

THEREMINO ROBOT WORKSHOP

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www.theremino.org

Workshop: 9 April 2022

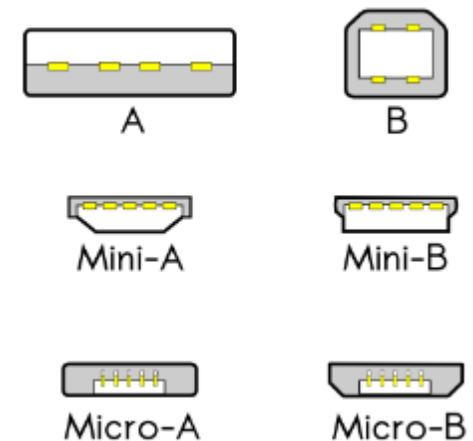
**L1-Buildingg A2, Hangcheng Innovation Park, Xixiang Street,
Bao'an Districh, Shenzhen, China**

What we do today:

- Know the story of the dead of the parallel port and the born of the SUB port on PC.
- Know the main difference using the USB port in COMx: and the HID at high speed.
- Why we re-invent the communication protocol and the role of Microchip company.
- The use of the slots to transfer data between Windows PC and the Theremino Master.
- The hardware functionality of the Theremino Master.
- The stepper motor, its use and the big diffusion thanks to Arduino and the 3D printer.
- The firmware inside the Theremino Master to simplify the stepper motor management.
- The SCARA arm, using the stepper motor.
- The language Theremino Automation to easily manage the stepper motor.
- The sequence file used by Theremino Automation.

- 了解PC上并口的消亡与SUB口的诞生的故事。
- 了解使用 COMx 中的 USB 端口和高速 HID 的主要区别。
- 为什么我们重新发明通信协议和 Microchip 公司的角色。
- 使用插槽在 Windows PC 和 Theremino 大师之间传输数据。
- Theremino 大师的硬件功能。
- 步进电机，由于 Arduino 和 3D 打印机，它使用和大扩散。
- Theremino Master 内的固件以简化步进电机管理。
- SCARA 臂，使用步进电机。
- Theremino 自动化语言轻松管理步进电机。
- Theremino 自动化使用的序列文件。

USB 1.0 - 2.0



History of Theremino System

The seed of the theremino system was put by Bill Gates the day in which I introduced Windows 95 in 1995 and when they connected the scanner to the PC, the operating system went to blue screen.

To see the original video click on the link.

Theremino 系统的种子是比尔盖茨在 1995 年我推出 Windows 95 的那一天，当他们将扫描仪连接到 PC 时，操作系统进入蓝屏。要查看原始视频，请单击链接。



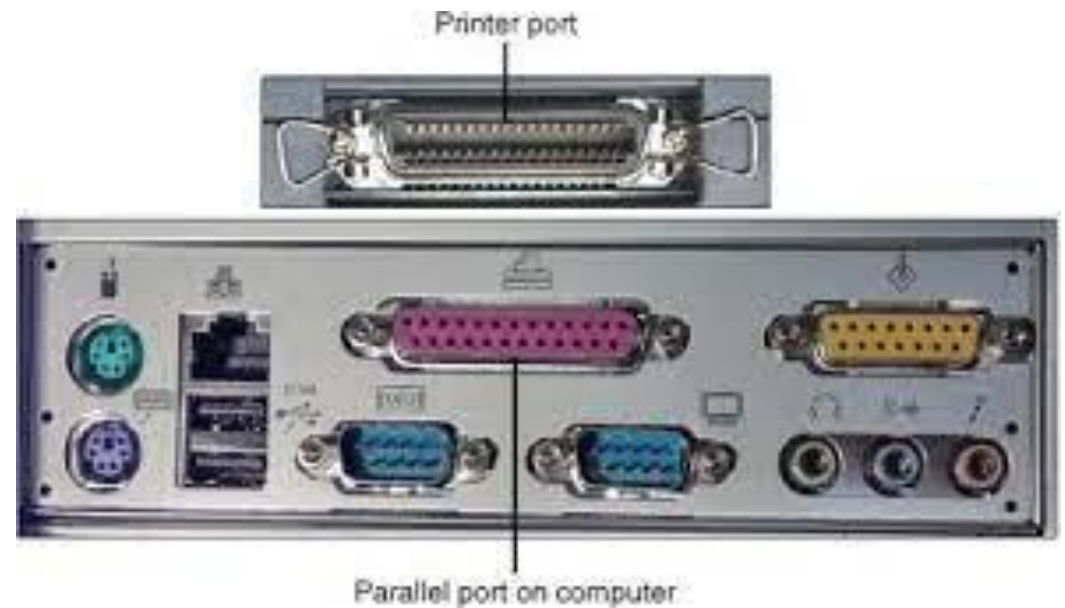
<https://youtu.be/LfNQ0Or9aR8>

History of Theremino System

With Windows 95 the USB port was introduced and in fact the end of the parallel port was decreed.

Up to that date, interfacing the PC with sensors and actuators was very simple and intuitive. An 8-bit read and write bus was available which could transfer thousands of bytes per second.

在 Windows 95 中引入了 USB 端口，事实上并行端口的终结已被颁布。迄今为止，PC 与传感器和执行器的连接非常简单和直观。8 位读写总线可用，每秒可传输数千字节。

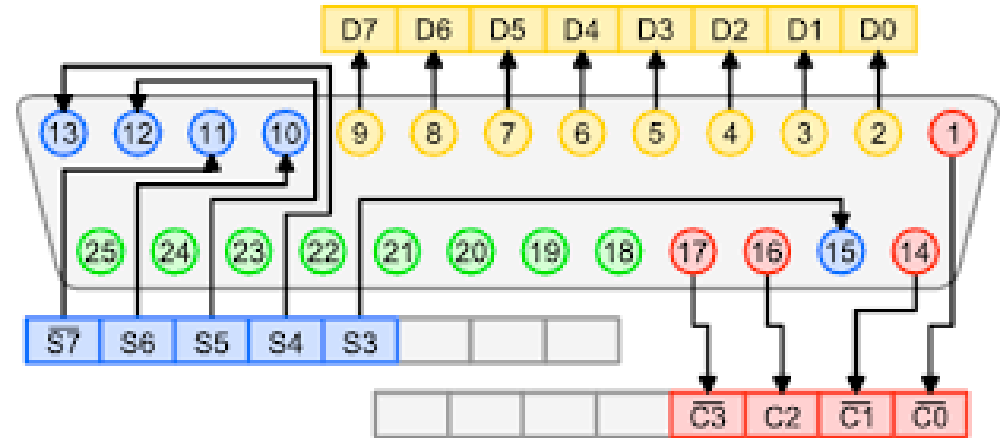


History of Theremino System

The whole community of PC interface developers began studying the new USB 1.0 standard with enormous difficulties in interfacing and recognizing the operating system.

整个 PC 接口开发人员社区开始研究新的 USB 1.0 标准，但在接口和识别操作系统方面遇到了巨大的困难。

Looking into Parallel port socket on PC



History of Theremino System

With the arrival of Windows 98SE, USB 2.0 also arrived. Things improved a bit on the Microsoft side, and it became common to use the serial port to communicate with sensors and adapters.



随着Windows 98SE的到来，USB 2.0也来了。微软方面的情况有所改善，使用串行端口与传感器和适配器进行通信变得很普遍。



History of Theremino System

The serial port has speed limits and to drive stepper motors or ADC converters or complex interfaces it is not enough.

Furthermore, the USB protocol is very complicated and contradictory information can be found in the official documentation.

A help to solve these problems comes from Microchip a chip with the integrated USB2.0 stack in HID mode. The chip is named PIC 24FJ64GB002.

串行端口有速度限制，驱动步进电机或ADC转换器或复杂的接口是不够的。

此外，USB协议非常复杂，在官方文档中可以找到相互矛盾的信息。

解决这些问题的一个帮助来自 Microchip 的芯片，该芯片在 HID 模式下集成了 USB2.0 堆栈。该芯片命名为 PIC 24FJ64GB002。



USB enumeration

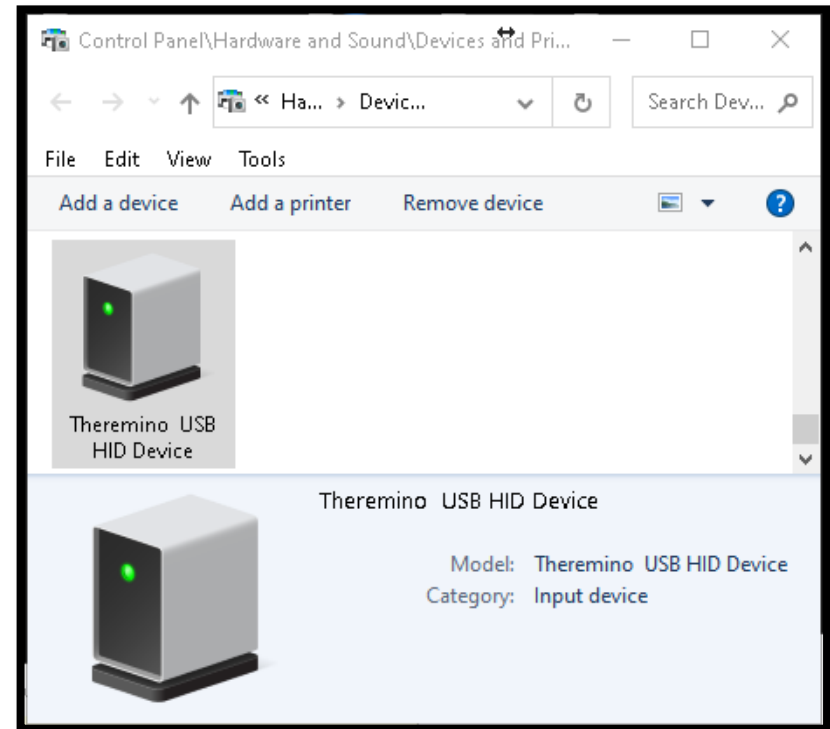
Microchip obtains the VID and Vendor Identification and Product Identification (VID) from the USB organization and has the high-speed HID communication protocol.

The identification can be used by Microchip customers after an agreement.

This allows the THEREMINO MASTER to be recognized immediately by Windows without installing any specific driver.

Microchip 从 USB 组织获得 VID 和供应商标识和产品标识 (VID)，并具有高速 HID 通信协议。

经协议，Microchip 客户可以使用该标识。这使得 Windows 可以立即识别 THEREMINO MASTER，而无需安装任何特定的驱动程序。



PIC 24FJ64GB002



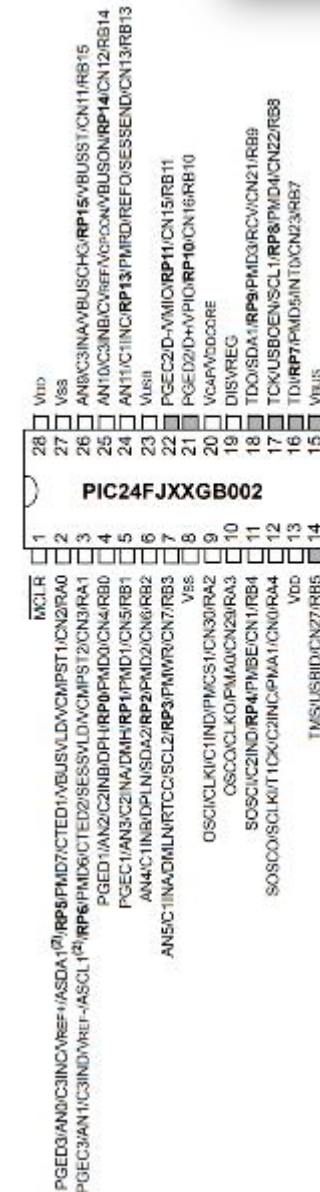
Microchip's microcontroller PIC 24FJ64GB002 is a powerful 16-bit MCU with RISK structure and therefore extremely fast and efficient. Inside, the processing speed in the USB section runs at a frequency of 98 Mega Hertz. The user manual has 352 pages.

Microchip 的微控制器 PIC 24FJ64GB002 是一款功能强大的 16 位 MCU，具有 RISK 结构，因此非常快速和高效。在内部，USB 部分的处理速度以 98 兆赫兹的频率运行。用户手册有 352 页。

PIC 24FJ64GB002 特性

The PIC 24FJ64GB002 features

- 16 MIPS performance
- 16 x 16 Hardware Multiply, Single Cycle Execution
- 32-bit x 16-bit Hardware Divider
- C Compiler Optimized Instruction Set
- Internal oscillator support - 31 kHz to 8 MHz, up to 32 MHz with 4X PLL
- On-chip LDO Voltage Regulator
- JTAG Boundary Scan and Flash Memory Program Support
- Fail-Safe Clock Monitor – allows safe shutdown if clock fails
- Watchdog Timer with separate RC oscillator
- eXtreme Low Power Managed Modes Run, Idle and Sleep modes
- Deep sleep mode for lowest current consumption
- Multiple, Switchable Clock Modes for Optimum Performance and Power Management
- 10-bit ADC, 13 channels, 500k samples per second
- 3 Analog comparators
- 2 UART Modules with LIN and IrDA® support, 4 Deep FIFO
- 2 SPI™ Modules with 8 Deep FIFO
- 2 I2C™ Modules with Master and Slave Modes
- Five 16-bit Timer Modules
- Up to 5 Input Capture and 5 Output Compare / PWM, all with dedicated timers
- Hardware RTCC, Real-Time Clock Calendar with Alarms
- PMP, Parallel Master Port, with 16 Address Lines, and 8/16-bit Data
- Peripheral Pin Select for remapping digital peripherals to I/O
- Charge Time Measurement Unit (CTMU) for capacitive touch interface
- Universal Serial Bus Features
- USB v2.0 On-the-Go compliant
- Dual role capable, can act as either Host or Device
- Low speed(1.5Mb/s) and full speed(12 Mb/s) operation in host mode
- Full speed USB operaton in Device mode
- Supports 32 endpoints
- On-chip USB transceiver



History of Theremino System

In 2012 a group of experts in different sectors decided to share their experiences and skills generating the OPEN SOURCE THEREMINO system aimed at simplifying and sharing information

The site www.theremino.org and the first version of the Theremino Master is born.



2012年，不同部门的一组专家决定分享他们的经验和技能，以创建旨在简化和共享信息的OPEN SOURCE THEREMINO系统。网站 www.theremino.org 和 Theremino 大师的第一个版本诞生了。



The Master

The first commercial version was the V3, later in 2016 the V5 version was released, stable able to manage 12 input and output pins.

The wiring diagram and the firmware and Gerber files are freely downloadable from the website www.theremino.org

第一个商业版本是 V3，2016 年早些时候发布了 V5 版本，稳定可以管理 12 个输入和输出引脚。接线图和固件和 Gerber 文件可从网站 www.theremino.org 免费下载



The SLOTS

The resolution of the hardware interface is only half of the need to connect sensors and actuators.

Using the standard USB protocol, once again, the difficulties were enormous.

The theremino team decides to rewrite the USB protocol, introducing the concept of slot.

A "slot" is a simple container for a number or text like the slot machine.

There are 1000 slots to read and 1000 to write which are continuously exchanged between Windows and the Master.

There are only two instructions for manipulating slots:

variable = Slot (nn)

Slot (nn) = variable

硬件接口的分辨率只有连接传感器和执行器所需的一半。

再次使用标准 USB 协议，困难是巨大的。

Theremino 团队决定重写 USB 协议，引入插槽的概念。

“老虎机”是数字或文本的简单容器，例如老虎机。

有 1000 个可读的插槽和 1000 个可写入的插槽，它们在 Windows 和 Master 之间不断交换。

操作槽只有两条指令：

变量 = 插槽 (nn)

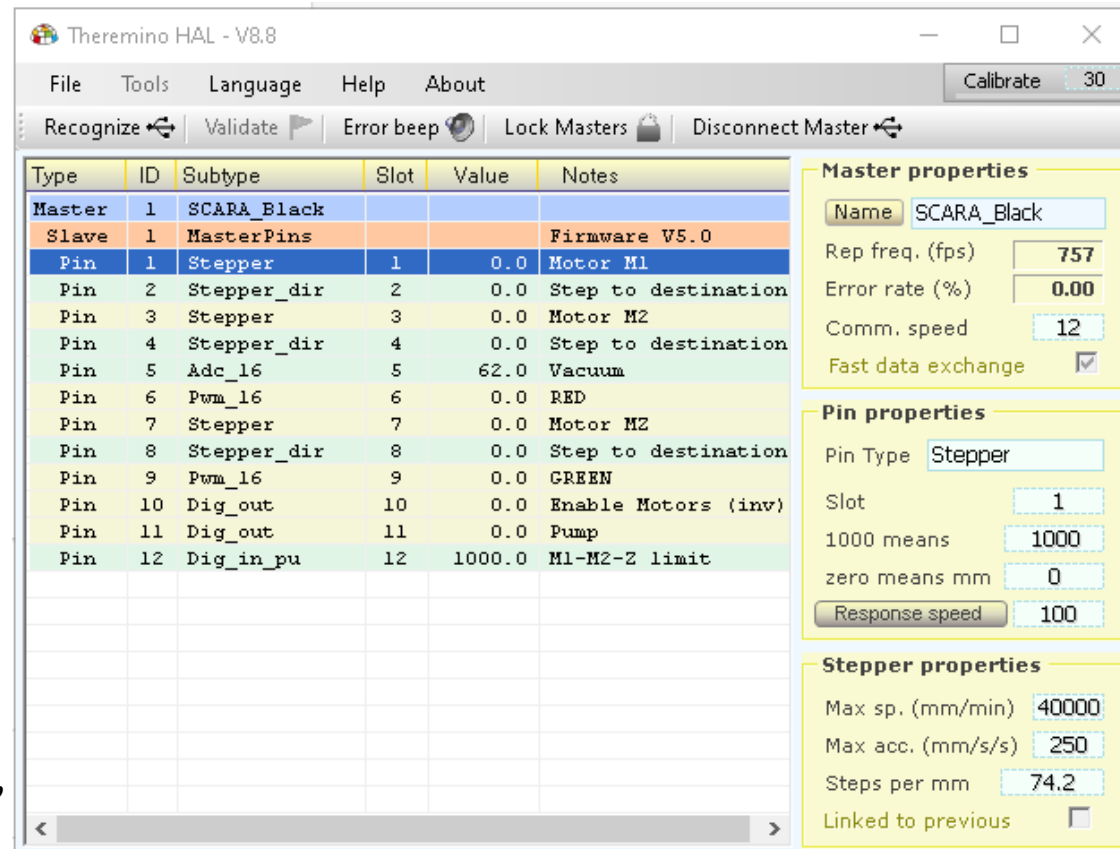
插槽 (nn) = 变量



The software modules: The “HAL”

The HAL (Hardware Abstraction Layer) module takes care of electrical interfacing and signal processing functions in collaboration with the Master, as well as communication with the PC via USB in HID mode and with external components. It typically transfers over 700 frames per second over USB 2.0.

HAL（硬件抽象层）模块负责与主站协作的电气接口和信号处理功能，以及通过 HID 模式下的 USB 和外部组件与 PC 进行通信。它通常通过 USB 2.0 每秒传输超过 700 帧。



Type	ID	Subtype	Slot	Value	Notes
Master	1	SCARA_Black			
Slave	1	MasterPins			Firmware V5.0
Pin	1	Stepper	1	0.0	Motor M1
Pin	2	Stepper_dir	2	0.0	Step to destination
Pin	3	Stepper	3	0.0	Motor M2
Pin	4	Stepper_dir	4	0.0	Step to destination
Pin	5	Adc_16	5	62.0	Vacuum
Pin	6	Pwm_16	6	0.0	RED
Pin	7	Stepper	7	0.0	Motor M2
Pin	8	Stepper_dir	8	0.0	Step to destination
Pin	9	Pwm_16	9	0.0	GREEN
Pin	10	Dig_out	10	0.0	Enable Motors (inv)
Pin	11	Dig_out	11	0.0	Pump
Pin	12	Dig_in_pu	12	1000.0	M1-M2-Z limit

Master properties

Name: SCARA_Black

Rep freq. (fps): 757

Error rate (%): 0.00

Comm. speed: 12

Fast data exchange:

Pin properties

Pin Type: Stepper

Slot: 1

1000 means: 1000

zero means mm: 0

Response speed: 100

Stepper properties

Max sp. (mm/min): 40000

Max acc. (mm/s/s): 250

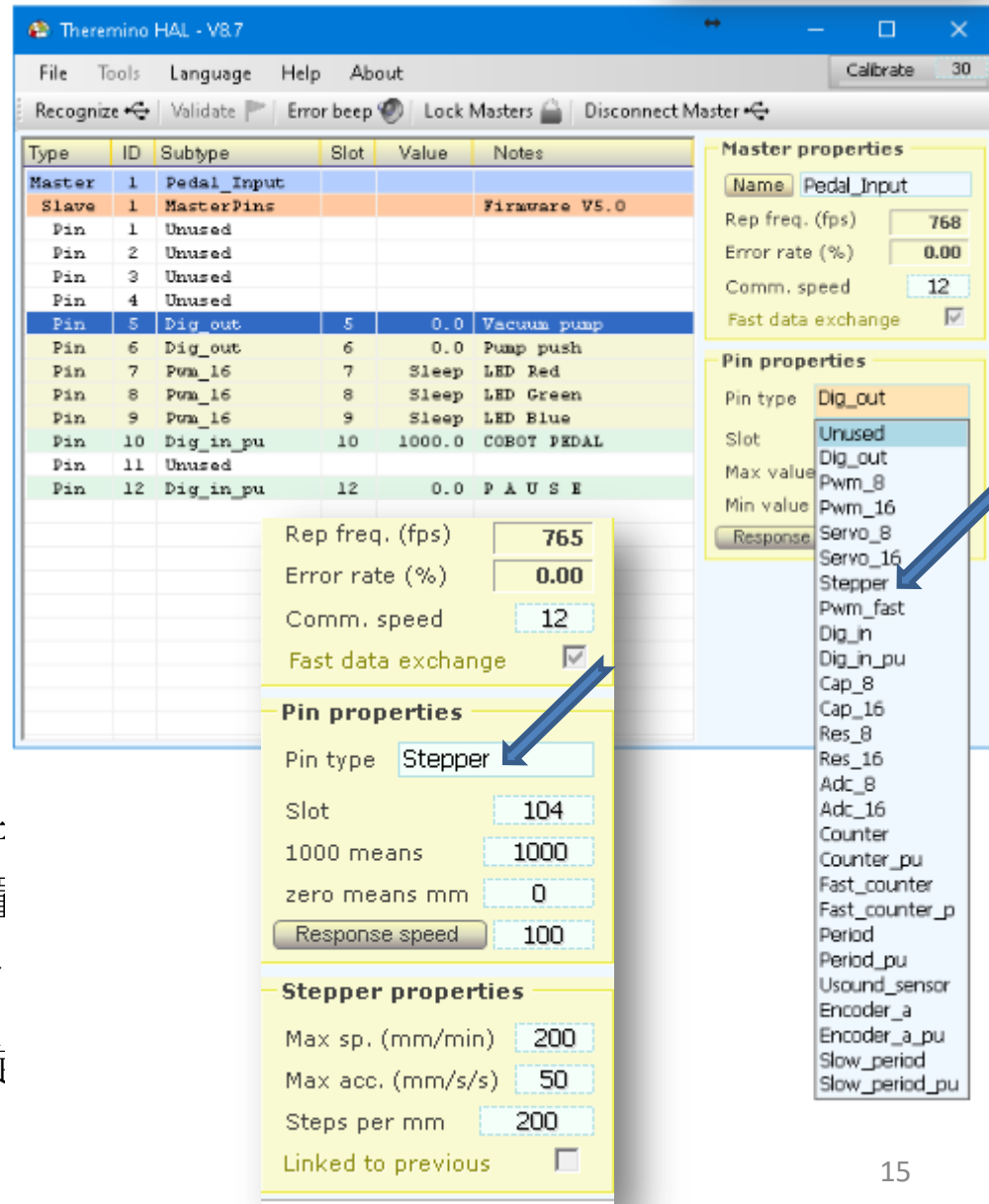
Steps per mm: 74.2

Linked to previous:

The easy configuration of the I/O pins

The software module called HAL (Hardware Abstraction Layer) allows in a simplified way to assign the hardware functions to the external pins and to set their parameters. Currently there are 26 possible configurations, and each configuration can have a specific set up. For example, for the stepper motor we have the maximum speed, the acceleration and the steps per millimeter and the direction of rotation.

称为 HAL（硬件抽象层）的软件模块允许的方式将硬件功能分配给外部引脚并设置参数。目前有 26 种可能的配置，每种配以有特定的设置。例如，对于步进电机，最大速度、加速度和每毫米的步数以及旋



The screenshot shows the Therenino HAL - V8.7 software interface. It features a menu bar (File, Tools, Language, Help, About) and a toolbar with buttons for 'Recognize', 'Validate', 'Error beep', 'Lock Masters', and 'Disconnect Master'. A 'Calibrate' button is also present with a value of 30.

The main window is divided into several sections:

- Table:** A table listing pins with columns for Type, ID, Subtype, Slot, Value, and Notes.

Type	ID	Subtype	Slot	Value	Notes
Master	1	Pedal_Input			
Slave	1	MasterPins			Firmware V5.0
Pin	1	Unused			
Pin	2	Unused			
Pin	3	Unused			
Pin	4	Unused			
Pin	5	Dig_out	5	0.0	Vacuum pump
Pin	6	Dig_out	6	0.0	Pump push
Pin	7	Pwm_16	7	Sleep	LED Red
Pin	8	Pwm_16	8	Sleep	LED Green
Pin	9	Pwm_16	9	Sleep	LED Blue
Pin	10	Dig_in_pu	10	1000.0	COBOT PEDAL
Pin	11	Unused			
Pin	12	Dig_in_pu	12	0.0	P A U S E
- Master properties:** Includes fields for Name (Pedal_Input), Rep freq. (fps) (768), Error rate (%) (0.00), Comm. speed (12), and a checked 'Fast data exchange' option.
- Pin properties:** A dropdown menu for Pin type is open, showing options like Dig_out, Pwm_8, Servo_8, Servo_16, Stepper, Pwm_fast, Dig_in, Dig_in_pu, Cap_8, Cap_16, Res_8, Res_16, Adc_8, Adc_16, Counter, Counter_pu, Fast_counter, Fast_counter_p, Period, Period_pu, Usound_sensor, Encoder_a, Encoder_a_pu, Slow_period, and Slow_period_pu. The 'Stepper' option is selected.
- Stepper properties:** A separate panel for the selected Stepper pin type, showing:
 - Rep freq. (fps): 765
 - Error rate (%): 0.00
 - Comm. speed: 12
 - Fast data exchange:
 - Pin type: Stepper
 - Slot: 104
 - 1000 means: 1000
 - zero means mm: 0
 - Response speed: 100
 - Max sp. (mm/min): 200
 - Max acc. (mm/s/s): 50
 - Steps per mm: 200
 - Linked to previous:

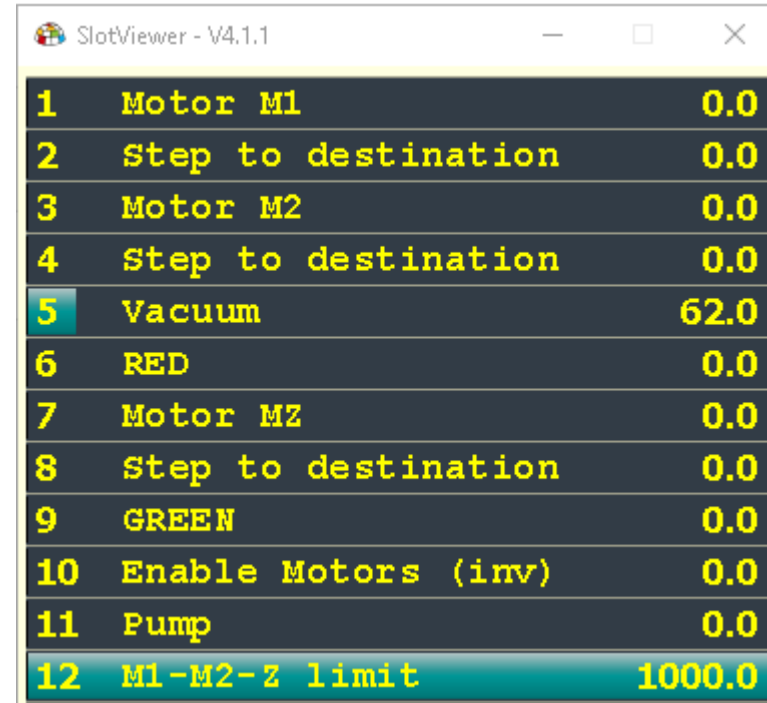
The software modules: The “Slot Viewer”

The "SlotViewer" module allows you to view the status of the slots in real time.

Slots are a simplified version of the communication between the HAL module and the applications in a Windows environment.

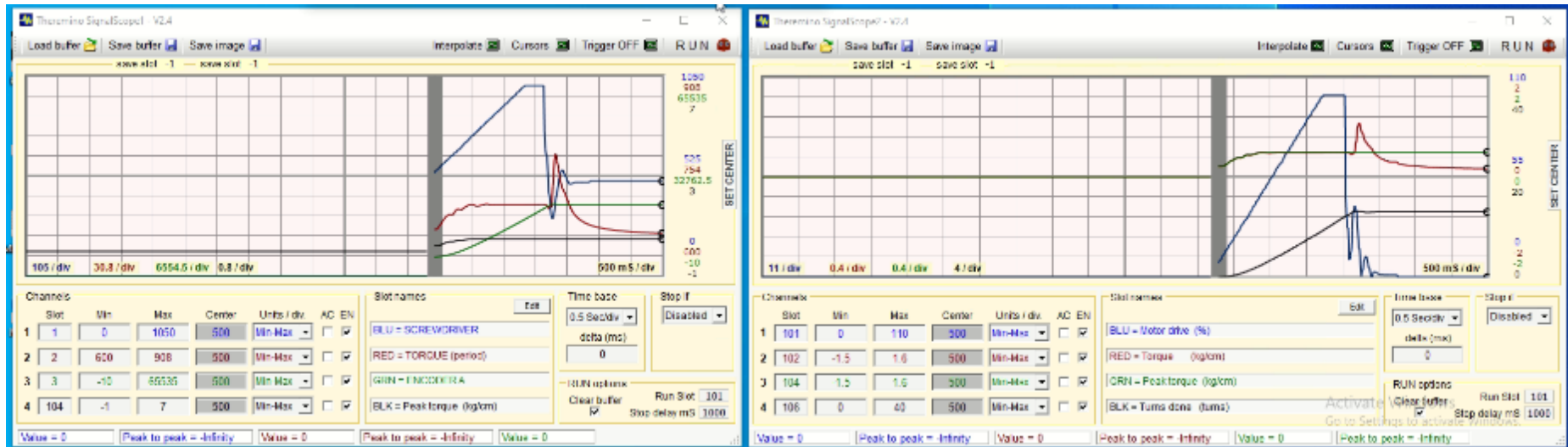
Through this module it is possible to intervene in real time on the contents of the slots.

“SlotViewer”模块可让您实时查看插槽状态。插槽是 HAL 模块与 Windows 环境中的应用程序之间通信的简化版本。通过这个模块，可以实时干预插槽的内容。



Slot ID	Slot Name	Value
1	Motor M1	0.0
2	Step to destination	0.0
3	Motor M2	0.0
4	Step to destination	0.0
5	Vacuum	62.0
6	RED	0.0
7	Motor MZ	0.0
8	Step to destination	0.0
9	GREEN	0.0
10	Enable Motors (inv)	0.0
11	Pump	0.0
12	M1-M2-Z limit	1000.0

The software modules: The “SignalScope”

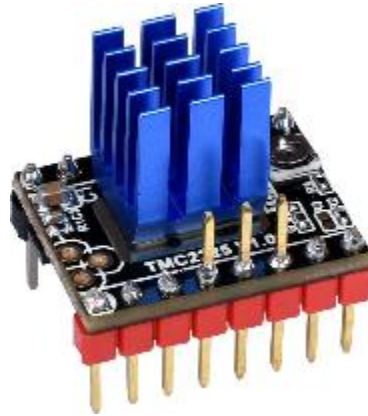
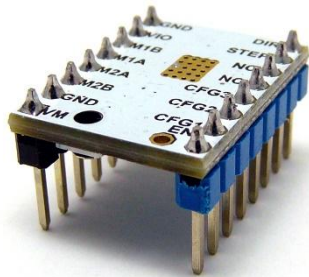


The "SignalScope" allows you to view the status of the slots in real time, like a logic analyzer or oscilloscope.

The slots are a redesigned and simplified version of the communication protocol between the HAL module and the application in a Windows environment. This module has functions for storing the waveform and history.

“SignalScope”允许您实时查看插槽的状态，就像逻辑分析仪/示波器一样。这些插槽是 HAL 模块与 Windows 环境中的应用程序之间的通信协议的重新设计和简化版本。该模块具有存储波形和历史的功能。

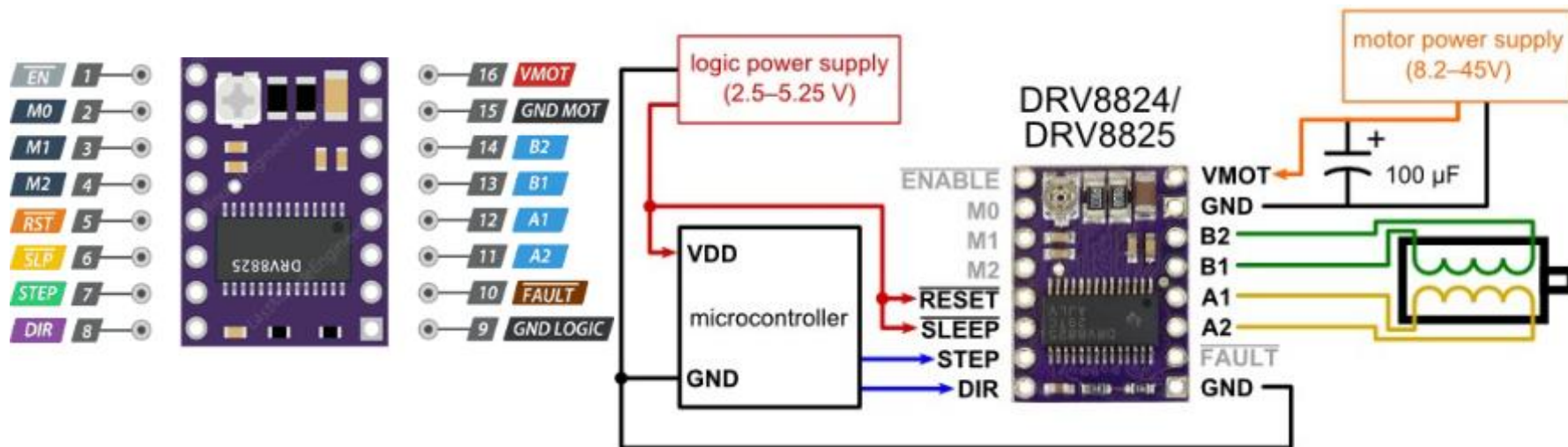
Stepper drivers



On E-commerce there are a lot of different stepper driver circuits with different price and performances.

在电子商务中，有许多不同价格和性能的步进驱动器电路。

Stepper driver DRV8825 of Texas Instrument



We decide to use the Texas Instrument based driver, the DRV8825, for its good performances, low price and greath availability .

我们决定使用基于德州仪器的驱动程序 DRV8825，因为它具有良好的性能、低廉的价格和高可用性。

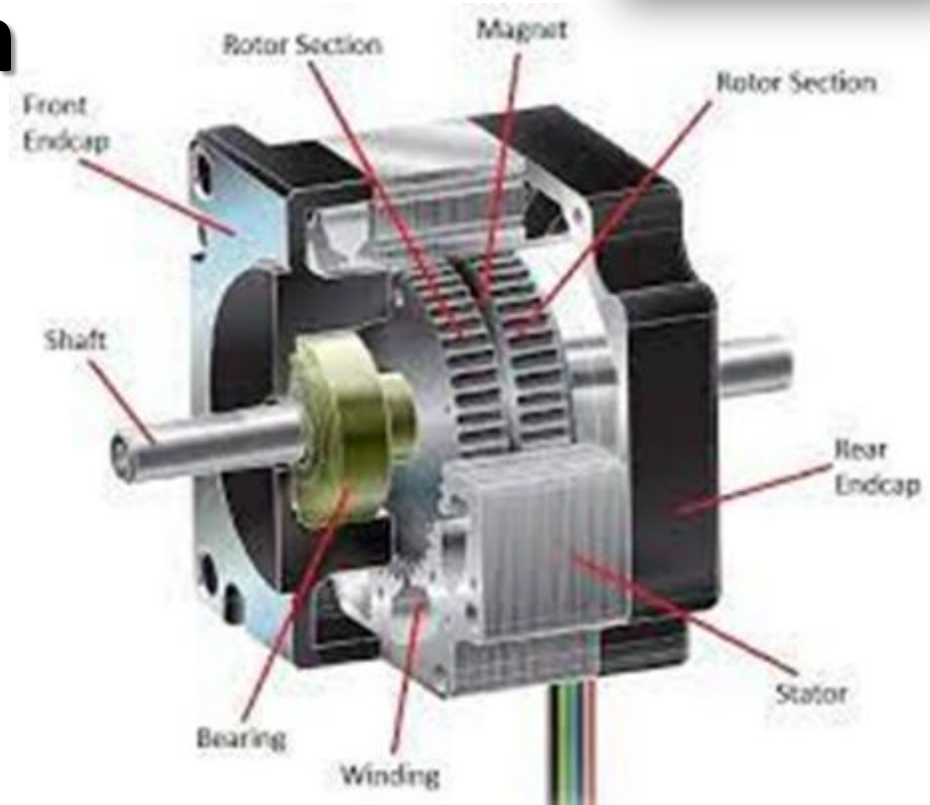
Stepper driver PCBA



This device can manage up to 5 standard DIP driver for the stepper motor.

该设备最多可管理 5 个标准 DIP 驱动器用于步进电机。

Stepper Motor theory of operation



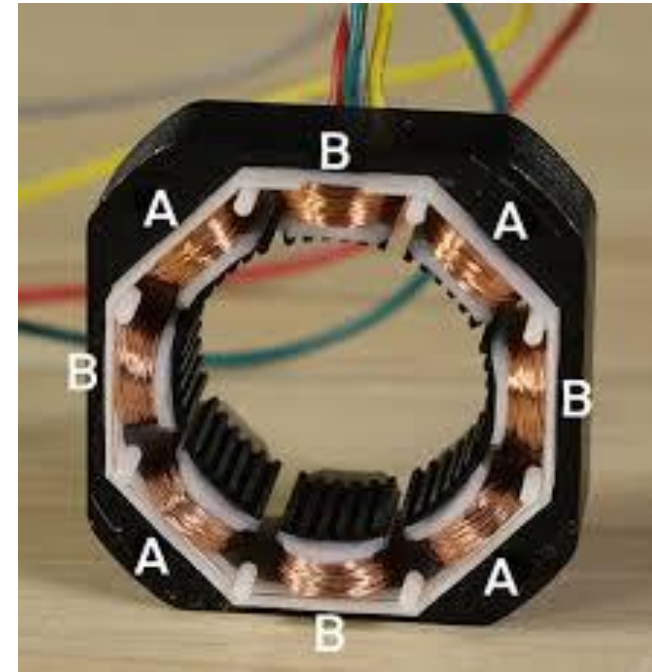
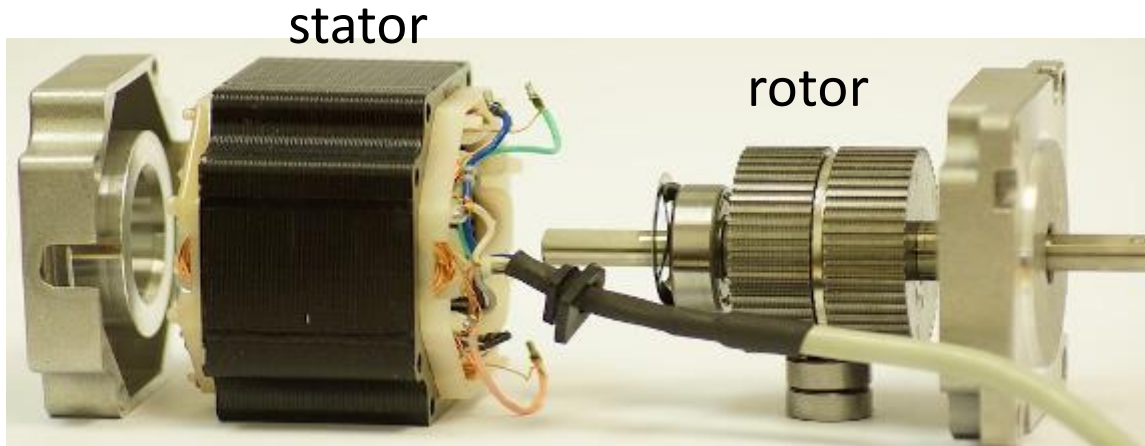
The stepper motor is a kind of motor that run by steps. The most commons need 200 steps to make one turn.

One step generate a movement of 1.8 degree.

步进电机是一种分步运行的电机。最常见的需要 200 步才能转一圈。

一步产生 1.8 度的运动。

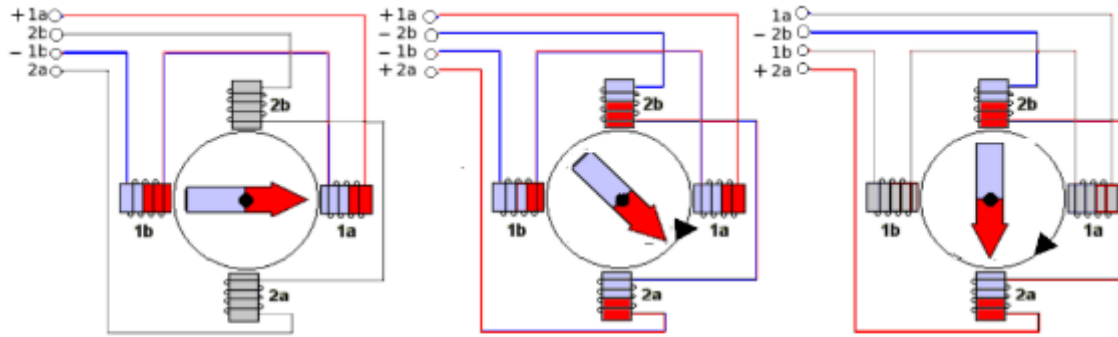
Stepper Motor theory of operation



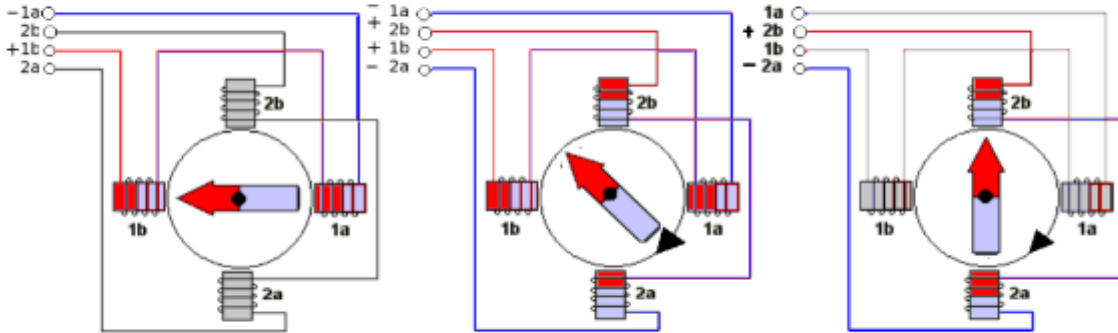
There are the stator with two set of coil A and B and the rotor that have the fixed magnetic fields aligned alternatively with the stator.

有带有两组线圈A和B的定子和具有与定子交替排列的固定磁场的转子。

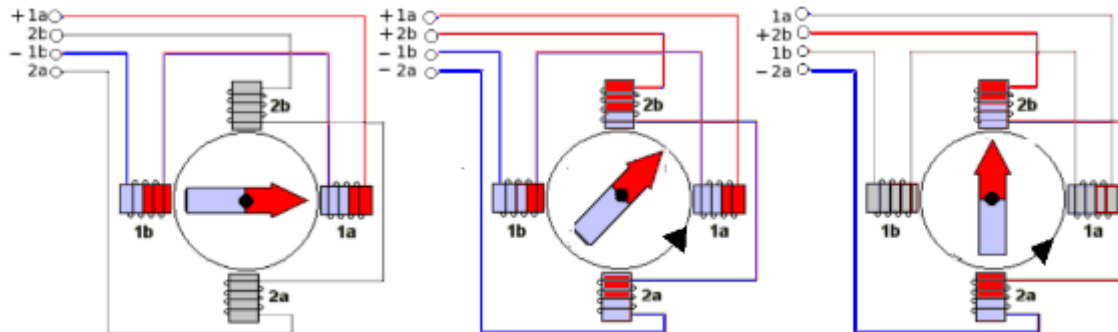
Movement



current in 'forward' direction producing a clockwise rotation



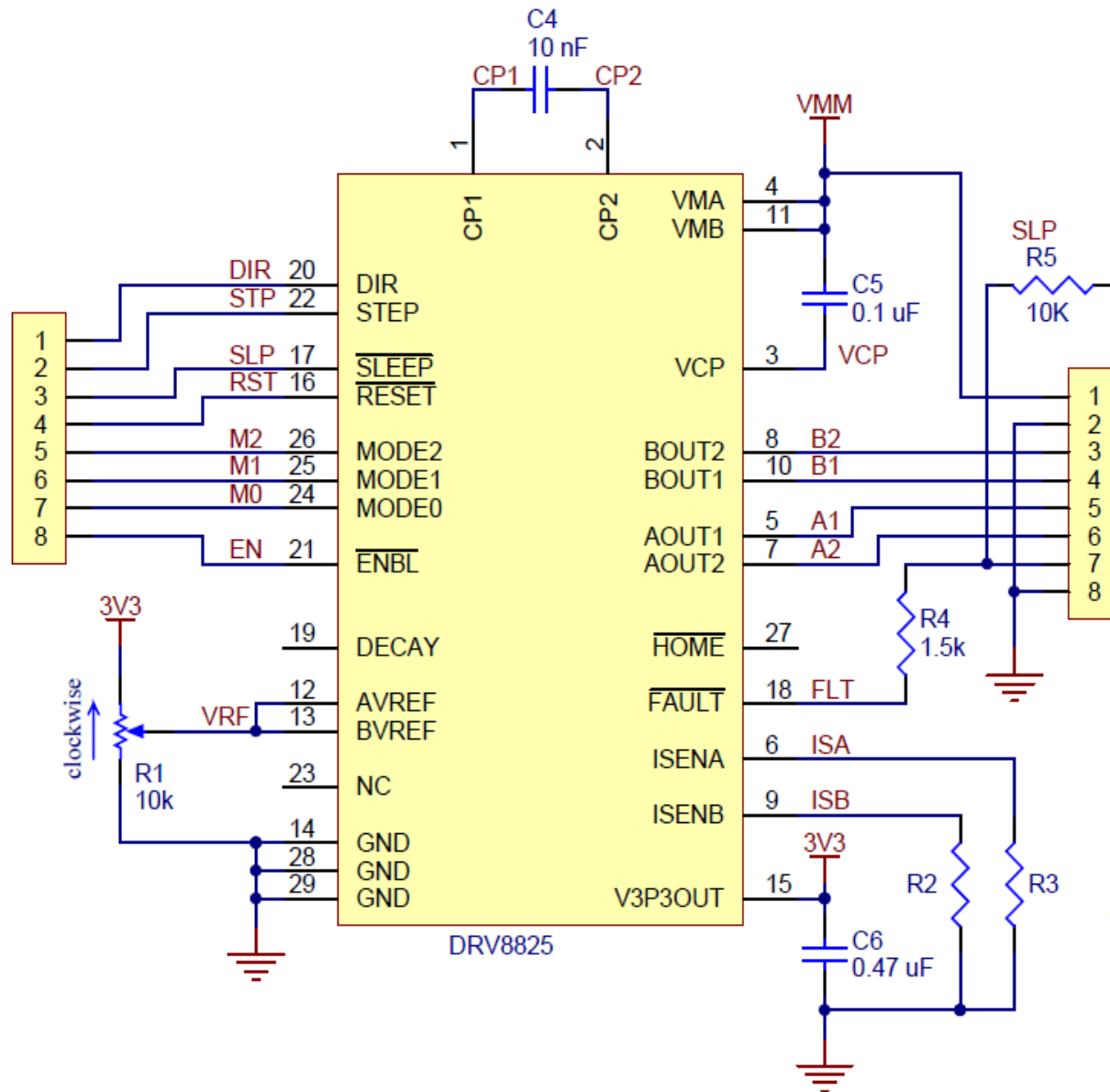
Reversing current in both coils does not change the direction of rotation



Powering alternatively and sequentially the stator coil, the rotor consequently are attracted and repulsed in phase with the coil.

交替地和顺序地为定子线圈供电，因此转子与线圈同相地被吸引和排斥。

TI DRV8825

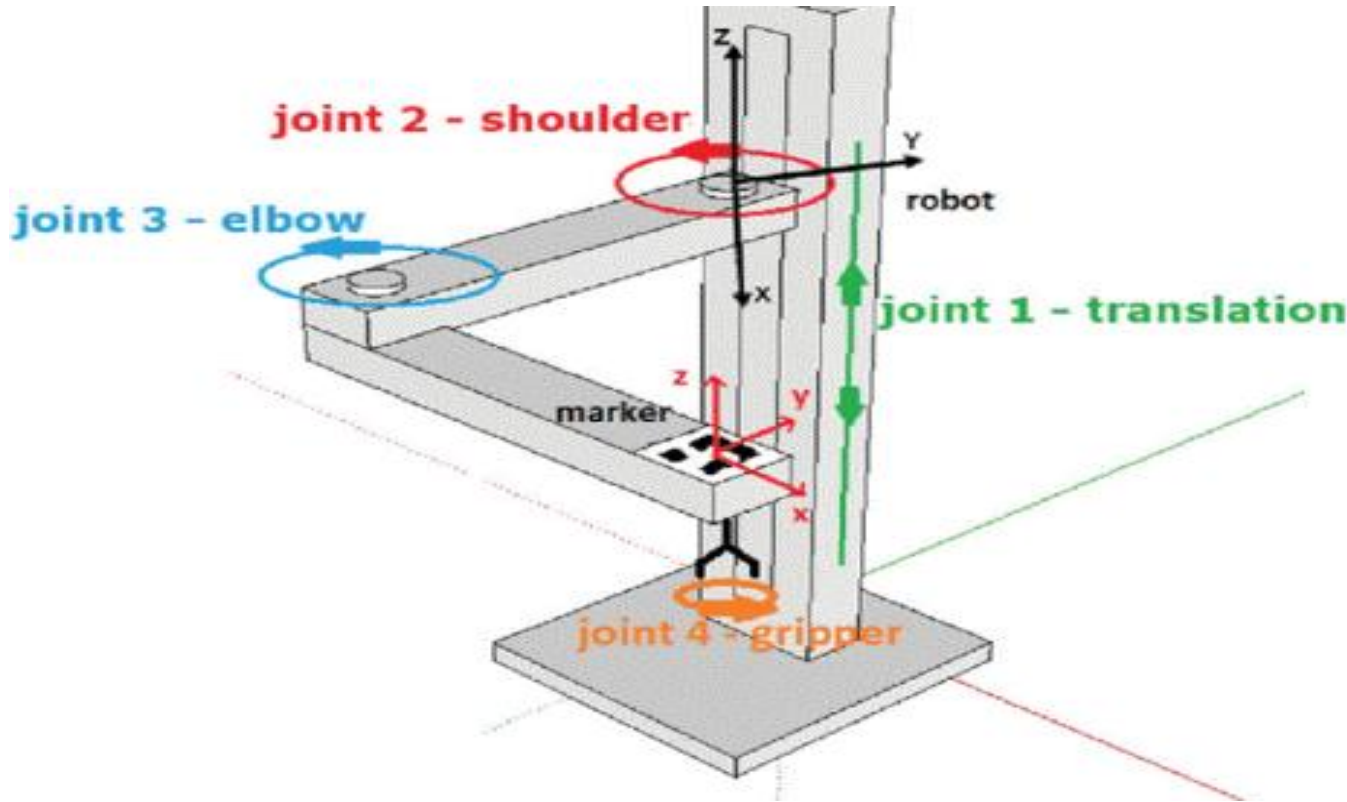


DIR = up CW, low CCW
 STEP = each pulse one step
 A1-A2 = coils
 B1-B2 = coils
 Mode 0,1,2 = microstep

DIR = 上顺时针，低逆时针
 STEP = 每个脉冲一步
 A1-A2 = 线圈
 B1-B2 = 线圈
 模式 0,1,2 = 微步。

SCARA

Selective Compliance Articulated Robot Arm



Structure:

- Simple
- Strong
- Easy

结构:

- 简单的
- 强的
- 简单

We do not use X,Y and Z, we made it more simple, using simple angle.

我们不使用 x、y 和 z，我们使用简单的角度使其更简单。

SCARA



Our SCARA is made using plastics, but can be used any other materials

我们的 SCARA 使用塑料制成，但可以使用任何其他材料

Motor M1 and M2 - angles



We send command to the M1 and M2 directly in angle.

Data is send over the Theremino Master, using slot and the programming language called Theremino Automation.

我们直接以角度向 M1 和 M2 发送命令。

数据通过 Theremino 主机发送, 使用插槽和称为 Theremino 自动化的编程语言。

Theremino Automation

Theremino Automation - V7.3.18 - Program : SCARA_black_V16.txt

Controls

Home

Home MZ

Home M1

Home M2

Start Pump

Stop Pump

Enable Motors

Disable Motors

Edit sequence

RUN SEQUENCE

Sequence
BallPlay.seq

Cloche

CLOSE ALL

STOP

Program : SCARA_black_V16.txt

Name: SCARA_Black_V16.txt Date: 18 Mar 2022
 Author: Leonardo DE PALO Ph.D.
 Scope: SCARA management

Hardware: Standard Master and stepper driver
 Limit switches
 Vacuum motor, valve and sensor
 Red/Green light
 Voice messages
 JoyPad PXN F-16
 Set Speed-PAUSE with analog input

Slot 202 = 1000
 Option Speed 9

```

===== HARDWARE
MicroStepper stepper 1/32 stepper as step for run
Gear ratio for M0 and M1 1:4 Step x mm = 800 x 360 / 360 = 59.556 ?
Leadscrew: 4mm for one turn

===== HARDWARE SET UP DVR8825
Motor M1 current 200 mA
Microstep "ABC" 32 Speed 40000 Acc 250 Step/mm /4.2 reduction ratio 4:1
Motor M2 current 200 mA
Microstep "ABC" 32 Speed 50000 Acc 250 Step/mm /4.2 reduction ratio 4:1
Motor Z current 200 mA
Microstep "BC" 8 Speed 2000 Acc 100 Step 400 leadscrew: 4mm turn

Load SCARA_Z_M1_M2.jpg
TTS SelectVoice "ENG"
TTS SetVolume 100
TTS SetSpeed -1
s1 = TTSvoices
Beep "2000 50"

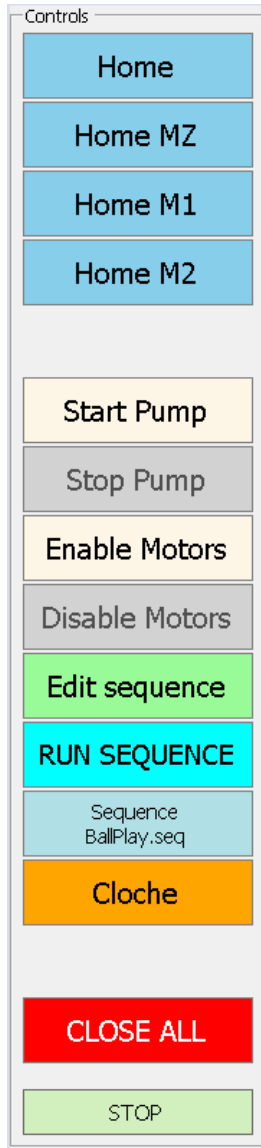
[ BUTTONS ]
Button 1 Text Home
Button Home Text "Home"
      
```

Speed Zoom Transp. Scroll disabled

Ln: 2 Col: 1 Lines: 1001

Loaded program : SCARA_black_V16.txt (load time = 1223 mS)

Theremino Automation



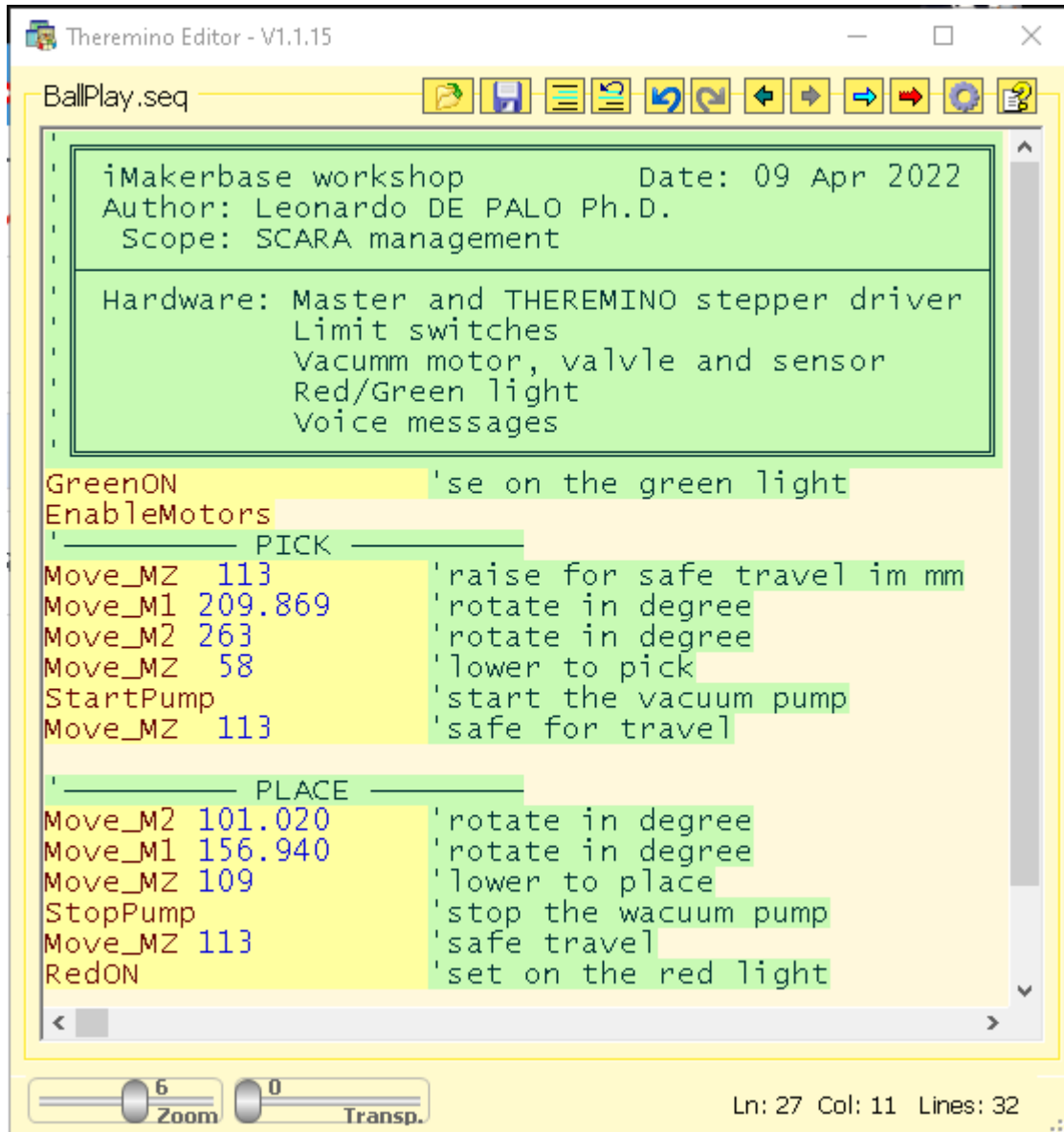
The language Theremino Automation is an OPEN SOURCE project, that was invented to simplify the interaction between sensor and actuator, with particular attention to the Stepper Motor, for the users that are not a professional programmer.

To store the instruction to send to the robot, we use a text file called SEQUENCE.

www.theremino.com/downloads/automation

语言 Theremino 自动化是一个开源项目, 发明它是为了简化传感器和执行器之间的交互, 特别注意步进电机, 对于不是专业程序员的用户. 为了存储发送给机器人的指令, 我们使用了一个名为 SEQUENCE 的文本文件。。

Sequence of Theremino Automation



```
Theremino Editor - V1.1.15
BallPlay.seq
iMakerbase workshop      Date: 09 Apr 2022
Author: Leonardo DE PALO Ph.D.
Scope: SCARA management

Hardware: Master and THEREMINO stepper driver
Limit switches
Vacumm motor, valvle and sensor
Red/Green light
Voice messages

GreenON                    'se on the green light
EnableMotors
'----- PICK -----
Move_MZ 113                'raise for safe travel im mm
Move_M1 209.869           'rotate in degree
Move_M2 263               'rotate in degree
Move_MZ 58                'lower to pick
StartPump                  'start the vacuum pump
Move_MZ 113               'safe for travel

'----- PLACE -----
Move_M2 101.020           'rotate in degree
Move_M1 156.940          'rotate in degree
Move_MZ 109              'lower to place
StopPump                   'stop the wacuum pump
Move_MZ 113              'safe travel
RedON                      'set on the red light

Zoom 6  Transp. 0
Ln: 27 Col: 11 Lines: 32
```

The commands stored into the Sequence file are very simple, intuitive and self explanatory.

The special editor avoid to use type mistake in the commands

存储在序列文件中的命令非常简单、直观且一目了然。

特殊编辑器避免在命令中使用类型错误。

Theremino other applications



On a web page we have reported all the applications, some totally innovative.

All strictly OPEN SOURCE.

www.theremino.com/en/applications

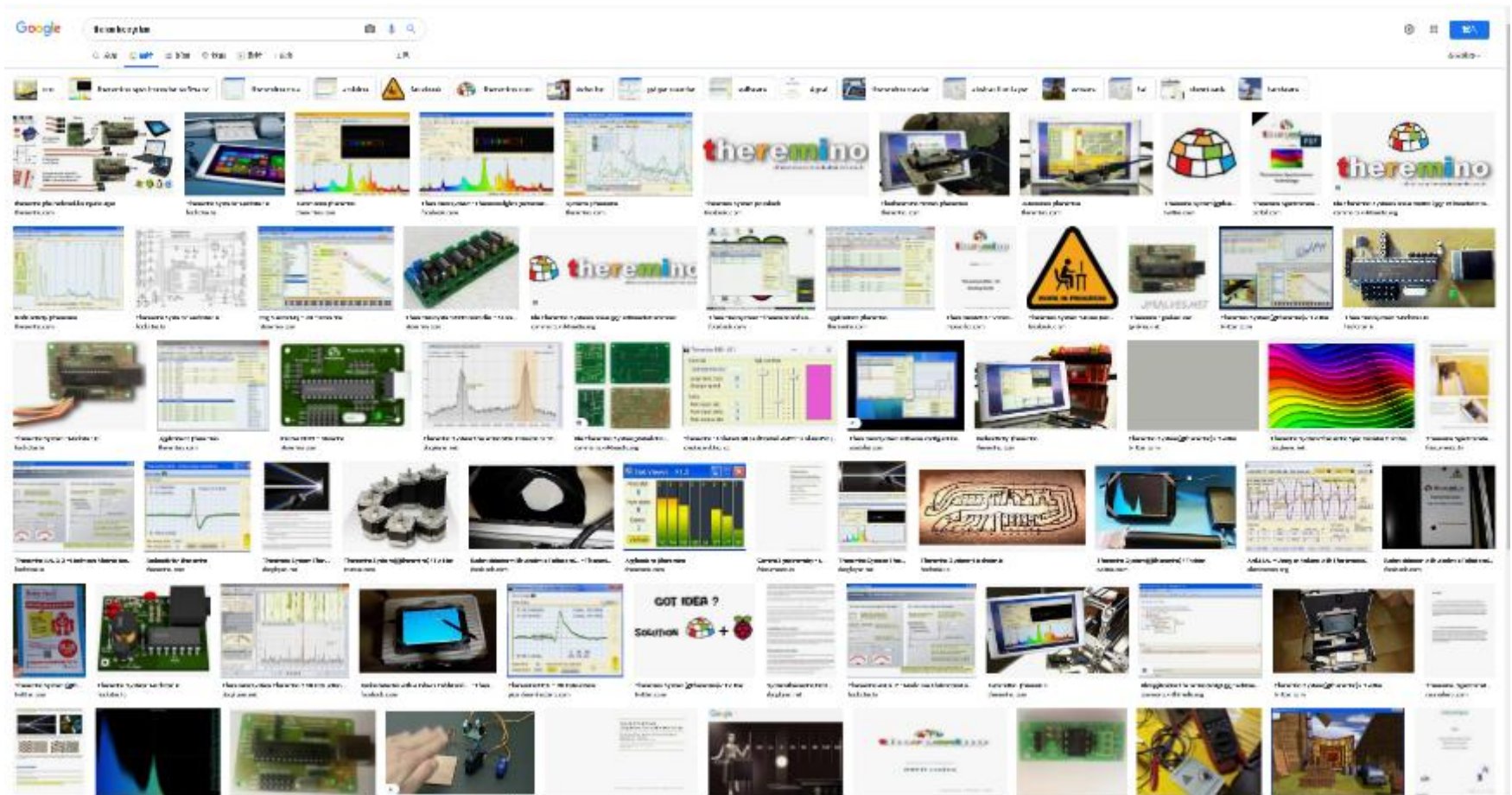
在一个网页上，我们报告了所有的应用程序，其中一些是完全创新的。全部严格开源。

www.theremino.com/zh/applications。

Theremino devices

... and much more.

.....还有许多其他人。



**For more info, search the word:
“theremino”**

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THANKS FOR YOUR TIME

谢谢你的时间