

1 **Supplementary Information**

2 Technical note: Development and field validation of SMART-ASF, a low-cost
3 automated soil gas flux monitoring system for long-term field observations

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Xy_SensorBOX Specification

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Product Name : Xy_SensorBOX (Ver: E0.31361536)

Environmental/Educational Data Logger

Introduction

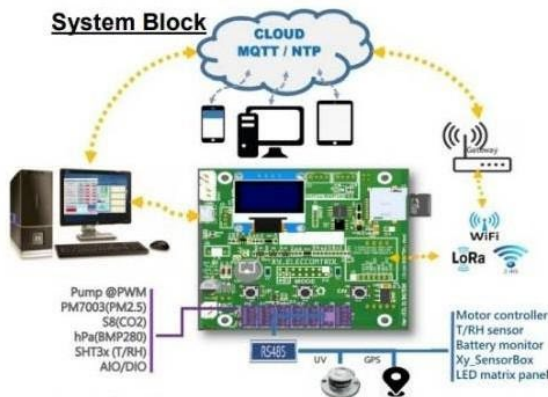
The Xy_SensorBOX is a highly integrated data logger suitable for environmental and educational monitoring applications. It quickly integrates commonly used sensor (T/RH/Pressure(hPa)/VOC /CO2/PM2.5) to meet a variety of professional measurement and analysis needs.

The Xy_SensorBOX provides an engineered user interface and supports raw data acquisition and control functions, including: real-time I/O control mode, programmable mode, and alarm trigger mode.

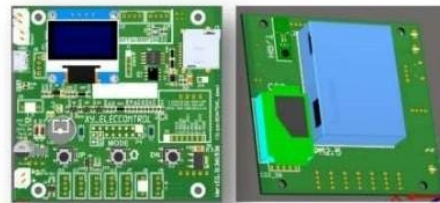
The built-in RF module interface can be used as a gateway for various RF networks:(Lora/2.4G)<->WiFi.

Function

- Onboard sensor:
BMP280(hPa), SHT3x(T/RH), S8(CO2), PMS7003 (PM2.5).
- Communication interface :
USB*1, I2C*1, UART*4(Incl. RS485*1), 2.4G_WiFi, Lora_433MHz.
- 12bit (ADC*4 / DAC*2).
- RS485(5VDC/GND/A/B) for extension.
- Pump driver *2 : 12VDC with PWM Ctrl.
- Supports MQTT Client and Onboard web-server for UI(optional).
- Supports 0.96" OLED (128 * 64).



PCBA 3D



User Interface



Specification

item	Min	Typical	Max	Units
Voltage	5.0	5.5	16	DCV
Operation(T)	-10	--	80	°C
Storage(T)	-30		+85	°C
I/O port	AIO / DIO*(up to 4) / PWM_Out*2			
Sensor	BMP280/SHT3x/G7/S8_CO2			
communication	UART*4(Incl.RS485)/ I2C/ USB/ WiFi			
Memory card	MicroSD card (up to 32GB), FAT			
Dimension	80mm *80mm *30mm			

Figure S1. Detailed hardware specifications and operational parameters of the custom built Xy_SensorBOX developed for the SMART-ASF system. The figure presents the overall hardware architecture, functional modules, communication interfaces, technical specifications, printed circuit board assembly, and graphical user interface of the Xy_SensorBOX, which functions as the central control and data processing unit of the ASF system.

20 **Table S1. Main components used in the development of the SMART-ASF system**

No.	Component/Module	Function/Description	QTY	Manufacturer/Source	Cost (USD)
	ASF System	Integrated automated soil gas flux monitoring unit consisting of gateway (GW), sensor unit (SU), and associated power and communication modules.	1 set		Total: 2637
1	ASF_SU (Sensor Unit)	Main measurement module housing gas sensors, pumps, and data acquisition board.	1 set	XY ELEECONTROL TECHNOLOGY	
1.1	SU Case	Waterproof enclosure for sensor unit (200 × 200 × 130 mm, IP67), with cable glands.	1 set	XY ELEECONTROL TECHNOLOGY	\$28
1.2	SU ASSY	1. Internal sensor–pump assembly for gas flow and chamber connection. 2.XY_eBOX PCBA (E0.31361653), with SU_FW	1 set	XY ELEECONTROL TECHNOLOGY	\$200
1.3	CO ₂ gas sensor	K30 CO ₂ NDIR sensor for concentration measurement	1 pc	Senseair	\$75
1.4	SO ₂ gas sensor (Optional)	ES4 SO ₂ 1000 module	1 pc	ECSense	\$200
1.5	H ₂ S gas sensor (Optional)	H ₂ S sensor 500 module	1 pc	ECSense	\$150
1.6	SHT31 Mini Module	Measures soil gas temperature and relative humidity.	1 pc	XY ELEECONTROL TECHNOLOGY	\$16
1.7	Gas Sensor Chamber	Provides an airtight gas chamber for sensor installation and calibration.	1 set	XY ELEECONTROL TECHNOLOGY	\$21
1.8	Dual Pump Unit (PX215B1, DC12 V)	Regulates chamber air circulation and flushing.	2 pc	Guanlian Industrial Co., Ltd.	\$75
2	ASF_GW (Gateway Unit)	Central control module for data transmission and system synchronization.	1 set	XY ELEECONTROL TECHNOLOGY	
2.1	GW Case (with 4C_cable assembly)	Waterproof enclosure for sensor unit (100 × 100 × 40 mm, IP67).	1 set	XY ELEECONTROL TECHNOLOGY	\$15
2.2	GW_ASSY	1. XY_eBOX PCBA (E0.31361653), with GW_FW 2.WiFi Module (ESP32 with FW)	1 set	XY ELEECONTROL TECHNOLOGY	\$215
3	Power and Charging System	Provides stable 9 V DC supply for sensor and pump operation.	1 set	XY ELEECONTROL TECHNOLOGY	
3.1	Li-ion Battery Pack (24 V, 63.7 Ah)	Main power supply (Samsung INR21700-50E, 4S13P).	1 set	Samsung SDI	\$430
3.2	Solar Panel (300 W, 33 V) + Controller (PS-15M) (Optional if AC power is available)	Enables autonomous charging and energy management for field deployment.	1 set		\$350
3.3	DC-DC Converter (with voltage monitor, RS485)	Regulates voltage for pump and sensor operation.	1 set	XY ELEECONTROL TECHNOLOGY	\$44
4	Auxiliary Components	Structural and connection elements	1 set	Various	

		supporting the ASF system.			
4.1	Baseplate (180 × 180 mm, 3D printing)	Fixation platform for SU components.	1 pc	XY ELEECONTROL TECHNOLOGY	\$7
4.2	Drying Tube & Bracket	Gas dehumidification to protect sensors.	1 set	Perma Pure	\$650
4.3	USB to RS485 adapter (A Type USB to M10_4P_Male)	SU and GW communicate with the PC	1	XY ELEECONTROL TECHNOLOGY	\$10
4.4	Temperature sensor unit (with RS485, IP65)	Measures soil temperature.	2	XY ELEECONTROL TECHNOLOGY	\$38

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