

Actimetre System

Summary Overview

Actimetre is short for "Activity Metre". It is intended to measure the activity of lab animals, typically rats in cages, using commodity electronic components. For a hardware cost of less than 10€ per cage, the system can record 6 axes of activity (acceleration XYZ and gyroscope XYZ) at up to 100Hz.

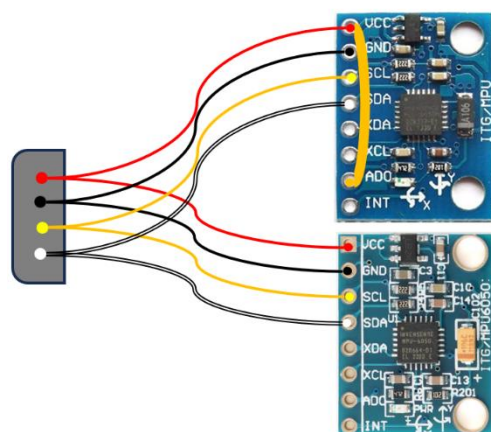
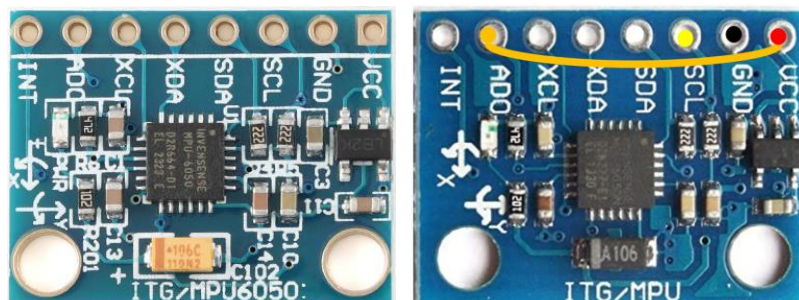
At the base of the system is the MPU-6050 sensor which measures XYZ-axis acceleration and XYZ-axis rotational speed at up to 4kHz. At the next level is a ESP32-S2 which has 2 I2C ports. It can therefore control up to 4 sensors (2 addresses on 2 ports). The ESP32-S2 supports WiFi, so it connect to the Actiserver. The latter is an OrangePi Zero3 running Debian Linux, and provides the WiFi AP service to the ESP32-S2, as well as being the data repository. It is also connected via Ethernet to the central dashboard which helps monitor and manage the system. The whole system can theoretically contain up to 35000 sensors.

The entire system is fairly robust to disruption, except the Central component which is assumed to be highly available. Installation and configuration requires some amount of technical knowledge.

Acticentral is a single central server currently running on AWS Lightsail. It has a fixed IP address. Actiservers communicate with Acticentral via HTTP and MQTT. A single instance of the smallest Lightsail type is sufficient for controlling over a dozen Actiserver, and probably much more.

The MPU-6050 sensor

Datasheet here : [MPU-6500 | TDK InvenSense](#). Invensense says it's not recommended for new designs, but it's the only 6-axis sensor chip sold on a consumer-grade module at low cost.



The AD0 pin can be connected to either GND (0x20) or VCC (0x21) to control the sensor's I2C address. The 0x20 is called the "A" sensor, the 0x21 unit is "B".

We need four lines (VCC, GND, SDA, SCL) to reach the S2. One "A" sensor and one "B" sensor forms a pair, and their cables join in a single JST 2.54 4-pin connector.

The cable also has a USB type-A connector for easily attaching/detaching sensors to the Actimetre.

The Lolin S2 mini module

Presentation here: [S2 mini — WEMOS documentation](#). There are numerous copycat modules being sold on AliExpress.com. Most copycats have now solved their quality issues, and the units are reliable. However for best results it is recommended to use Wemos' original units, sold on their official storefront.

The OLED display

The 0.96 inch 128*64 OLED screen with a SSD1306 controller on I2C interface is a ubiquitous component. It can be found from many places from AliExpress.com. Be sure to use the newer, more compact version with yellow and blue lines.

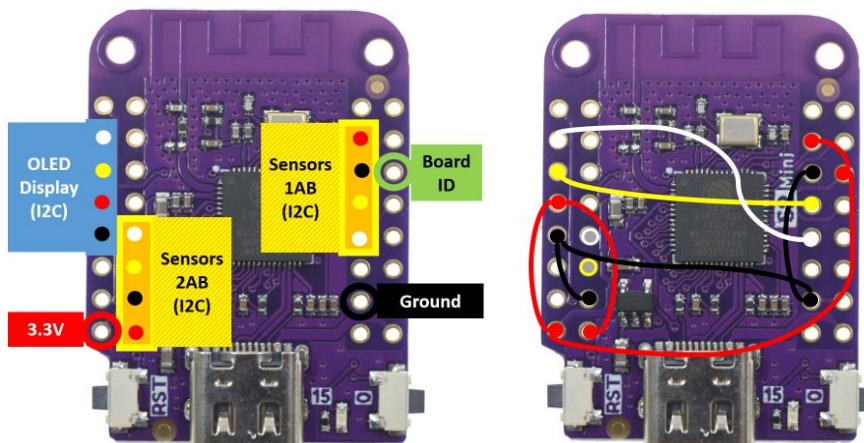
The Actimetre module

An Actimetre is composed of:

- a Lolin S2 mini module made by Wemos (https://www.wemos.cc/en/latest/s2/s2_mini.html)
- a 0.94-inch diagonal 128x64 OLED I2C display
- two 4-pin 2.54mm ports for connecting sensors

Note that these components are directly soldered on the S2 mini module, so the Actimetre doesn't require additional PCB. Each Actimetre draws less than 250mA at most, so they can be powered by low-cost USB 2.0 hubs and 1A power supplies.

The display is on the "up" side, which is the side of the module with the USB connector. The connectors to the sensors (I2C, 4-pin JST 2.54) will be on the opposite side. The display is sharing the I2C port with Sensor pair "1".



There are 9 lines to connect, preferably by wrapping. The JST connectors must be soldered because the legs don't have enough length for wrapping. The screen will be soldered last and will cover all the wires.

Cabling information for S2x board

```

o EN      1 x
:sda: (i)3 2 x
OLED:scl: (j)5 4 x
Disp:vcc: (ac)7 6 x
:gnd: (vz)9 8 o
x 11 10 o
x 12 13{v}
(ab)3V3 14{c}

          x 40 39 x
:vcc:{d}38 37 x
Sens:gnd:{w}36 35(bd)
#0:scl:{j}34< 33 x
:sda:{i}21< 18 x
          x 17 16 x
          (wz)GN1 GN2 x
          X 15 VBUS X
  
```

Cabling information for S3i board. The I2C0 connector's position is different.

```

X EN      1 x
x 2      3 x
x 3      5 x
:sda: (i)12 6 x
I2C:scl: (j)13 7 o
Disp:vcc: (ac)11 8 o
:gnd: (yz)10 9{y}
(ab)3V3 14{c}

          x 33 43 x
          x 37 44 x
          x 38 36 x
          x 34 35 x
          x 21< 18 x
          #0:scl:{j}17< 16 x
          :gnd:{z}GN1 GN2 x
          :vcc:{b}15 VBUS X
  
```

The Actiserver can be any Linux-based SBC (single-board computer) with both Ethernet and WiFi. It must support WiFi AP (which some USB dongles don't). 1GB of RAM is recommended. The software has been tested on Raspberry

Pi3, Pi3, CM4; NanoPi NEO3 (1GB); OrangePi Zero2 (1GB) and Zero3 (1GB). The OrangePi Zero3 (1GB) has the best cost/performance ratio and support an external antenna for better reception.

The ACTI protocol

Communication between Actimetre and Actiserver is a simple socket connection.

Acticentral communication

Acticentral provides a HTTP CGI entry point.

MQTT

The Acticentral also acts as a MQTT broker for the system.

Recap total BOM for 80-sensor system with 2 servers. Prices are taken from the lowest found on AliExpress.com, including delivery to France. Unit: EURO(€). Acticentral cost is not taken into account. Cost would rise by ~23€ (0,30€ per sensor) if using S3 (capable of 100Hz sampling rate) instead of S2.

Component	Unit price	Units in system	Cost for system	Pro-rated cost per sensor	Note
Sensor	1,60	80	128,00	1,60	In batches of 10
I2C Cable (2x1m 4P)	1,50	40	60,00	0,75	In rolls of 10m or more
USB type-C plug	0,25	80	20,00	0,25	
USB type-A pair	0,90	40	36,00	0,45	
S2 mini module		20	98,58	1,23	Copycats are half this price
OLED display	2,33	20	46,60	0,59	
JST 2.54 4P connector 2 pairs	0,10	20	2,00	0,03	
Power supply (1A)	0,90	5	4,50	0,06	
USB 2.0 hub 4-port	2,30	5	11,50	0,15	
Zero3 (1GB)	21,30	2	42,60	0,54	
256GB microSD (A1)	14,50	2	29,00	0,37	Lowest €/GB ratio
Power supply (2A)	1,50	2	3,00	0,04	
External antenna	1,75	2	3,50	0,04	With APX-to-SMA cable
Total cost excl. assembly			486,68	6,08	

Limitations and Future work