B14

B14 is a board initially designed as intelligent hardware for an advanced baby monitor. During evolution of design new items are been added, and now is something more than a YAMB (yet another microprocessor board). It has some features, individually not new, but not found together on availables commercial products.
Then now is ready for many other different applications.

Let's start from the beginning. A baby monitor is something controlling a newborn, and warning parents in other rooms, usually by radio, if something wrong happens. The simplest system is just a couple of walkie talkie, transmitting acoustically the cry of the baby. A more advanced system is a solid state accelerometer placed under it. The sensor is activated even by small movements, like the breath. If everything stops, parents are warned. In both types a loud noise can be added, to awake parents during night sleep.
The accelerometer must be almost in contact with the kid, and also must be the transmitting antenna. Usually Wi-Fi or Bluetooth are used, but a better option is available. The 2.4 Ghz band is easily absorbed, and to cross two or three rooms in a old house with thick walls, maximum available power is required. Moreover protocols send more or less often, but continuously, radio packets just to keep communication open.

B14 has been built around new available LoRa technology, using spread spectrum modulation. It is not fast, works better between 10 and 1000 bit per second, but has a range of kilometers with few miliwatts, and works between 130 and 1100 Mhz, a frequency range less absorbed than 2.4 Ghz. Perfect for this application: in case of alarm just a bit has to be sent ! Moreover it is an open protocol. Data packet to be sent are decided by your program and not by the stack. Again perfect to minimize the exposition of the newborn to RF. Can be zero, if nothing wrong happens.

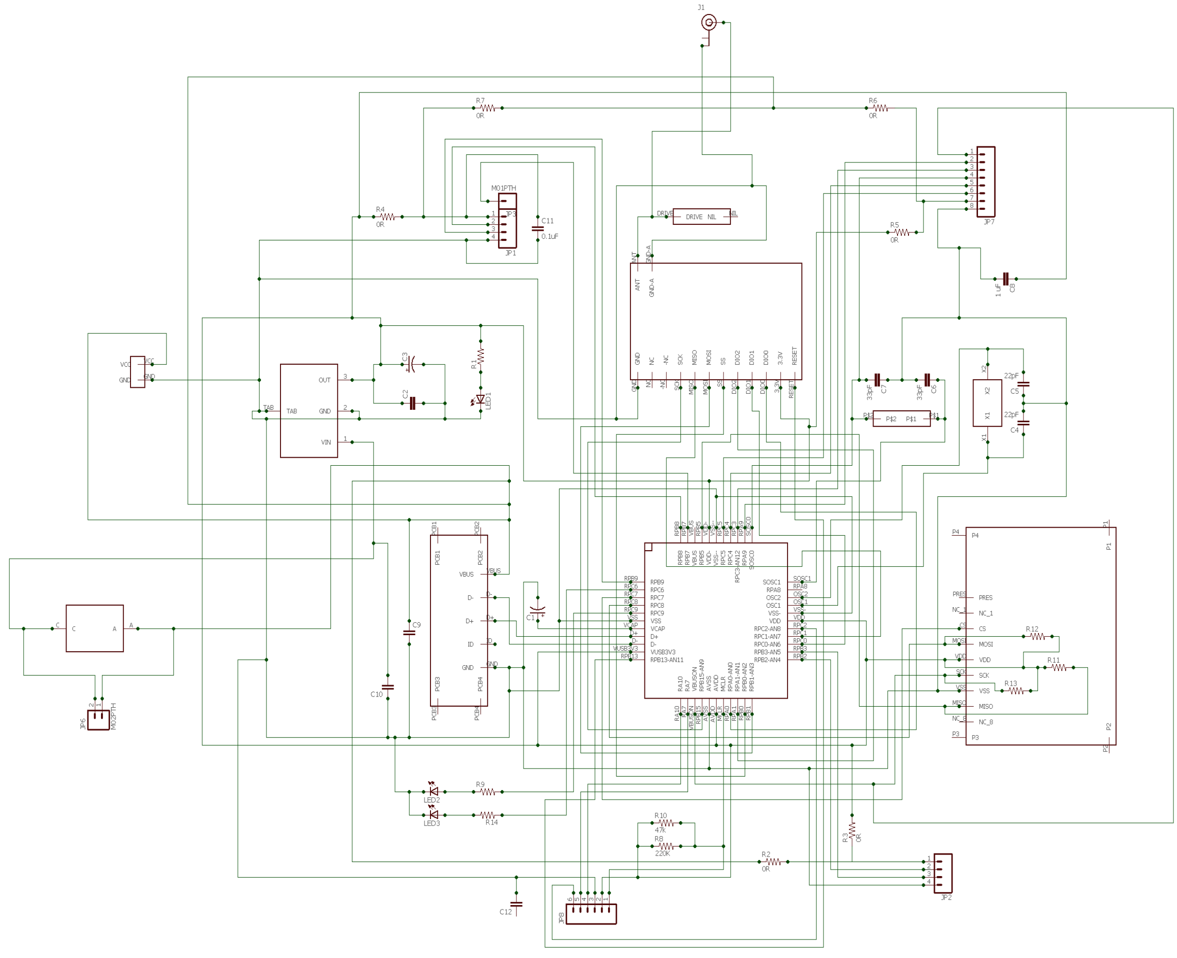
In his first working release the board is built around the PIC32MX270F256D, a 32 bit MicroMIPS processor built by Microchip, and a LoRa module for the 434 Mhz ISM band, based on SemTech SX1278 chip.
The PIC is a microcontroller packaged in a 44 pin TQFP package, with 0.8 mm pin-pitch. It has 32 bit architecture, a maximum speed of 50 mhz, a processing power of 80 MIPS, and memory size is available up to 64k RAM and 256K flash.

Having software running in flash (and not in RAM) and the security bit option, it is virtually immune to wireless hacking. The Lora module has a RF sensitivity in reception of -126 dBm, a maximum transmit power of 20 dBm (100 mW) and a frequency range from 433 to 435 Mhz, covering this ISM band. The maximum transmit power covers and, in some countries, can exceed, legal limits for license-free transmission. In Italy, for instance, the limit in this band is 10 mW. Anyway transmit power can be easily set by program, option not always available on Wi-Fi, for instance.

As a basic resources of the board a micro-SD socket and a micro USB connector are been added. The micro-SD gives memory to do also logging and not only monitoring. And, for free, an extra booting option, to be explained more ahead, is offered by Microchip.
The connector offers USB functionality, since the PIC has this peripheral, acting at will as host or device. It can even drive a USB webcam, acquiring low resolution images, for micro-SD storage or (slow) LoRa transmission.
Finally on one edge of the board is placed a multilayer chip antenna. Solid, not fragile, and not protruding. The final result is a gumstick 30.5 X 72.3 mm, small enough for any wearable application. The board could be even smaller, but this is a real "open source". I mean the board can be easily built, and soldered, by an average hobbist, as prototypes are been.

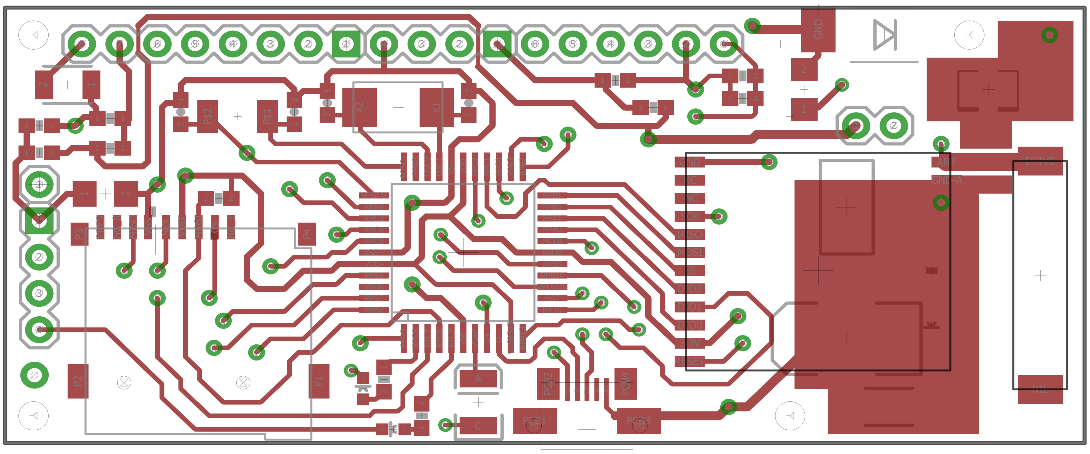
Let's examine in detail schema and options of this board.

In the following picture there is the electric schema:

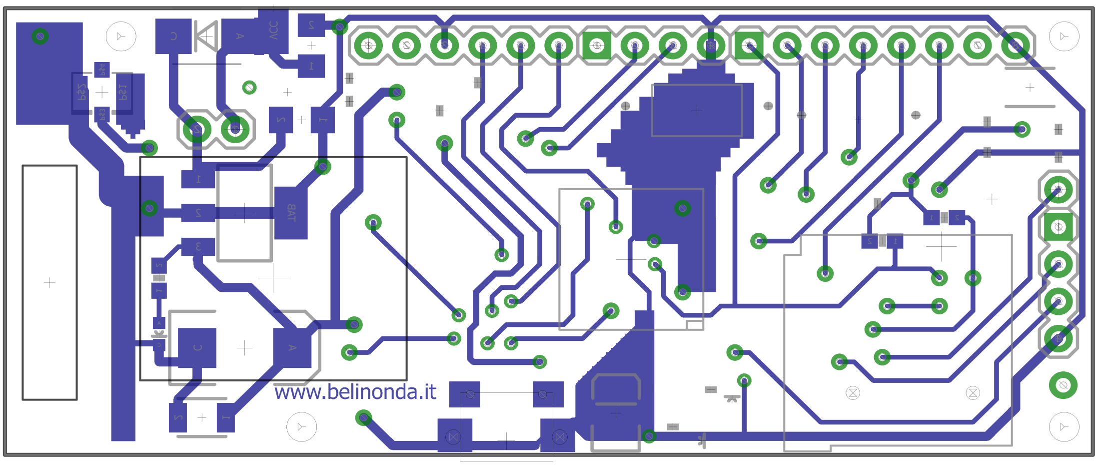


In the following pictures there is the board layout.

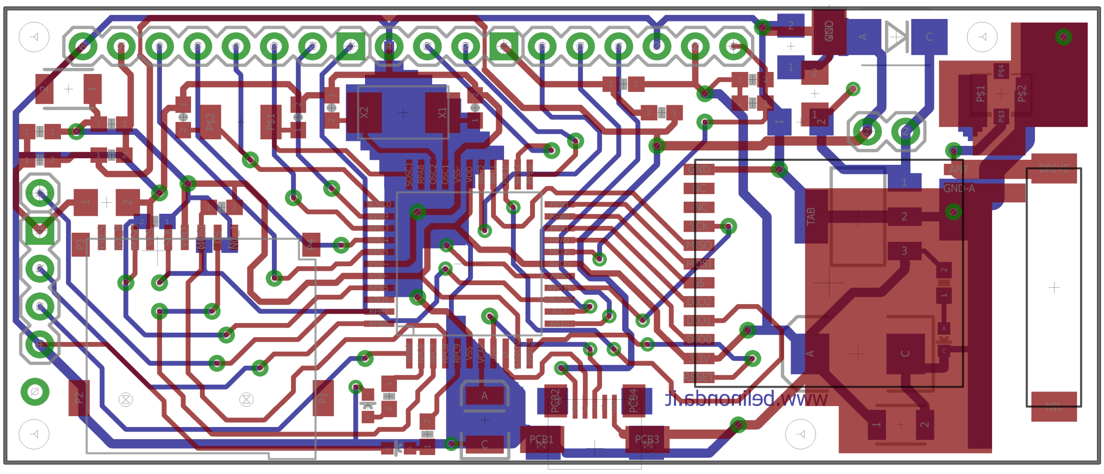
Top:



Bottom:



and both layers superposed:



Peripherals:
included on the board are the LoRa module, connected on SPI2, and a microSD connected on SPI1

Connectors:
The board has a total of six connectors. 1) micro USB - 2) protection diode bypass - 3) UFL for an optional external antenna - 4) 2 pin power - 5) J1 18 pin - 6) J2 5 pin.

The PIC has a nice possibility: many pins are reconfigurable to act as different peripherals. In both J1 and J2 some pins can be configured as UARTs (Tx and Rx) or I2C (SDA and SCL). Then the board can be configured with two UARTs, two I2C or an UART and an I2C.

J1 has 18 pins, three powers, three grounds, MCLR, PGED, PGEC (for ICSP) and other 9 GPIO pins, reconfigurable in different ways.
ICSP contacts are the first five pins of the 18. As PGED and PGEC are used RA10 and RA7. After programming they can be used as GPIO pins.
In this connector RPB2 RPB3 can be configured as UART, as I2C, or GPIO pins.
RPB14 is the SCK1 pin of the SPI1 controlling the micro-SD.
It can not be used when the card is in use, but can be used as a GPIO pin when card is not in use.
Moreover, when micro-SD is not in use, the full SPI1 can routed here on J1 connector. It is not necessary to remove the micro-SD, it is enough to keep high RPC7, his chip select pin.
On the same connector RPB4 is also one of the pin of secondary oscillator.
It can be not used as a GPIO pin when secondary oscillator is in use, but secondary oscillator can be switched on and off under program control.

J2 has five pin, ground, power and RPB7, RPB8 and RPB9.
RPB8 and RPB9 can be configured as UART, as I2C, or GPIO pins. The fifth pin RPB7 can be used for a supplementary function on UARD or I2C connected peripheral.
For instance: reset (required by GSM-GPRS M2M serial modules),
set (used in HC-04, HC-05, HC-06, HC-10, HC-11 serial-to-Bluetooth modules),
A0 (to connect two identical I2C accelerometers),
end of conversion interrupt (not included in I2C specs, but often used).

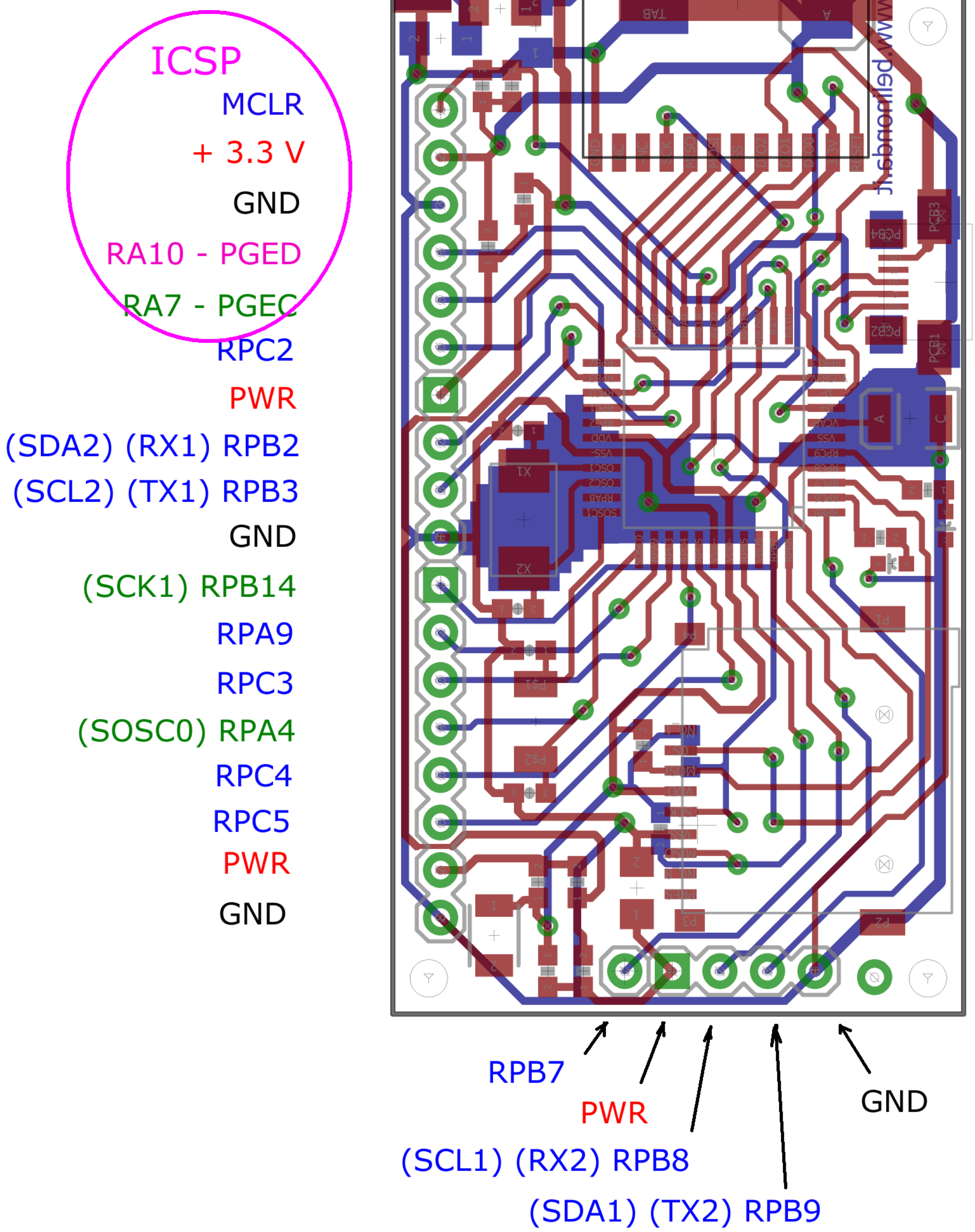
Including ICSPDAT (RA10) and ICSPCLOCK (RA7), left free after programming, a total of 14 GPIO pins are available to the programmer,
Five of them can also be analog inputs.

Other pins of the PIC are used by OSC, SOSC, USB, LoRa and micro-SD. Two (RPC9) and (RPC9) are connected to a couple of status LEDs.

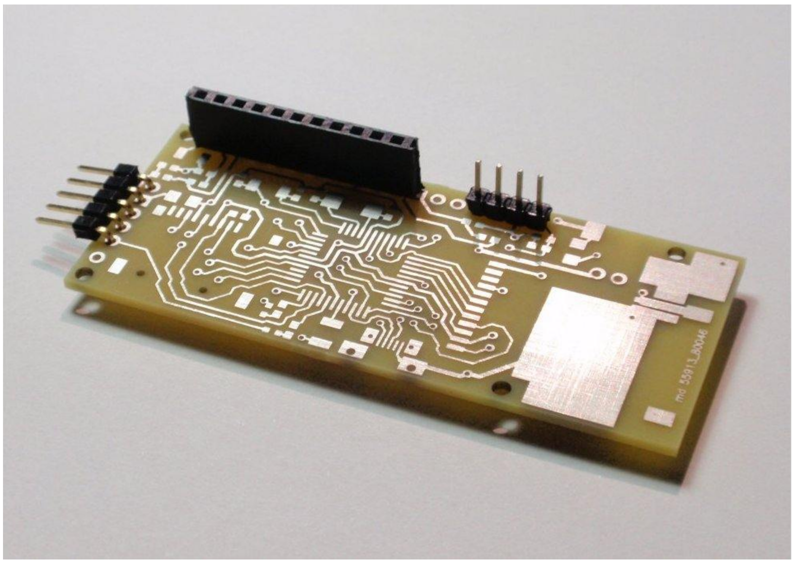
In the picture is described the whole pinout of B14 board.

PINOUTS

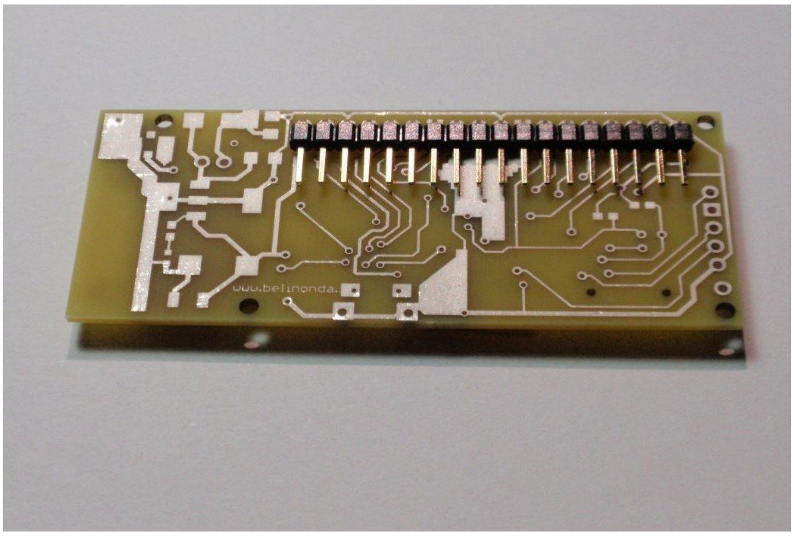
Note: PWR can be 3.3 or 5 volt, according to chosen jumper



To the holes of the board J1 and J2 any connector 0.1" pitch can be soldered, male, female, straigt or right angle.

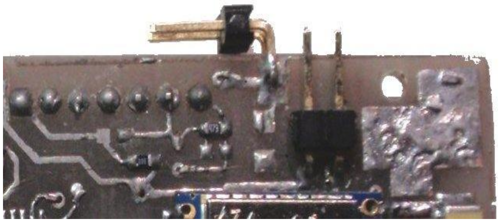


But, and this is uncommon, layout and components positions on the board allow the configuration shown in the picture.



A zone of the board is completely empty, and right angle male connectors can be directed TOWARDS the board. This way board, peripherals, and wiring to them can be assembled in a very flat, wearable configuration.
The board is designed to be built from an hobbist, and for antenna two options ara possible: the Rainsun 1603-433 multilayer chip antenna, or something connected using the UFL (IPEX) RF connector soldered on the board.

Finally the 2 pin power is just a couple of standard 0.1" pin soldered on two SMD lands on both sides of board.



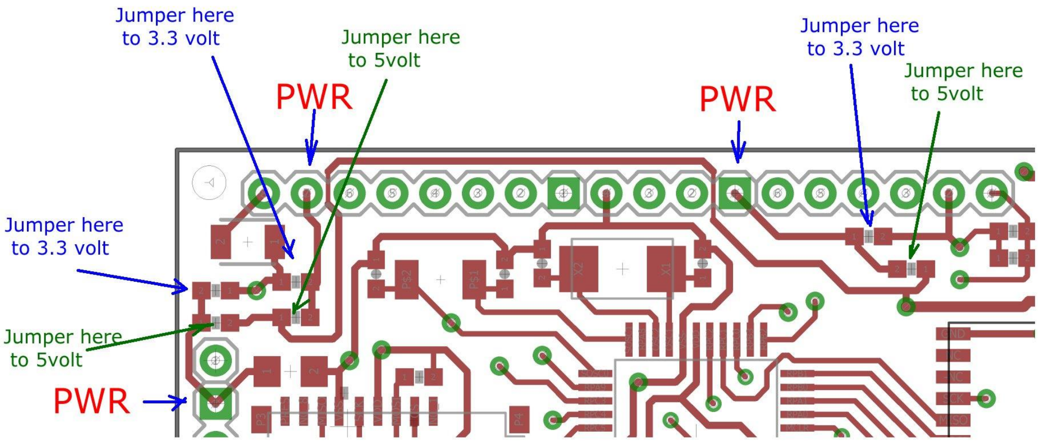
Using right angle pins power cable can go away parallel to the board. Plus and minus are directly connected with +5 and GND of micro USB connector. Finally, the purpose of diode bypass will be explained in the power section.

Power: board is designed to be powered, and to power peripherals, in many different configurations. Basic components, PIC, LoRa and micro-SD are powered 3.3 volt, and signal levels also are 3.3 volt. Power to them is supplied by a Microchip TC1262, a low dropout voltage regulator in SOT223 package. Power can come from a 5V power bank via micro USB, or something else via the 2 pin power conector. In this last configuration should be remembered that maximum input voltage to TC1262 is 6 volts, and power pins of micro USB are in parallel with 2 pin power. More than 5.25 volts cannot be routed to USB peripherals when PIC acts as a USB host.
Board can also be powered using a 3.7 volt LiPo battery, like cellphone batteries or RC quadcopter batteries. 3.7 V is a nominal value, but actual value spans from 4.2 volt, fully charged, to 3.4 volt fully discharged. Considering a voltage drop of the TC1262 of 150 mV, battery can be used down to 3.45 volt, that is more than 95 % of the capacity.
Between 5V input and voltage regulator there is a protection diode against polarity inversion. Even using a low power Schottky diode, the voltage drop of 400 mV is too much for the battery. Then there is a connector to be shorted with a jumper to bypass diode when using a battery.

Beware !

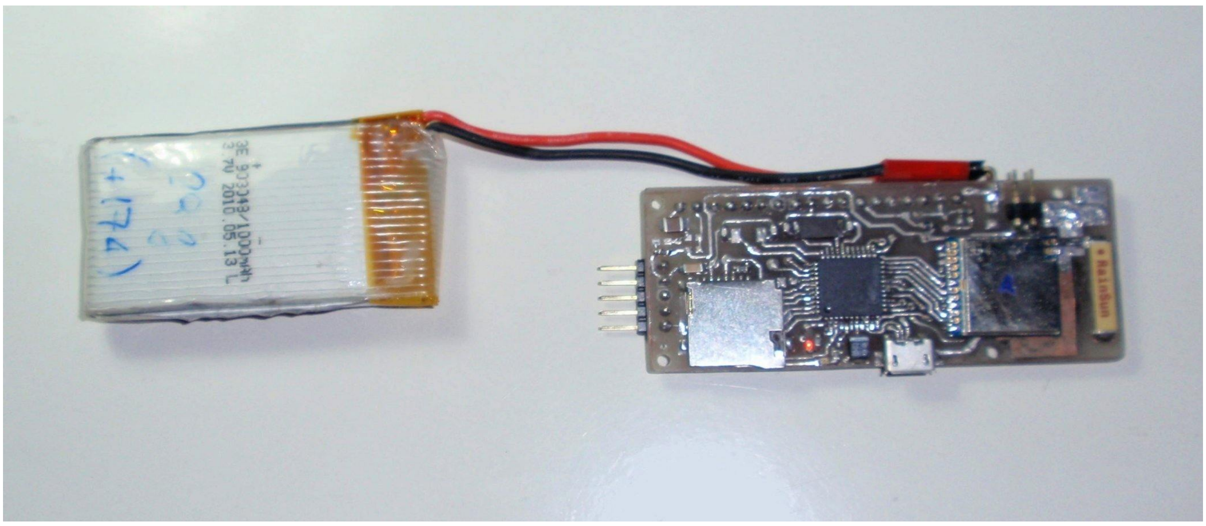
USING JUMPER, PROTECTION AGAINST POLARITY INVERSION IS DISABLED !

Expansion connectors can power peripherals connected to them. In the ICSP the voltage is 3.3 volts. Each one of the three power lines can be connected, soldering a 0R 0603 jumper, to the 3.3 V line or to the 5 V (or 3.7 V bat) line.



This way every connector can be configured to the voltage request of the connected peripheral. Connection requires soldering, and change requires de-soldering and re-soldering of jumper, but this is accettable for a DIY board.

Beware ! There is a difference. 3.3 volt is an OUTPUT. Board cannot be powered here, or the voltage regulator can be damaged. Board must be powered by a line connected to 5 V or battery. If the power line of the connector, instead, is soldered to the 5 V (or battery) line can be used as an input to power the board.
The shape of B14, finally, can match well the shape of many electric quadcopter batteries, in general 30 mm wide, 50-60 mm long, and about 5 mm thick. An assembly with this kind of battery produces something still very flat and wearable.



Battery charging circuitry is not provided. Should be provided externally, connected to a solar panel, for instance.

General consideration: better solder the power line of output connectors to 5 V or 3.3 v ? Depends on peripheral board you are planning to use. In general I2C sensor breakout boards, or GPS boards, have included a small, low dropout voltage regulator. If you see a small, 3 pin IC marked 662K or a 5 pin IC marked KB33, it is just that. Module can be powered with 5 V or battery. If the expansion board is a DIY, you can avoid the voltage regulator on it and connect to 3.3 V. Finally, if you connect a GSM-GPRS module, it is mandatory, for current peak reasons, to use a LiPo battery, and connect power to it. Transmission technique of GSM, in fact, is pulsed, with on-off duty cycle about 0.5-4.5 ms. During pulses current consumption can rise up to 2 amps. A powerful (and bulky) voltage regulator is necessary for this. Fortunately all GSM modules are designed to be powered from LiPo batteries, accepting the full voltage range from 4.2 to 3.4 volt. This type of battery in fact, has no problem supplying peaks of 2 amps, and even more.
In conclusion B14 allows configuration of J1 and J2 to the request of every peripheral board.

Furthermore, on J1 connector, there is another possibility. Some recent sensor breakout boards have no more voltage regulator, and must be powered at 3.3 volts. With 5 volts they are damaged. Fortunately many sensors have a current absorption of few milliamps. They can be powered by a GPIO pin, since on the PIC they have a source capability of 10 mA or more
! Beware ! It is not so easy . Every IC must be powered before having voltage applied to any pin, and the status of any pin of the PIC, used for I/O or to power the peripheral, in general at power on is undefined. You can't guess which pin goes high first.
Fortunately the pins RPB2 and RPB3, used in J1 connector for I2C, have also analog capability. According to Microchip specifications, pins with analog capability at power-on are by default in analog input configuration and do not supply voltage outside. Then the good sequence is: use the near pin RPC2 to power the peripheral, setting it as an output, and high. Next, writing to register ANSELB, switch to digital the pins RPB2 and RPB3. At this point, with peripheral already powered, I2C2 peripheral can be safely opened and used. Beware ! RPC2 from now must be kept output and high forever.

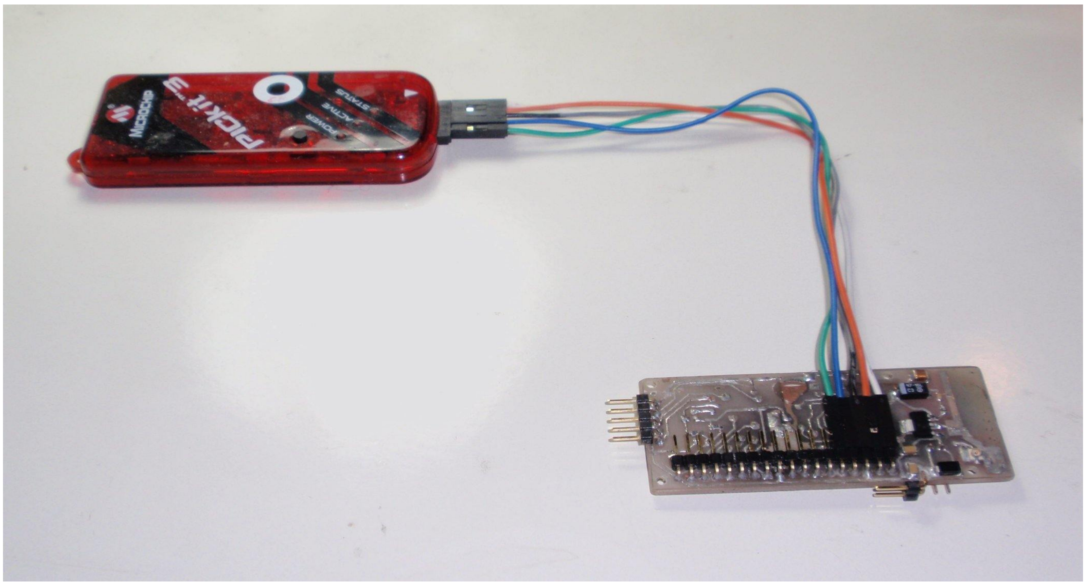
USB connector is a micro USB female connector. VBUS, GND, D+ and D- are used. USBID is not connected. This way the PIC can act as host or device, OTG is not supported. In host mode the connected device is powered, in device mode B14 is powered from host, a PC or smartphone, for instance. Microchip says maximum USB speed is 1.1 full speed, that is 12 Mbit/s. Only one device can be connected, and hubs are not supported. All four USB modes, control, interrupt, bulk and isochronous are supported. Some types of USB webcams are supported, most Logitech models for instance, and low resolution images can be acquired and saved on micro-SD. On request, subsequently, they can be transmitted away via LoRa or Bluetooth.

Oscillators: the PIC can run from a RC oscillator, but, for USB use, a crystal oscillator is mandatory. On the board a 8 Mhz quartz is used. The Abracom ABM7 (RS part number 703-1938) is well tested and works fine with the PIC. Also used is secondary oscillator (SOSC). Driven by a 32768 Hz EuroQuartz EQ160 (RS part number 727-6276) crystal, can drive a real time clock calendar. The PIC can switch system oscilator from 8 Mhz primary to 32 Khz secondary, and back.
Using secondary oscillator as system clock, processing power is reduced to about 50'000 instructions per second. Only minimal monitoring can be performed, but current consumption is reduced to microamps.
The PIC can run for a year and more from a battery, and in case of need, processing power can be raised again to 80 MIPS in less than 2 millisecond.
As a curiosity, the navigation computer driving Apollo Lunar Module on the Moon, had just a processing power of 50'000 instruction per second.

The PIC32 has plenty of interfaces, and most GPIO pins can be reconfigured in many different ways. It has two SPI, both used by micro-SD and LoRa, two UARTs, and two I2C. Other interfaces are free to be used, but the two SPI's are already connected to LoRa and micro-SD.
What happens when another SPI peripheral must be connected to B14 ?
Thanks to reconfigurability SPI1, driving micro-SD, can be also brought to connector J2.
SD card can no more be accessed, but it is not necessary to remove it.
Pin RB5, connected to MISO, becomes a generic GPIO, and must be set in input mode.
Pin RC7, connected to SS1, must be set in output mode, and MUST be set high. This way SD card is not selected, and all pins are set in high impedance mode and do not care.
Reconfigurability can be locked or unlocked, depending on the value of a configuration bit. When unlocked SPI1 can be switched between micro-SD and peripheral on J2 in a matter of milliseconds.
Refer to Microchip manuals and data sheets for more details.

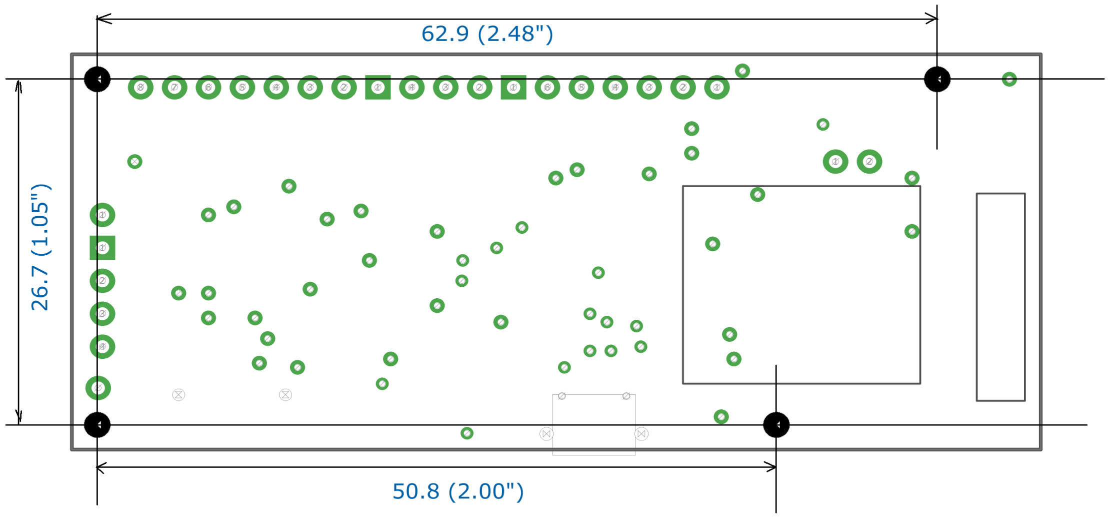
The PIC 32 has a FAT32 filesystem offered free from Microchip.
SD and SDHC up to 32 GB are supported. SDXC are not supported.
SD can be used to save logs, pictures and possibly (under development) low resolution movies. As a graceful gift offered by Microchip there is also the micro-SD bootloader, as explained in the programming section.

Programming: basically every Microchip microcontroller can be programmed using Mplab X software, and different hardwares. The most used is the very cheap and affordable PICKIT 3. Due to very tight spacing between connectors, it can not be inserted directly, but the intermediate of DuPont cables is required, as in the picture.



It is possible to use the PICKIT only once, to install a serial or USB bootloader, to be used subsequently for easy programming. For instance american company Digilent, producer of ChipKit boards, offers for free a plugin enabling Arduino IDE to program the PIC32 in Arduino mode. Some settings of pin names are to be made, but B14 is compatible. Moreover, and this is an unicum of Microchip, exists a bootloader able to reprogram the PIC32 at power-on reading a file on micro-SD. Binary is created using Mplab X environment, and written by PC on a card. This way reprogramming can be done without physical contact, and even programming-on-the-air, via LoRa, can be performed.

Finally, four holes, 2 mm in diameter, are on the board, to fix it to a box. Relative positions are shown in the picture.



An enclosure box, to be released in .stl open source, is under development.

As a final warning, remember: the LoRa chip is very flexible, and power, frequency and bandwidth can be set in many different ways. Every country has his own laws and regulations. Values proposed in the sample software are just a template. It is your responsibility to be compliant to the law of the country where you are operating.
Be careful and have fun !

Torino (ITALY), may, 2017