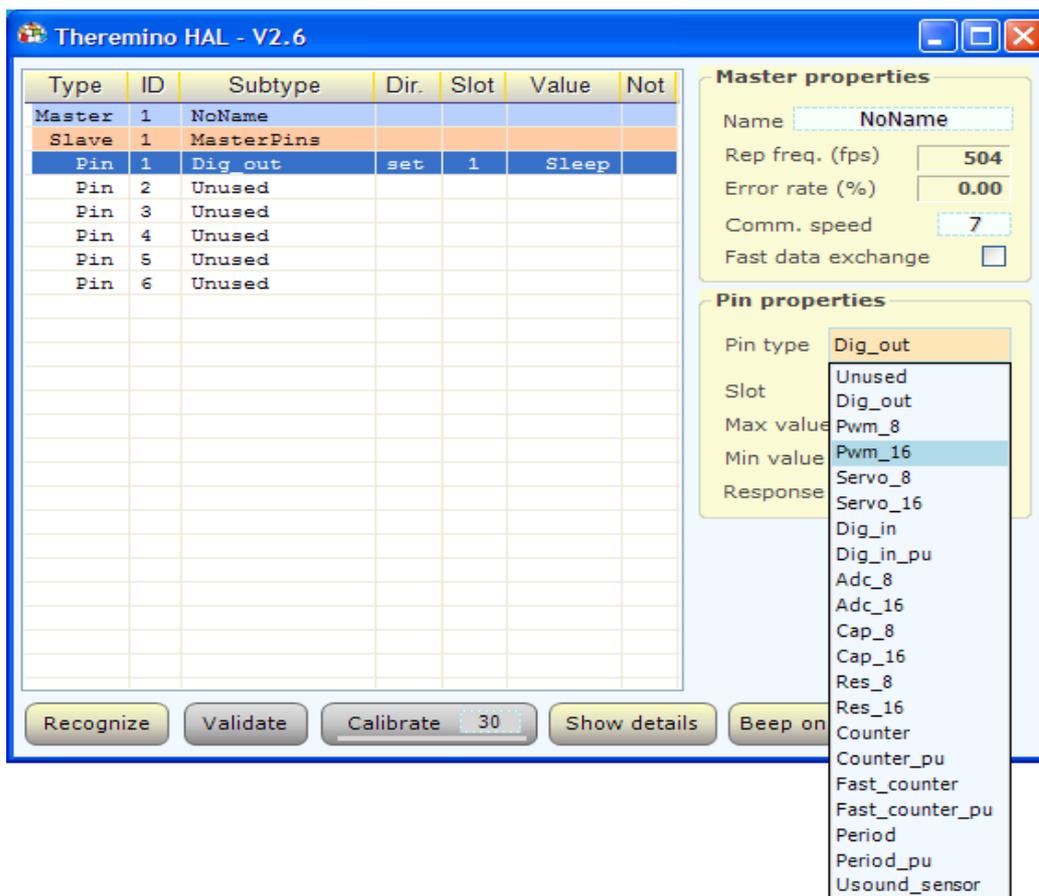


Type	ID	Subtype	Di
Master	1	NoName	
Slave	1	MasterPins	
Pin	1	Unused	
Pin	2	Unused	
Pin	3	Unused	
Pin	4	Unused	
Pin	5	Unused	
Pin	6	Unused	

To turn on the LEDS you must configure their "Pins" as DIG_OUT, Pwm_8 or Pwm_16

With the DigOut type we could just turn on and off the led, but with the Pwm types we can also adjust the brightness. The type Pwm16 communicates with 16-bit and is more accurate.

So, for this test, we will use Pwm_16, which uses some more bits in the serial line, but provides the best chance of control.

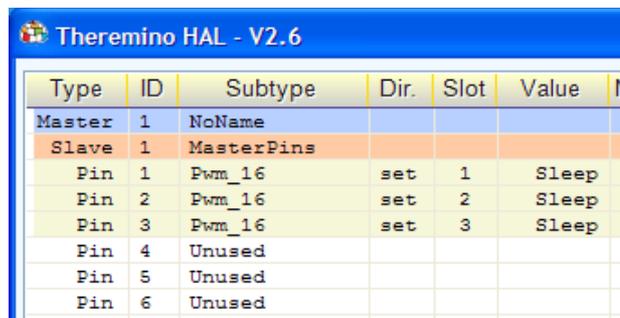


Select the row of "Pin 1" (that turns blue as you can see above), then press the left button of "Pin type" and choose "Pwm_16"

Set "Pin type = Pwm_16 " also for "Pin 2" and "Pin3"

At the end the list should look like the image on the right.

Now position the mouse pointer on one of the words "Sleep", press the left button, hold it down and move the mouse upwards.



The "Sleep" changes to a number from 0 to 1000, and the brightness of the LED of that line is adjusted from minimum to maximum. For better adjustment in the lower area, set "Logarithmic response" to all LEDs.

A little experiment is to set the "Slot 1" for the Pin 2 and 3, and try to adjust the brightness as before, you will see that all the LEDs, reading the same "slot" will change together.

Using external control programs (in the download folder you can find anything) or by creating them in Dot Net or Theremino Script you can use these LEDs, and any other sensor or actuator in many different ways.

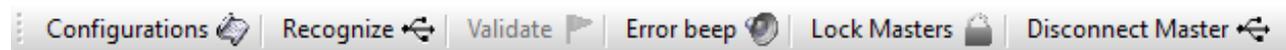
The HAL application commands

For more detailed instructions read the documentation that you download with the HAL application.



Auto reconnect - If enabled (orange color) tries to reconnect the Hardware if the communication is lost.

Calibrate - Is used only if there are connected "Slave" modules of type "CapSensorHQ"



Configurations – Is used to access the configuration file, for manual editing.

Recognize - Can serve if you connect the Master late or if you change the hardware configuration.

Validate - is used if you change the hardware configuration. If you add or remove Master or Slaves then the configuration is no longer valid and the "Validate" becomes active. If the configuration is not valid, the program HAL does not work. At this point you can choose to press "Validate" and to validate the new configuration or to restore the original configuration by adding or removing the Master and Slaves as needed and press "Recognize"

Error beep - If pressed communication errors are highlighted with a sound.

Lock Masters - If pressed the HAL will connect only to the Masters having their names in the current list. In this way you can keep (in separate folders) different HAL applications, each linked to its specific hardware.

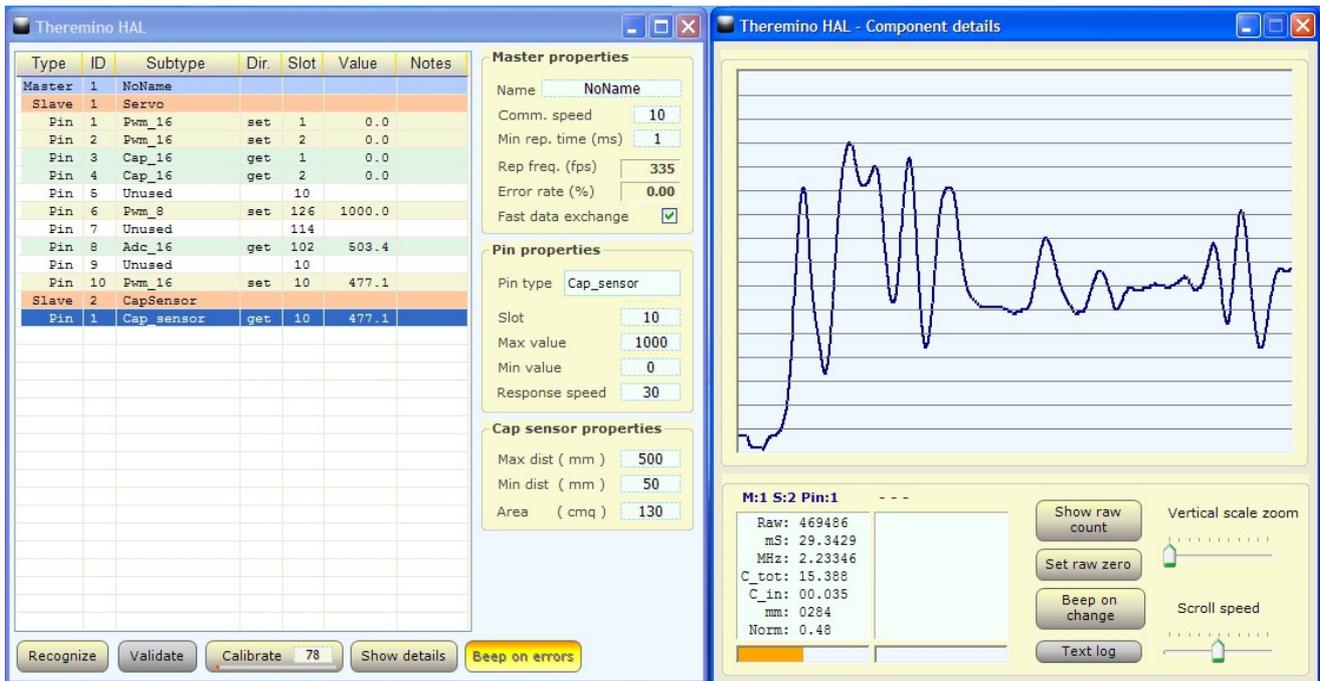
Disconnect master - Removes the selected master from the list. In this way we can eliminate the master side without having to physically disconnect them from the USB. After being eliminated is advisable to press "Block Master", so the next boot will be reloaded the desired Masters only.

How to use the HAL

The more recent list of Types are in the pages [Technical-PinTypes](#) e [Hardware-Devices](#). For detailed instructions read also the documentation that you download with the HAL application.

To communicate with the hardware, you use the HAL (Hardware Abstraction Layer)

The "Theremino_HAL.exe", requires no installation and can be run in any folder on your system. The latest version of HAL can be downloaded from here: www.theremino.com/downloads/foundations



To communicate with the hardware you need to keep active the HAL, you can minimize but do not close it.

Using the HAL alone, even without specific applications, you can check the hardware, try manually sensors and actuators and configure the properties of the InOut pins.

Double-clicking on a line opens the graphics window that shows the trend of the signal on that line. With a single click on a first line and with one click on another you can view them simultaneously.

All the numerical boxes are editable with the keyboard, with the mouse up/down, with the mouse wheel and the up and down arrows.

During the tests, it is very convenient to change the values in the column "Value" with the mouse (press left button on a number of the column "Value", hold the button and move the mouse up and down)

In these videos you can see how to connect modules and configure Pins

www.youtube.com/watch?v=iCWvIxAQw7I

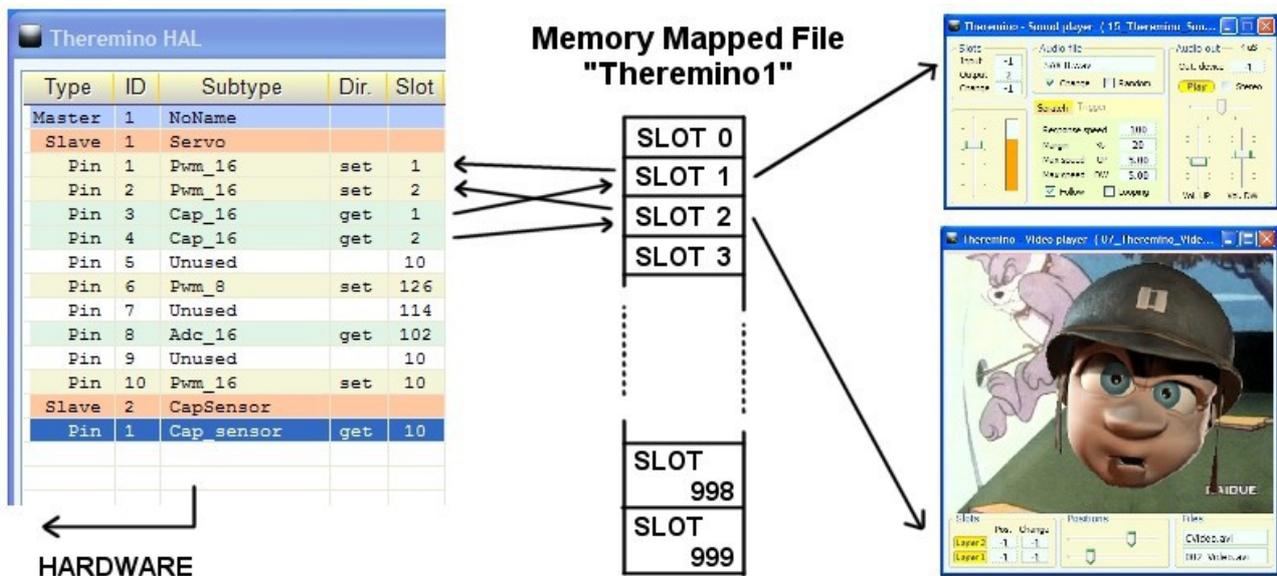
www.youtube.com/watch?v=2nHv_RVNeY8

How to use the Slots

Each line of the configuration corresponds to a hardware physical "Pin"

Each "Pin" corresponds to a sensor or actuator and is controlled with an appropriate "Pin type" and a "Slot"

- For the "Sensors" you configure the "Pin" as Input (Direction = get)
- For the "Actuators" you configure the "Pin" as Output (Direction = set)



The HAL program continuously repeats the following two steps:

- Reads hardware sensor and writes their values in the "Slot" assigned to each of them.
- Writes the value of each hardware actuator taken from the assigned "Slot".

The "slots" are in the "Memory Mapped File" called "Theremino1". This so-called "file" is not really a file, but a quick access memory area, shared by all the Theremino System applications.

Therefore one or many applications can, also simultaneously (**Note 1**), use the same slot to read the sensors, move motors or exchange data between them.

The HAL program serves only to communicate with the hardware via a master module and must remain lit, visible or minimized. However, if there are not hardware modules, the program HAL is not needed.

(Note 1) Slot communication must respect the following rules:

- One slot can be read by many applications and from the HAL, even simultaneously.
- Only a single application (or HAL) can write to a specific slot (otherwise they alternate randomly)

Configure the Master module

The twelve In-Out pins can be configured as:

- Not used
- Digital output
- PWM output
- Output for servo-controls
- Output FAST-PWM with high resolutions for DAC (firmware V3.0 and up)
- Uscita STEPPER per controllare i motori passo passo (dal firmware V3.0 in poi).
- Ingresso di controllo della distanza raggiunta dagli STEPPER (dal firmware V3.0 in poi).
- Digital input
- Input ADC for potentiometers and transducers
- Input for capacitive buttons
- Input for resistive transducers
- Count input, frequency and period
- Input for special transducers

Valid configurations

Not all the Pins are configurable with every possible Pin Type.

The more recent list of Types are in the pages [Technical-PinTypes](#) e [Hardware-Devices](#).

For detailed instructions read also the documentation that you download with the HAL application.

Voltages and currents

The Input-Output pins work with analog signals from 0V to 3.3V. On the connectors is available the 5 Volt and a 3.3 Volt stabilized useful for some sensors. The maximum current for pins configured as output is +/-15mA. For those that configured as input instead, should limit the voltage from -0.3 Volt to +3.6 Volt and not exceed these thresholds with currents greater than +/-100uA (see [technical/pin-types](#) and [technical/tables-and-notes](#) for more information on currents and voltages)

Connectors

From version 4 onwards, all the connectors have been replaced with the connectors for the [standard female-female cables](#)



Pin types table

INPUT PIN TYPES												
PIN	DigIn	Adc	Cap	Res	Counter	Fast counter	Period	Slow period	Usound sensor	Stepper Dir	Encoder A	Encoder B
1	0	0	0	0	0	0	0	0	0		0	
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0		0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0		0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0				0	0	0	0	0		0	0
8	0				0	0	0	0	0	0	0	0
9	0				0	0	0	0	0		0	0
10	0				0	0	0	0	0	0	0	0
11	0				0			0			0	0
12	0				0			0				0

OUTPUT PIN TYPES					
PIN	DigOut	Pwm	Servo	Stepper	PwmFast
1	0	0	0	0	0
2	0	0	0		0
3	0	0	0	0	0
4	0	0	0		0
5	0	0	0	0	0
6	0	0	0		0
7	0	0	0	0	0
8	0	0	0		0
9	0	0	0	0	0
10	0	0	0		0
11	0	0	0		
12	0	0	0		

I2C INTERFACE			
PIN	SDA	SCL	INT 0
1			
2			
3			
4			
5			
6			
7	0		
8		0	
9			0
10			
11			
12			

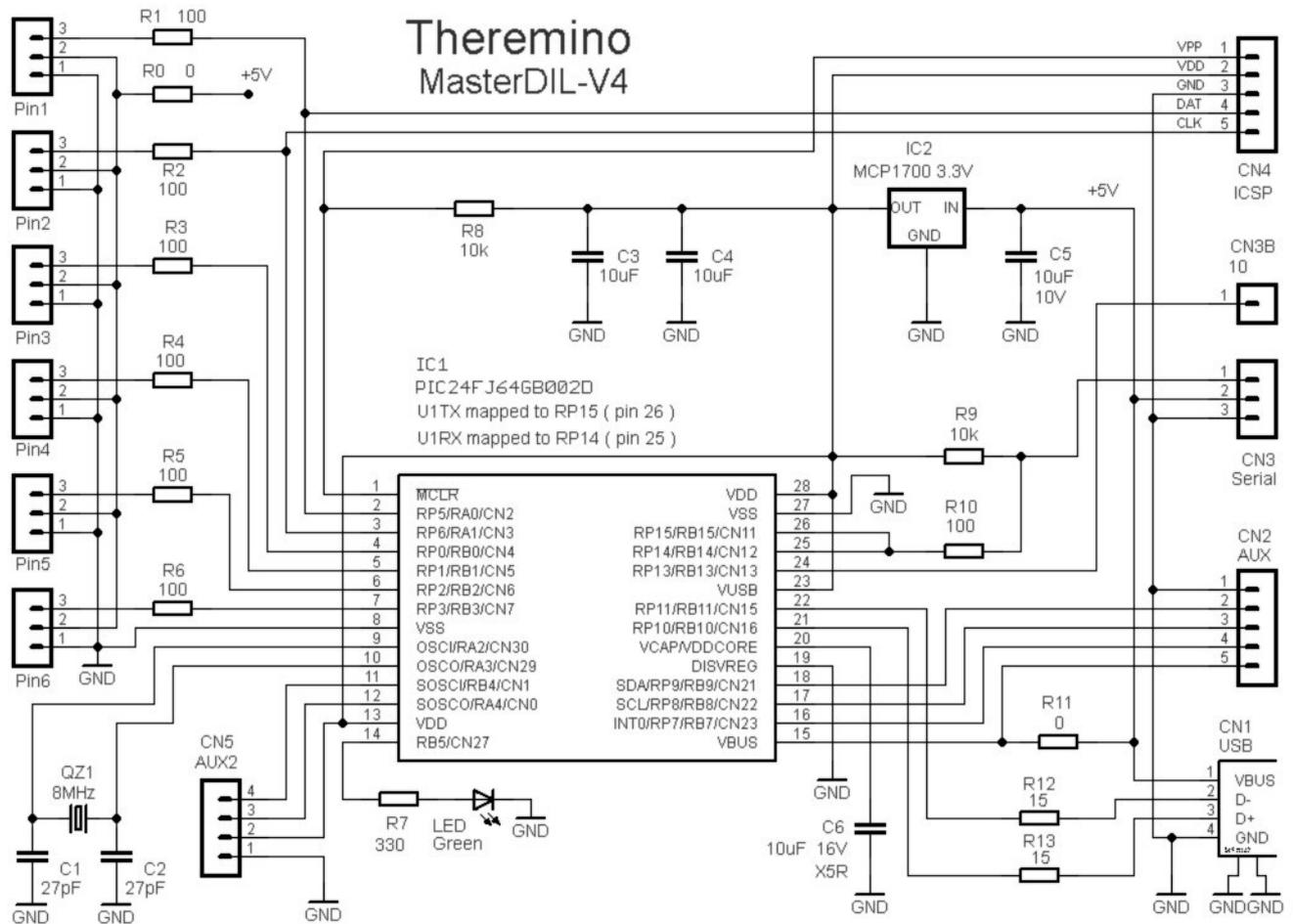
The three pins of the I2C interface can currently only be used to connect the ADC24 module.

Connecting other modules in I2C is theoretically possible but would require modifying the firmware of the Master and the software of the HAL application.

Therefore in these cases we recommend using an Arduino Nano and our ArduHAL application.

- **Stepper** and **PwmFast** added together can use a maximum of five PINs in total.
- **DigIn, Adc, Cap, Count, FastCount, Period, SlowPeriod, e Encoder** can be followed by "PU" to make them **PULL-UP** inputs.
- **Pwm, Servo, Cap, Res e Adc** can be followed by "8" o "16" to indicate that you want them to be **8 bit** or **16 bit**.

Electric schematics



The six connectors Pin1 to Pin6, with protection resistors R1 to R6, provide six InOut generic pins, configurable to connect all kinds of sensors and actuators with the standard: GND / +5 V / Signal

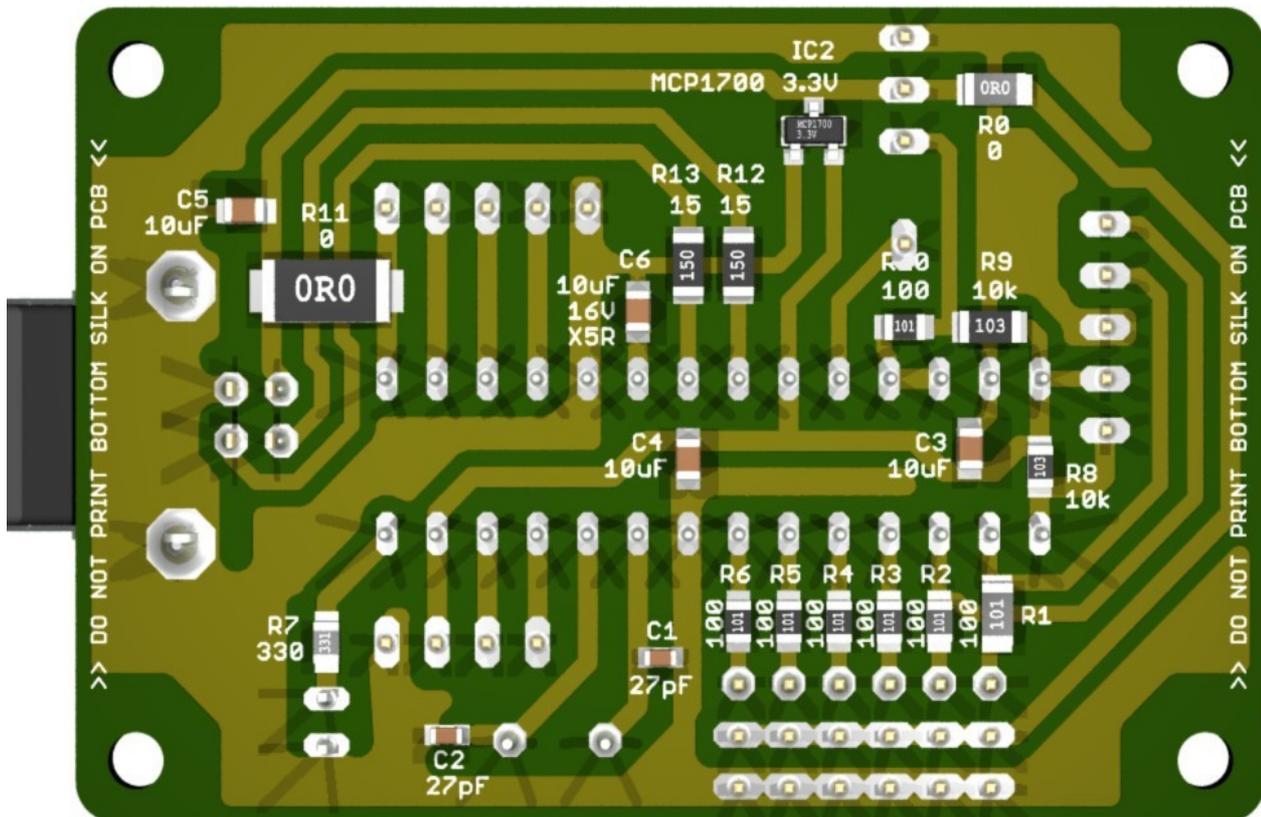
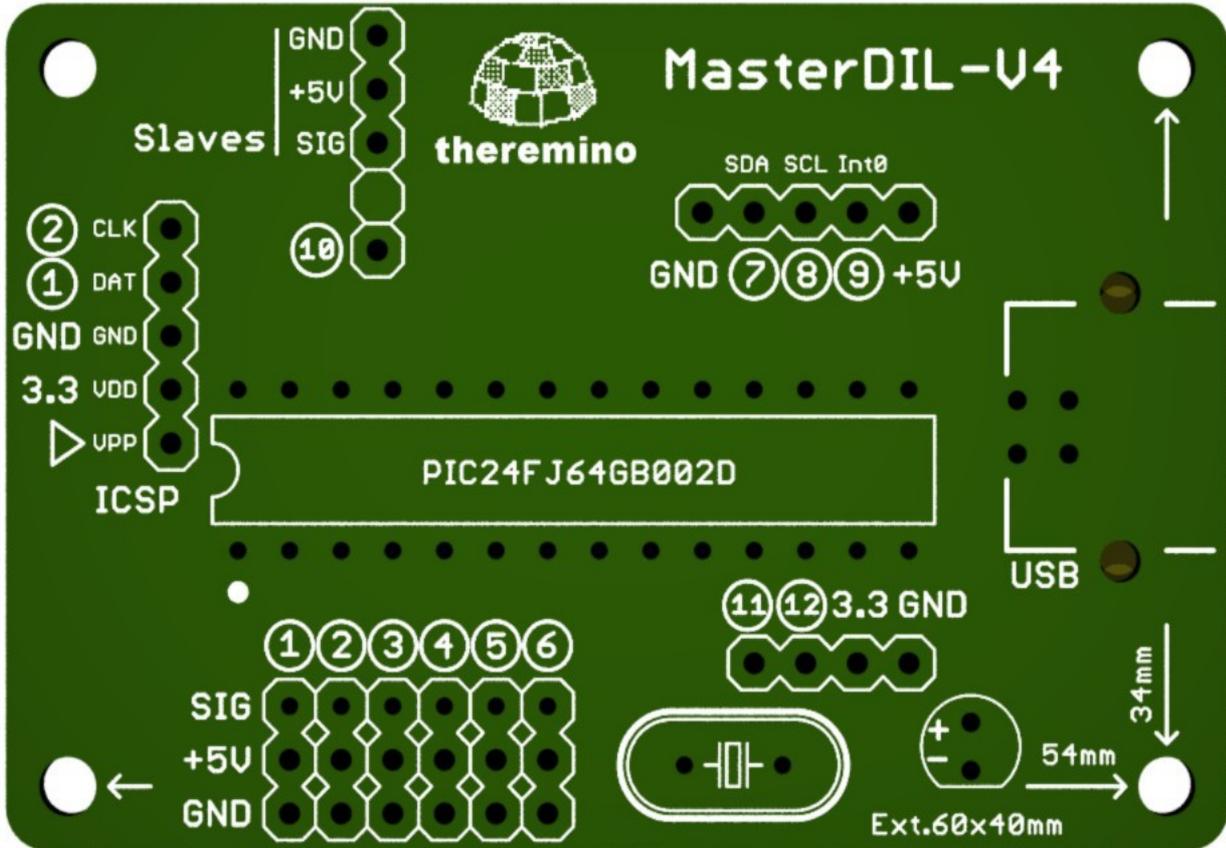
The regulator IC2 and the power circuits components R9, C3, C4 and C5 stabilize the very inaccurate and noisy USB Voltage to a well stabilized 3.3 Volt. The use of three high capacity (10uF) ceramic capacitors allows to eliminate any trace of noise from the ADCs measurements. The capacitor C6, with features even better (dielectric XR5), stabilizes the voltage "VDDCORE" produced by the processor internal switching.

Communications: CN3 allow bidirectional serial communication, recognition, and automatic configuration of the slave modules. CN1 is for connecting with the USB. CN2-AUX is used to access the interrupt pin INT-0 and to connect precision devices, via I2C or SPI. *The AUX connector is used to connect the module "Theremino ADC 24" (very low noise for measure instruments, Geophones and Accelerometers. and up to 900 samples per second with 16 channels simultaneously and synchronous between them, for Seismic Refraction)*

The CN4 connector has two functions: PINS 1-2: the same pins 1 and 2 of the connectors of InOut but, unlike normal InOut pins, on this connector there is the +3.3 volt stabilized instead of the +5 Volt. The 3.3 Volt stabilized is useful to power sensors whose output signal depends on the supply voltage. ICSP: This connection allows you to reprogram the Master module with a PicKit1, 2 or 3, for firmware upgrades or to add new features. The white dot indicates pin 1 (VPP)

Timing: The QZ1 provides main timing and LED1 provides a visual indication of proper operation. *The rate of repetition of the firmware is twenty times the speed of flashing, if blinking quickly then everything is OK.*

PCB - Components side and solder side



Connect the Slave modules

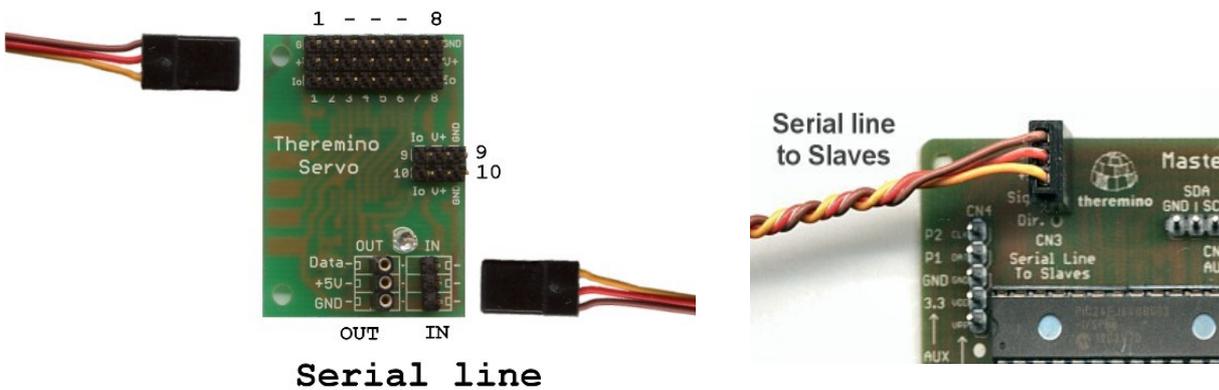
The cables to connect the serial line that goes to the Slaves are the same used to connect sensors and actuators to the Input / Output Pins.



But you should not confuse the two lines, wiring errors not cause damage, but if you do not make the right connections, these will not work.

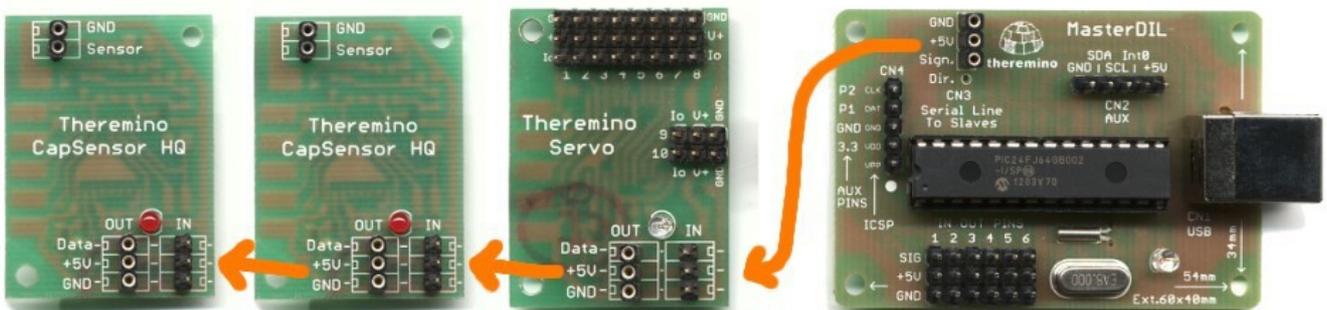
Even if the connectors are the same, be careful! The "Pin" connectors are used for sensors and actuators while the "Serial" connectors are used to connect "Master" and "Slave" modules one to each other.

In-Out Pins 1 to 10



The serial line from the Master must be connected to the "IN" of the first "Slave"

To add a second slave, the "OUT" connector of the first slave is used, and so on up to 200 slaves.



The slaves can be connected in any order but if you change their disposition or their number the hardware configuration will be misaligned from the HAL program

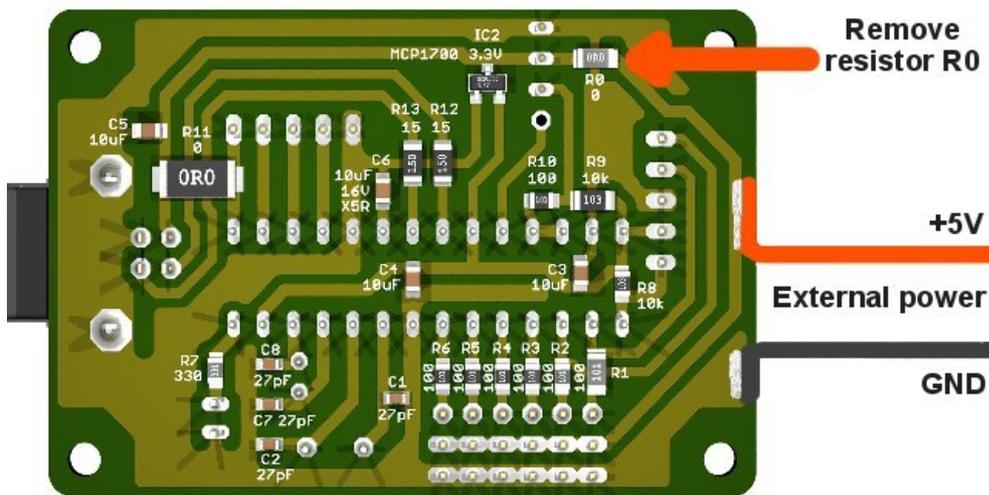
Therefore, after connecting the Master and Slave chain, you press the button "Recognize" and then eventually "Validate", to accept the new hardware configuration to Theremino_HAL

Apply an external power supply

To power motors and actuators with strong currents, the simplest and safer solution is to use a USB HUB connected to a 5 Volt and some Ampere power supply.

Otherwise it is possible to discontinue the serial line to the slave modules, with an adapter and an external power supply (see at the end of this page: www.theremino.com/hardware/outputs/actuators)

For applications without slave modules, or to provide more current (to the six master Pins only), you can make this change:



Unsolder (or break with the clippers) the resistor R0 and solder red and black wires to bring the +5 Volt from an external power supply.

We recommend, as far as possible, to avoid the use of additional power supplies.

When designing a system that is also connected to a wall outlet, you should pay attention to:

- Place correctly the GND wires (star connections)
- Do not let the noise coming from the power supply cross the delicate connections and produce errors.
- Avoid strong current pulses caused by lightnings that may damage the components.
- Avoid construction errors or faults that can damage components or cause hazards to users.



Precautions to be taken: The Theremino System is a "Freeware", "Open Source" and "Not for Profit" project and its components are "mounting kit" and not "finished products". Therefore **when connecting the modules in a system, you must respect the limits of the law**, radio frequency emissions and obtain the necessary certifications. To reduce noise to the law limits, might be necessary, depending on the case, to use shielded cables and metal containers or other techniques. Manufacturers and retailers of the system Theremino are not aware of the actual conditions of use of the modules and therefore can not respond to improper use, illegal or dangerous of them. For more information, see this page: www.theremino.com/contacts/copyrights

Provide high current without external power supply

Motors, actuators and servos can have a current "surge" of more than the 500 mA (or 1000 or 1800) supplied by USB, but the average current is much lower. This means that it is able to drive four servos at the same time, but just one of them at full speed for a moment, can stop the USB communication. Depending on the model of the servo and of their power this problem may be more or less serious.

Some PCs and notebooks do not suffer from this problem, if you exceed the current they lower the 5Volt and restore as soon as the current falls. The actuator slows down a bit, it takes more time to get into position and then everything goes happily.

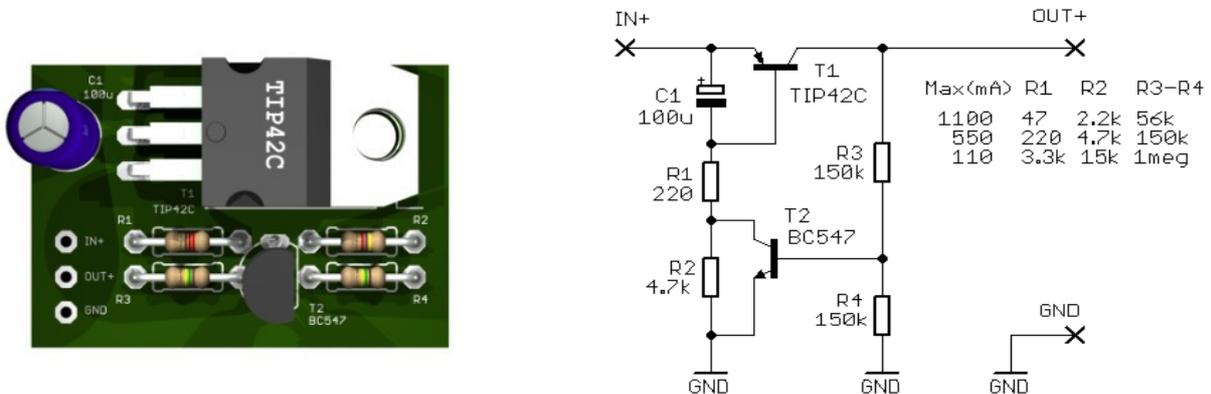
Other manufacturers have included a sadistic "warning" circuit that, as well as to warn, blocks all the USB connection. These machines are very picky, also prevent very short duration current bursts, thus preventing to solve the problem with a large electrolytic which can satisfy the surge current of the engines. If you add, for example, a 4700 uF capacitor, the USB port does not light up, that is, turns on, fails to charge the capacitor, exceeds the current, turns off immediately and stops, waiting for a human to press OK.

So who encounters these problems, should try first of all to connect a 2200 or 4700 uF capacitor between GND and +5 Volt and try to move all the engines repeatedly, trying to get him to use more current as possible.

If with the capacitor everything falls into place you stop here, otherwise you can add, in addition to the large capacitor, a "current limiter".

Limit the current

A current limiter, followed by a large electrolytic capacitor, can solve even the most difficult situations, without having to add an external power supply. The limitation is precise, much better than that of PTC normally used for the USB and in case of short circuit the output "shuts down", and "restores" automatically as soon as you remove the short ("foldback" operation)



Changing the values of the resistors you can choose the maximum current.

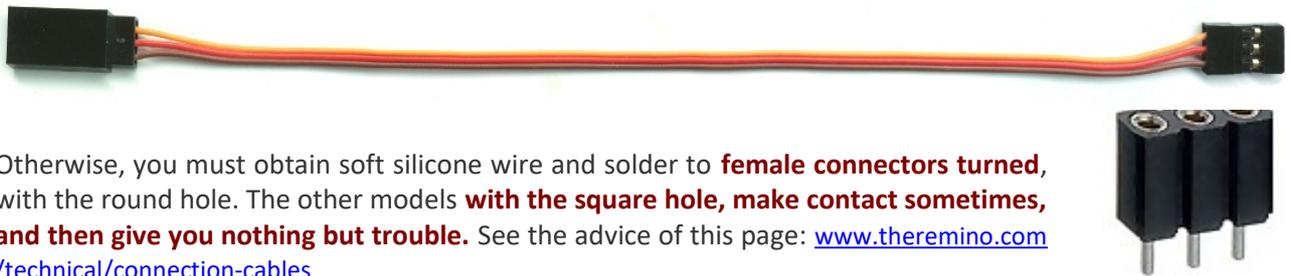
The limiter must be interposed between the +5 Volt coming from the USB and the power track that goes to Pins, this can be done on both the Master and Slaves, cutting the trail that leads to the +5 Volt to Pins and soldering three wires.

Note: Only the Pins power should be limited, not the processors power supply. You do not have to interpose limiters along the serial line.

Full Eagle projects, 3D images and LTSpice simulations for this limiter and for a smaller version, can be downloaded from here: www.theremino.com/hardware/outputs/actuators (at the end of the page)

Connect capacitive buttons

It would be good to procure a certain number of standard extensions, cost little and can be cut in order to obtain females and males, with the wires connected, at a price so low that it is not worth of make them.

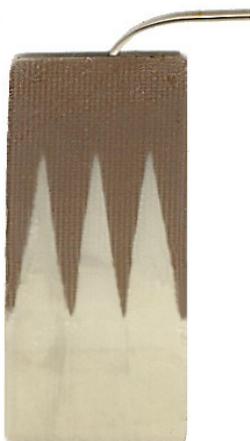


Otherwise, you must obtain soft silicone wire and solder to **female connectors turned**, with the round hole. The other models **with the square hole, make contact sometimes, and then give you nothing but trouble**. See the advice of this page: www.theremino.com/technical/connection-cables

Some pieces of thread, alone or with squares of copper or aluminum tape attached, can act as capacitive keyboard.

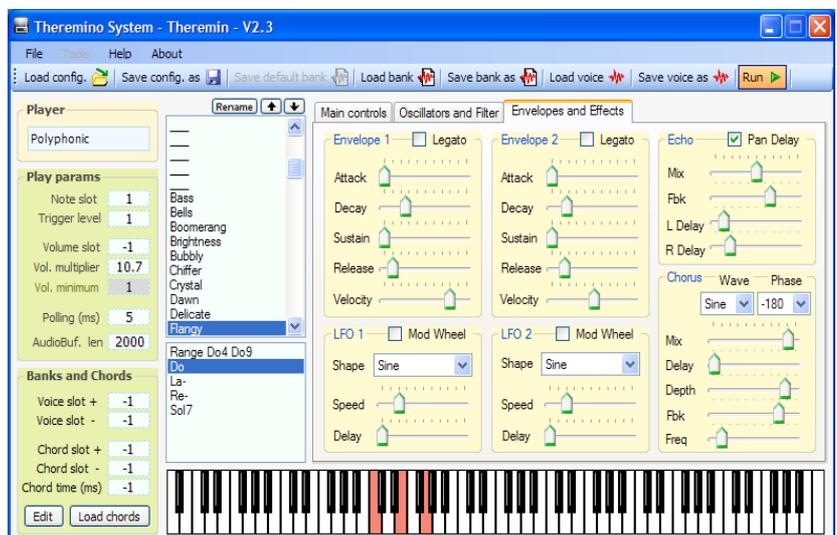
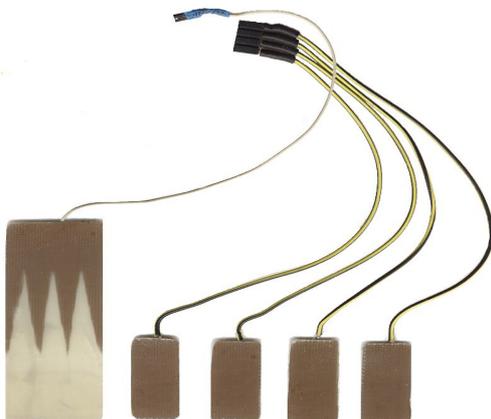
This is a video on the capacitive keys (comfortable, fast and bounce-free) [CapTouch Sensors](#)

Musical Keyboards



With the capacitive keys of the Master module combined with the Theremin (Polyphonic Synthesizer) and Sound Player (sampler) you can build musical instruments never seen before. To expand the number of buttons use "Servo" slaves.

More information in the instruction sheets Theremino Theremin application that you download from here: www.theremino.com/downloads/multimedia



Advice

Master Pins can be configured to measure capacitance, resistance and voltage, but are not designed to replace a tester. First of all, could only measure very small capacitance, resistance up to 50K and then you should carry out laborious calibration, in order to have a reasonable accuracy.

The Input Pins could be used for process control, to adjust positions and adjust a volume or scroll through a video. In these applications it is important to make absolute measurements but it is essential to do many tens of measurements per second. For control applications, you do not need to know the exact value but, on the other hand, the value must be very stable, and have the least possible noise so you do not "shake" the object under control.

The system Theremino works with very high resolution, up to one part in 65000, much higher than the resolution of a normal tester (1 part in 2000), also the values are very stable, low noise and sampling rates are higher by hundreds if not thousands of times compared to those of a tester.

On the other hand the accuracy of the measurements is poor. With standard input-output Pins, the achievable accuracy is of the order of one percent, and it can be up to 0.1% or so, with a hardworking individual calibration in the measuring instrument software.

System scalability

Although the system could, in theory, withstand up to 200 Servo modules, there are limits to the speed of the serial line communication, limitations due to the demands of total reliability and limits the ability to manage systems of great complexity, with a simple Pin list.

We therefore recommend to restrict the system to few modules and the In-Outs to a maximum of 50 or 100. During the design of large systems, consult us or experiment to see if the speeds obtainable are sufficient, and whether the final system is sufficiently reliable, and manageable.

The Theremino system is designed for simple automation on the benches of a laboratory, **not for home automation**. The serial line does not have the resistance to interference, that would be required to coexist with the electrical system. The risk of a complete black-out would be too high.

Precautions to be taken

The Theremino system is a "Freeware", "Open Source" and "Not for Profit" project, and its components are "mounting kit" and not "finished products".

Therefore **who is responsible for connecting the modules in a system, comply with the limits of the law**, and obtain necessary certifications about radio frequency emissions. To reduce noise might be necessary, depending on the case, to use shielded cables and metal containers or other techniques.

Manufacturers and retailers of the Theremino system are not aware of the actual conditions of use of the modules and therefore can not respond to improper use, illegal or dangerous of them.

For more information, see this page: www.theremino.com/contacts/certifications