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# Controller Design and Fabrication Supporting Services An Introduction

by

**DMSF**  
Design & Manufacturing Services Facility

09/01/2017

Controller Design & Fabrication Supporting Service - an Introduction

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- ❖ Introduction of DMSF – DS Service
- ❖ Outline of available technology and resources
- ❖ Case studies and experience sharing

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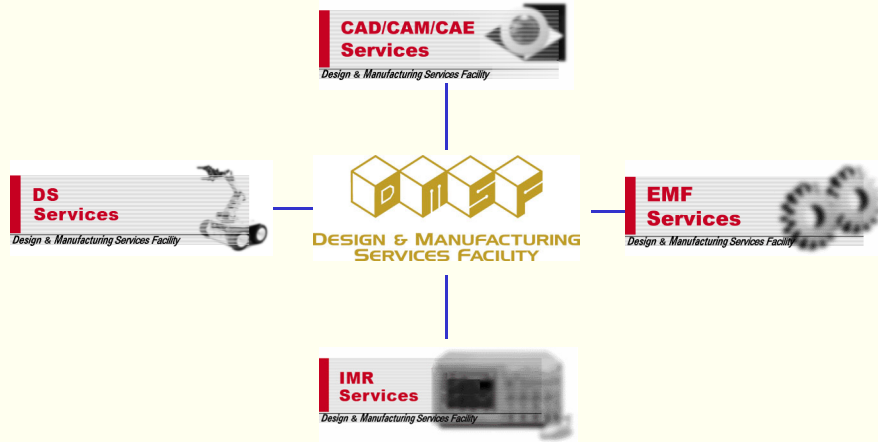
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# Introduction of DMSF – DS Service



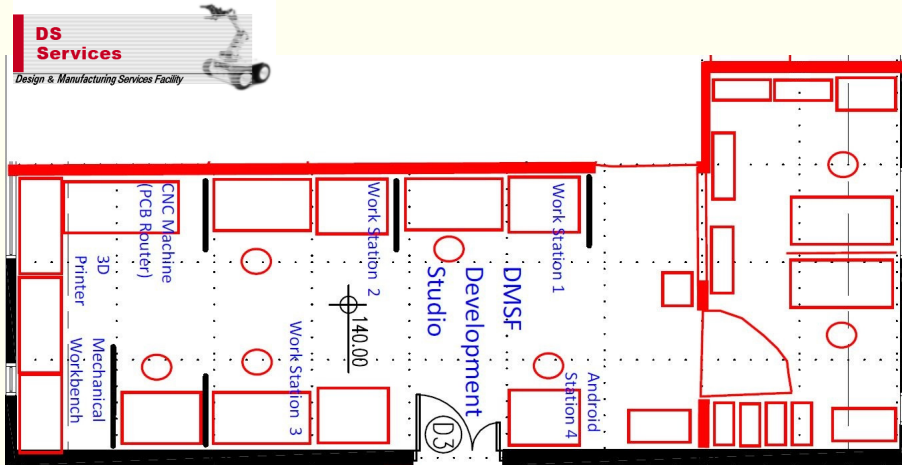
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# Introduction of DMSF – DS Service



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## Introduction of DMSF – DS Service

- Room 4610 Annex 4/F (Lift 31 or 32).
- Controller design and fabrication supporting
  - Teaching and learning activities, academic research and industrial collaboration projects.
- 3 x Workstations & 1 x Android Station
  - Various types of controller boards, MCUs, cam, motors, sensors (environmental, motion, light, etc.).
- Technical interflow and/or practicing the controller design and fabrication tasks
- Advance booking or drop-in:
  - Mr. William Tai (2358.8097) / Mr. Anthony Yam (2358.8900).

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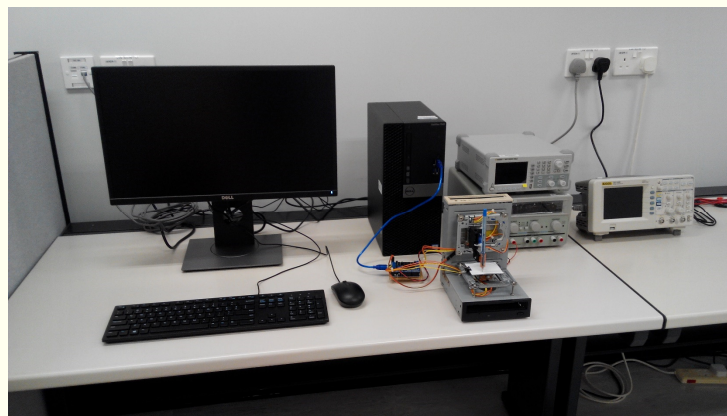
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## DS – Rm4610

- Workstations for development



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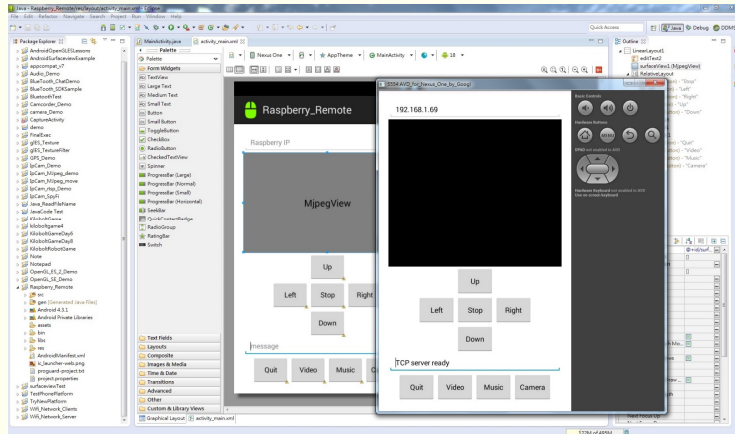
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# DS – Rm4610

- Eclipse for android Development



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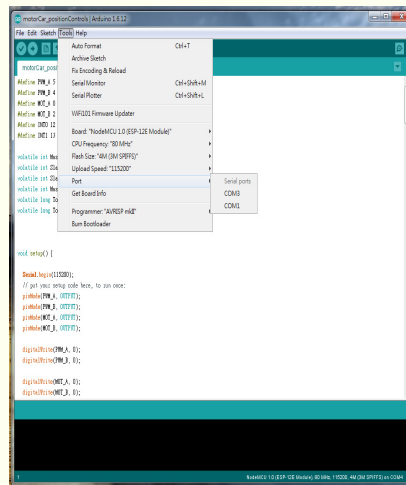
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# DS – Rm4610

- Arduino IDE
- For Raspberry Pi, SSH (putty) is used.



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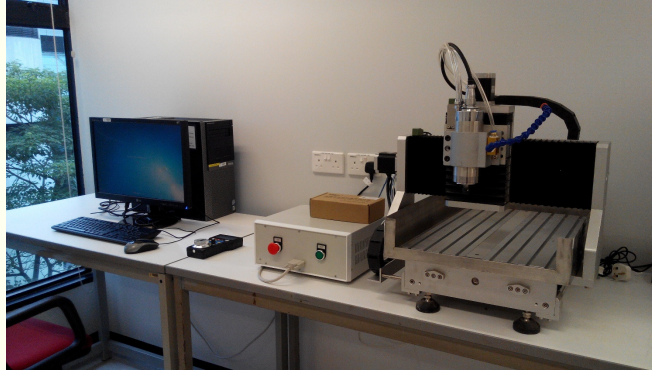
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## DS – Rm4610

- PCB milling CNC machine



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## DS – Rm4610

- 3D printer



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## Tailor-made vs Standard development board

- Tailor-made board:
- Circuit design + PCB layout => requires solid electronic background.
- PCB assembling, such as surface mount IC soldering, is not an easy job.
- Component purchasing is also a time consuming task.
- If the PCB assembly has problem, trouble shooting is very difficult.
- The overall production cost will be very high.



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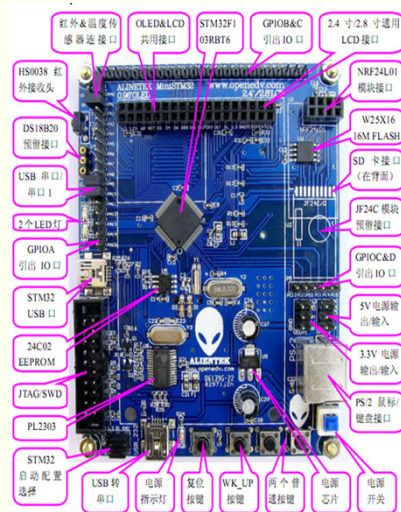
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## Development board

- The development board module has a lot of I/O ports, it's easy to plug in add-on module



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## Controller Candidates

- 8051/8052/C8051F
- stm32
- Arduino
- Raspberry Pi



## 8051/C8051F

- C8051F320/F340: 8 bit, 25Mhz
- Enriched peripherals : UART, PWM, ADC, DAC, ISC, SPI ...
- Language : Assembly, C
- RTOS : ucosII, RTX51 Tiny Real-Time Kernel (Keil, not free)
- IDE : Keil C for 8051
- Tools : U-EC6





# Stm32

- 32 bit, RISC (48 ~ 216 Mhz)
- High speed, rich in peripherals (ADC DAC PWM UART...)
- Language : C
- RTOS: ucos II/ucosIII
- GUI : ucgui
- 3.3V input/output  
not 5V compatible !!!



# Keil C / debugger

```

13  * TIME. AS A RESULT, STMICROELECTRONICS SHALL NOT BE HELD LIABLE FOR ANY
14  * DIRECT, INDIRECT OR CONSEQUENTIAL DAMAGES WITH RESPECT TO ANY CLAIMS ARISING
15  * FROM THE CONTENT OF SUCH FIRMWARE AND/OR THE USE MADE BY CUSTOMERS OF THE
16  * CODING INFORMATION CONTAINED HEREIN IN CONNECTION WITH THEIR PRODUCTS.
17  *
18  * ch2<center>copy: COPYRIGHT 2011 STMicroelectronics</center></h2>
19  *****
20  */
21
22  /* Includes ----- */
23  #include "stm32f10x.h"
24  /* Private typedef ----- */
25  /* Private define ----- */
26  /* Private macro ----- */
27  /* Private variables ----- */
28  /* Private function prototypes ----- */
29  /* Private functions ----- */
30
31  /**
32   * @brief Main program.
33   * @param None
34   * @retval None
35   */
36  int main(void)
37  {
38  }
39  while(1);
40
41  /**
42   * ***** (C) COPYRIGHT 2011 STMicroelectronics *****END OF FILE*****

```

J-link V8



ULink2







# Arduino

- Easy to program (C language)
- Low development cost
- Tons of information and libraries (C++) are available in the internet.
- Large number of sensors and add-on shields
- Programmer/debugger: not required.
- IDE free to download



# Arduino board Comparison

	Processor	Processor Voltage	Supply Voltage	Flash	SRAM	Digital I/O Pins	PWM Pins	Analog Inputs	Hardware Serial Ports	Dimensions	Shield Compatibility	Notes and Special Features
Uno	16MHz Atmega 328	5v	7-12v	32Kb	2Kb	14	6	6	1	2.1"x2.7" 53x75mm	Excellent (most will work)	
Uno Ethernet	16MHz Atmega 328	5v	7-12v	32Kb	2Kb	14	6	6	1	2.1"x2.7" 53x75mm	Very Good (some pin conflicts)	Has Ethernet Port. Requires FTDI cable to program.
Mega	16MHz Atmega 2560	5v	7-12v	256Kb	8Kb	54	14	16	4	2.1"x4" 53x102mm	Good (some pinout differences)	
Mega ADK	16MHz Atmega 2560	5v	7-12v	256Kb	8Kb	54	14	16	4	2.1"x4" 53x102mm	Good (some pinout differences)	Works with Android Development Kit.
Leonardo	16MHz Atmega 32U4	5v	7-12v	32Kb	2.5Kb	20*	7	12*	1	2.1"x2.7" 53x75mm	Fair (many Pinout Differences)	Native USB capabilities. USB Micro B programming port.
Due	84MHz ARM SAM3X8E	3.3v	7-12v	512Kb	96Kb	54	12	12	4	2.1"x4" 53x102mm	POOF (voltage and pinout differences)	Fastest processor. Most memory. 2-channel DAC. USB micro B programming port. Native micro AB port.
Micro	16MHz Atmega 32U4	5v	5v	32Kb	2.5Kb	20*	7	12*	1	0.7"x1.9" 18x49mm	N/A	Smallest board size. Native USB capabilities.
Flora	8MHz Atmega 32U4	3.3v	3.5-16v	32Kb	2.5Kb	8*	4	4*	1	1.75" dia 44.5mm dia	N/A	Sewable Pads. Fabric-friendly design. Native USB Capabilities
DC Boarduino	16MHz Atmega 328	5v	7-12v	32Kb	2Kb	14	6	6	1	0.8"x3" 20.5x76mm	N/A	Can build without headers or sockets for smaller size. Requires FTDI cable for programming.
USB Boarduino	16MHz Atmega 328	5v	5v (USB)	32Kb	2Kb	14	6	6	1	0.8"x3" 20.5x76mm	N/A	Can build without headers or sockets for smaller size. USB Mini B programming port.
Menta	16MHz Atmega 328	5v	7-12v	32Kb	2Kb	14	6	6	1	0.8"x3" 20.5x76mm	Excellent (most will work)	Mini-Tin Size and Prototyping Area. Requires FTDI cable for programming.





# Arduino Yun

- Dual CPU
- Microcontroller: ATmega32U4
- Processor: Atheros AR9331 (400MHz)  
OS : Openwrt
- Ethernet: 802.3 10/100Mbit/s
- WiFi: 802.11b/g/n 2.4 GHz
- USB Type: 2.0 Host
- Card Reader: Micro-SD



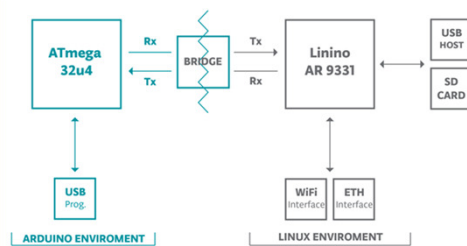
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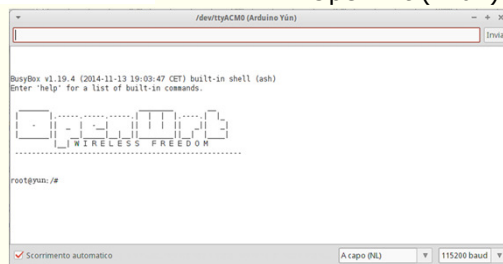


# Arduino Yun



2 processors communicate by UART

Openwrt (Linux)



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## Arduino nano

- ATmega328 16 MHz 5 V
- SRAM: 2 KB
- Analog I/O: 8
- EEPROM: 1KB
- Digital I/O Pins:22
- PWM Output:6
- Small form factor



## Arduino Ethernet shield

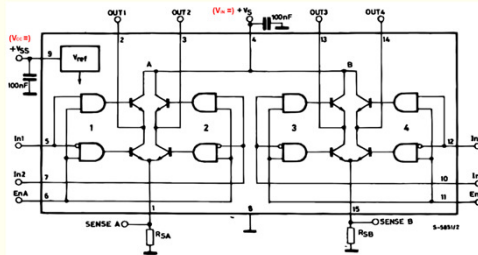
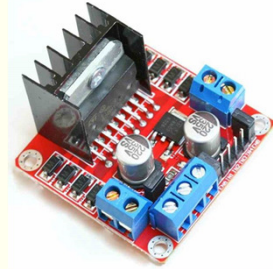
- W5100
- Support Hardwired TCP/IP Protocols : TCP, UDP, ICMP, IPv4 ARP, IGMP, PPPoE, Ethernet
- 10/100BaseTX Ethernet PHY embedded
- Internal 16Kbytes Memory for Tx/Rx Buffers





# Arduino motor shield

- L298N
- 2 H-bridge driver (5~35V, 25W max)
- 2 DC/stepper motor



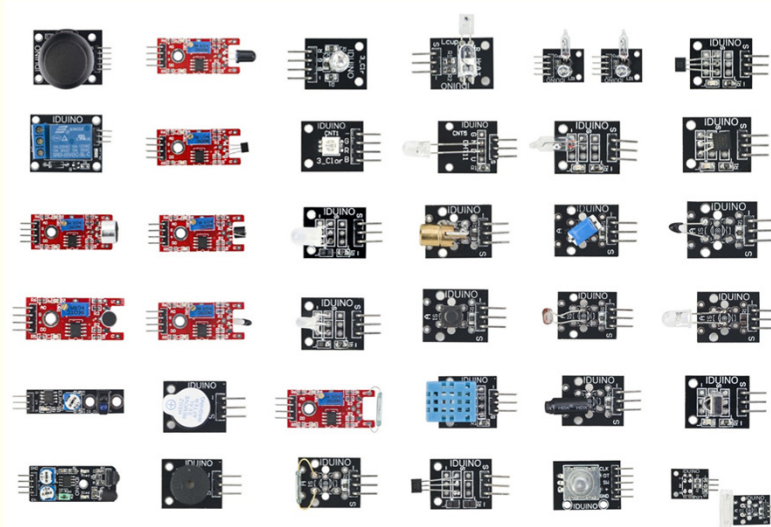
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# Arduino sensors



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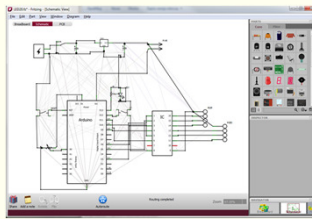
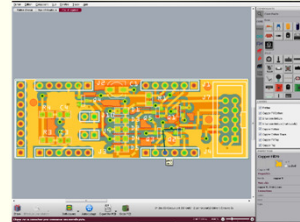
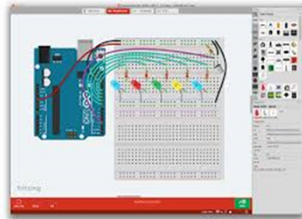
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## Free tool

- Fritzing schematics/PCB drawing tools



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## GUI Accessory

- USART HMI
- Screen size: 2.2", 2.4", 3.2", 3.5", 4.3", 7"
- Connection : 4 wire only (Tx, Rx, 5V, Gnd)



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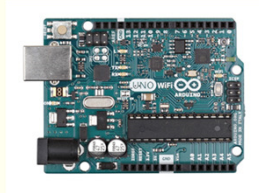
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# Arduino connectivity

- Wi-fi

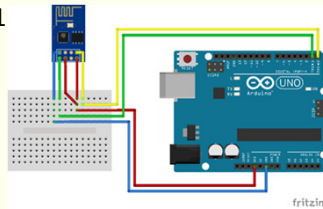


UNO WiFi



WiFi Shield

ESP-01



Yun



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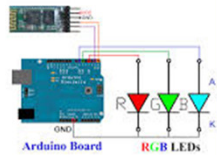
# Bluetooth



Android Device

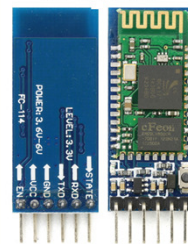


Bluetooth Module

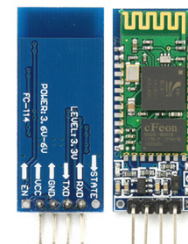


## HC05, HC06

HC-05 FC-114



HC-06 FC-114



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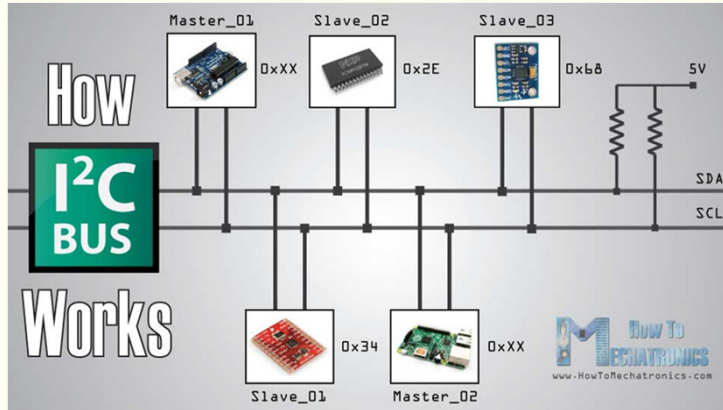
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# I<sup>2</sup>C



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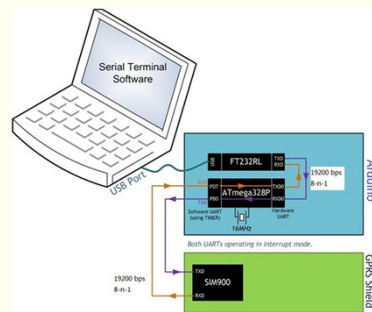
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# USB / UART

- Connects the Arduino board to PC via the USB port.
- Using C# or VB.net to write a program to communicate with the Arduino. (client)
- Arduino acts as a command decoder (server)
- USB to Serial convertor (TTL)



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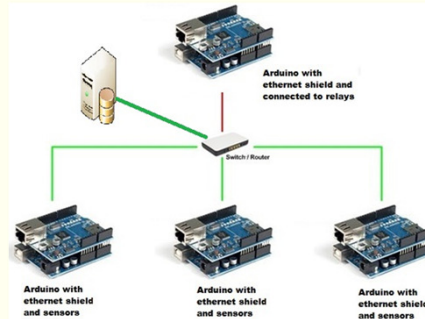
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## Ethernet RJ45

- Each Arduino board with the Ethernet shield has a unique IP address.
- Arduino acts as the sensor node.



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## Typical Application

- Typical framework:
- Add database server to the sub-net, and each Arduino inserts sensors data to the database periodically.
- LAMP (Linux + PHP + Apache + mysql)  
<https://bitnami.com/stack/lamp/installer>
- WAMP (Windows + PHP + Apache+ mysql)  
<http://www.wampserver.com/en/>
- Operator can view sensor data via browser.

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# Raspberry Pi

- SoC: Broadcom BCM2837 CPU: 4× ARM Cortex-A53, 1.2GHz, single 5V operated.
- OS: Raspbian, Windows 10 iot-core, Ubuntu, OSMC .....
- 2 mode: X-window and text mode
- RAM: 1GB LPDDR2 (900 MHz)
- GPU: Broadcom VideoCore IV
- Networking: 10/100 Ethernet, 2.4GHz 802.11n wireless
- Bluetooth: Bluetooth 4.1 Classic, Bluetooth Low Energy
- Ports: HDMI, 3.5mm analogue audio-video jack, 4× USB 2.0, Ethernet, Camera Serial Interface (CSI), Display Serial Interface (DSI)



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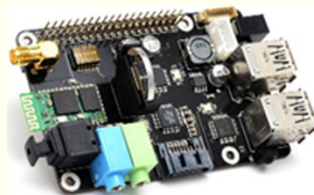
# RPi Accessories



X100



X200



X300



X505

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# RPi Accessories

KEY FEATURES	X100 热卖中	X105 新产品	X200 热卖中	X300 热卖中	X500 暂不供应	X505 新产品	
适用于树莓派版本	Model B	Model B+				Compute Module	
	RASPBERRY (Debian Wheezy)						
	6~23Vdc	6~23Vdc	6~21Vdc	6~21Vdc	6~21Vdc	6~21Vdc	
支持操作系统							
宽电压输入	6~23Vdc	6~23Vdc	6~21Vdc	6~21Vdc	6~21Vdc	6~21Vdc	
自供电 USB 接口	3	3	3	3	8	8	
主板排针扩展	✓	✓	✓	✓	-	-	
VGA 输出	✓	✓	✓	✓	✗	✗	
实时时钟 (RTC)	✓	✓	✓	✓	✓	✗	
8路 GPIO 控制 (LJLN2803)	✓	✗	✓	✓	✗	✗	
IR 红外接收 (38KHz)	✗	✗	✓	✓	✓	✗	
RS232 DB9 串口	✓	✓	✗	✗	✗	✗	
WiFi (IEEE 802.11b/g/n)	✗	✗	✓	✓	✓	✗	
蓝牙串口通讯 V2.1+ EDR	✗	✗	✗	✓	✗	✗	
3.5mm 麦克风输入插座	✗	✗	✓	✓	✓	✓	
3.5mm 立体声音频输出插座	✗	✗	✓	✓	✓	✓	
音频输入输出连接器	✗	✗	✓	✓	✓	✗	
SPDIF 光纤输出	✗	✗	✓	✓	✓	✗	
立体声音频功放 3.3W x2	✗	✗	✓	✓	✗	✗	
SATA 接口	✗	✗	✗	✓	✓	✓	
电源输出连接器	✗	✓	✓	✓	✓	✗	
Micro-SD 卡槽	✓	✓	✗	✗	✗	✗	
主板复位开关	✓	✗	✗	✗	✗	✗	
按钮开关断开主板连接	✓	✓	✓	✓	-	-	
10/100 以太网 RJ45 座	-	-	-	-	✓	✓	
HDMI 输出	-	-	-	-	-	✗	
GPIO bank x2	-	-	-	-	✓	✗	
DSI 显示屏连接器 x2	-	-	-	-	-	✗	
CSI 相机连接器 x2	-	-	-	-	✓	✗	
DDR2 SODIMM module sock	-	-	-	-	-	✗	
Micro-USB 数据接口	-	-	-	-	✓	✗	

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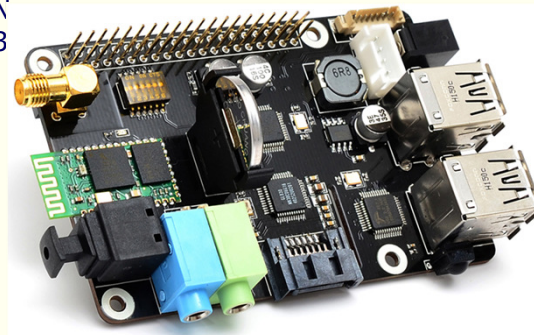
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# X300

- SATA- Allows you to connect SATA devices to your Raspberry Pi
- Real-time clock (RTC) Based on DS3231SN with included CR2032 battery
- WiFi (IEEE 802.11b/g/n) with external antenna
- IR sensor (38KHz)
- Bluetooth serial communication



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## Western Digital Pdrive

- Software included on SD card, low power consumption
- Capacity: 250GB -375GB, 1TB



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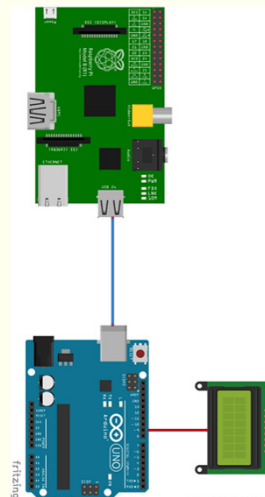


## RPi and Arduino connection

- Direct connect Arduino to Raspberry pi via USB
- Raspbian Jessie : =>/dev/ttyUSB0
- Python:  

```
import serial  
port = serial.Serial("/dev/ttyUSB0",  
    baudrate=9600, timeout=None)
```
- Node.js  

```
var com = require("serialport");  
var serialPort = new  
    com.SerialPort("/dev/ttyUSB0",  
    {baudrate: 9600,  
    parser:com.parsers.readline("\n")  
});
```



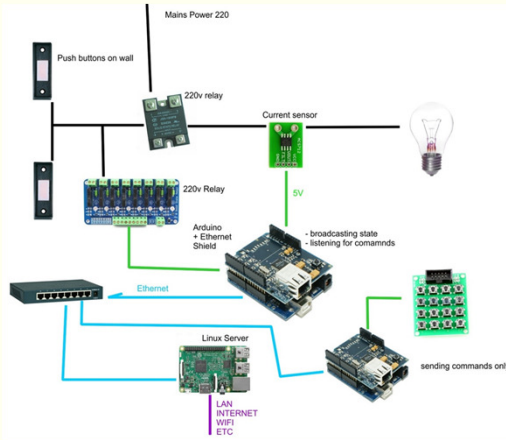
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# Ethernet/WiFi intranet



RPi – Database, Web server  
 Arduino - sensor node  
 Http Get Post(Arduino)



# Arduino code

- Arduino sends :  
<http://192.168.1.98/addrrecord.php?temp=23&humidity=70&light=50>
- 192.168.1.98 is the server address

```
#include <Ethernet.h>
...
byte mac[] = { 0x00, 0xAB, 0xBA, 0xBC, 0xDD, 0x02 };
EthernetClient client;
...
...
Ethernet.begin(mac);
...
...
client.print("GET 192.168.1.123/addrrecord.php?");
client.print("temp=");
client.print(temperature_value); // temperature_value=23
client.print("&humidity=");
client.print(humidity_value); // humidity_value=70
client.print("&light=");
client.print(light_value); // light_reading=50
...

```





## PHP: addrecord.php

- addrecord.php :

```
<?php
include("connect.php");
$link=Connection();
$sql="insert into environment_table (temp,humidity,light) values ('".$_GET["temp"]."',
".$_GET["humidity"]."', '".$_GET["light"]."')";
mysql_query($sql,$link);
header("Location: view_data.php");
?>
```



## PHP: connect.php

- RPI side:
- connect.php :

```
<?php
function Connection(){
if (!$link=mysql_connect("127.0.0.1","root","nopassword")) {
echo "mysql connection failed !";
exit();
} else {
echo "mysql connection ok !";
}
if (!mysql_select_db("environment_db",$link)){
echo "db connection failed !!!";
exit();
} else {
echo "db connection ok !!!";
}
return $link;
}
?>
```





## PHP: view\_data.php

```
• <html>
• <head>
• <title>Data of Sensor</title>
• </head>
• <body>
• <h1>Data from the DHT-11 and Light sensor</h1>
• <hr>
• <?php
• include("connect.php");
• $link=Connection();
• $result=mysql_query("select * from environment_table order by id desc",$link);
• ?>
• <table border="1" cellspacing="1" cellpadding="1">
• <tr>
• <td>&nbsp;Temperature &nbsp;</td>
• <td>&nbsp;Humidity &nbsp;</td>
• <td>&nbsp;Light &nbsp;</td>
• </tr>
• <?php
• while($row = mysql_fetch_array($result)) {
• printf("<tr><td> &nbsp;</td><td> &nbsp;</td><td> &nbsp;</td></tr>",
• $row["temp"], $row["humidity"],$row["light"] );
• }
• mysql_free_result($result);
• ?>
• </table>
• </body>
• </html>
```

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## View by browser

Temperature	Humidity	Light
5	5	5
18	20	23
27	37	47
30	31	32
25	77	50
13	50	60
25.60	78	45

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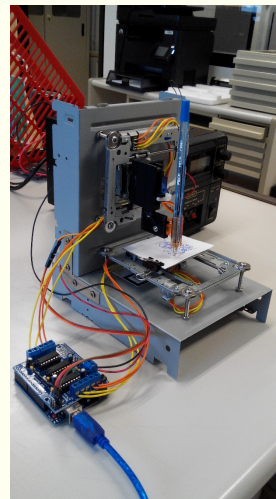
## DMSF Projects related to Raspberry Pi and Arduino

William Tai and Anthony Tam



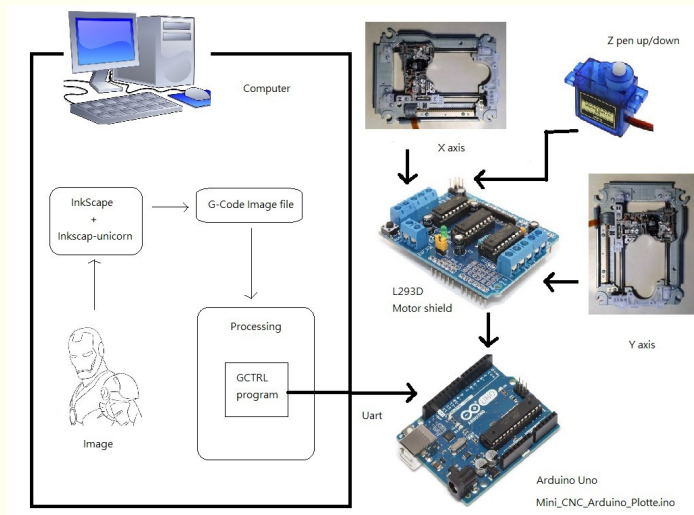
## Arduino mini CNC plotter

- Arduino Uno and L293D motor shield use to drive.
- G-code file uses to command Arduino to move X-, Y- and Z-axis.
- X- and Y-axis are two stepper motors and rails from DVD drives.
- Z-axis is a small servo motor that moves the pen up and down.

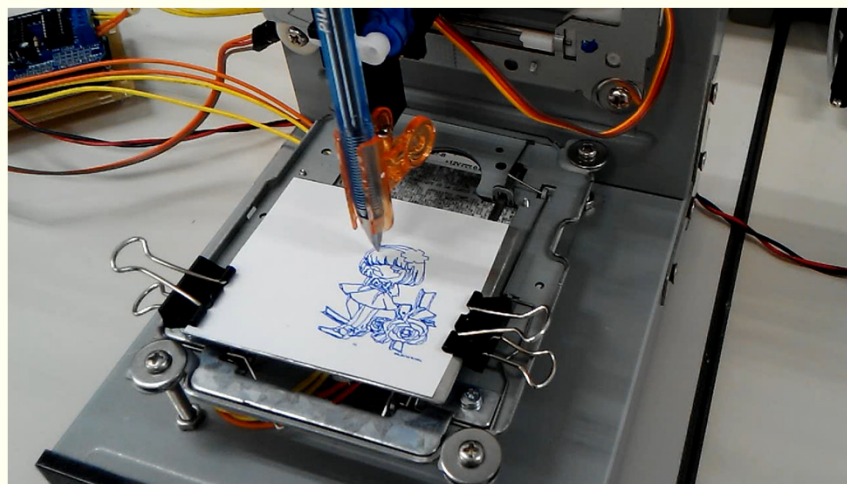




## Arduino mini CNC (win 10)



## XY Plotter performance







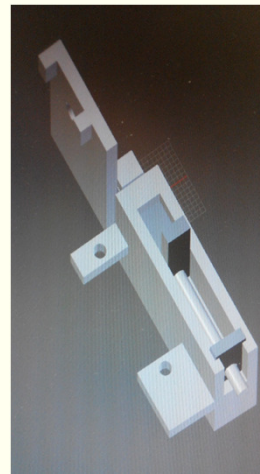
## Why we choose this project

- Most likely, the coding and design can be used at later project
  - XY table is a very common device.
  - G-code also is the most widely used CNC Language.
- Can emulate the fabrication process of 3D printing
- Potential for further development



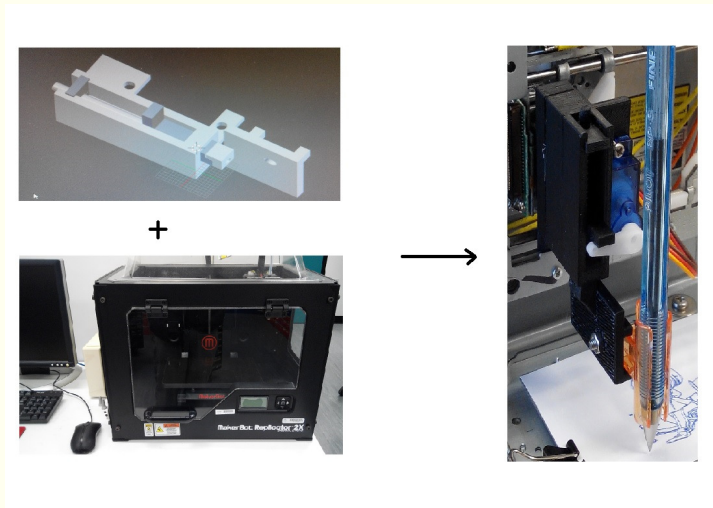
## Z axis pen up/down - 3D printing

- Blender 3D is used to model the pen holder.
- Export STL file to MakerBot 3D printer.
- The final parts dimension is not quite accurate.
- The outer dimension is OK but not for small parts, some holes and slots.
- A little adjustment are necessary

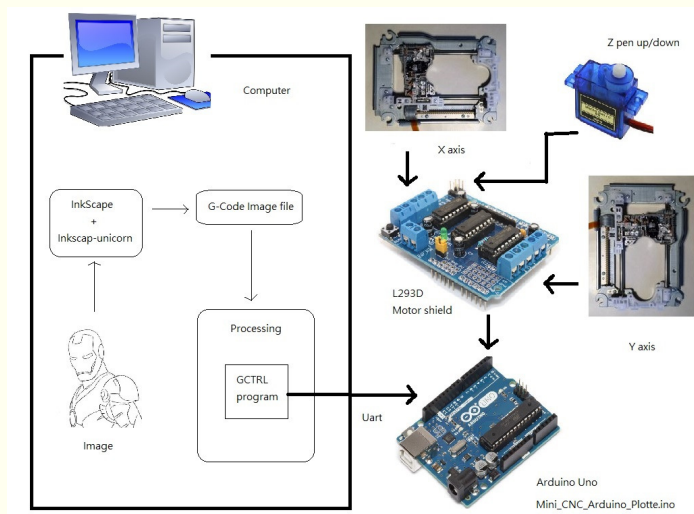




## Z axis pen up/down - fabrication

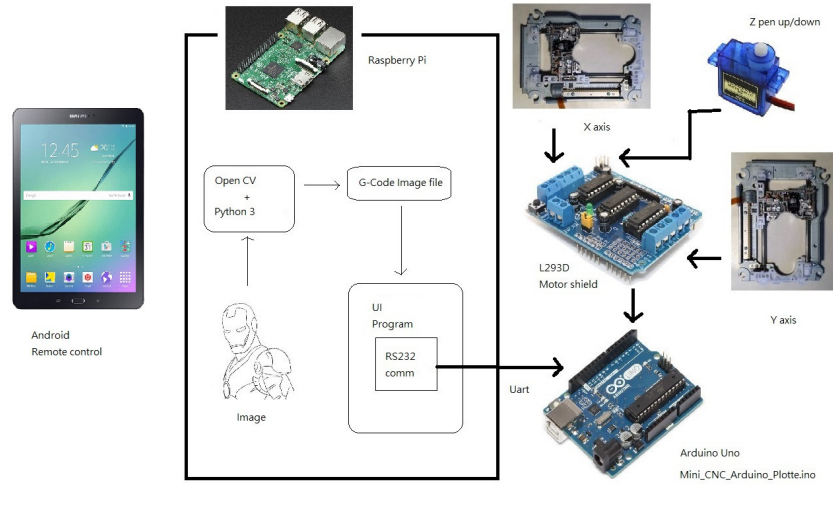


## Further development of mini CNC

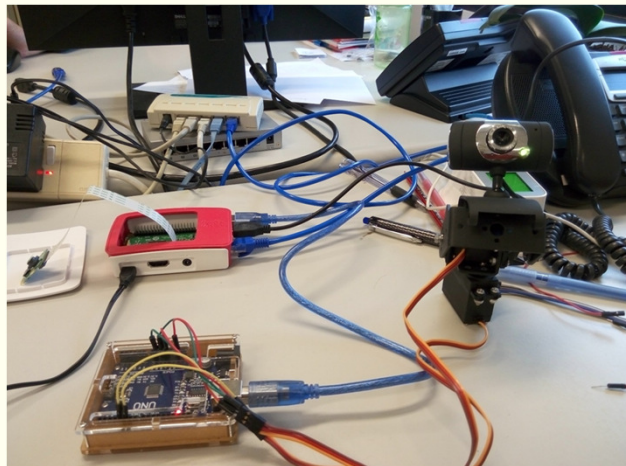




# Arduino mini CNC (Raspberry Pi)



# Web Camera Controller





## Web Camera Controller

- Both Arduino and Webcam are plugged into USB port of the RPI.
- RPI : node.js -> express + socket.io + johnny-five + serialport
- USB Web camera : `mjpg_streamer' -i "input_uvc.so" -o "output_http.so -w /usr/www"`
- Raspi-camera : `mjpg_streamer' -i "input_raspicam.so" -o "output_http.so -w /usr/www"`
- Arduino : Standard Firmata
- Two servo are connected to PIN 4 and 5 of the Arduino.

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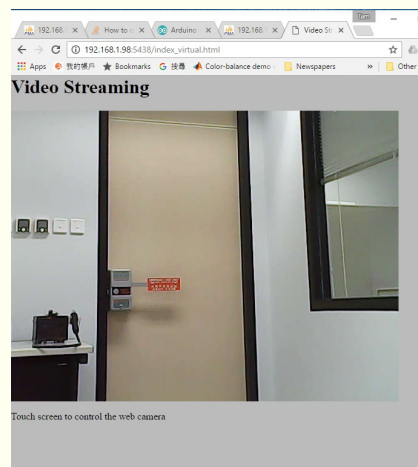


## Web Camera Controller

In the browser, type :

[http://192.168.1.98/index\\_virtual.html](http://192.168.1.98/index_virtual.html)

to enter into the web page,  
then uses the touch panel  
to control the two servo.



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## PLC (Programmable Logic Controller)



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## Why PLC ?



- I/O ready: relay, transistor output, optical isolated.
- Easy HMI.
- Power supply ready.
- Very reliable.
- Good for positioning control.
- Functions build-in: PID, hardware acc/dec, pwm, encoder...

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## PLC

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- Big.
- Expensive-- PLC HK\$ 1000, HMI HK\$1000
- Slow--1ms/scan
- Limited connection port, limited memory, no video / audio / WiFi...



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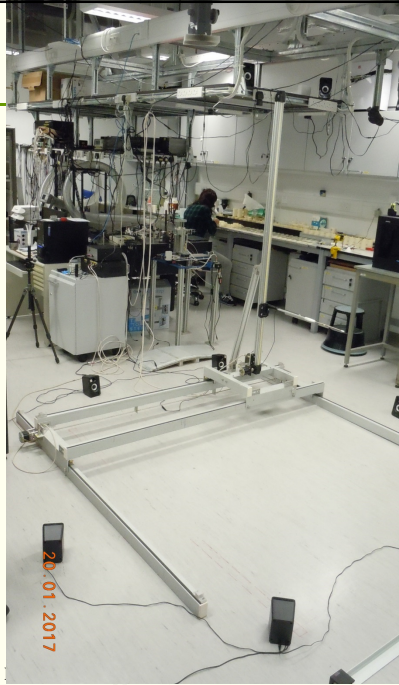
## PLC Projects





Acoustic sensor carrier

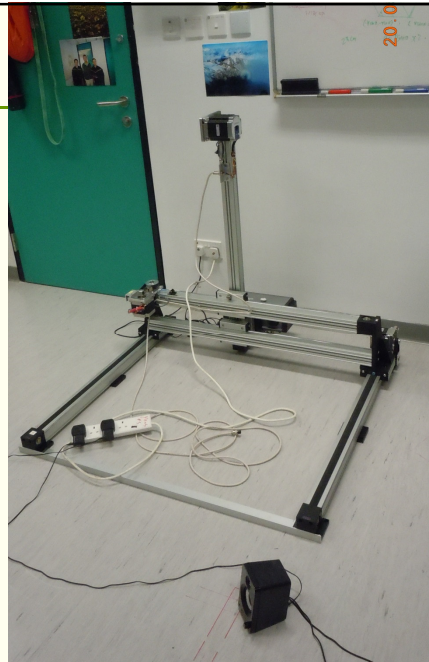
3d  
2m x 2m x 2m



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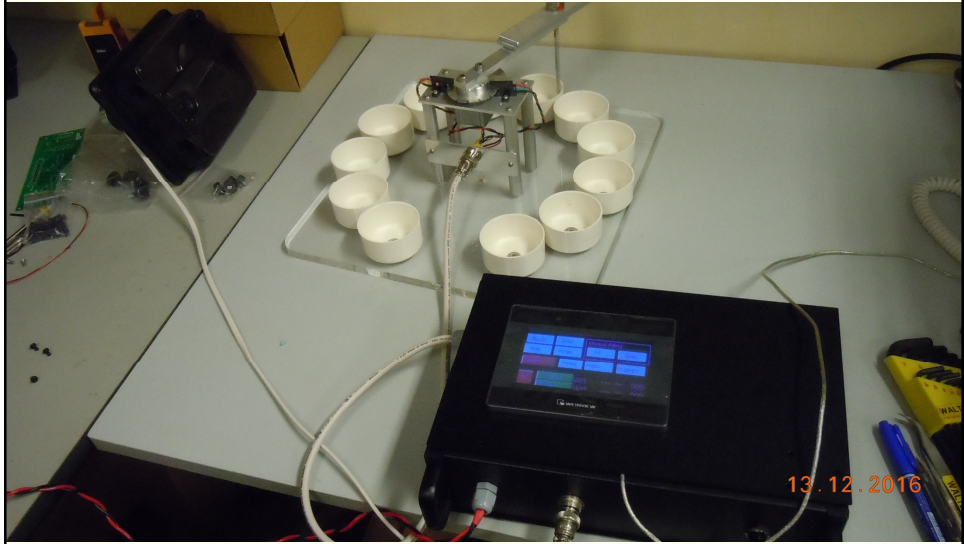
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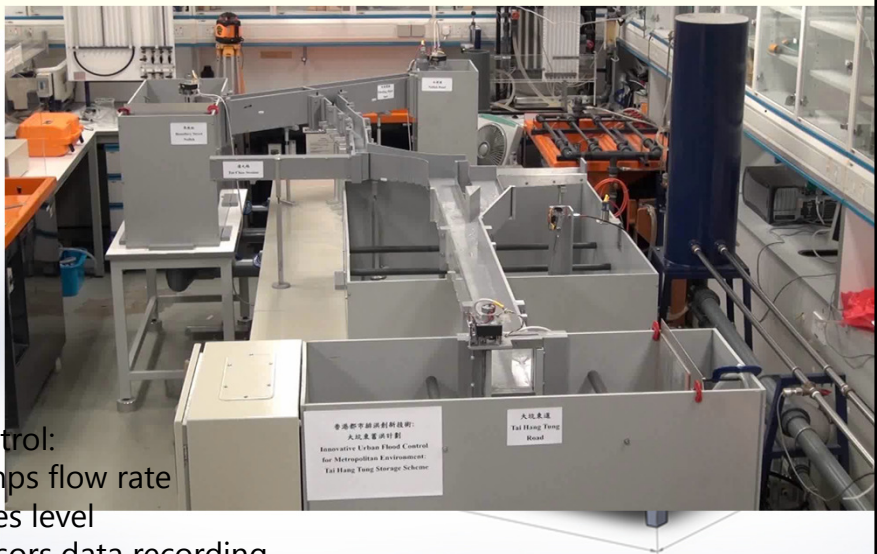
# Water sampler



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Control:  
Pumps flow rate  
Gates level  
Sensors data recording

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## Ion Etcher system

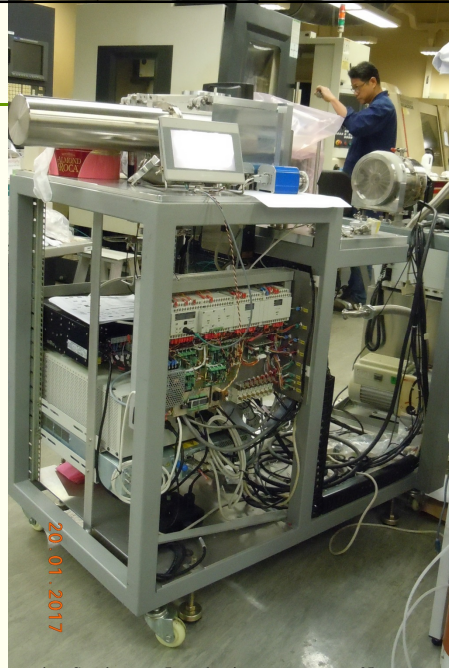
Control valves, HV pumping, Vacuum gauges, Vacuum gates, Loading/Unloading, Electrode movement, Gas pressure...

Handle 47 groups of logic sequence.

Parameter setting.

Display running status and Error message.

Communicate with PC.



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# Case Demo

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