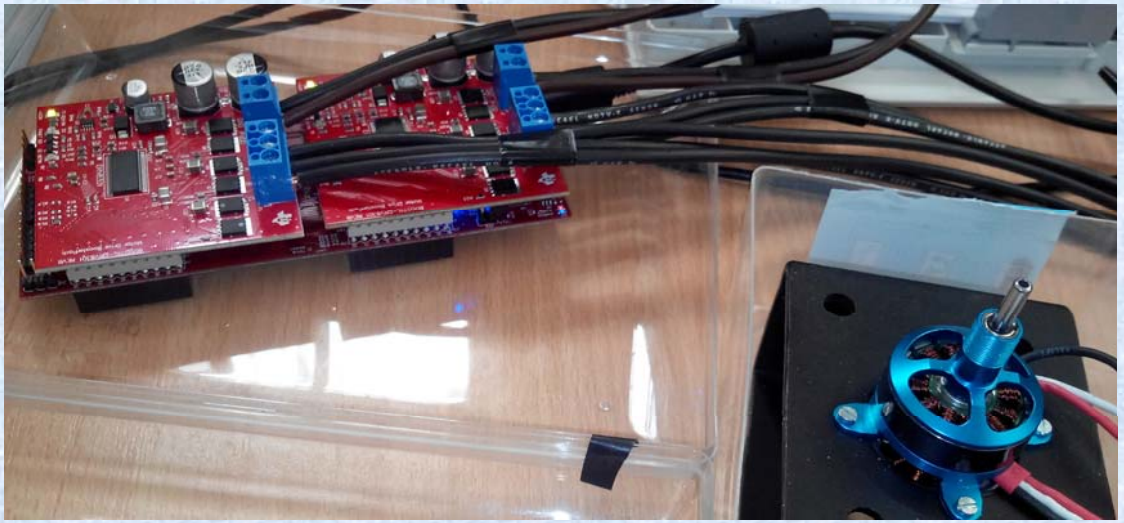
Etat de l'art sur les µC / DSC pour la Commande de Machines et l'IoT



Séminaire du 22 janvier 2017 au LAT

Pr Lotfi BAGHLI
Lotfi.Baghli@univ-tlemcen.dz
Université de Tlemcen

Plan

- Introduction
- Définition (µC, DSC) et leurs caractéristiques
- Critères de choix
- Catégories des composants et des cartes
- Outils
- Quelques cartes et réalisations
- Conclusion

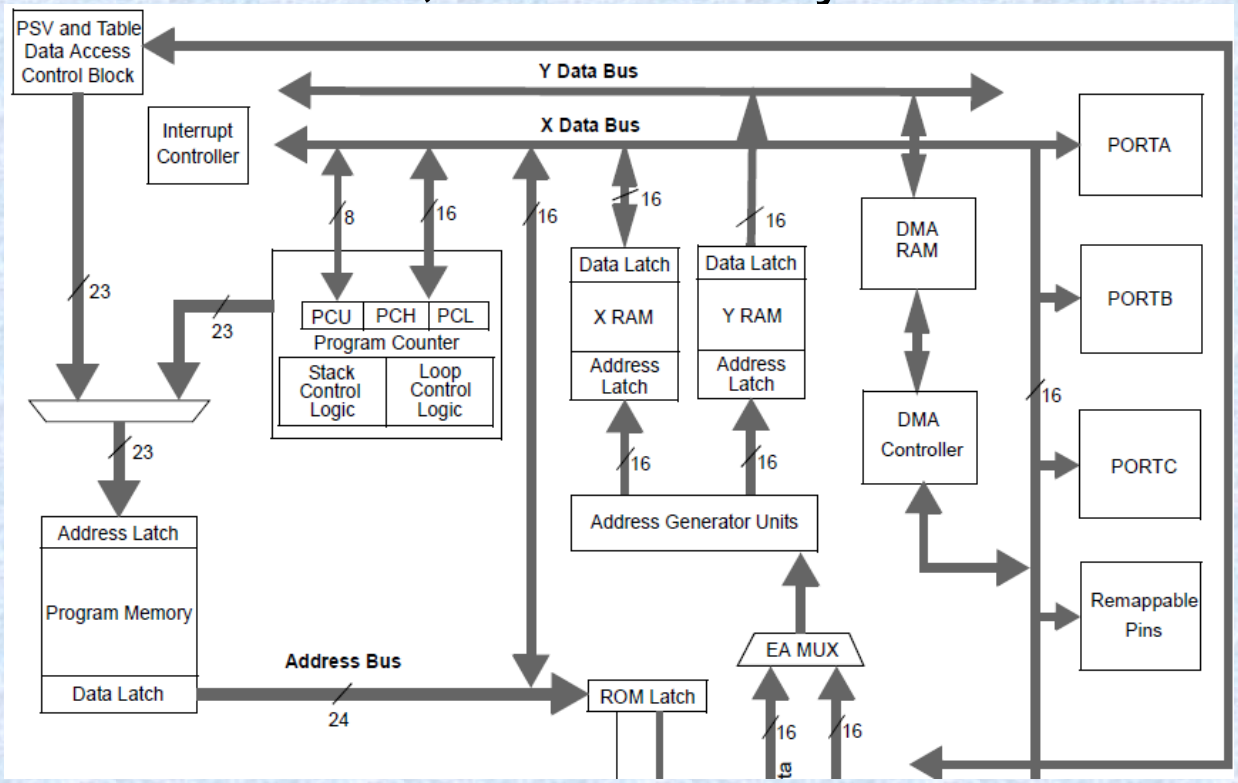
Dénomination et définitions

- µC : microcontrôleur = Micro processor (µP) + mémoire + périphériques = PC dans 1 puce
- DSP : Digital Signal Processor
  - Micro processor (µP), cœur d'un ordinateur
  - Modules matériel (hardware) additionnels pour accélérer certaines opérations de calcul (SOP)
- DSC : Digital Signal Controller
  - Micro contrôleur (µC) + cœur DSP en une puce
  - Combinaison de la puissance du DSP avec la mémoire et le périphériques du (µC)
  - Le DSC représente la solution optimale pour le contrôle temps réel des systèmes embarqués nécessitant une grande puissance de calcul.

$$y = \sum_{i=0}^{3} coeff[i] * data[i]$$

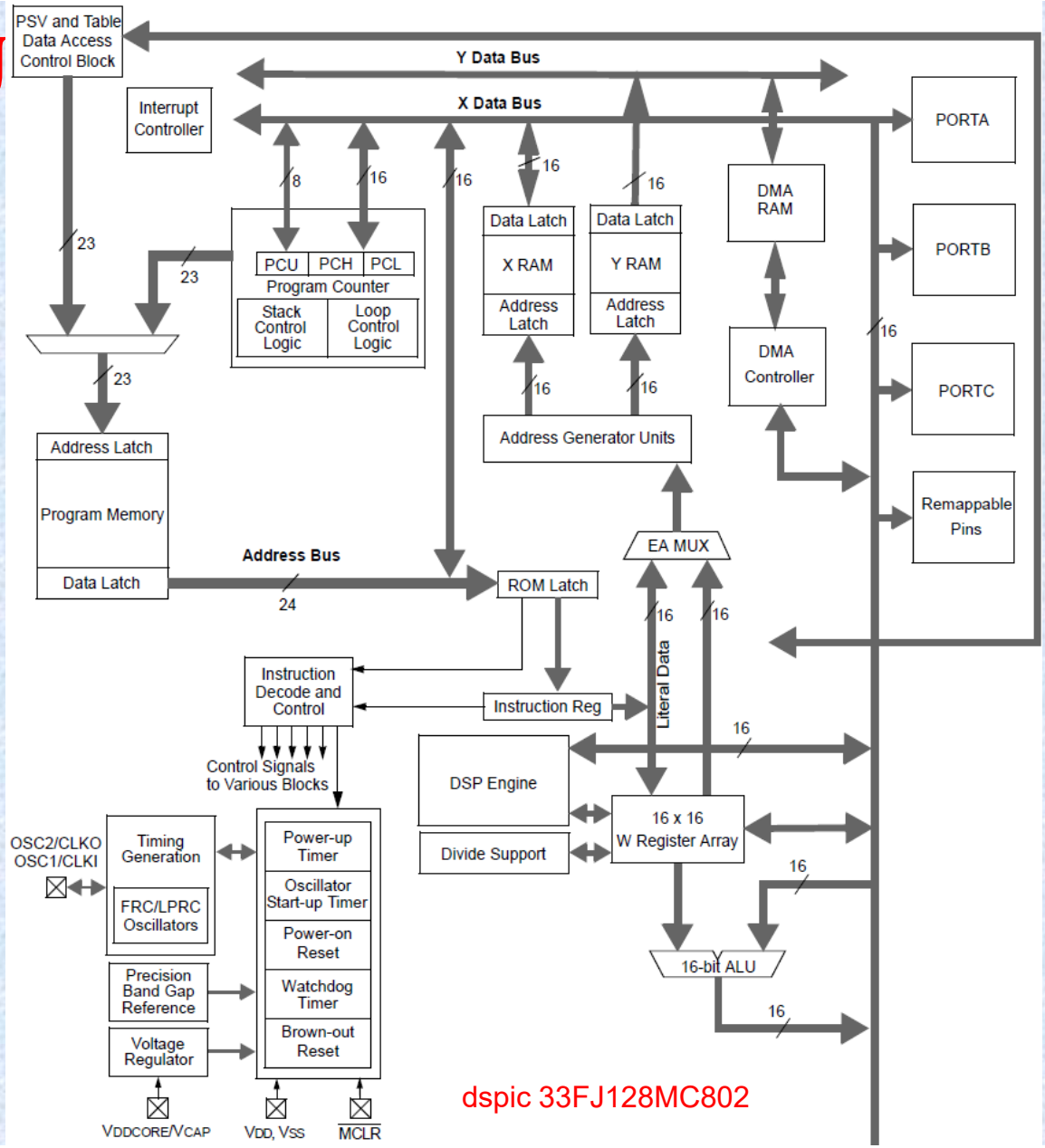
Mémoire

- FLASH : Mémoire programme, 10k à 100k cycles Erase/Write, Code protected
- RAM : peu, rapide
- EEPROM : 5V, 100k à 1M cycles Erase/Write



dspic 33FJ128MC802
3.3V ⇒ no EEPROM

CPU

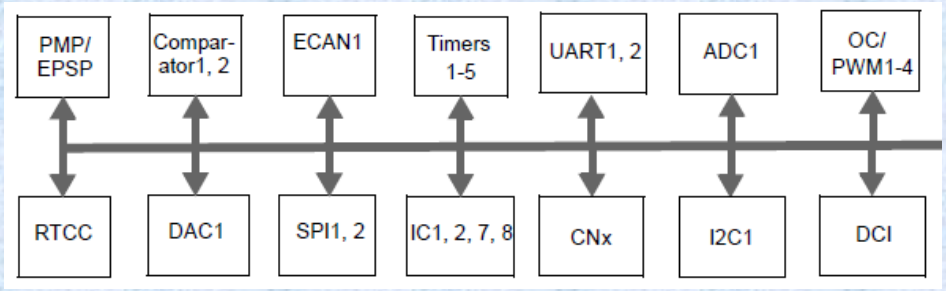


dspic 33FJ128MC802

Périphériques

- Digital Input / Output Lines, pull-up, Change Notification (CN), wake
- Analogue to Digital Converter (ADC), SOC sources, Interrupt.
- Digital to Analogue Converter (DAC)
- Timer / Counter units, prescaler, cascadables, WatchDog
- Pulse Width Modulation (PWM), trigger ADC SOC
- Digital Capture Input Lines
- RTCC
- Communication Interface Units:
  - Serial Communication Interface (SC
  - Serial Peripheral Interface (SPI)
  - Inter Integrated Circuit (I2C) – Bus
  - Controller Area Network (CAN)

dspic 33FJ128MC802

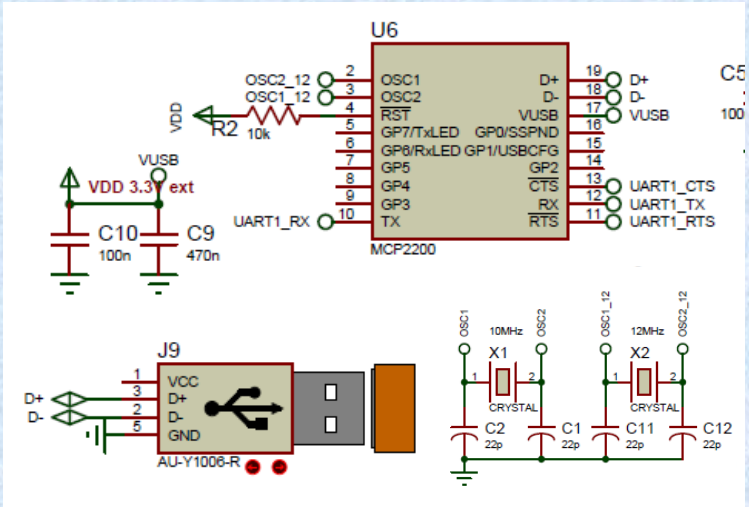


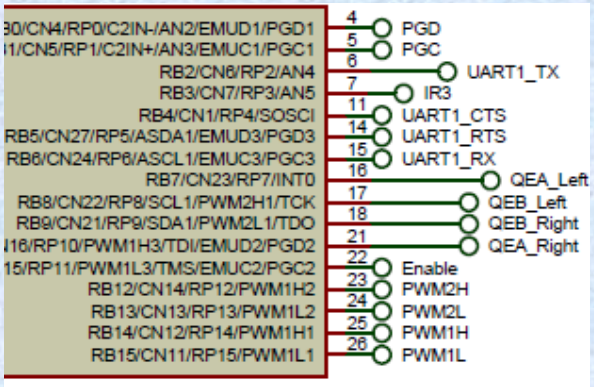
Périphériques

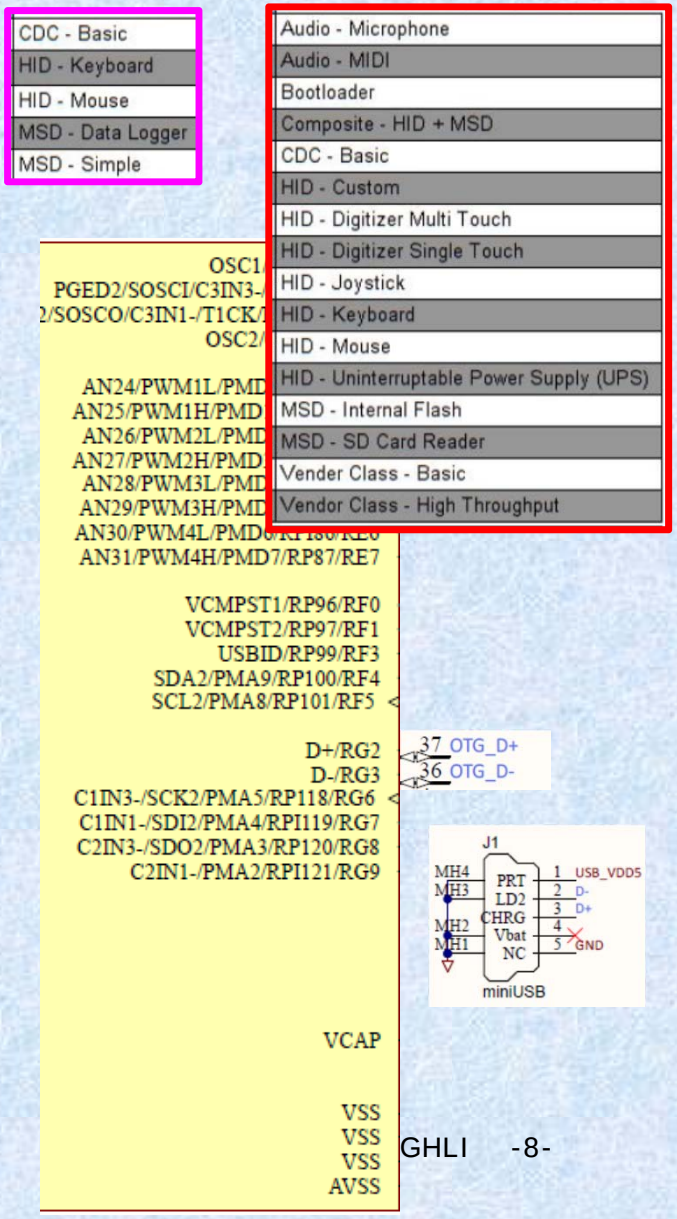
- Pour la communication IoT :
  - Universal Serial Bus (USB)
  - Local / Wide Area Networks (Ethernet)
  - Wifi / Bluetooth (external)
  - Nordic n24L01+ : 2.4 GHz, 1 à 2 Mbps en burst, domotique, jouets
  - Zigbee
  - Zwave : domotique, retransmission de signal
- Nécessite pile logicielle ou matérielle :
  - USB
  - TCP-IP
  - Bluetooth : 3, 4, **BLE**

USB

- USB mode :
  - Device mode : CDC, HID (Keyboard, Mouse)…
  - Host mode
  - On-the-Go (OTG)
- Microchip Libraries for Applications (MLA)
- Port COM over USB :
  - FTDI 232RL, 2xxx (exemple Arduino)
  - MCP2200
  - Ch340, CP210x (exemple Arduino clones)

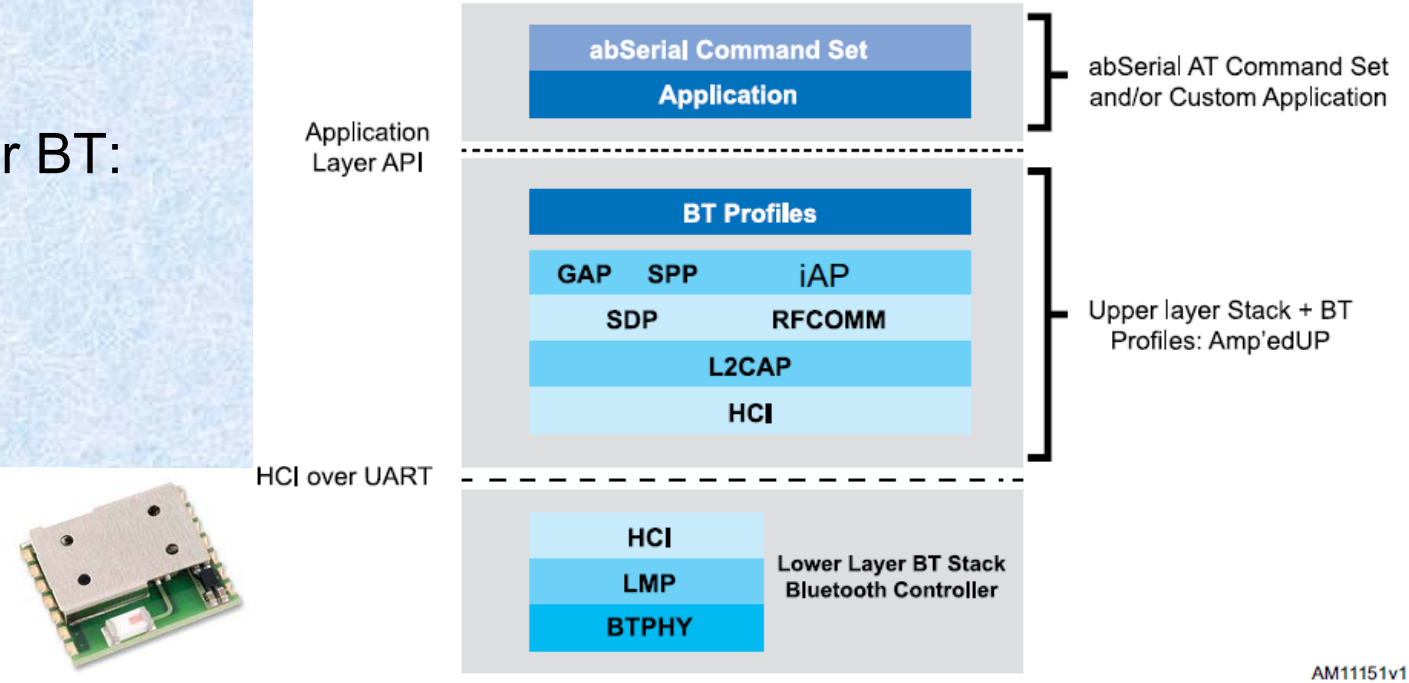


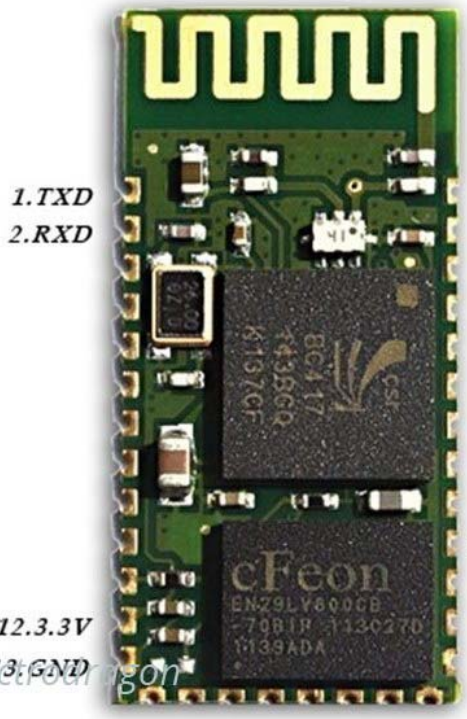


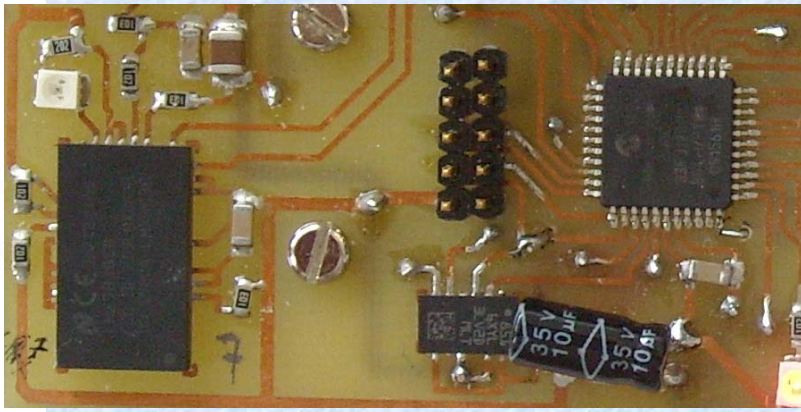


Bluetooth

- Port COM over BT:
  - SPBT2632CA
  - BC-04
  - RN41
  - LMX9838

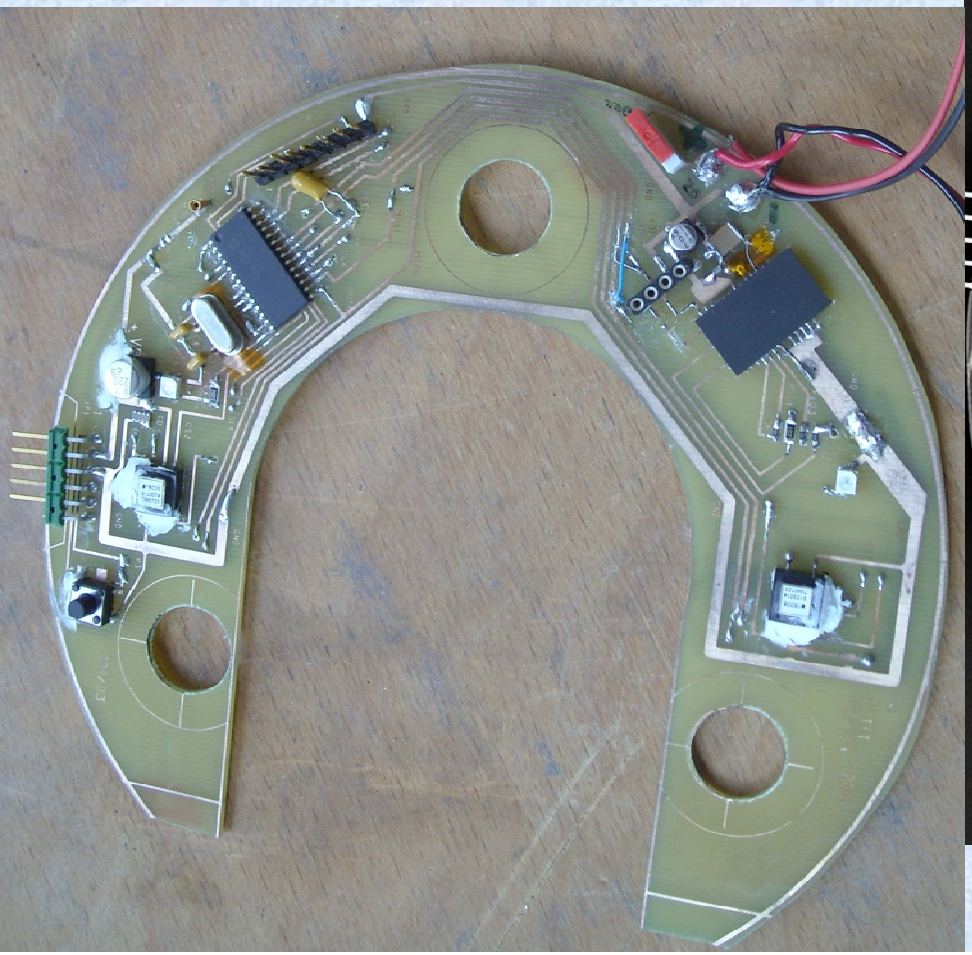


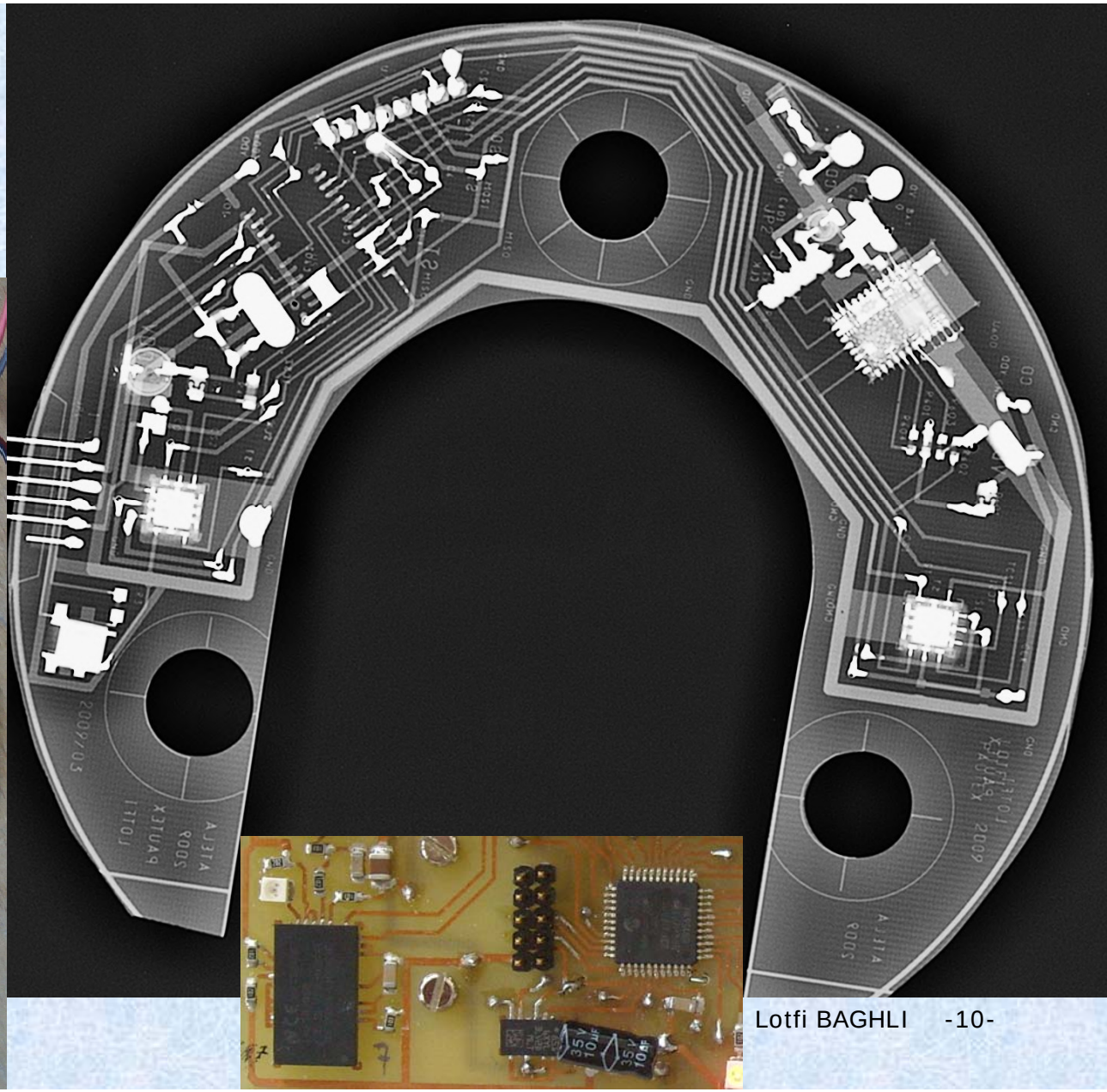




Bluetooth

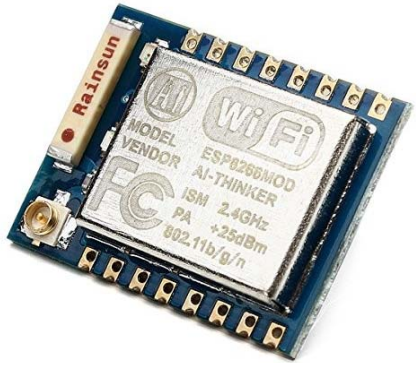
- Port COM over BT:
  - LMX9838

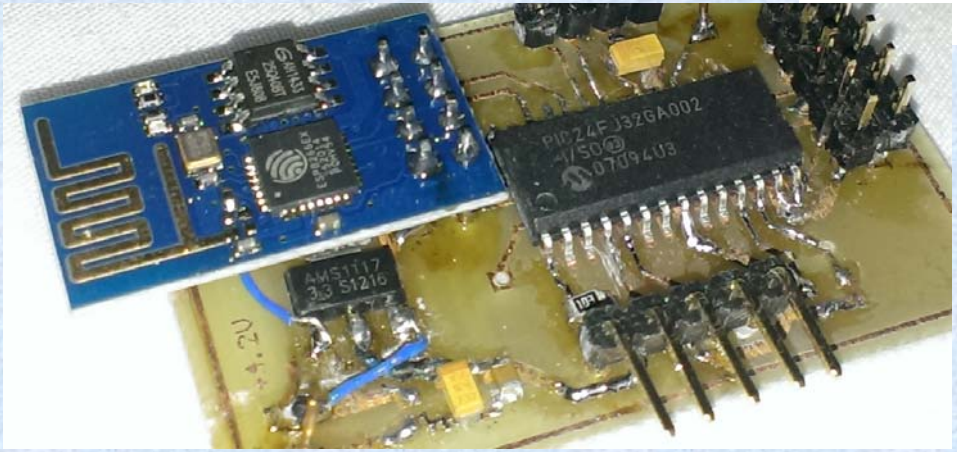




Wifi

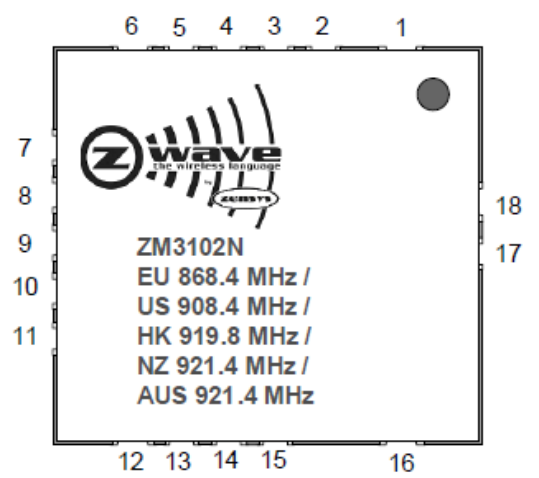
- MRF24WG0MA :
  - Interface SPI
  - Microchip Libraries for Applications (MLA) : Pile TCP-IP logicielle sur host
- ESP 8266 01 / 12 / 14
  - Interface UART
  - Pile TCP-IP embarqué

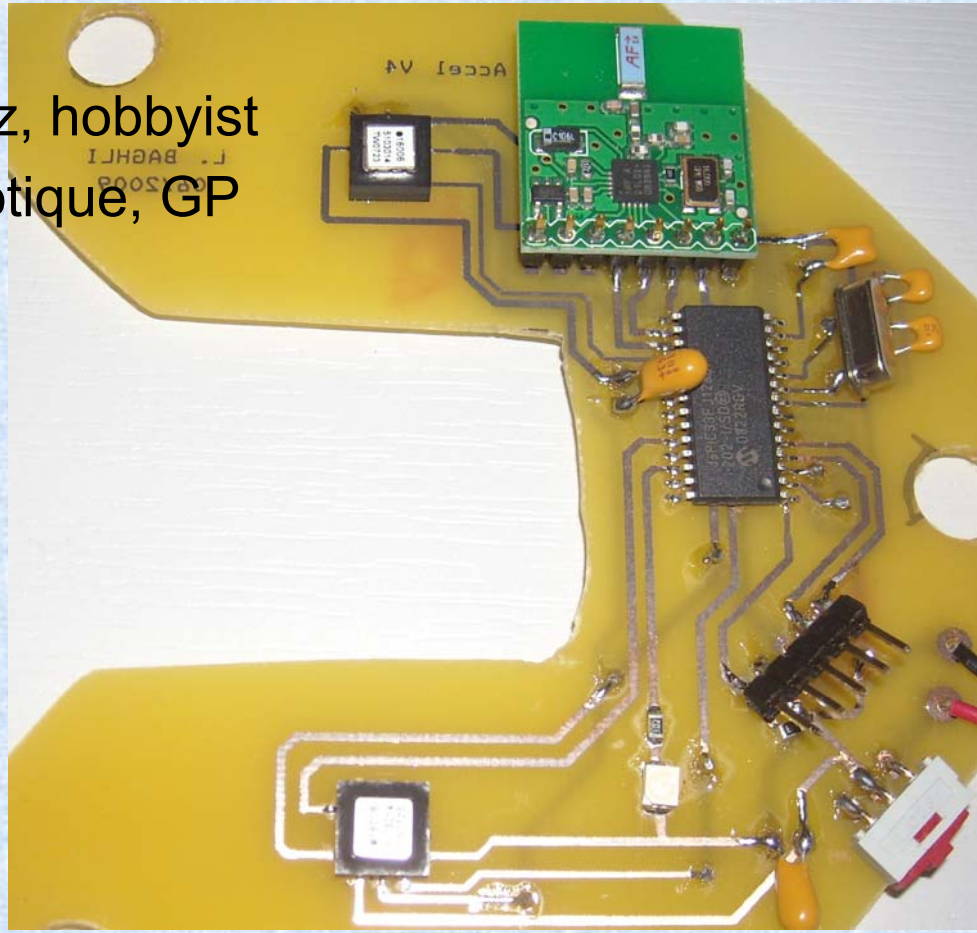




Autres

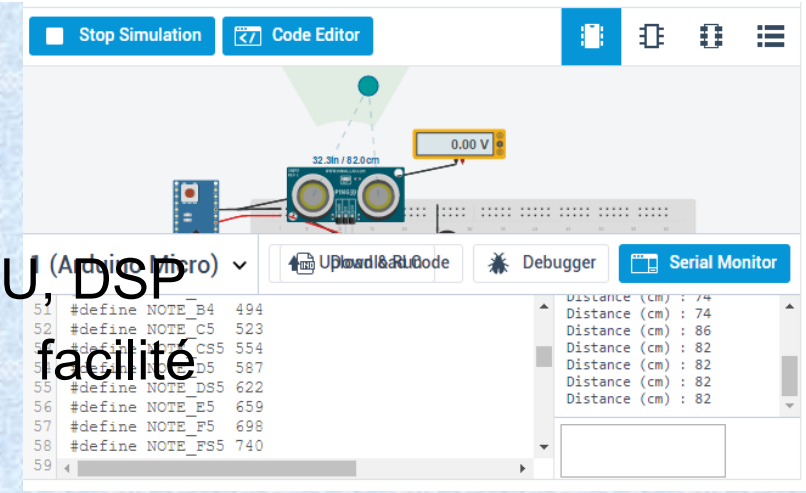
- Nordic n24L01+ : 2.4 GHz, 1 à 2 Mbps en burst, domotique, jouets, R/C
- Zigbee : 868, 915 MHz, 2.4 GHz, hobbyist
- CC1101 : multifréquence, domotique, GP
- Zwave : ZM3102
  - Domotique
  - Plusieurs fréquences / pays

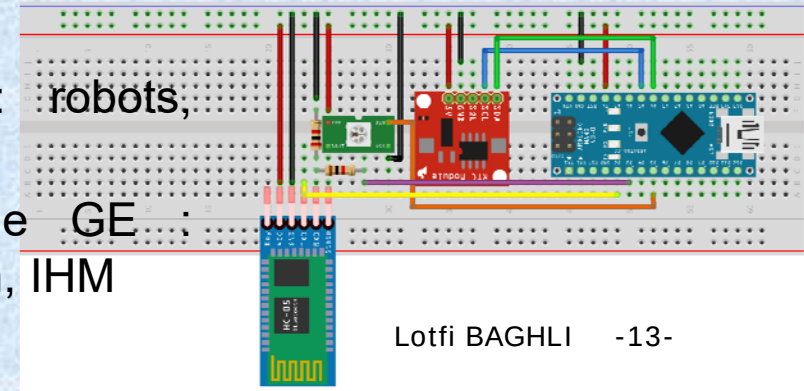




Critères de choix

- Prix du composant ou de la carte d'essai
- Performances : 8/16/32/64 bits, MHz, FPU, DSP
- Outil de développement : gratuité, facilité d'utilisation, débuggage, IHM
- Outils de simulation et de prototypage : circuit.io, Fritzing, Altium, Eagle, Proteus
- Popularité : présence dans les forum, tutoriaux, user's guides, application notes
- Catégorie d'utilisation :
  - Initiation à la µ-électronique (µC)
  - Projet de club d'étudiants / Lycéens : robots, interactions,…
  - Projets de fin d'études et de recherche GE… : Commande de machines, EP, communication, IHM

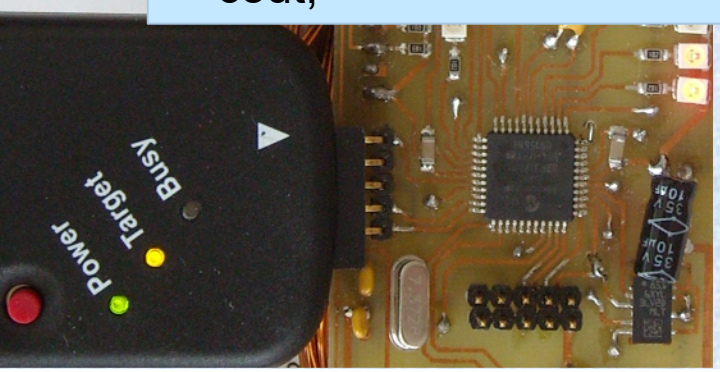


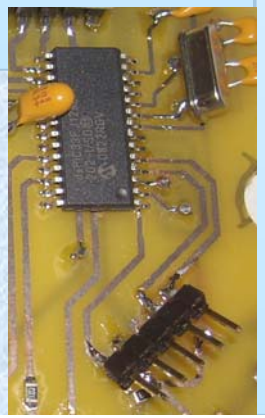


Catégories

Composants

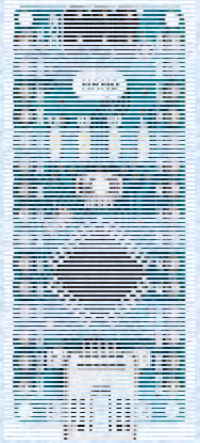
- 8 bits : AVR, PIC 18F, MSP430
- 16 bits : PIC 24F, dspic 30F, 33F, 33E
- 32 bits : PIC 32, Piccolo F28027F / F28069M, Delfino F283xxx, STM32, Cortex M3, M4
- Nécessite un Circuit Imprimé
- Connecteur et programmateur (ICSP, JTAG, ISP AVR : 5 à 500 USD)
- Quartz+2C, BP, LED, Connecteurs, Pads
- Solution optimisée / commerciale : taille, coût,





Cartes de développement

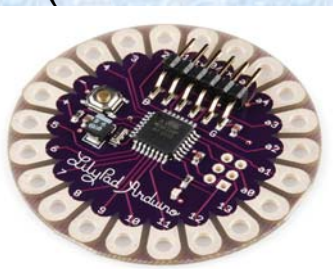
- 8 bits : Arduino Uno, nano, Lily pad, LaunchPad MSP430, Mplab Xpress PIC18855
- 16 bits : Curiosity PIC 24F, dspic 30F, 33F, 33E
- 32 bits : Teensy 3.2, Node MCU, ESP8266, Wemos, MBed, STM32 nucleo, LaunchePad C2000
- 64 bits : Raspberry Pi3, Pi zero
- Prix imbattable : 3 à 45 USD
- Directement opérationnelle, prototypage rapide, Bootloader, USB
- Format DIL (Mbed, STM, Arduino nano, Teensy) nucleo, Launch XL, Arduino uno
- Shields : Afficheurs LCD, OLED, 7-seg., Wifi, BT, DHT, EP, lumière, personnalisé



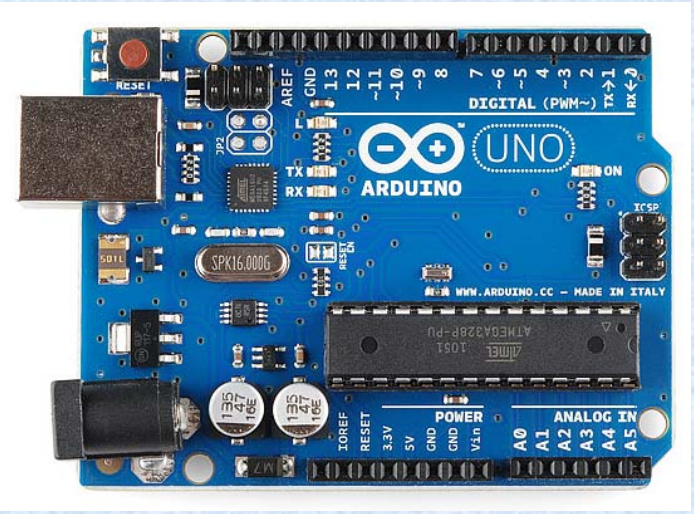
Arduino 8 bits

- UNO : AVR ATmega328P, 5V, 8-bit, 16 MHz, Flash 32 kB (0.5 kB used by bootloader), SRAM 2kB, EEPROM 1 kB
- nano : AVR ATmega328P, 5V
- Lilypad : AVR ATmega328, 2.7-5.5 V
- Shields

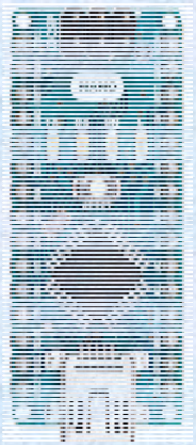
5-20 USD

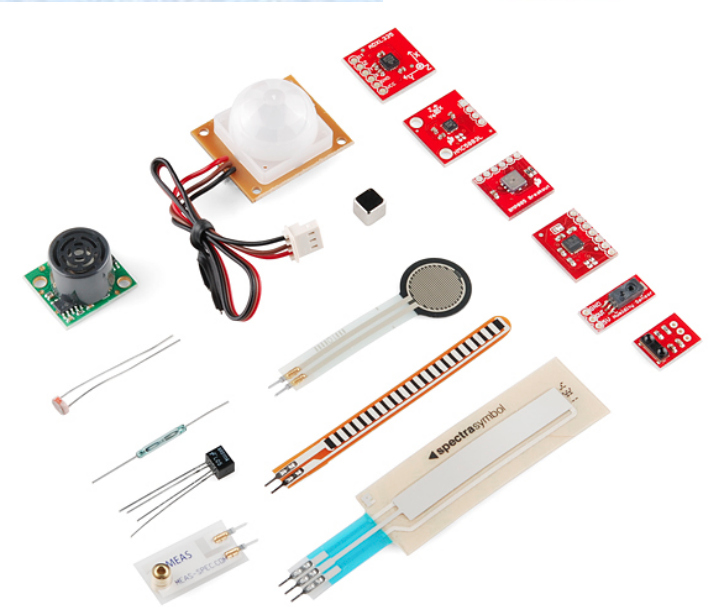


5-20 USD



3 USD

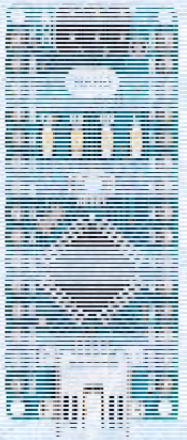




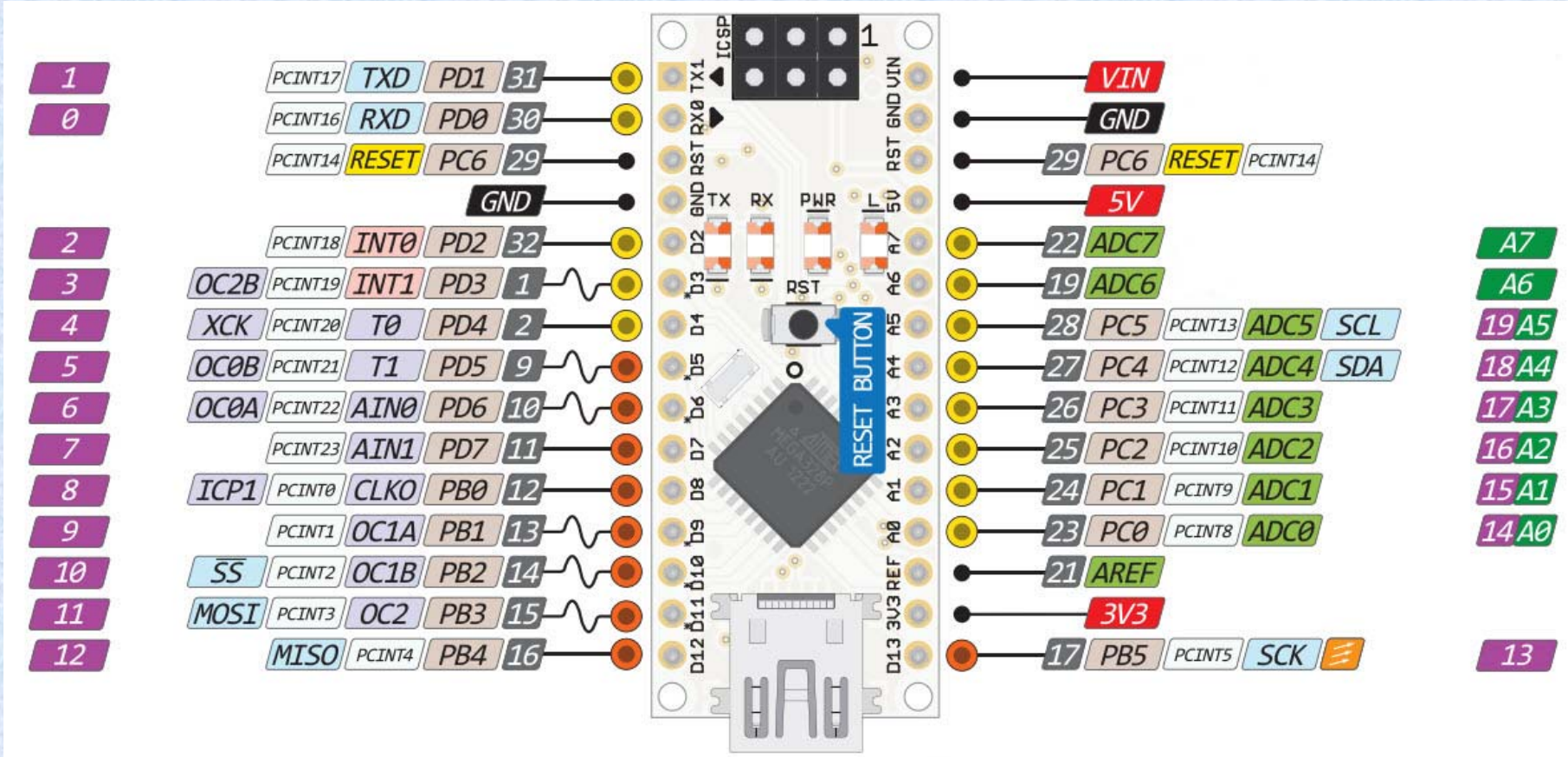
https://learn.sparkfun.com/tutorials/what-is-an-arduino
https://www.arduino.cc/en/Main/ArduinoBoardUno
http://www.arduino.org/products/boards/arduino-nano

Arduino 8 bits

3 USD



- nano : AVR ATmega328P, 5V, 8-bit, 16 MHz, Flash 32 kB (0.5 kB used by bootloader), SRAM 2kB, EEPROM 1 kB



LaunchPad 8 bits

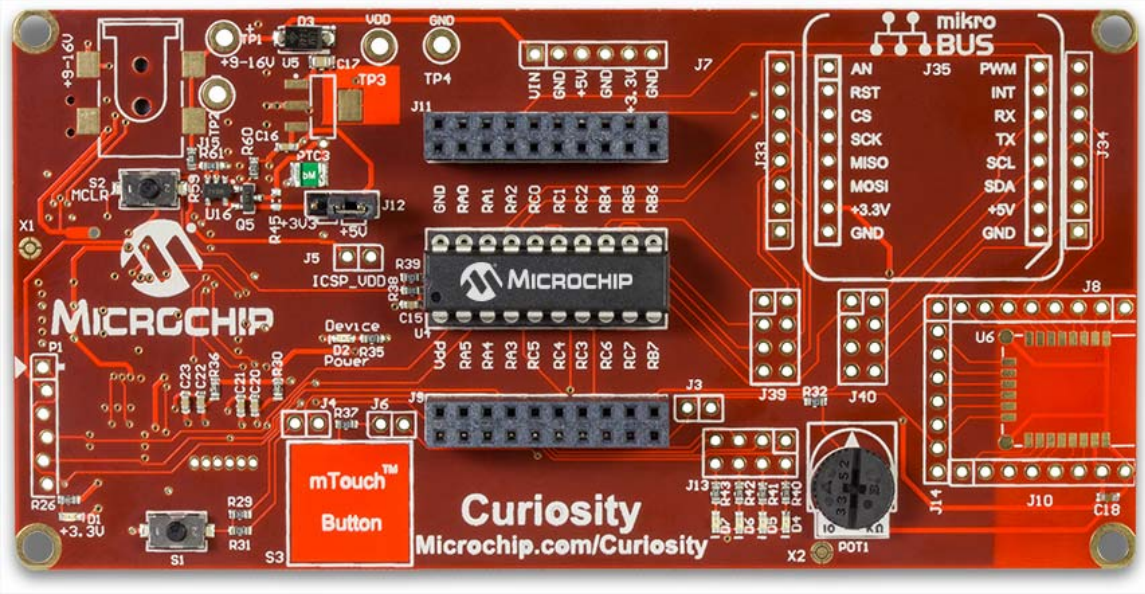
- MSP430 : MSP-EXP430G2 : 16kB Flash, 512B RAM, interruptible GPIOs (capacitive sense-capable), 16-bit timers, 8ch 10-bit ADC, Comparator, Serial Communication (USCI – I2C, SPI & UART) & more
- Cours MOOC

http://www.ti.com/tool/MSP-EXP430G2
https://dev.ti.com/bpchecker/ verify BoosterPack compatibility
http://pyrochat.github.io/mooc-led/cours/106/microcontroleur.html

Microchip 8 bits

- MPLAB Xpress : PIC16F18855, 14kB Flash
- MPLAB IDE ou Xpress (cloud based IDE)
- MPLAB Code Configurator
- Curiosity : 8-, 14-, 20-pin 8-bit PIC, Integrated Programmer/Debugger with USB Interface

20.00 USD

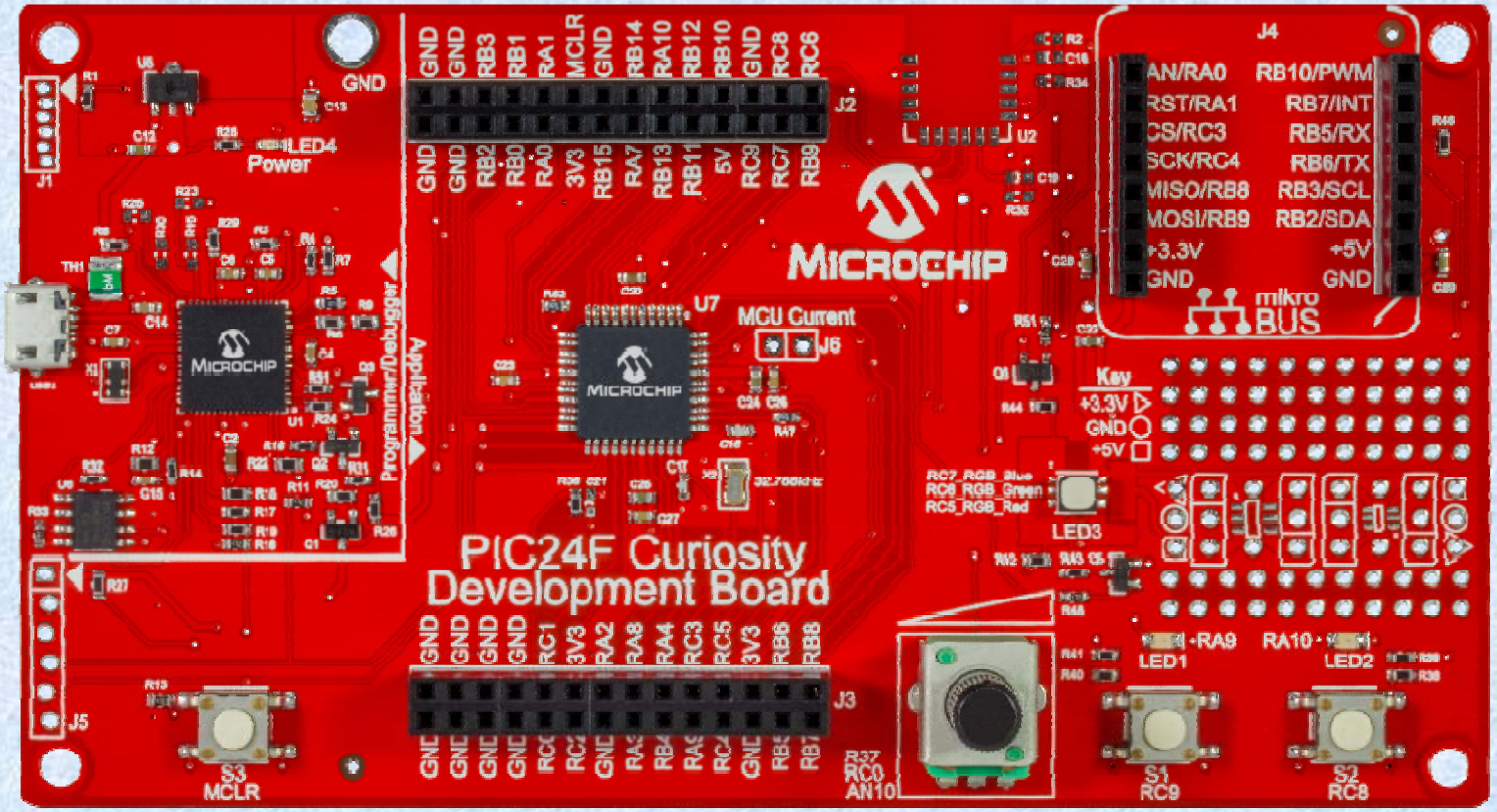


17.00 USD

http://www.microchip.com/mplab/mplab-xpress
http://www.microchip.com/DevelopmentTools/ProductDetails.aspx?PartNO=DM164137

Microchip 16 bits

- Curiosity : DM240004, PIC24FJ128GA204, BM71
  Bluetooth LE module footprint 25.00 USD



http://www.microchip.com/Developmenttools/ProductDetails.aspx?PartNO=DM240004

Arduino 32 bits

- MKRZero : SAMD21 Cortex-M0+, 3.3V, 32-bit ARM, 48MHz, 5V in, Flash 256 kB (8 kB used by bootloader), SRAM 32kB, no EEPROM

20.90 €

https://www.arduino.cc/en/Main/ArduinoBoardMKRZero

Teensy 32 bits

- Teensy 3.2 : 32 bit ARM **Cortex-M4 72 MHz**, 256K Flash, 64K RAM, 2K EEPROM, 21 Hi-Res ADC, 34 I/O,12 PWM, 7 Timers, USB, 3 UARTs, SPI, I2C, I2S,CAN Bus, IR modulator, I2S, RTC, 16 DMA, Touch Sensor Inputs 20 USD
- Teensy 3.6 : 32 bit ARM **Cortex-M4 180 MHz FPU**, 1M Flash, 256K RAM, 4K EEPROM, uC MK66FX1M0VMD18, 25 Hi-Res ADC, 2 DAC, 62 I/O, 22 PWM, 14 Timers, Hi speed USB, 6 UARTs, 3 SPI, 4 I2C, I2S, 2 CAN Bus, Ethernet mac, microSD, IR modulator, I2S, RTC, 32 DMA, 11 Touch Sensor Inputs, CRC 34 USD

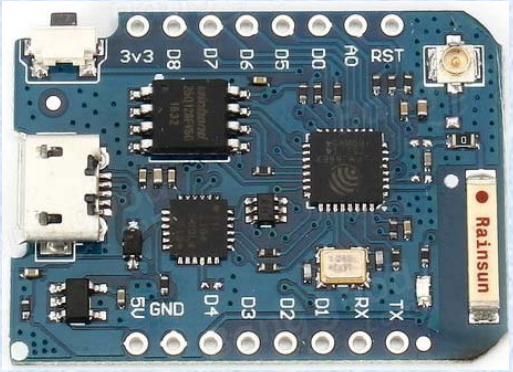
Teensy 3.2

Teensy 3.6

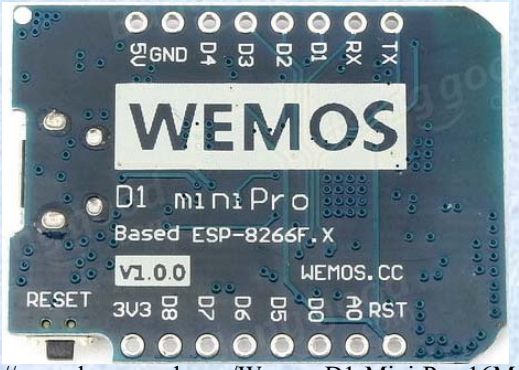
https://www.sparkfun.com/products/13736
https://www.sparkfun.com/products/14058
https://www.pjrc.com/teensy/index.html

Wemos

- Wemos D1 mini Pro : ESP8266Ex, **Wifi**, antenne pcb + FLU, 11 I/O, 1 Analog (3.3V), Interrupt/pwm/I2C/one-wire,16 MB Flash
- Shields: Relai, baromètre, DHT, RGB LED, microSD, DS18820



7.77 USD

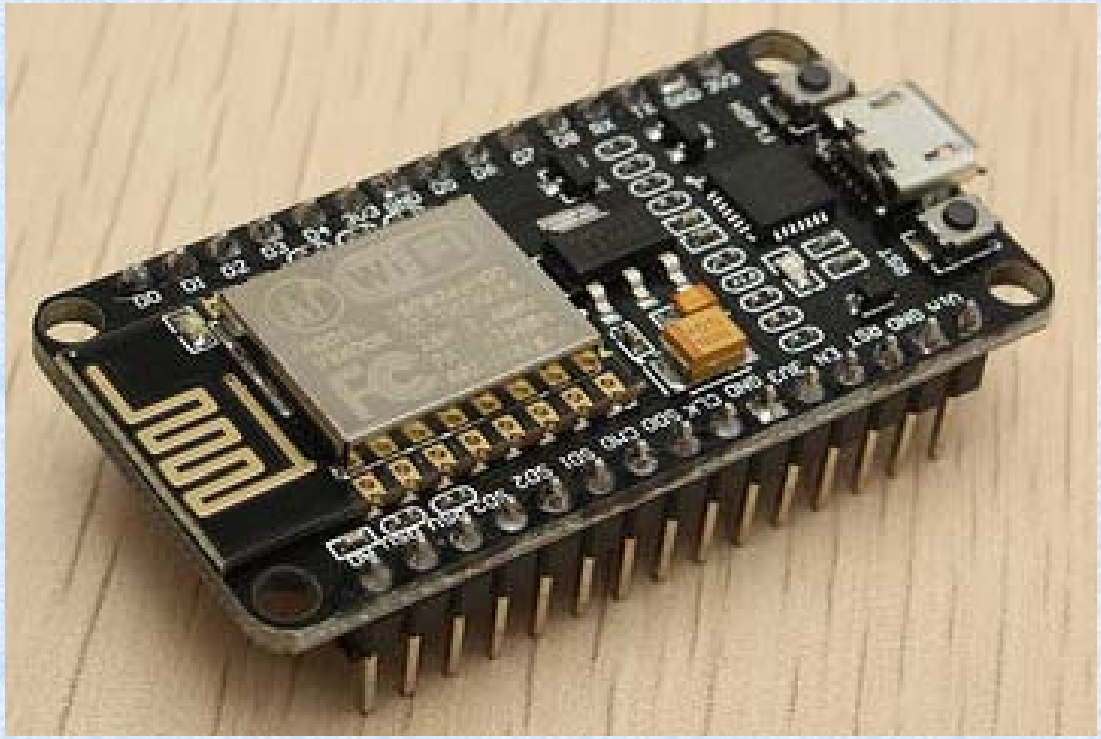


17.78 USD

http://www.banggood.com/Wemos-D1-Mini-Pro-16M-Bytes-External-Antenna-Connector-p-1107484.html

NodeMCU

NodeMcu Lua WIFI Internet Things Development Board Based ESP8266 CP2102 Wireless Module



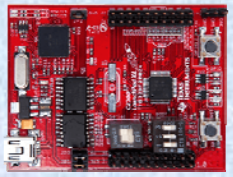
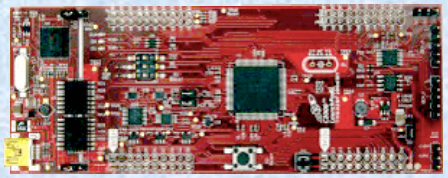
5.26 USD

http://www.banggood.com/NodeMcu-Lua-WIFI-Internet-Things-Development-Board-Based-ESP8266-CP2102-Wireless-Module-p-1097112.html

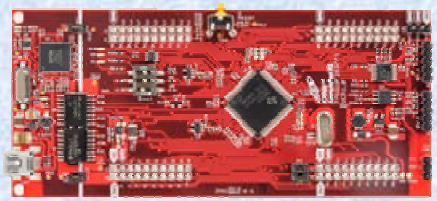
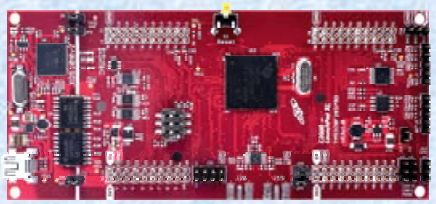
http://www.fais-le-toi-meme.fr/fr/electronique/tutoriel/programmes-arduino-executes-sur-esp8266-arduino-ide

LaunchPad C2000

http://www.ti.com/lsds/ti/tools-software/launchpads/launchpads.page#performance

Piccolo

Delfino

LAUNCHXL-F28027F
Real time MCU with InstaSPIN-FOC motor control software.

- Featuring the 32-bit C2000 TMS320F28027F MCU @ **60MHz**, 64kB Flash / 12kB RAM. InstaSPIN-FOC enabled.
- Includes 8 PWM channels (4 high resolution), 12-bit 4.6 MSPS ADC, 3x 32-bit timers, temperature sensor, comparator.
- Motor control software in ROM implements InstaSPIN-FOC solutions for 3 phase motors.

17.00 USD

LAUNCHXL-F28069M
High performance controller with InstaSPIN motor control software.

- Featuring the 32-bit C2000 TMS320F28069M MCU @ **90MHz**, **FPU,** 256kB Flash / 96kB RAM. InstaSPIN-MOTION and InstaSPIN-FOC enabled.
- Includes 16 PWM channels (8 high resolution), 16 channel 12-bit 4.6 MSPS ADC, 3x 32-bit timers, 6 channel DMA, temperature sensor.
- Motor control software in ROM implements InstaSPIN-FOC and InstaSPIN-MOTION solutions for 3 phase motors.

24.99 USD

LAUNCHXL-F28377S
High performance device for real-time control and signal processing applications.

- Featuring the 32-bit **Delfino** MCU TMS320F28377S: @ **200 MHz**, **FPU,** 1MB Flash / 164kB RAM with ECC.
- Includes 24 PWM channels (16 high resolution), 4x 16/12-bit ADC, 3x 12-bit DAC, 3x eQEP modules, 169 GPIO pins.
- Includes CLA real-time control coprocessor to respond to peripheral triggers and service time-critical functions.

29.99 USD

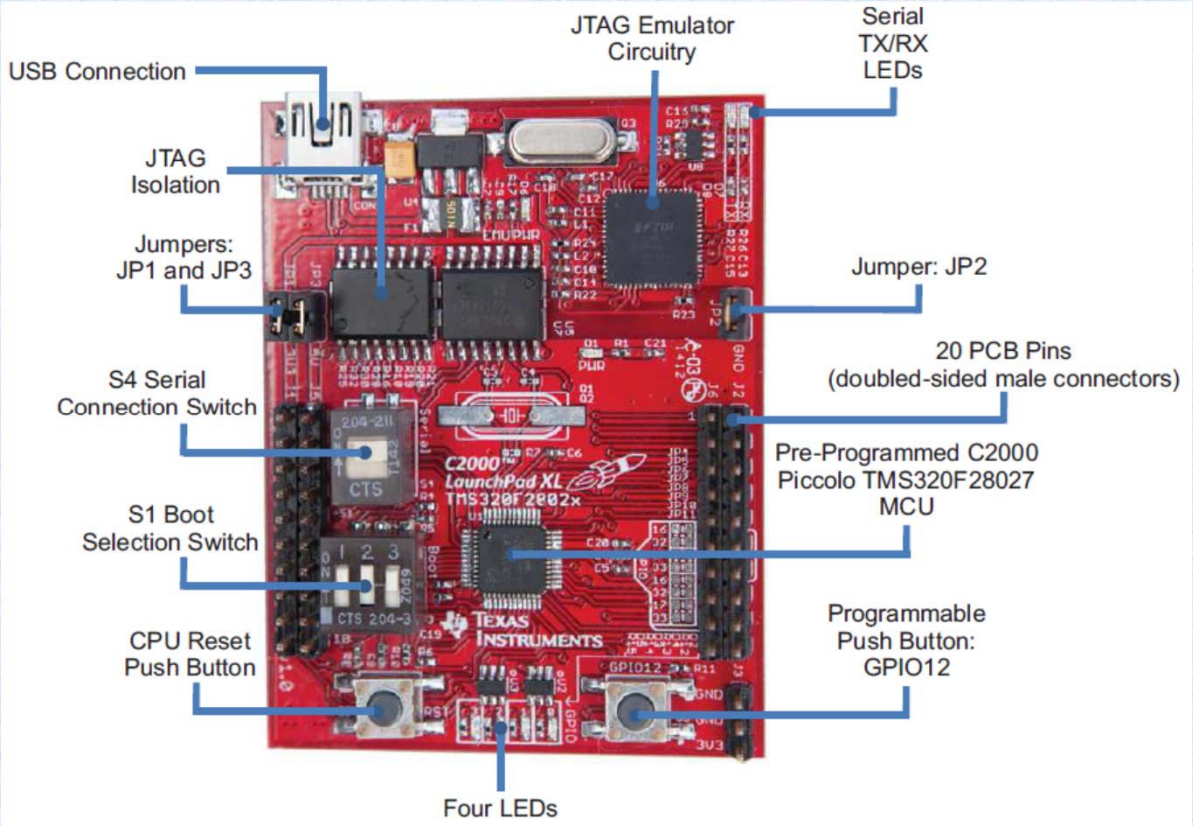
LAUNCHXL-F28379D
Dual Core MCU with highest level of peripheral integration in C2000 product family.

- Featuring the TMS320F28379D: **dual** 32-bit **Delfino** MCUs **@200MHz**, **FPU,** 1MB Flash/164KB RAM. Position Manager Enabled.
- 4 16/12-bit ADCs with on PCB instrumentational amplifiers. 3x 12-bit output DACs and 8 windowed comparators for asychronous output triggering.
- 24 PWMs (16 high resolution), 6 eCAP modules mapped to any GPIO,and 3 eQEP modules. 8 Sigma Delta Demodulator Inputs.

33.79 USD

LaunchPad C2000

- LaunchXL-F28027F QuickStartGuide sprz413.pdf
- LaunchXL-F28027F HW Exp guide spruhh2a.pdf
- http://www.ti.com/lsds/ti/tools-software/launchpads/launchpads.page#performance

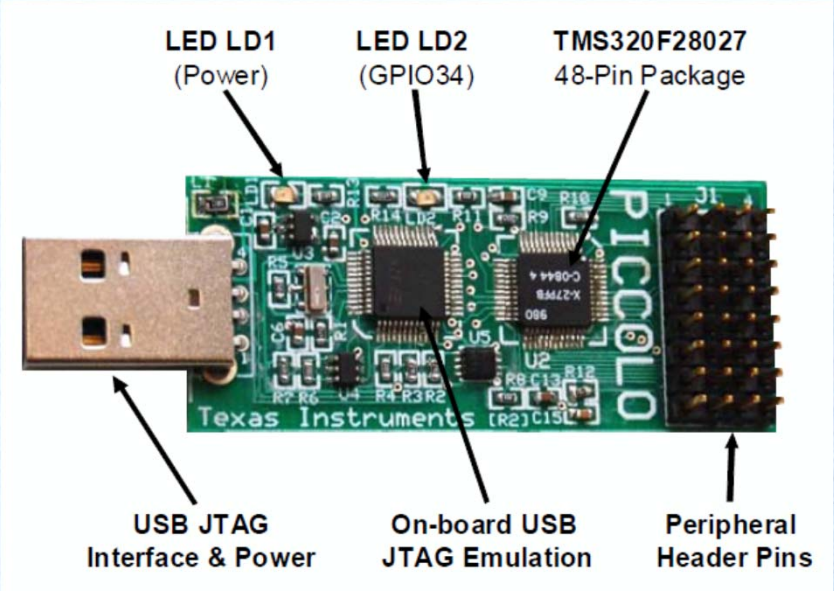


Real time MCU with InstaSPIN-FOC motor control software.

- Featuring the 32-bit C2000 TMS320F28027F MCU : @ 60MHz, 64kB Flash / 12kB RAM. InstaSPIN-FOC enabled. **No FPU**
- Includes 8 PWM channels (4 high resolution), 12-bit 4.6 MSPS ADC, 3x 32-bit timers, temperature sensor, comparator.
- Motor control software in ROM implements InstaSPIN-FOC solutions for 3 phase motors.

LaunchPad C2000

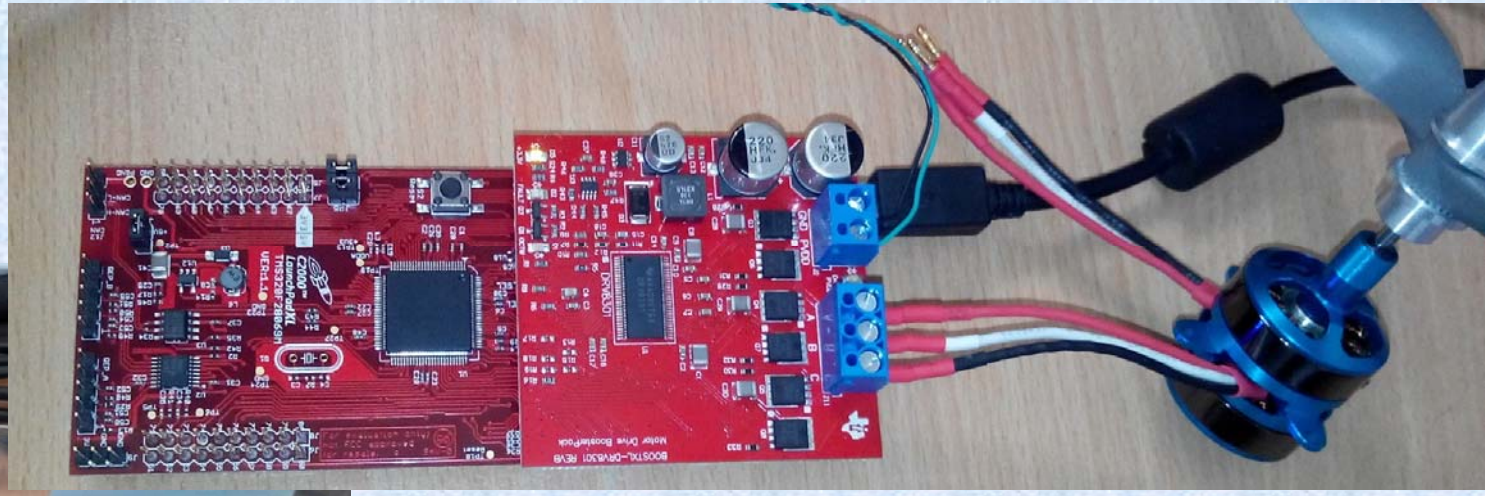
- Piccolo™ ControlSTICK sprt517b.pdf
- Explications

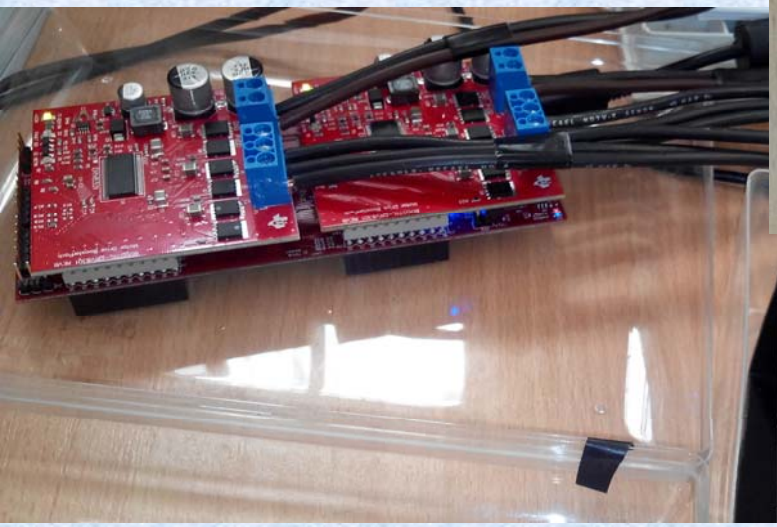


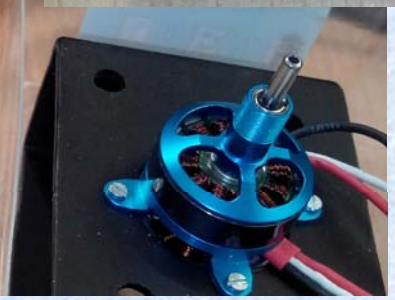
39.00 USD

LaunchPad C2000

- LaunchXL-F28069M QuickStartGuide sprui02.pdf
- LaunchXL-F28069M User s guide sprui11.pdf
- BoosterPack plug-in modules
  - BOOSTXL-DRV8301 : Onduleur triphasé 10A, 6-24V

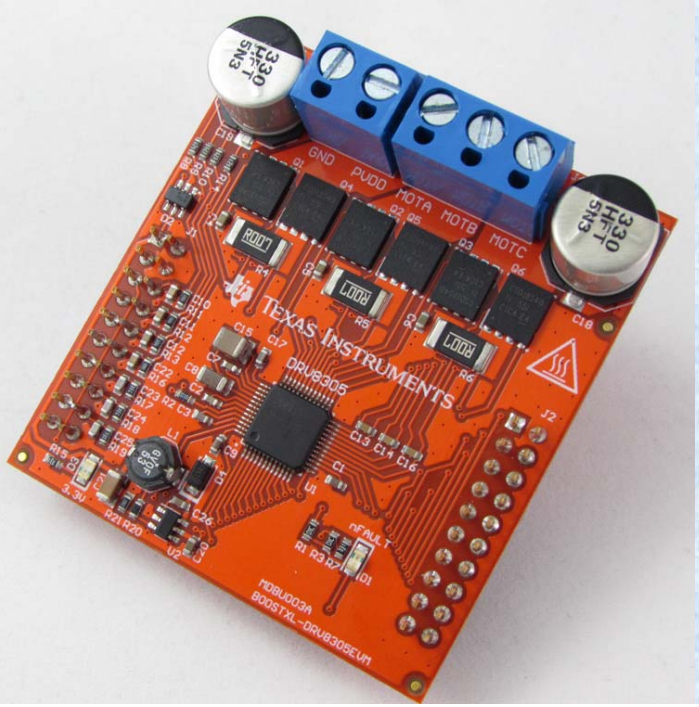






LaunchPad C2000

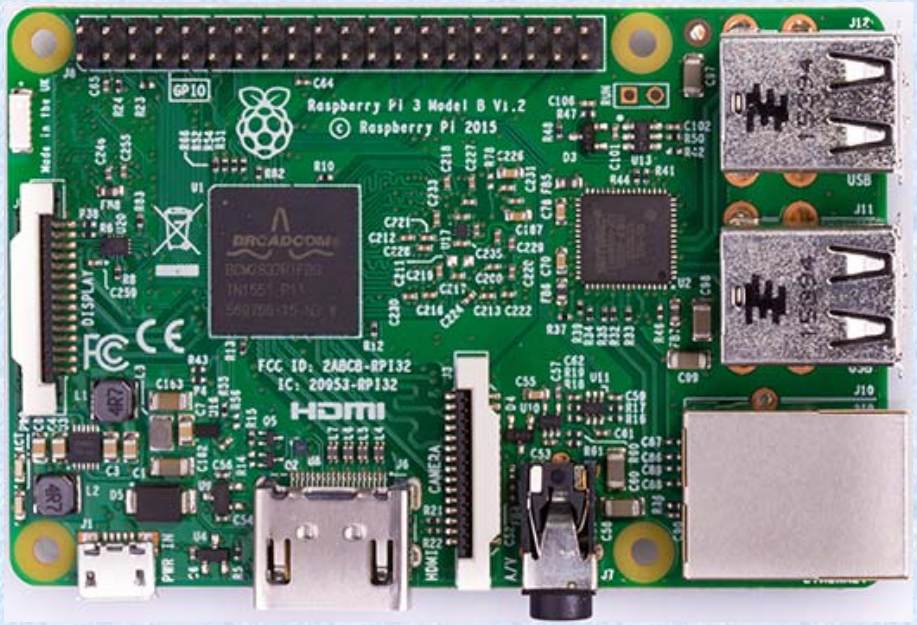
- BoosterPack plug-in modules (XL : 2 rangés x 2)
  - BOOSTXL-DRV8301 : Onduleur triphasé 10A RMS, 6 - 24V
  - BOOSTXL-8305EVM : Onduleur triphasé 15A RMS, 4.4 - 45V
  - BOOST-DRV8711 : Bipolar stepper motor drive 4.5A, 8-52V
  - Nokia 5110 LCD BoosterPack/Breakout PCB



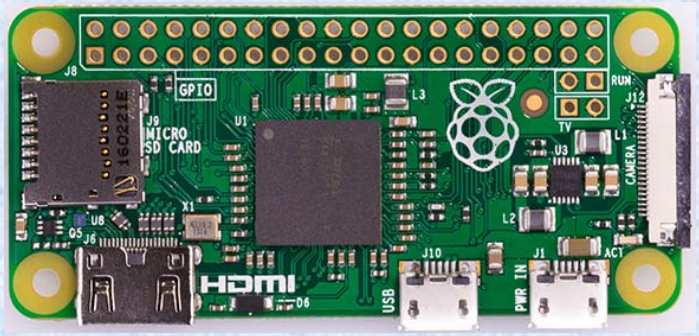
49.00 USD

Rasbperry Pi

- Pi 3 : 1.2GHz 64-bit quad-core ARMv8 CPU; Wifi 802.11n, Bluetooth 4.1 BLE, 1GB RAM, 4 USB ports, 40 GPIO pins, HDMI, Ethernet, 3.5mm audio / c-video, Camera interface (CSI), Display interface (DSI), Micro SD card slot
- Pi zero : 1Ghz, Single-core CPU, 512MB RAM, mini HDMI and USB OTG, Micro USB power, HAT-compatible 40-pin header



48 €



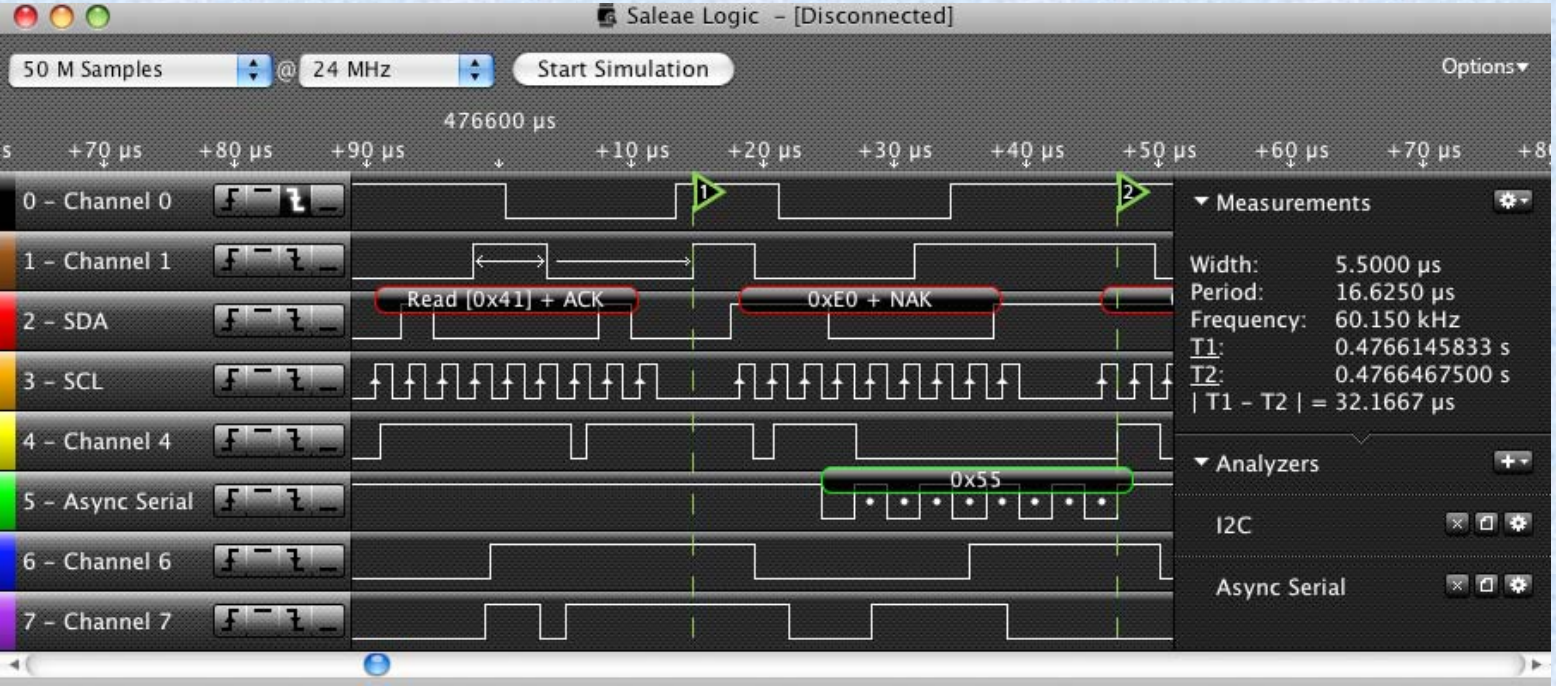
5 USD

https://www.raspberrypi.org/magpi-issues/ https://www.raspberrypi.org/products/pi-zero/

Outils de développement

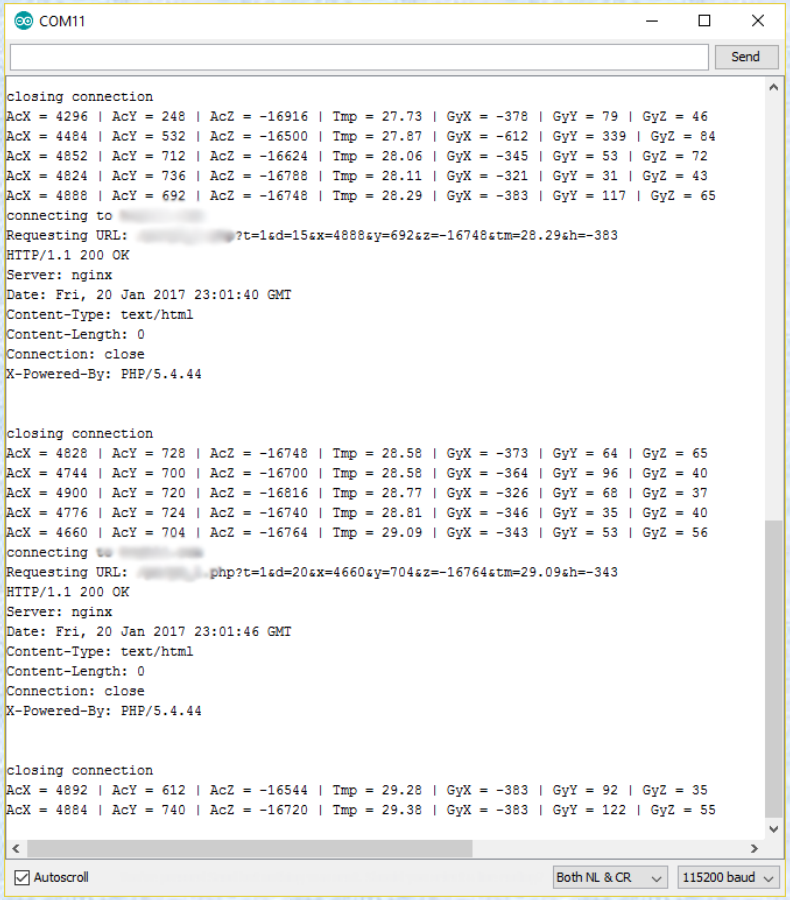
- Arduino IDE 1.81
- MPLAB X 3.50 + Moniteur : Putty
- Code Composer Studio (CCS) 7
- GCC (Raspberry Pi)
- Analyseur logique (SPI, UART, I2C, CAN)

https://www.arduino.cc/en/Main/Software
http://www.microchip.com/mplab/mplab-x-ide
http://www.ti.com/tool/CCSTUDIO



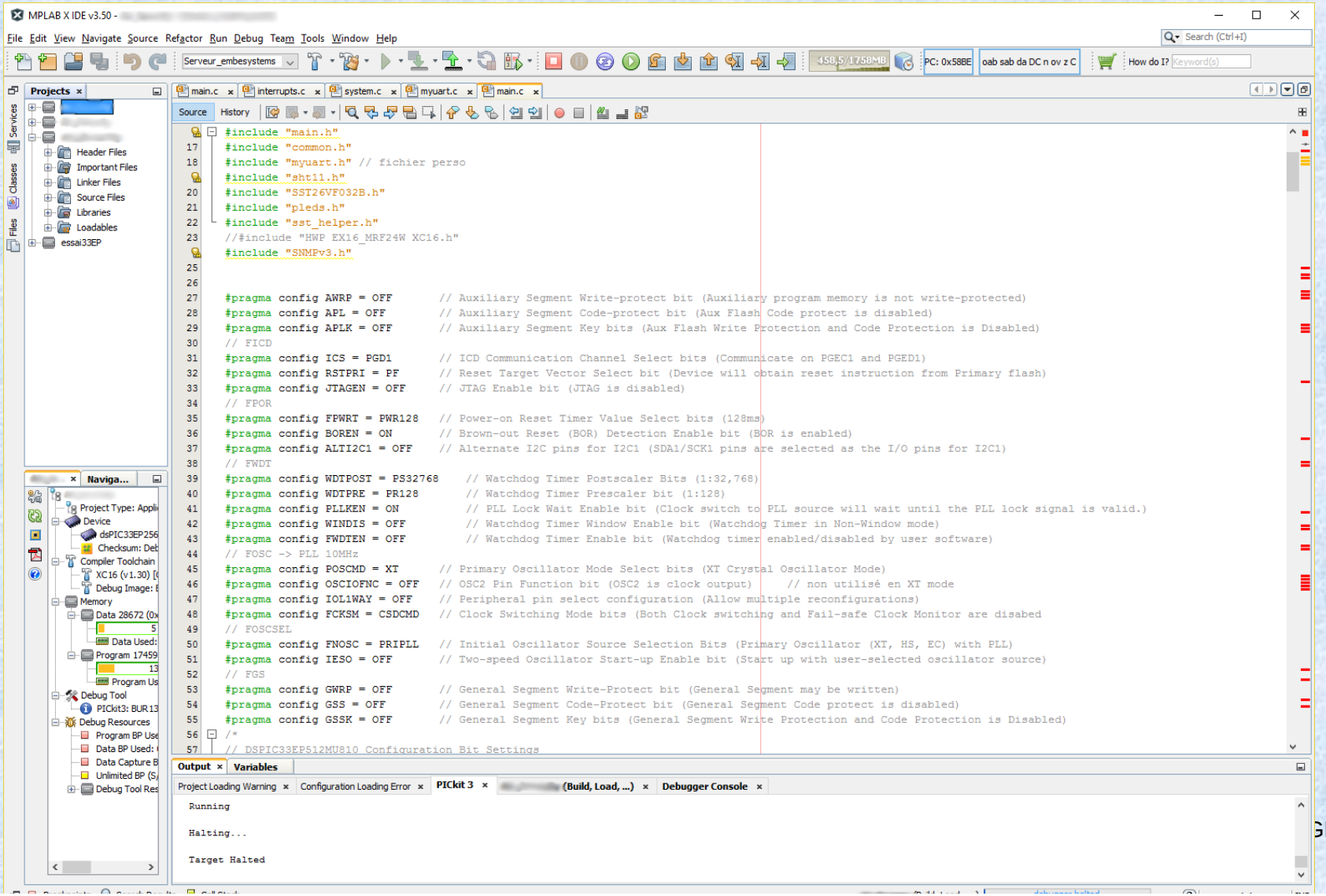
Outils

- Arduino IDE
- Monitor

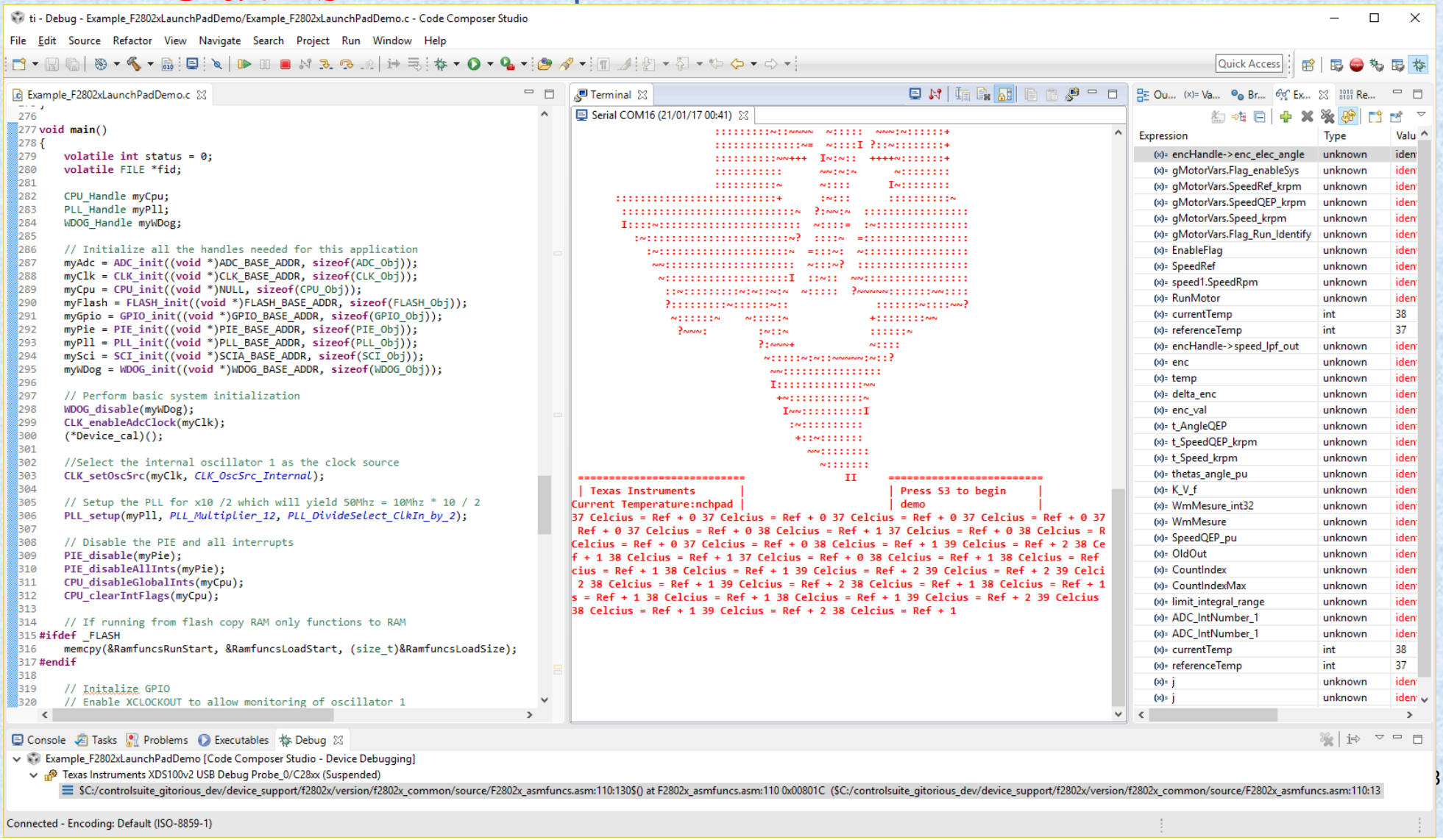


https://www.arduino.cc/en/Main/Software

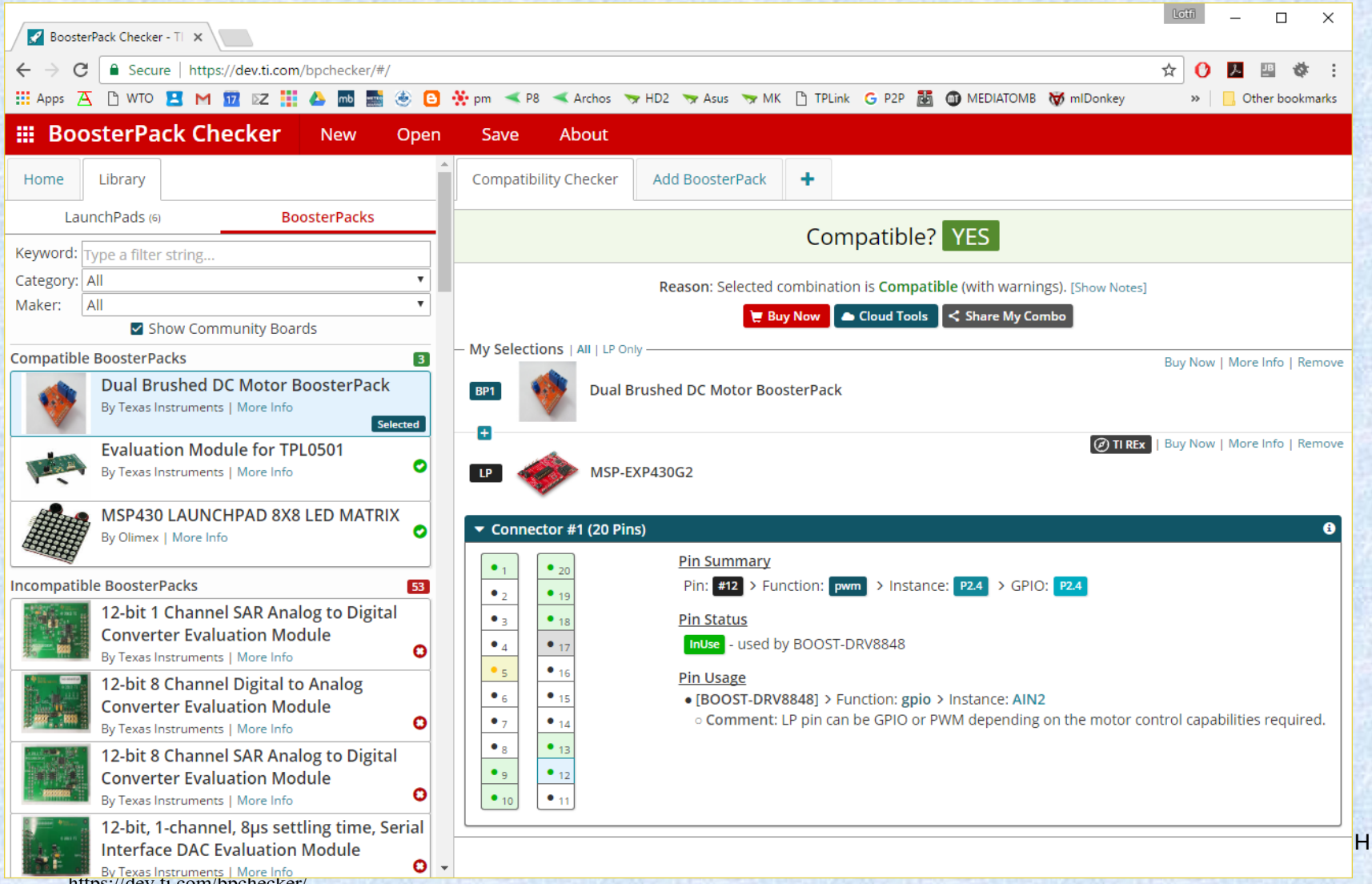
Outils MPLAB X



Outils Code Composer Studio

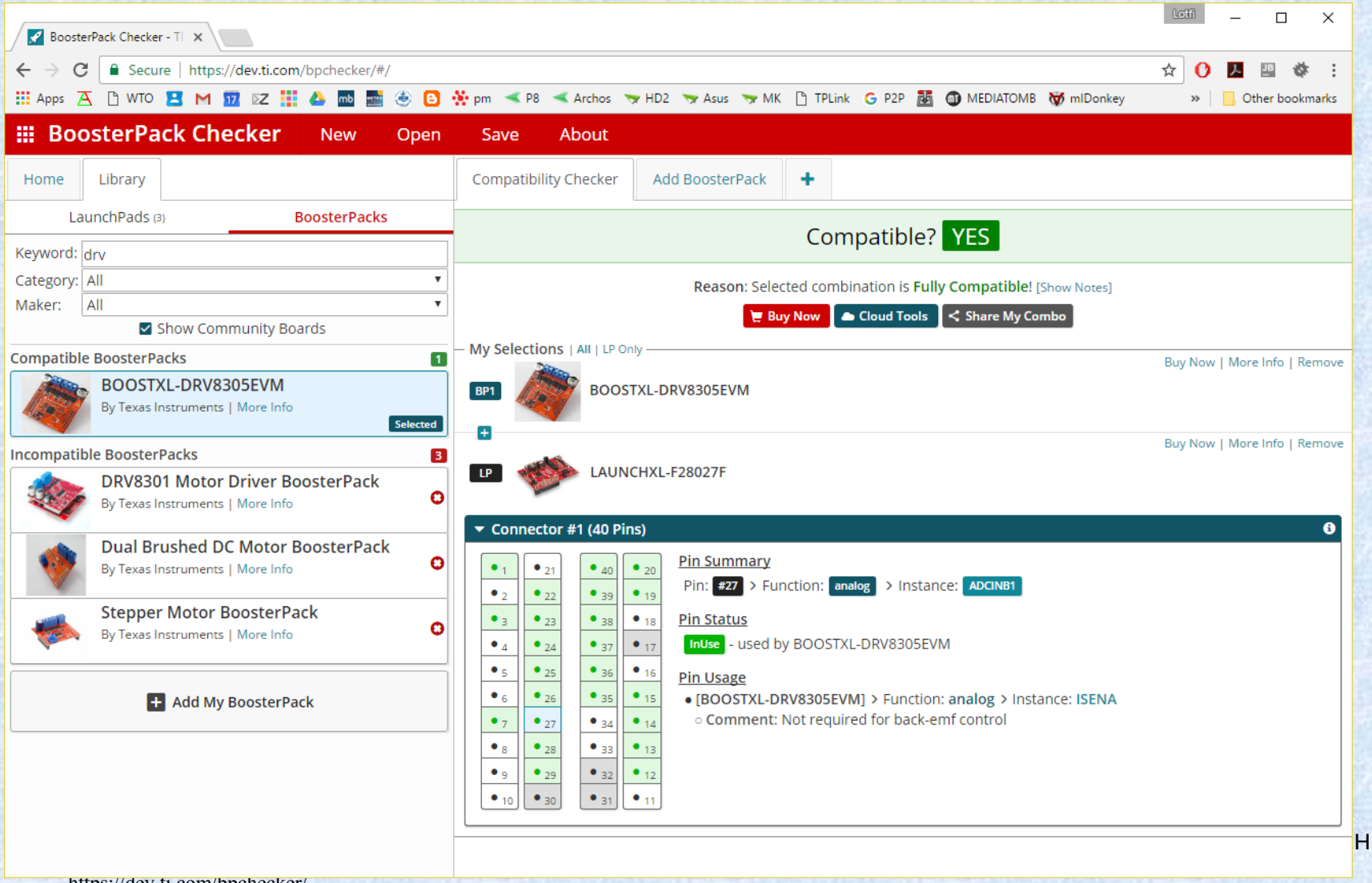


Outils BoosterPack Checker



https://dev.ti.com/bpchecker/

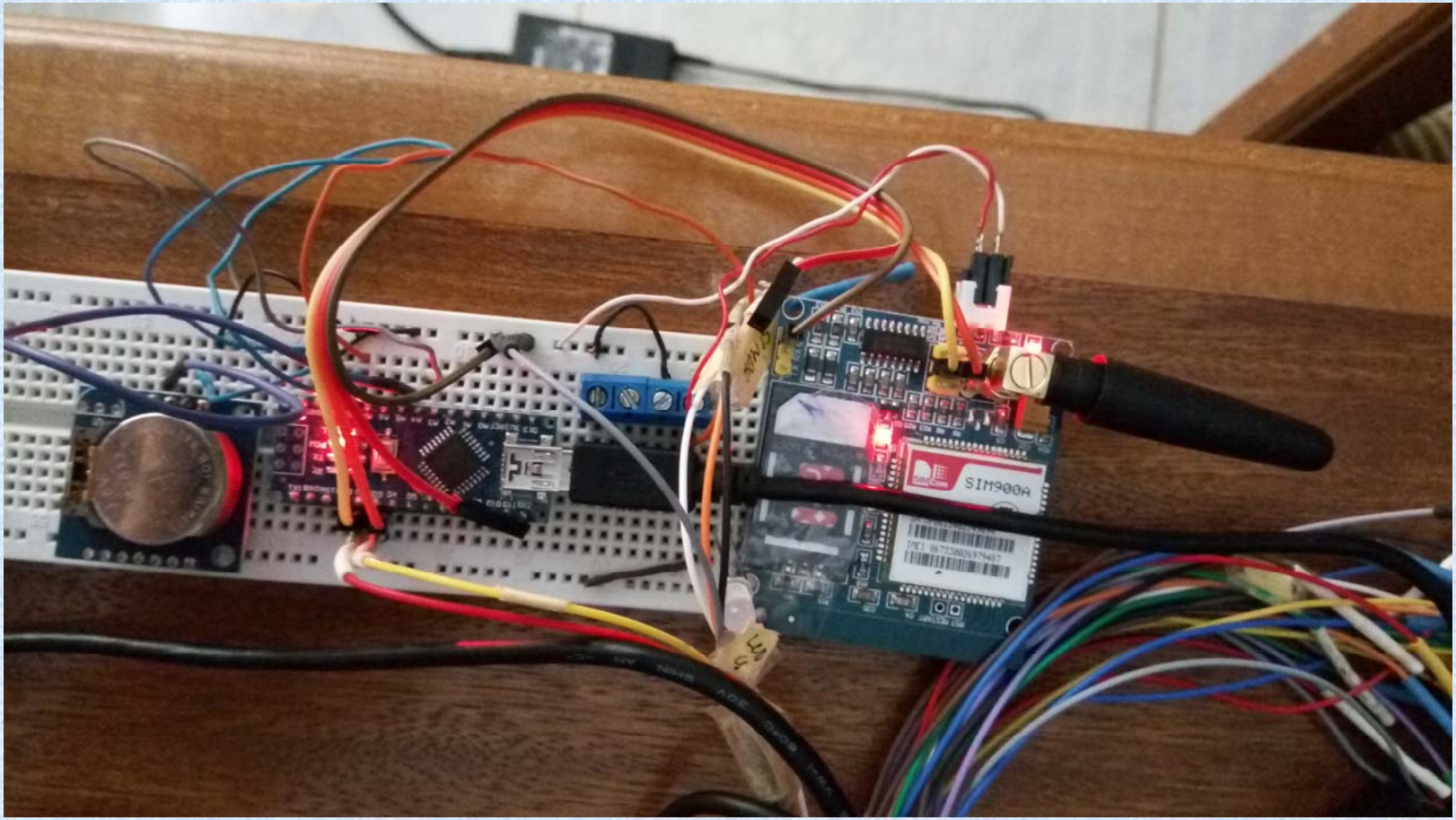
Outils BoosterPack Checker F28027F



https://dev.ti.com/bpchecker/

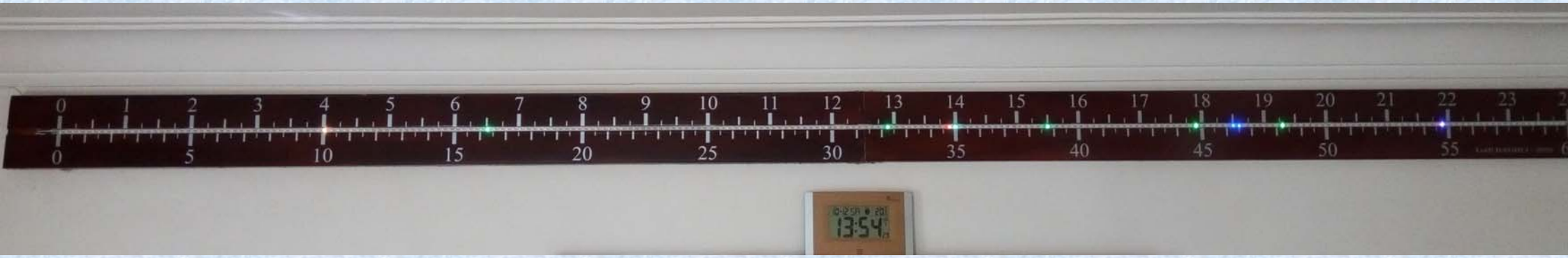
Réalisations

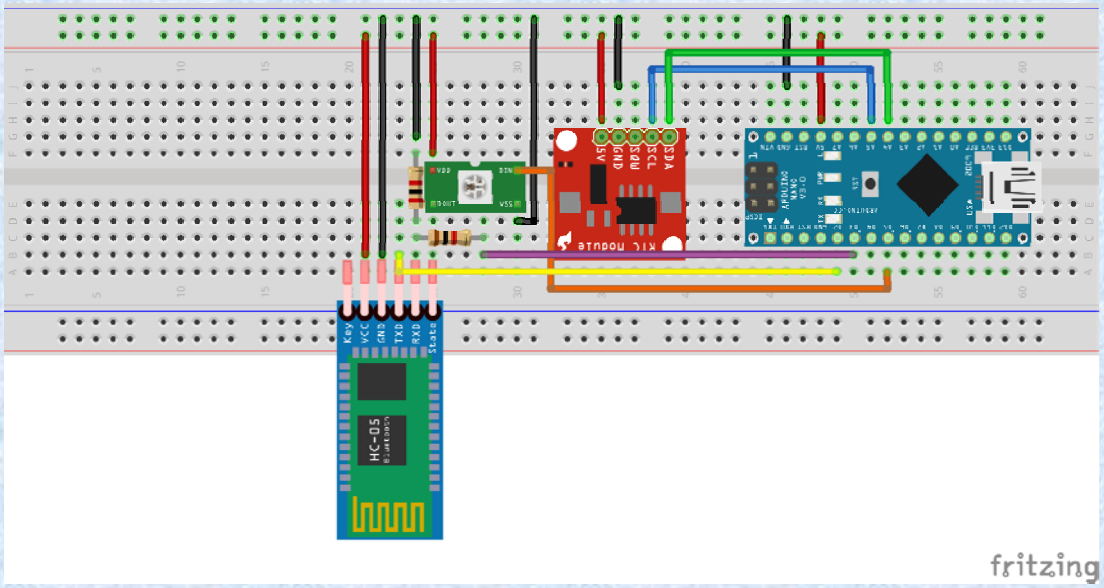
Arduino nano V3, RTC + Li rechargeble, SIM900A



Réalisations

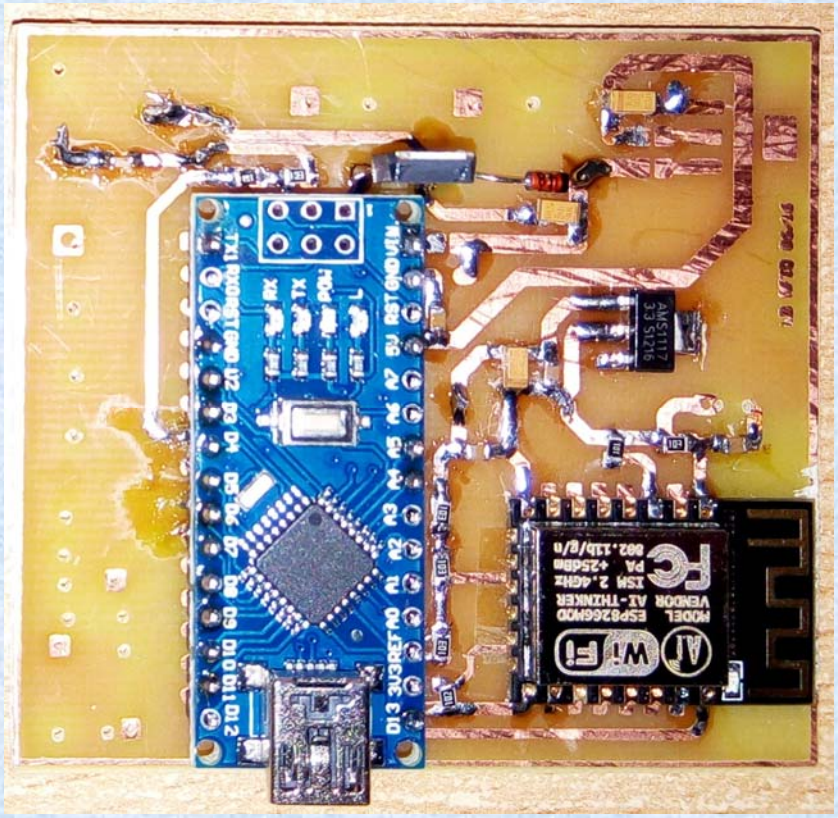
Arduino nano V3, RTC + Li rechargeble, BT HC05, LED RGB WS2812





Réalisations

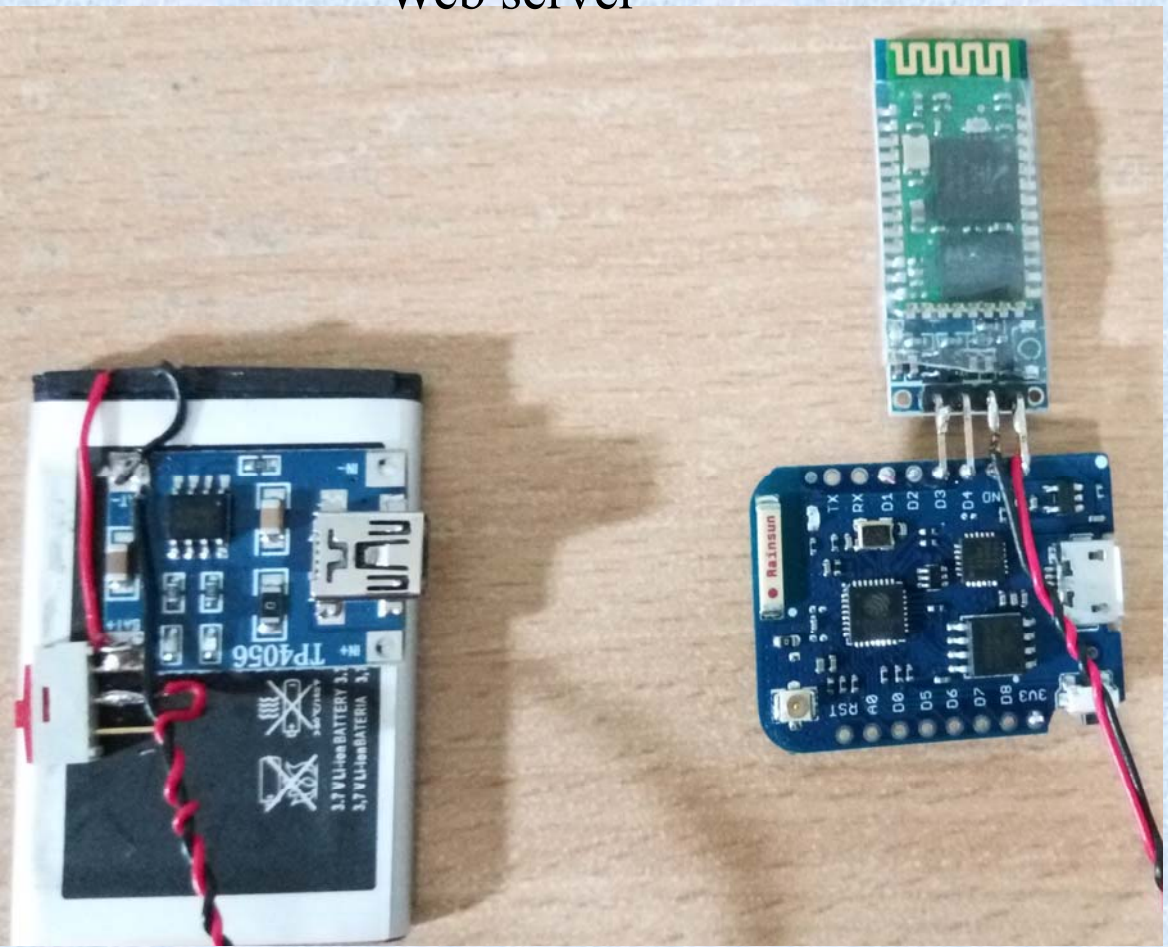
Arduino nano V3, Wifi ESP8266 pcb antenna, MOSFET, DRL, LDO 3.3V, RFID

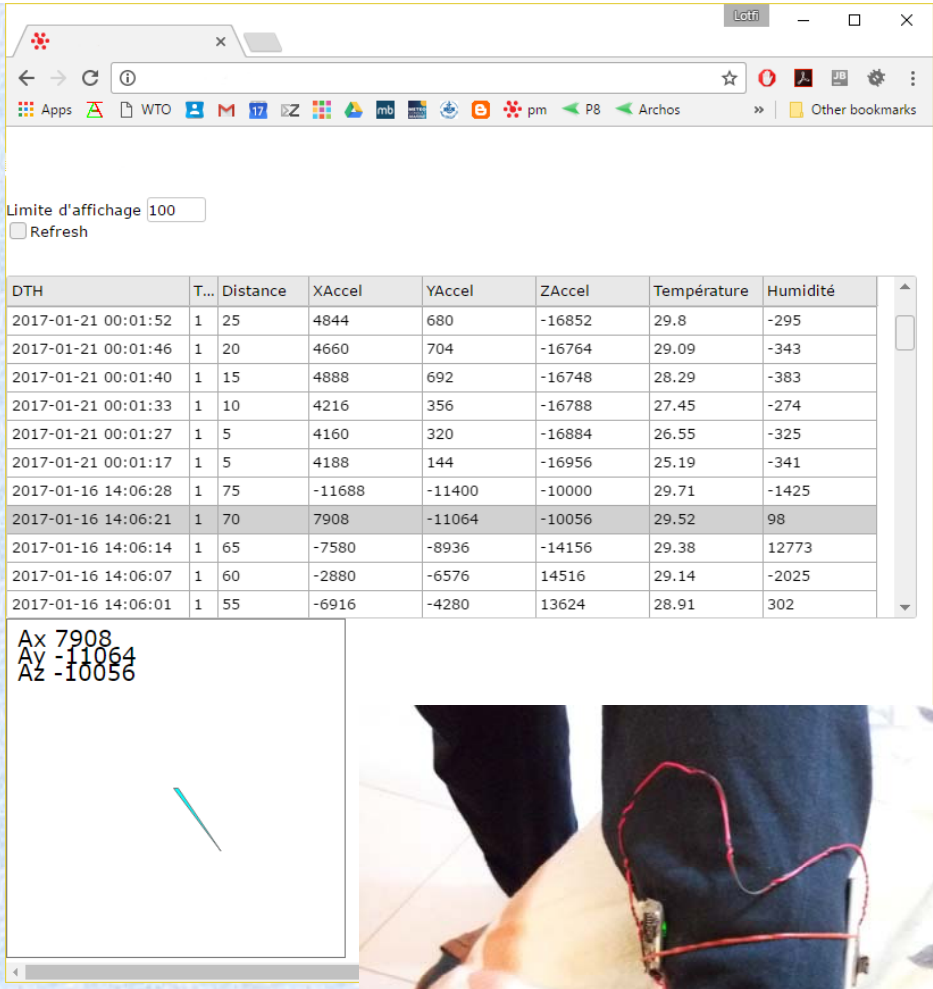


Réalisations

Wemos D1 mini pro (Wifi ESP8266 pcb antenna), BT, Li-Ion+chargeur

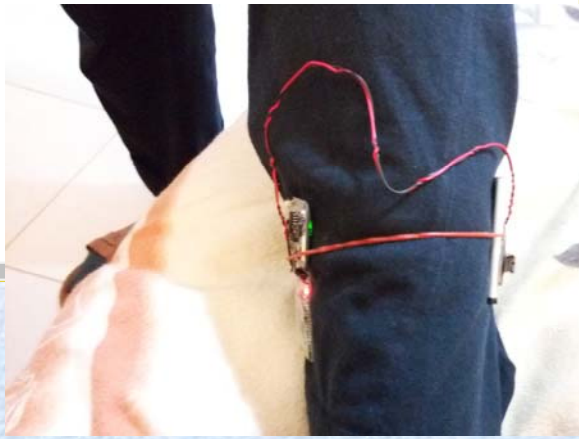
Web server





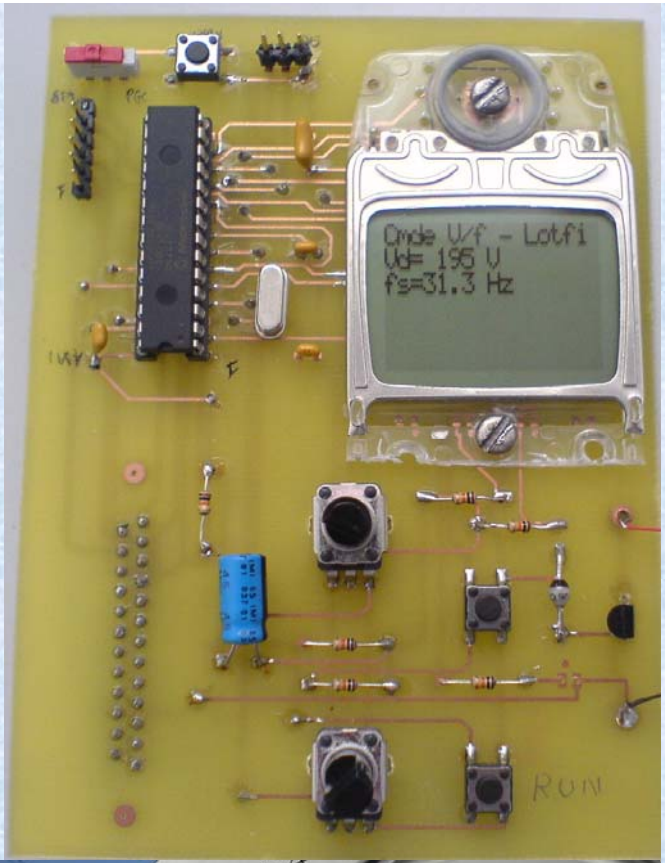
DTH	T...	Distance	XAccel	YAccel	ZAccel	Température	Humidité
2017-01-21 00:01:52	1	25	4844	680	-16852	29.8	-295
2017-01-21 00:01:46	1	20	4660	704	-16764	29.09	-343
2017-01-21 00:01:40	1	15	4888	692	-16748	28.29	-383
2017-01-21 00:01:33	1	10	4216	356	-16788	27.45	-274
2017-01-21 00:01:27	1	5	4160	320	-16884	26.55	-325
2017-01-21 00:01:17	1	5	4188	144	-16956	25.19	-341
2017-01-16 14:06:28	1	75	-11688	-11400	-10000	29.71	-1425
2017-01-16 14:06:21	1	70	7908	-11064	-10056	29.52	98
2017-01-16 14:06:14	1	65	-7580	-8936	-14156	29.38	12773
2017-01-16 14:06:07	1	60	-2880	-6576	14516	29.14	-2025
2017-01-16 14:06:01	1	55	-6916	-4280	13624	28.91	302

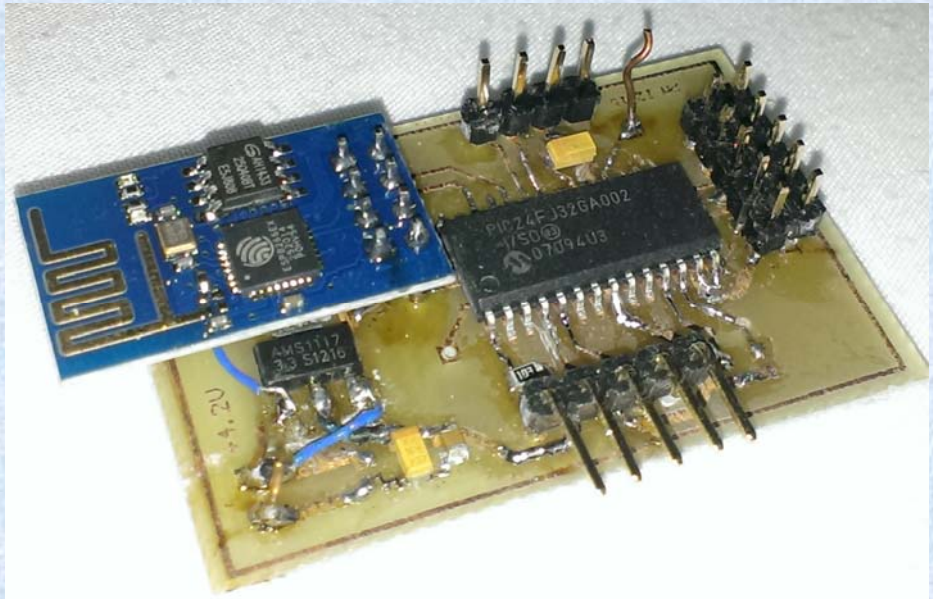
Ax 7908
Ay -11064
Az -10056

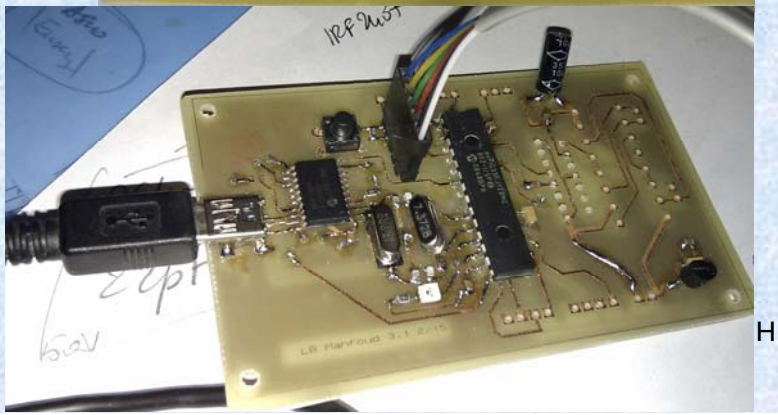


Réalisations

- dspic 30F3010, LCD 3310, V/f
- PIC 24FJ32GA002, ESP8266
- dspic 33FJ128MC802, MCP2200, L298 : Vidéo Mahfoud 3

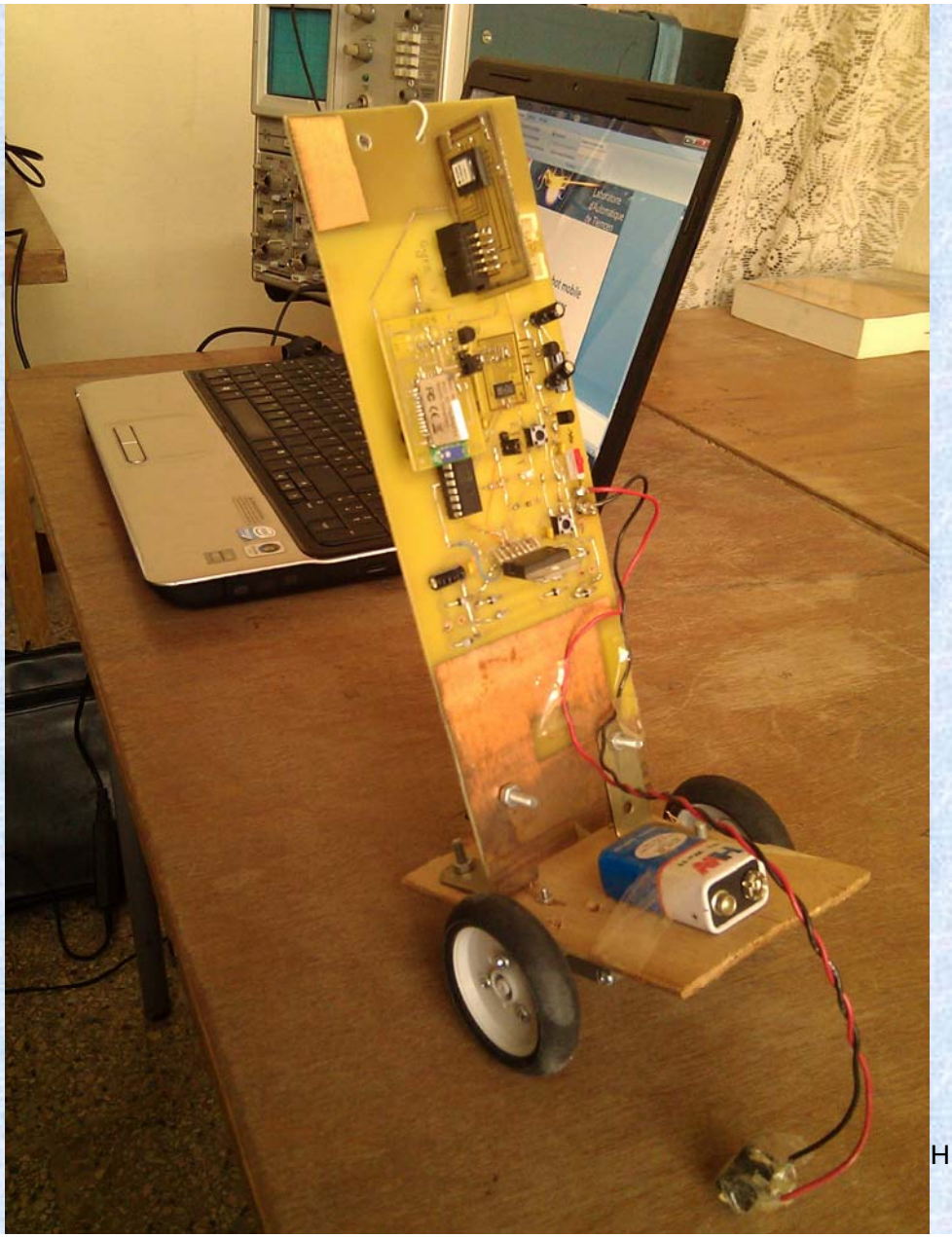






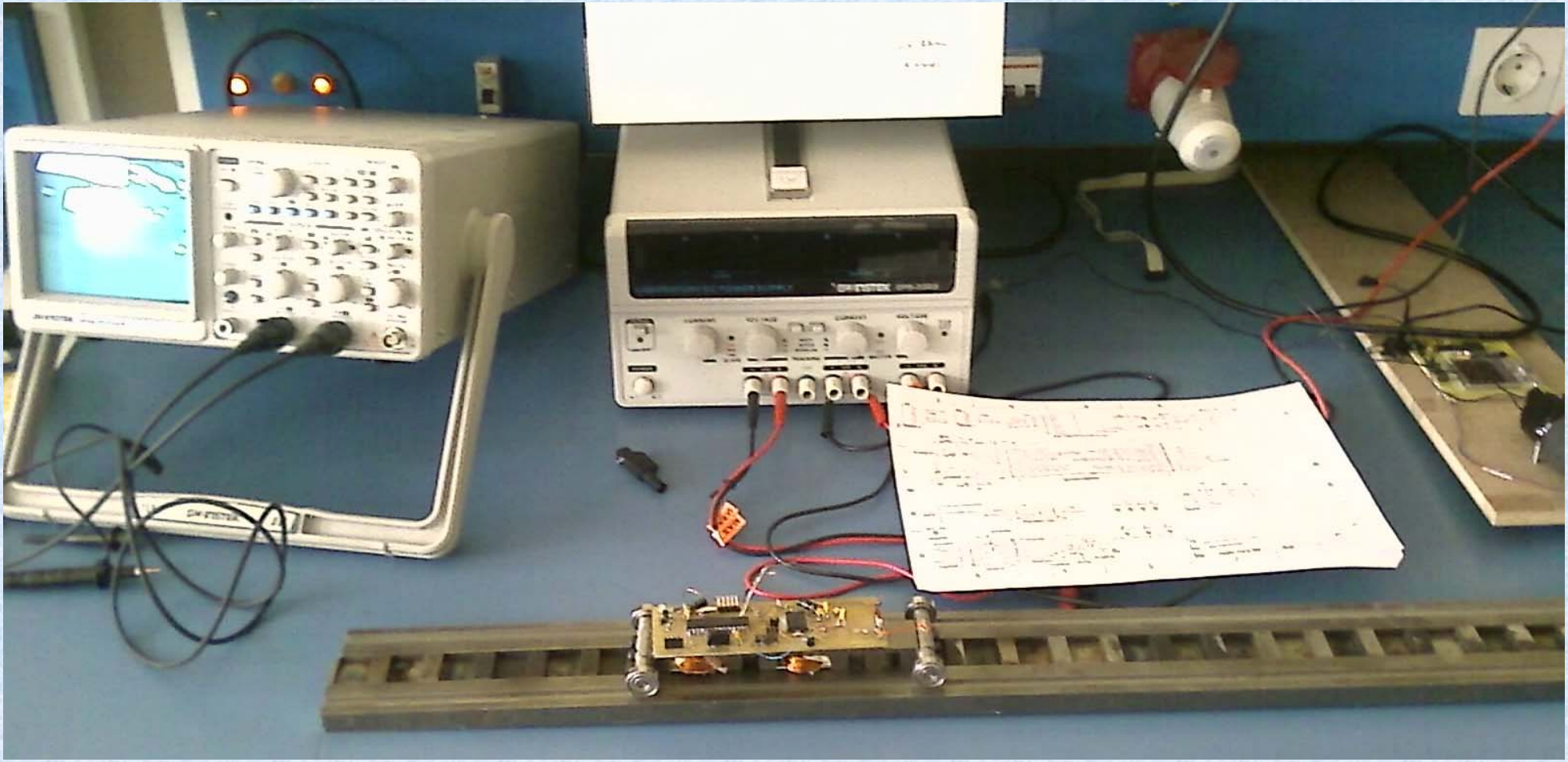
Réalisations

- dspic 33FJ128MC802, Hacheur 4Q L298, Gyro AD16250, Accel LIS3LV02DL, Bluetooth RN41



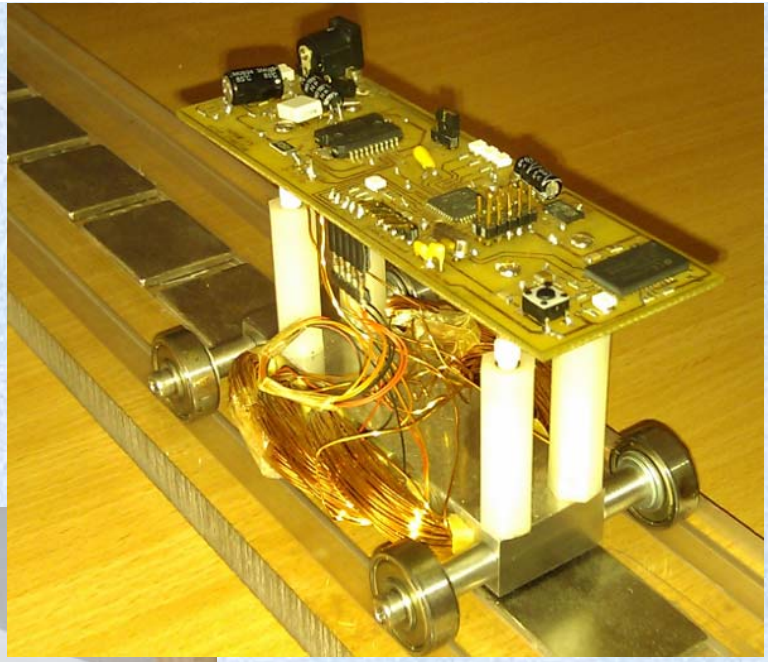
Réalisations

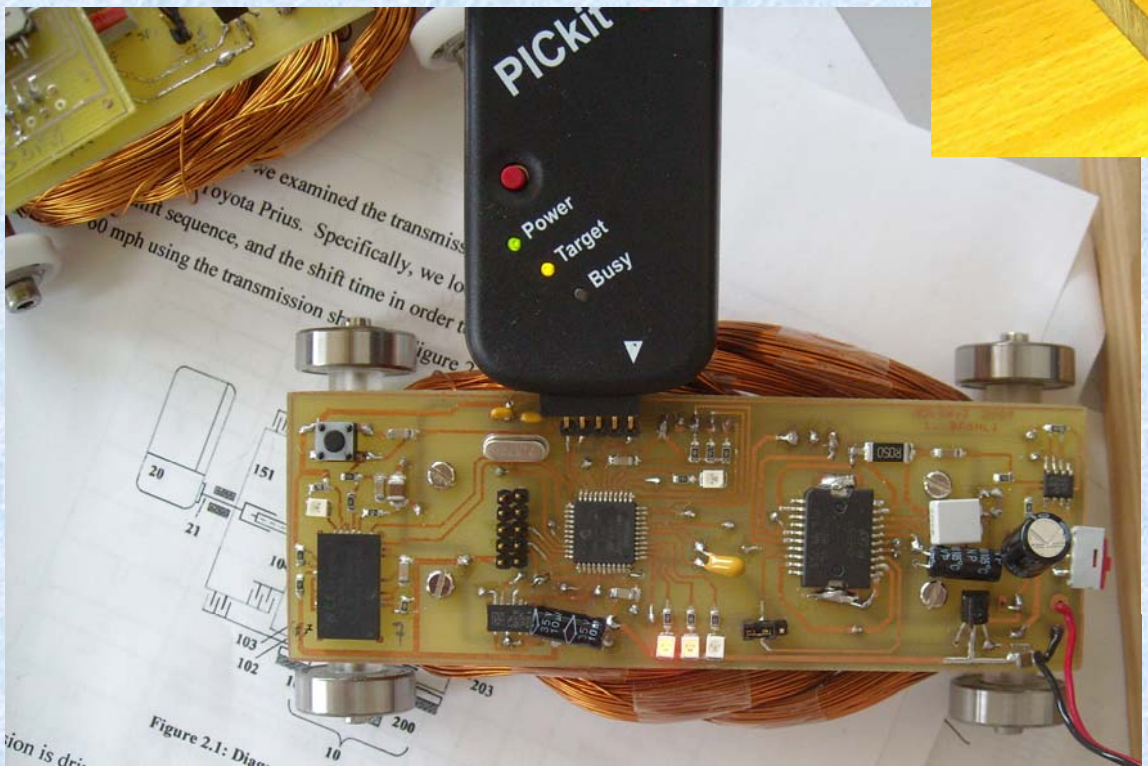
- dspic 33FJ128MC802, Onduleur L6234, Bobinage triphasé



Réalisations

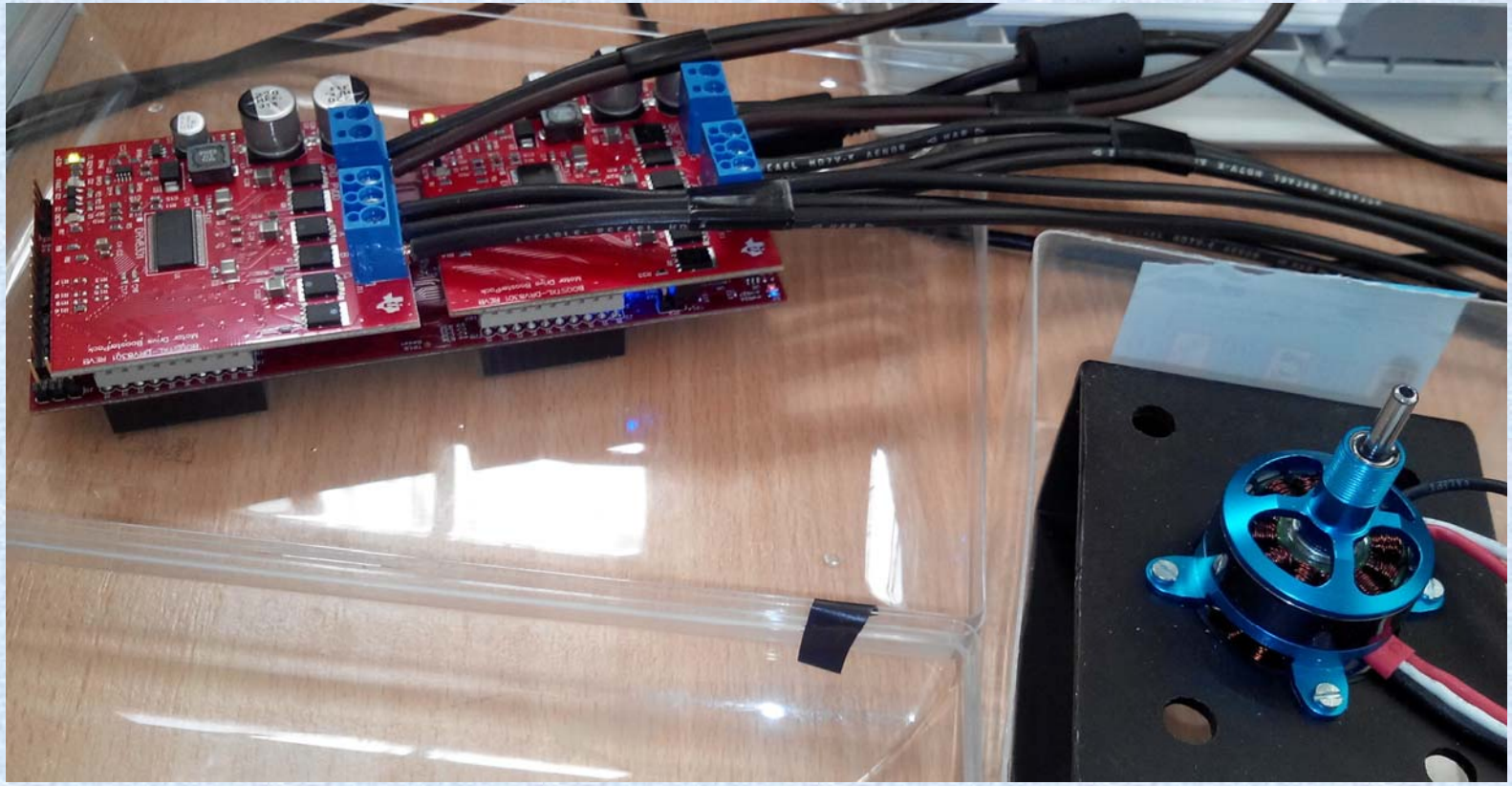
- dspic 33FJ128MC804, Onduleur L6234, Bluetooth LMX9838, AccelLIS3LV02DL, Hall SS40A, Bobinage triphasé : Vidéo

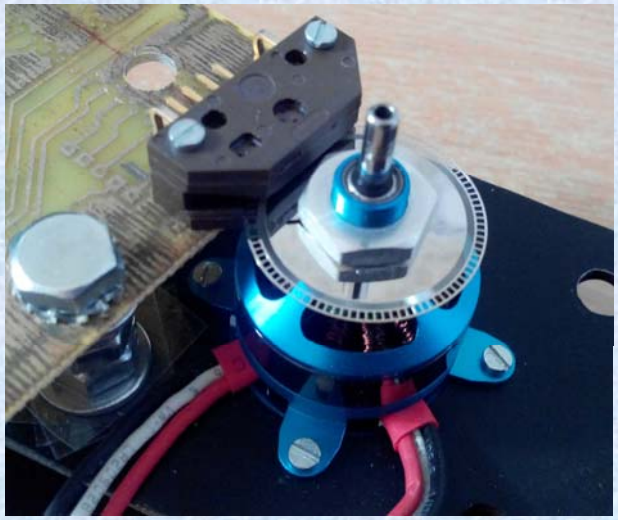


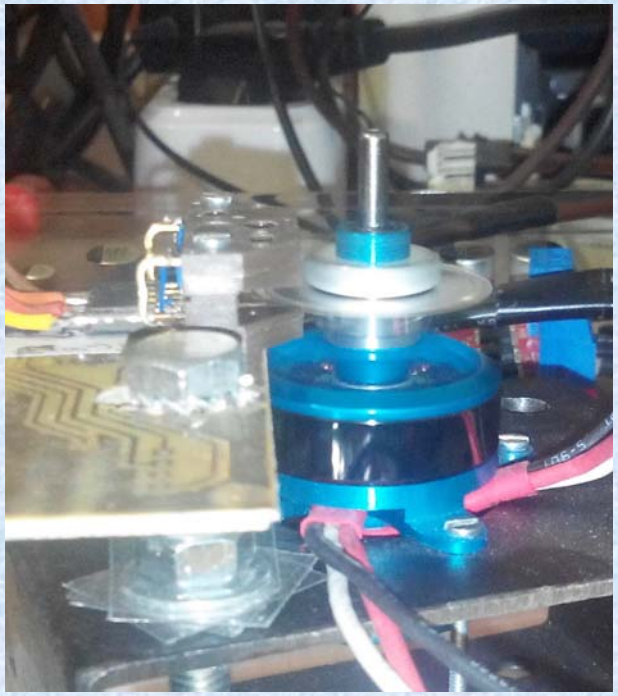


Réalisations

- LaunchpadXL F28069M, codeur incrémental, 2 x DRV8301, moteurs BLDC







Conclusions

- Evolution rapide des offres des constructeurs et des startups
- Démocratisation de la pratique des µC et DSC, engouement, tutoriaux,…
- Enseignement massif des µC aux lycéens et étudiants
- Faire le bon choix, courbe d'apprentissage : Arduino nano → Wemos / ESP8266 / Rasp Pi → PIC24F / dspic 33FJ / 33EP → LaunchPad XL Piccolo / Delfino

Merci pour Votre attention

Discussion