Electronic Project

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VEMAR 

Vehicle for Exploration, Mapping & Air-quality Recon

Overview

VEMAR is a radio-controlled modular reconnaissance vehicle. It's used to conduct recon in places such as caves, mines or collapsed buildings in order to assess the environment before sending in real people.

The system can be configured with a terrain-adapted vehicle chassis, mapping and/or vision sensors, and modules for specific air-quality measurements. Users are able to attach different modules without needing to reprogram the vehicle.

As the user drives the vehicle, sensor data is stored on the removable SD card and displayed on the screen of the controller, allowing safe and easy recon.

Table of Contents

Features

Remote Controlled Vehicle

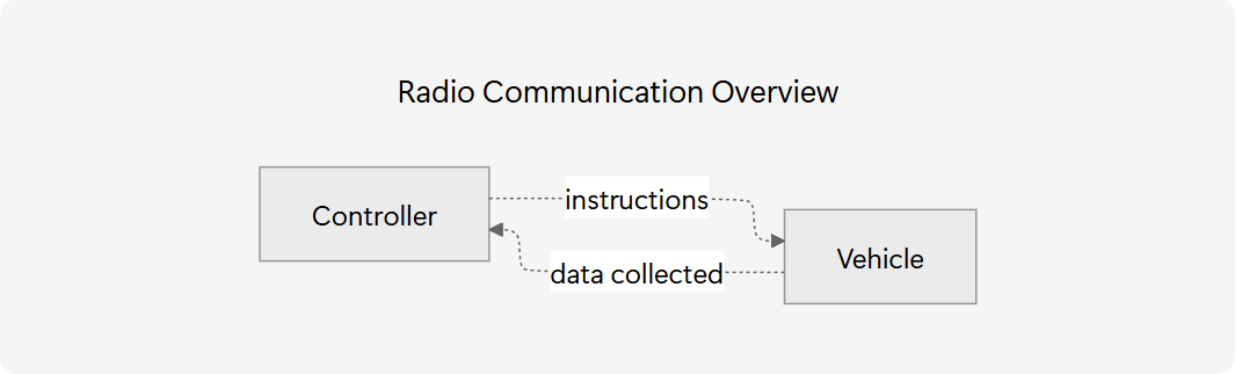
- Battery powered vehicle and remote
- A screen on the remote to display the data from vehicle sensors
- Vehicle options:
  - 4WD Remote controlled car with sensor slots.
  - Potential to add drones, boats or other vehicle options depending on the terrain

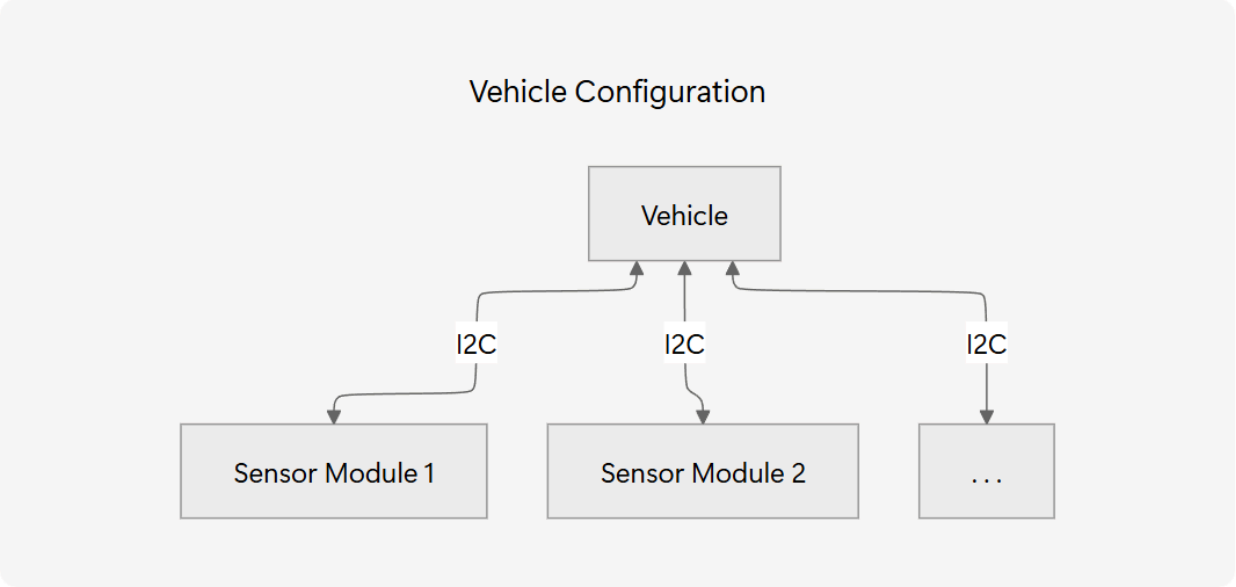
Modular Sensors

- Plug-and-play sensor modules that can be swapped out on the main board without needing to reprogram the vehicle
- Available sensor modules:
  - Lidar: 360° mapping
  - Atmosphere: particulate matter, temperature, humidity and atmospheric pressure
  - Gases: CO_2, O_2, NH_3, NO_2
  - Ionizing radiation (geiger) sensor
- Sensor data stored in onboard micro SD

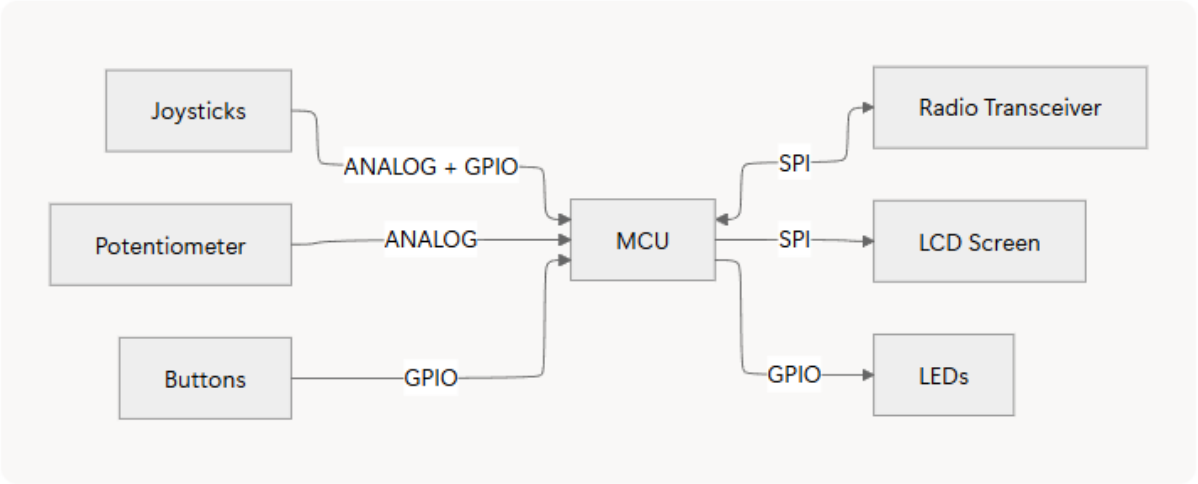
Functional Schema

Modules Interactions

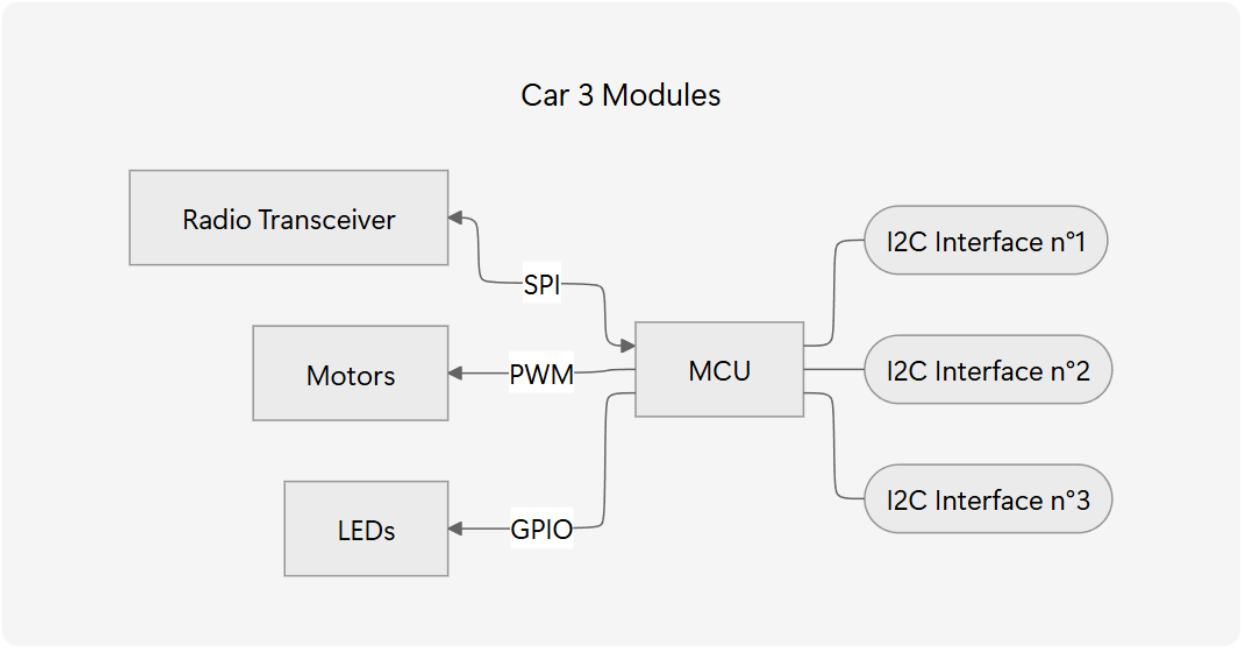




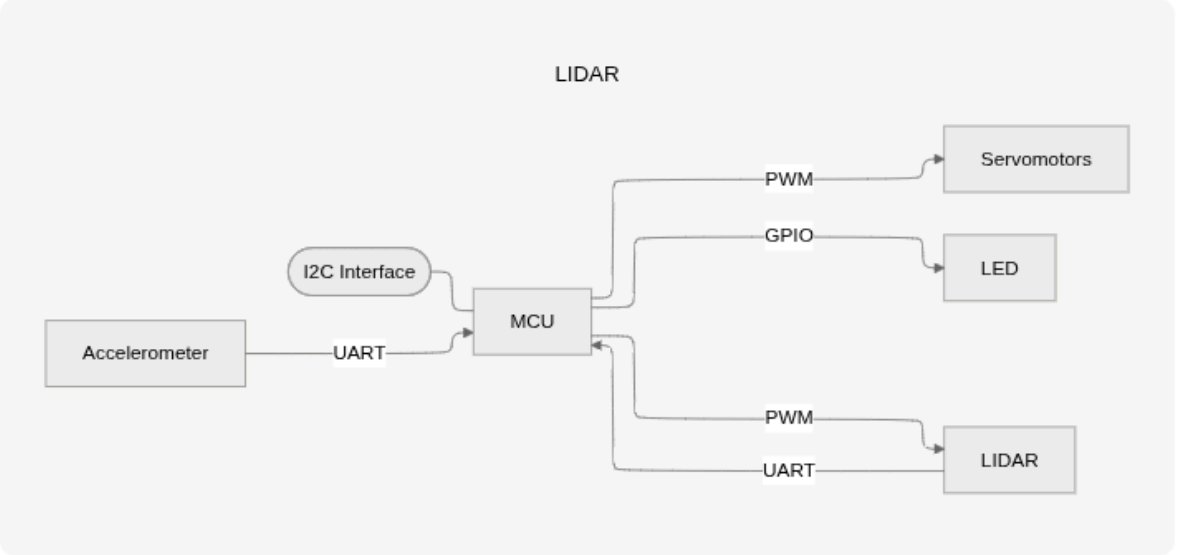
Controller

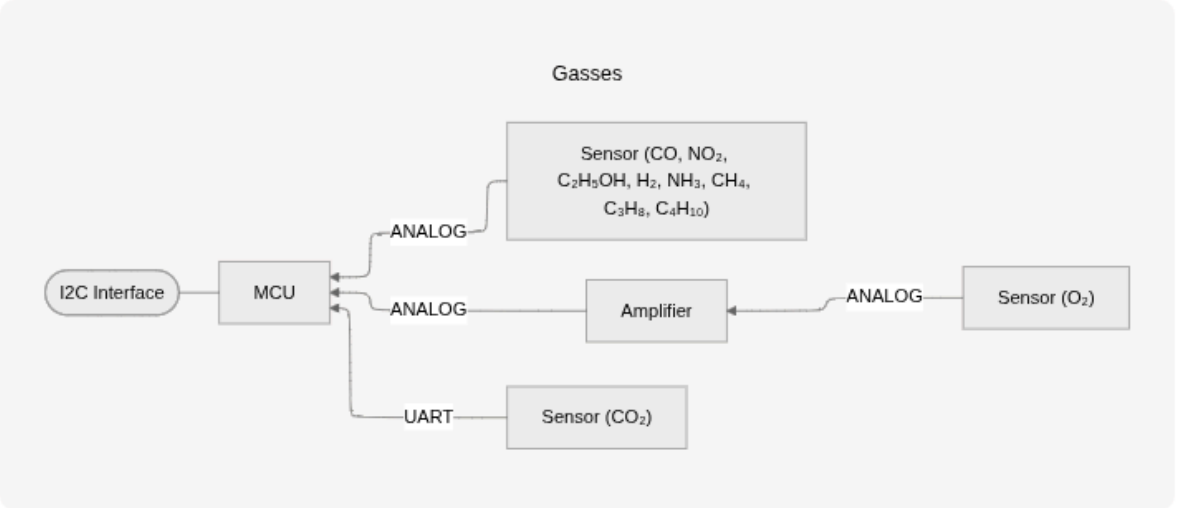


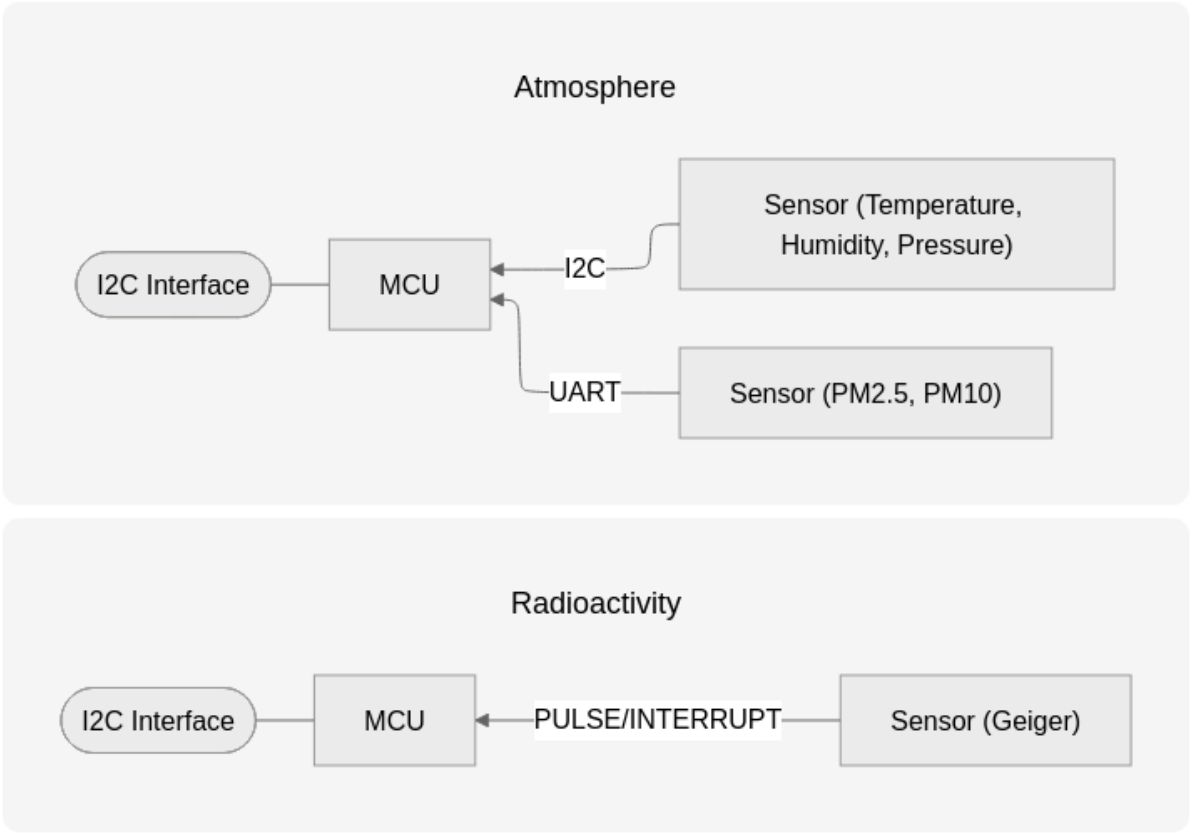
Vehicle



Sensors Modules






Atmosphere
I2C Interface
MCU
I2C
Sensor (Temperature, Humidity, Pressure)
UART
Sensor (PM2.5, PM10)
Radioactivity
I2C Interface
MCU
PULSE/INTERRUPT
Sensor (Geiger)

User Guide

Getting started

The user needs to choose a configuration adapted to his needs, then connect and lock all the sensor modules to the vehicle. The latter can also work without any modules.

For data collection, the user can insert a SD card into the slot.

To start VEMAR, put batteries in the vehicle and the controller and turn them on. A light signal will indicate when both devices are turned on and communication is established.

Controlling the vehicle

- **RC Car**:
  - Pushing the joysticks forward and backwards will make the car drive forwards and reverse.
  - Turning the joysticks to the left or right will make the car turn likewise.

The data received from the sensors is displayed in real time on the screen of the controller.

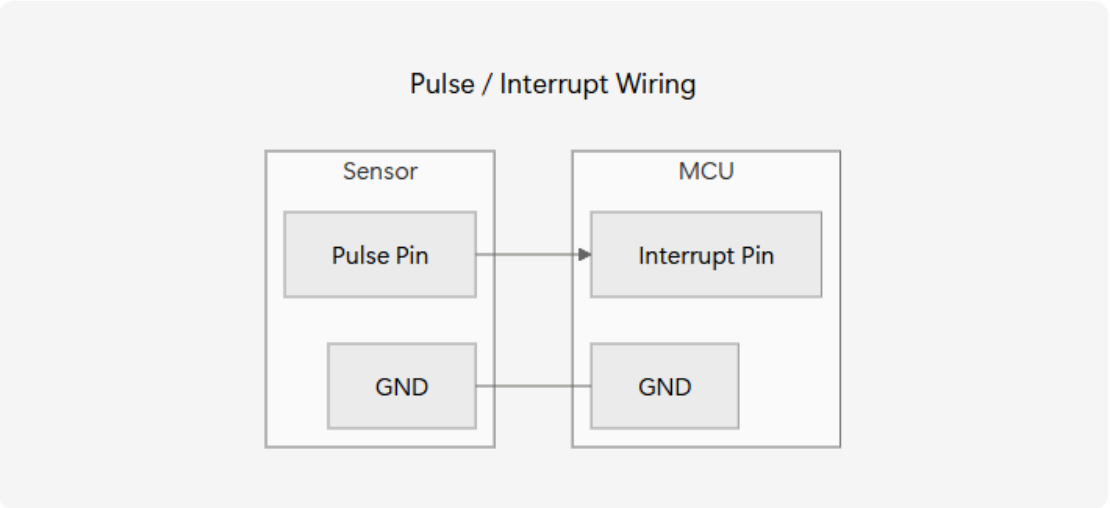
Exporting data

Once the vehicle is turned off the user is able to remove the SD card and upload the sensor readings to their devices for analysis.

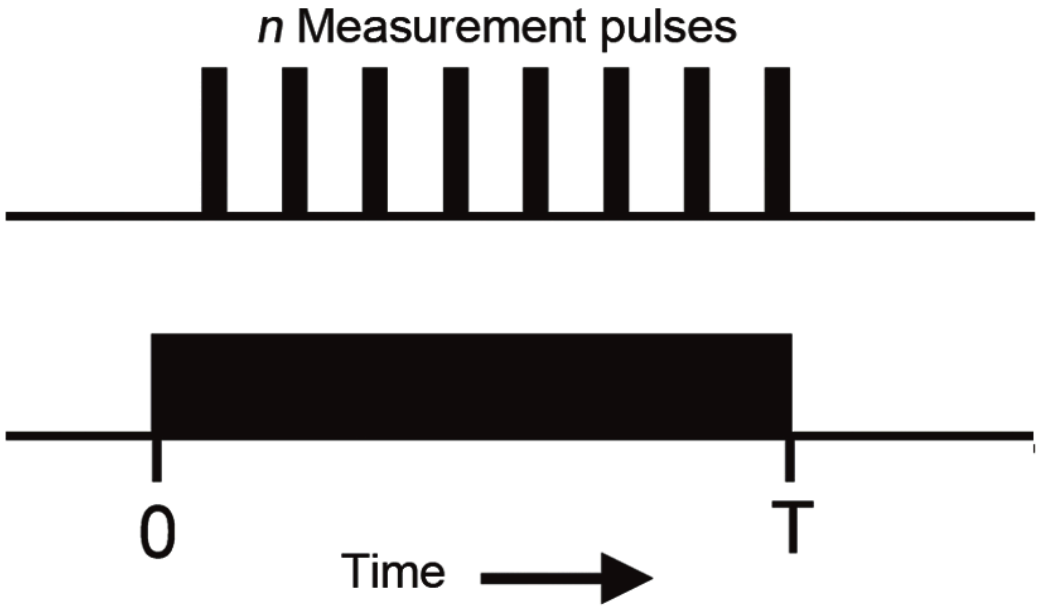
Protocols / Communication

Pulse / Interrupt

It's a method of communication that combines pulses (electrical signals on a wire) with interrupts (MCU events triggered when something happens on a pin).



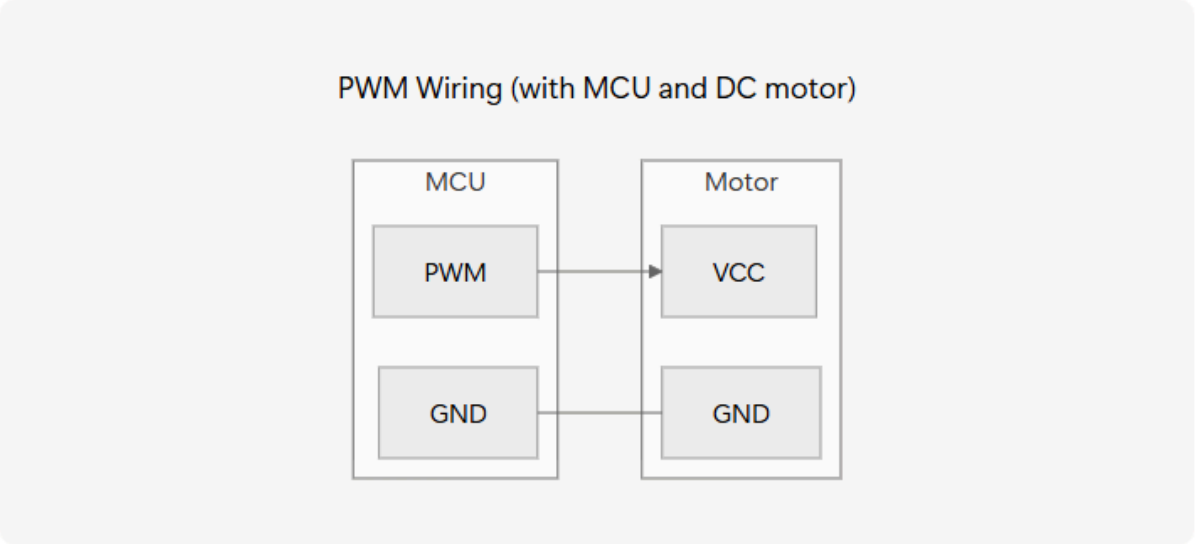
It works with a device that outputs pulses as data, and a MCU using interrupts to detect each pulse instantly. The MCU can therefore know that an event occurs or count the interrupts to obtain the data.



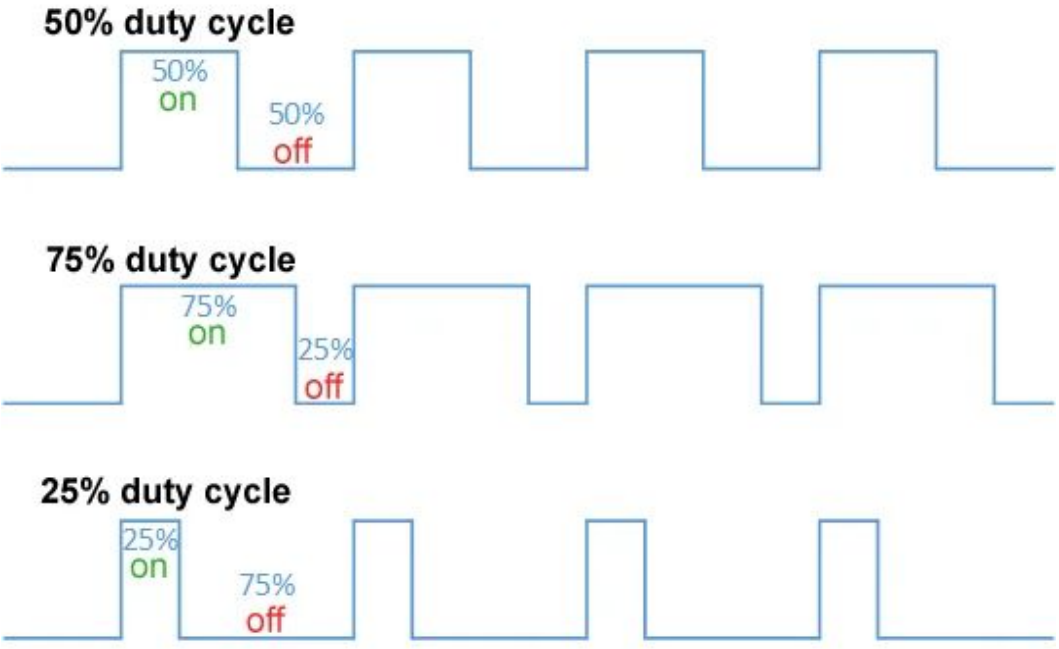
VEMAR's Geiger counter sends the measured data N by performing N pulses on the output pin. For example, 2000 pulses would correspond to a reading of 2000 cpm.

PWM

Pulse Width Modulation is a technique used to control the amount of power delivered to an electrical device without using a variable resistor.



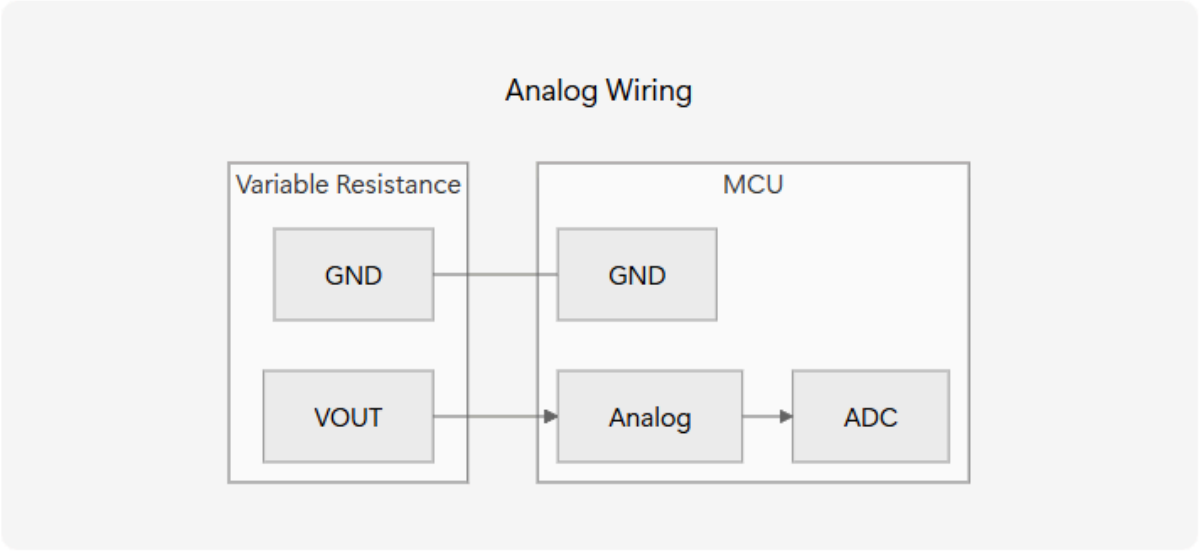
It works by switching the signal rapidly between HIGH and LOW. This creates a rectangular wave that we can adjust in duty cycle and frequency.



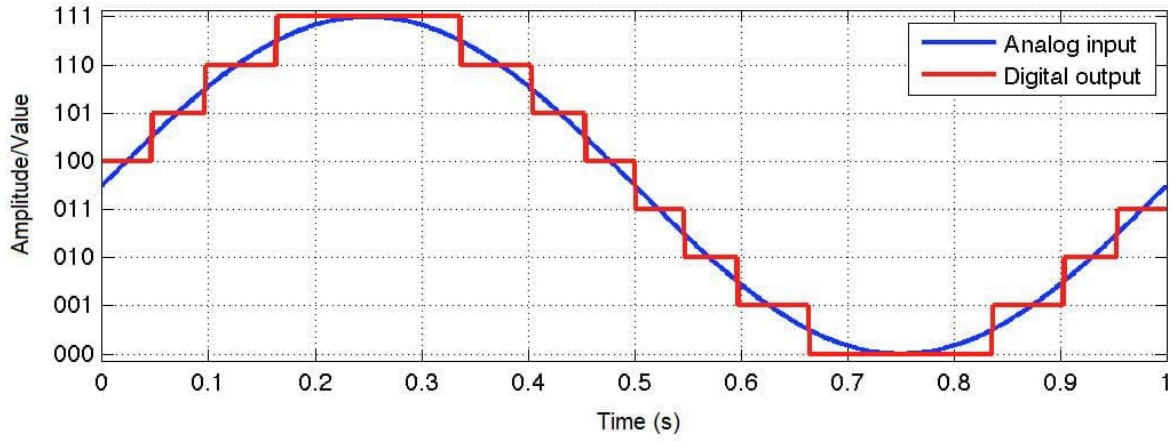
VEMAR uses PWM to control the speed of the car's motors, the speed of the lidar motor, and the angle of the servomotors on the lidar stabilization platform.

Analog

Analog refers to a type of signal or data that is continuous, meaning it can take any value within a range, rather than being limited to discrete steps like digital signals.



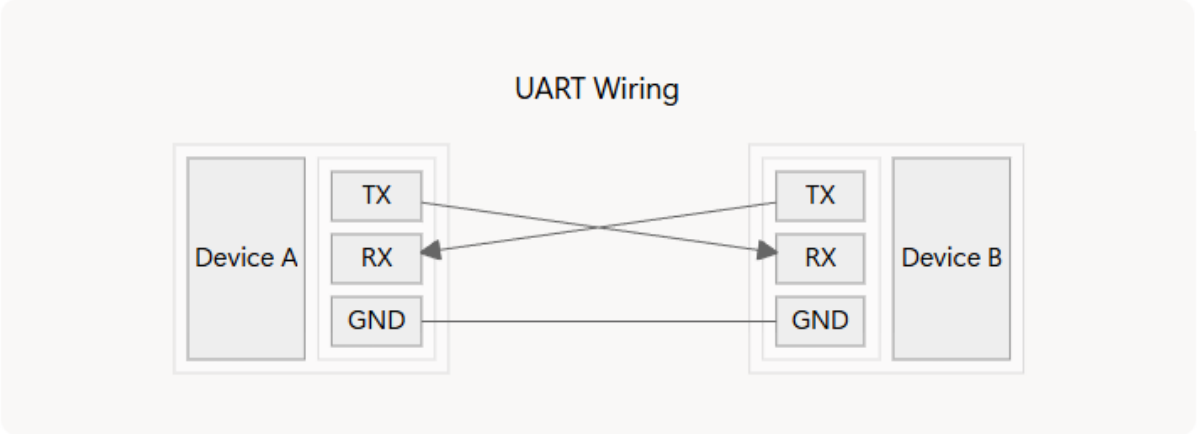
Microcontrollers use an ADC (Analog-to-Digital Converter) to read an analog voltage and convert it to a digital number.



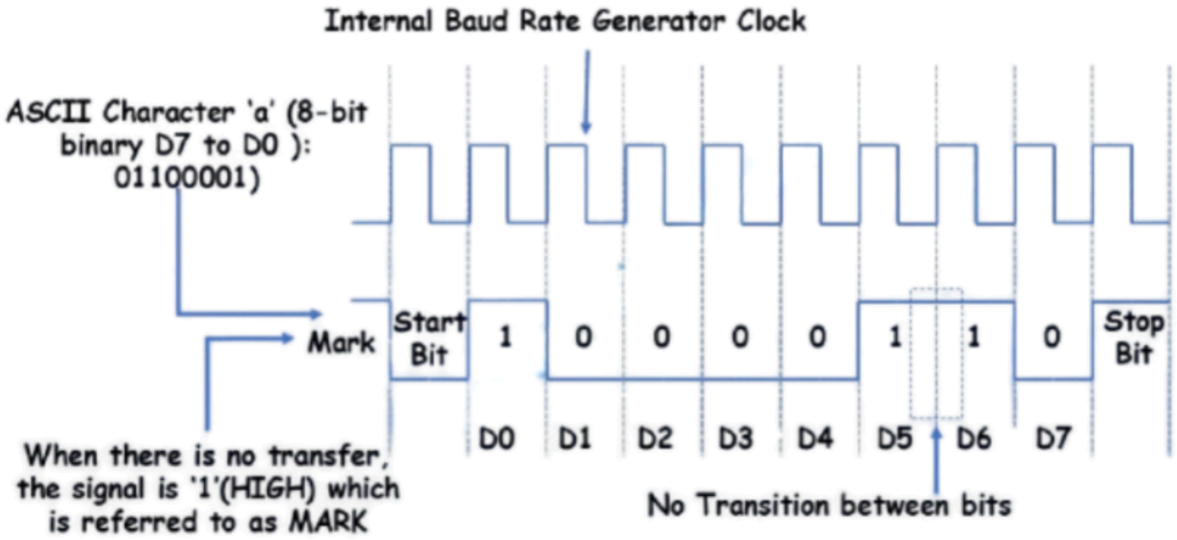
VEMAR uses analog signals for the potentiometers of the controller and the sensors within the gases module.

UART

Universal Asynchronous Receiver-Transmitter is a hardware communication protocol for serial communication between devices. It allows two devices to send and receive data bit by bit.



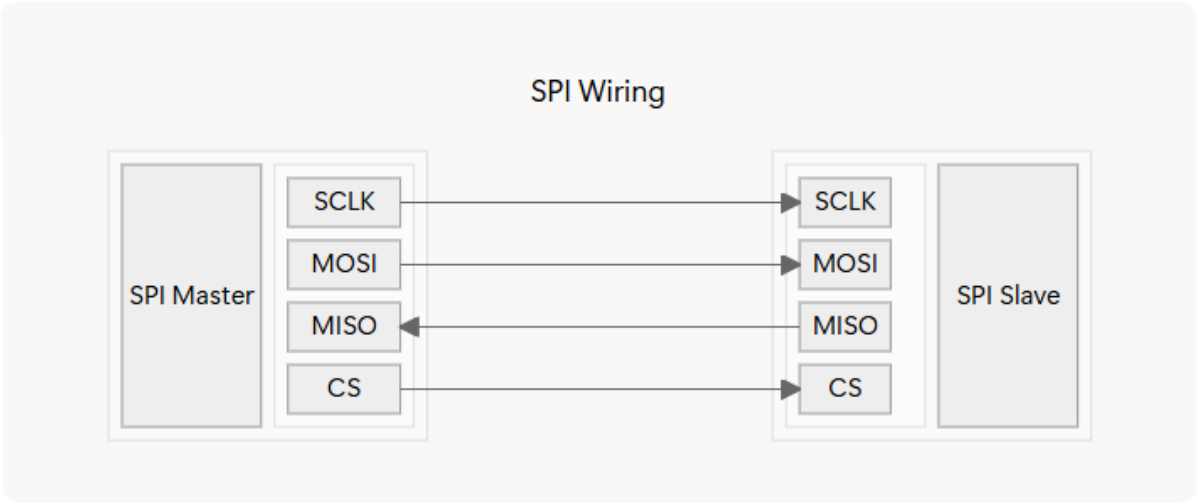
The transmitter and the receiver need to be configured with the same baud rate (speed), so there is no need for a clock signal. Each can send and receive data at the same time. The data is transmitted in packets composed of 1 start bit, 5 to 9 data bits, 1 optional parity bit, and 1 or 2 stop bit.



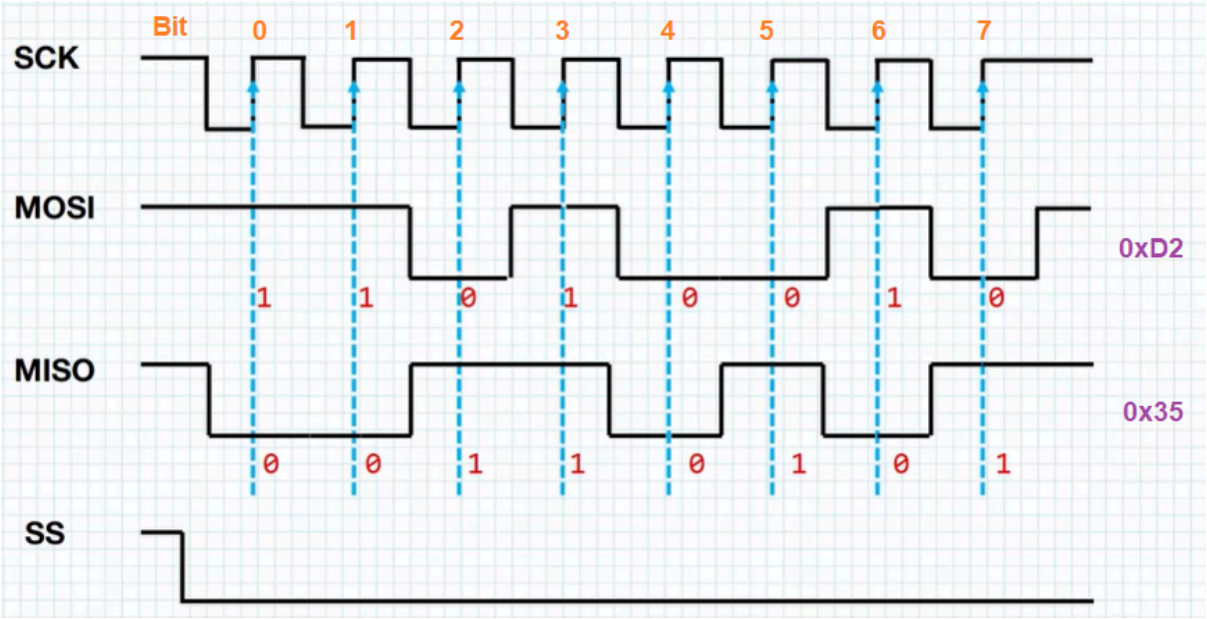
VEMAR uses UART to receive data from the lidar and the accelerometer of its stabilization platform, from the particulate matter sensor, and from the CO_2 sensor in the gases module.

SPI

Serial Peripheral Interface is a synchronous serial communication protocol for short distance and high-speed communication between a master and one or more slaves.



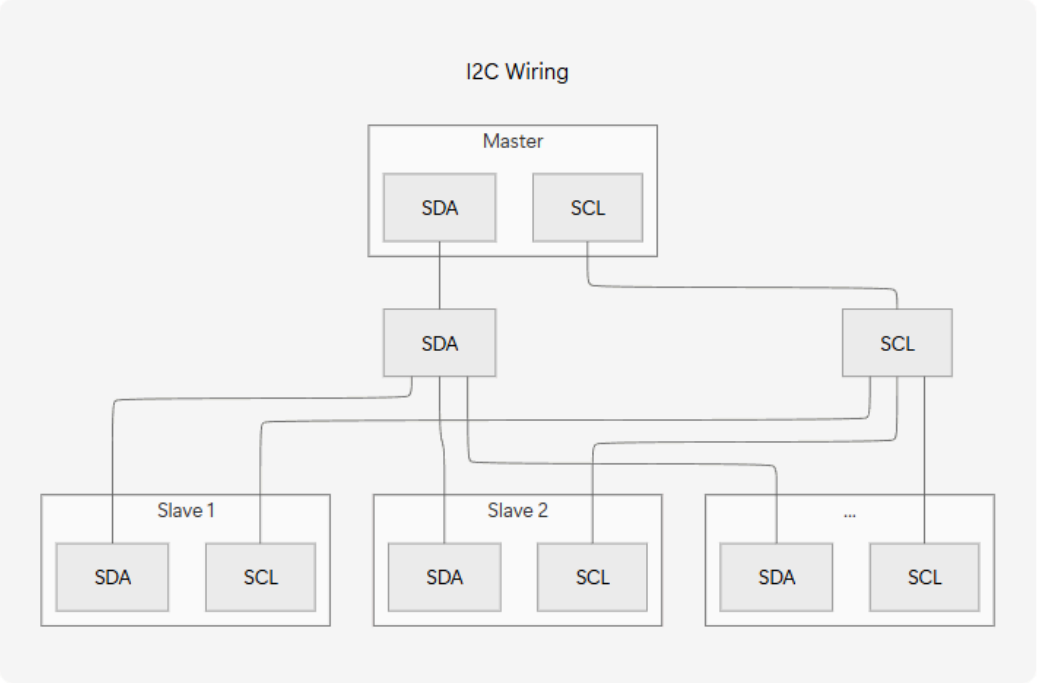
The master starts the communication with one or more slave devices by driving the SCLK (Serial CLocK) and CS (Chip Select) signals. Data can be sent via MOSI (Master Out Slave In) for the master and via MISO (Master In Slave Out) for the slave simultaneously.



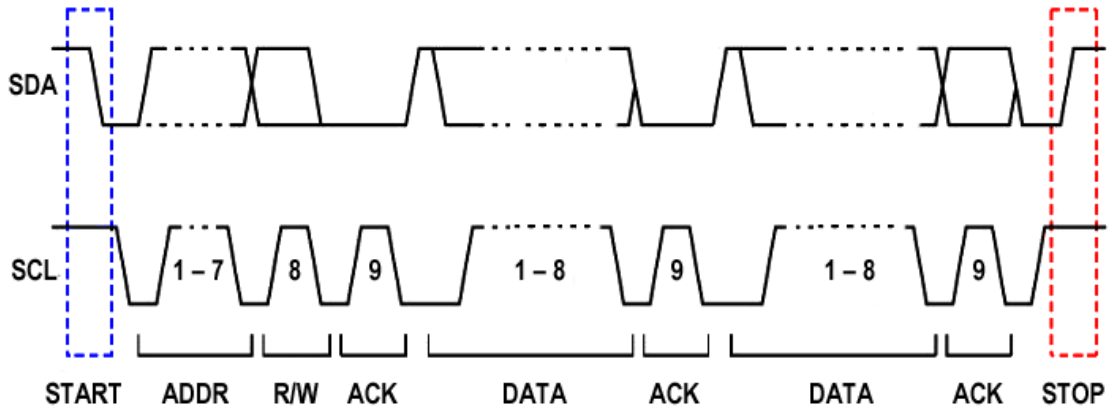
VEMAR uses SPI to communicate between the controller and vehicle via a radio transceiver, and control the LCD screen of the controller.

I2C

Inter-Integrated Circuit is a synchronous, serial, multi-device communications protocol for easy connection and lower speed communication between a master and one or more slaves.



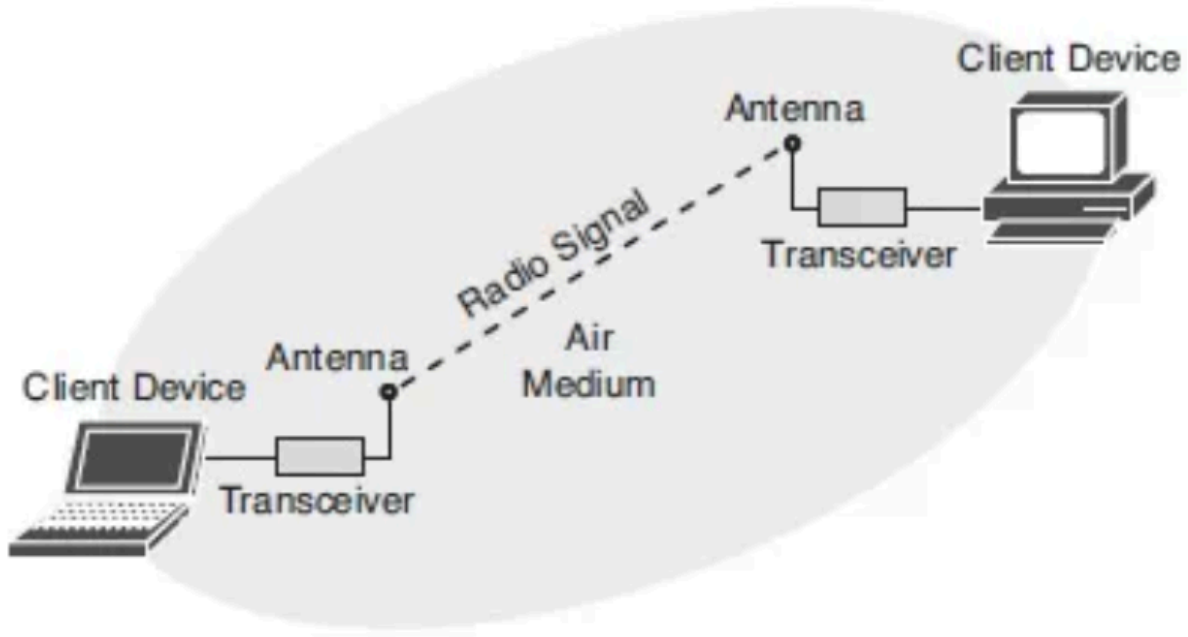
I2C only uses two signals, SDA (Serial DAta) and SCL (Serial CLock). It typically works in 4 steps : master sends a START condition followed by a slave address + read/write bit, addressed slave responds with ACK (acknowledge), master and slave exchange 1 or more data bytes, master sends STOP condition. Signals are interpreted according to states and changes on lines.



VEMAR uses I2C to communicate between the vehicle and all the sensor modules connected to it. It's also used for communication within the climate sensor.

Radio

Radio communication is a technique of sending information through electromagnetic waves that travel through the air without wires.



VEMAR uses it for the communication between the controller and the vehicle but we don’t implement it ourselves.

Pinout

MCU Pinout

Controller - ATmega328

MCU Pin	Name	Use
1	PCINT19	joystick1 digital
2	PCINT20	joystick2 digital
7	XTAL1	oscillator
8	XTAL2	oscillator
9	PD5	TFT CS
10	PD6	TFT RST
11	PD7	TFT DC
15	MOSI	SPI: transceiver & tft
16	MISO	SPI: transceiver & tft
17	SCK	SPI: transceiver & tft
23	PC0	joystick1 analog1
24	PC1	joystick1 analog2
25	PC2	joystick2 analog1
26	PC3	joystick2 analog2
27	PC4	linear potentiometer analog
30	PD0	transceiver CSN
31	PD1	transceiver CE

Car - ATmega328

MCU Pin	Name	Use
7	XTAL1	oscillator
8	XTAL2	oscillator
9	OC0B	PWM mosfet motor 0 CW +
10	OC0A	PWM mosfet motor 0 CCW +
11	PD7	mosfet motor 0 CW -
12	PB0	mosfet motor 0 CCW -
13	OC1A	PWM mosfet motor 1 CW +
14	OC1B	PWM mosfet motor 1 CCW +
15	MOSI	transceiver SPI
16	MISO	transceiver SPI
17	SCK	transceiver SPI
23	PC0	mosfet motor 1 CW -
24	PC1	mosfet motor 1 CCW -
30	PD0	transceiver CSN
31	PD1	transceiver CE

Lidar Module - ATmega128

MCU Pin	Name	Use
2	RXD	uart rx for lidar
5	OC3A	PWM for servomotor A
6	OC3B	PWM for servomotor B
7	OC3C	PWM for servomotor C
15	OC1A	PWM for lidar
21	VCC	power in
22	GND	power in
23	XTAL2	crystal
24	XTAL1	crystal
25	SCL	I2C interface for vehicle and accelerometer
26	SDA	I2C interface for vehicle and accelerometer
27	INT2	Interrupt for accelerometer

Gases Module - ATtiny214

MCU Pin	Name	Function	Use
1	VDD	Power in	
2	PA4	bi-dir	O2 analog in
3	PA5	bi-dir	NH3 analog in
4	PA6	bi-dir	NO2 analog in
5	PA7	bi-dir	CO analog in
6	TOSC1/PB3	bi-dir	NC
7	TOSC2/PB2	bi-dir	NC
8	PB1	bi-dir	TX for CO2
9	PB0	bi-dir	RX for CO2
10	PA0/RESET/UPDI	bi-dir	NC
11	PA1	bi-dir	SCL
12	PA2	bi-dir	SDA
13	PA3/EXTCLK	bi-dir	NC
14	GND	Power in	

Climate Module - ATtiny412

MCU Pin	Name	Function	Use
1	VDD	Power in	
2	PA6	bi-directional	RX for pm2.5
3	PA7	bi-directional	TX for pm2.5
4	PA1	bi-directional	SCL
5	PA2	bi-directional	SDA
6	PA0	bi-directional	NC
7	PA3	bi-directional	NC
8	GND	Ground	

Geiger Module - ATtiny412

MCU Pin	Name	Function	Use
1	VDD	Power in	
2	PA6	bi-directional	EXINT used for geiger readings via pulse/interrupt
3	PA7	bi-directional	NC
4	PA1	bi-directional	SCL
5	PA2	bi-directional	SDA
6	PA0	bi-directional	NC
7	PA3	bi-directional	NC
8	GND	Ground	

Generic Pinout

NRF24L01 (Transceiver)

Pin Number	Name	Pin Function	Description
1	CE	Digital In	Chip Enable Activates RX or TX mode
2	CSN	Digital In	SPI Chip Select
3	SCK	Digital In	SPI Clock
4	MOSI	Digital In	SPI Slave Data Input
5	MISO	Digital Out	SPI Slave Data Output, with tri-state option
6	IRQ	Digital Out	Maskable interrupt pin, Active *low*
7	VDD	Power	Power Supply (+1.9V to +3.6V DC)
8	VSS	Power	Ground (0V)
9	XC2	Analog Out	Crystal Pin 2
10	XC1	Analog Inp	Crystal Pin 1
11	VDD_PA	Power Out	Power Supply Output (+1.8V) for the internal power amp.
12	ANT1	RF	Antenna interface 1
13	ANT2	RF	Antenna interface 2
14	VSS	Power	Ground (0V)
15	VDD	Power	Power Supply (+1.9V to +3.6V DC)
16	IREF	Analog In	Reference current. Connect a 22kΩ resistor to ground
18	VDD	Power	Power Supply (+1.9V to 3.6V DC)
19	DVDD	Power Out	Internal digital supply output for de-coupling purposes.
20	VSS	Power	Ground (0V)

L298N (Dual full-bridge driver)

Pin Number	Name	Function
1	Sense A	Between this pin and ground is connected the sense resistor to control the current of the load
2	Out 1	Outputs of the bridge A; the current that flows through the load connected between these two pins is monitored at pin 1
3	Out 2	See above
4	Vs	Supply voltage for the power output stages. Anon-inductive 100nF capacitor must be connected between this pin and ground.
5	Input 1	TTL compatible inputs of the bridge A
6	Enable A	TTL compatible enable input; the L state disables the bridge A (enable A)
7	Input 2	TTL compatible inputs of the bridge A
8	GND	Ground
9	Vss	Supply voltage for the logic blocks, A 100nF capacitor must be connected between this pin and ground
10	Input 3	TTL compatible inputs of the bridge B
11	Enable B	TTL compatible enable input: the L state disables the bridge B (enable B)
12	Input 4	TTL compatible inputs of the bridge B
13	Out 3	Outputs of the bridge B. The current that flows through the load connected between these two pins is monitored at pin 15
14	Out 4	See above
15	Sense B	Between this pin and ground is connected the sense resistor to control the current of the load

MiCS-6814 (MOS sensor)

Pin Number	Name
A	Rs2
B	Rh1 RED, Rs1 RED
C	Rh1 NH3
D	Rs1 NH3
E	Rh2 NH3
F	Rs2 NH3
G	Rh2 RED
H	Rs2 RED
J	Rh1 OX, Rs1 OX
K	Rh2 OX

Note:

- OX: Oxidising gases
- RED: Reducing gases
- NH3: Ammonia

MH-Z1911A (CO2 sensor)

Pin	Type	Description
1	PWM output	Not connected as we’re using UART
2	UART TX	data out
3	UART RX	data in
4	Power in	+3.3V
5	GND	
6	NC	Not Connected
7	HD (zero point calibration)	Used for ‘0 point calibration’ (forcing the reading to 400 ppm in fresh air). Connect this pin to control calibration or leave disconnected to rely on automatic calibration.

SDS011 (Laser PM2.5 Sensor)

Pin Number	Name	Comment
1	NC	Not Connect
2	1μm	PM2.5: 0-999μg/m3; PWM Output
3	5V	5V Input
4	2.5μm	PM10: 0-999μg/m3; PWM Output
5	GND	Ground
6	R	RX of UART (TTL) @3.3V
7	T	TX of UART (TTL) @3.3V

AO-03 (Oxygen Sensor)

Pin Number
Vsensor+
Vsensor-

AD8552 (amplifier for O2 Sensor)

Pin	Type	Description
OUT A	Output	Amplifier Output (analog)
IN A -	Input	Inverting input of amplifier
IN A +	Input	non-inverting input of amplifier
VSS	Ground	Ground
VDD	Power	+3.3V
OUTB	Output	Amplifier Output (analog)

YDLIDAR X2

Pin	Type	Description
VCC	Power Supply	+5V
Tx	Output	System Serial Output
GND	Power Supply	Negative
M_SCTR	Input	Motor Speed Control Terminal

Geiger Counter

Pin	Type	Description
VCC	Power Supply	+5V
INT	Output	Interrupt / Pulse
GND	Power Supply	

TFT 3.2 Inch Display SPI — ILI9341

Pin Number	Name	Description
1	VCC	Power supply is positive (3.3V~5V)
2	GND	Power ground
3	CS	Selection control signal
4	RESET	Reset control signal
5	DC/RS	Register/Data selection control signal
6	SDI (MOSI)	SPI bus write data signal
7	SCK	SPI bus clock signal
8	LED	Backlight control signal (high level lighting, if you do not need control, connect to 3.3V)
9	SDO (MISO)	SPI bus read data signal (cannot be connected if not needed)
10	T_CLK	Touch Screen SPI bus clock pin
11	T_CS	Touch Screen chip select control pin
12	T_DIN	Touch Screen SPI bus write data pin
13	T_DO	Touch Screen SPI bus read data pin
14	T_IRQ	Touch Screen interrupt detection pin

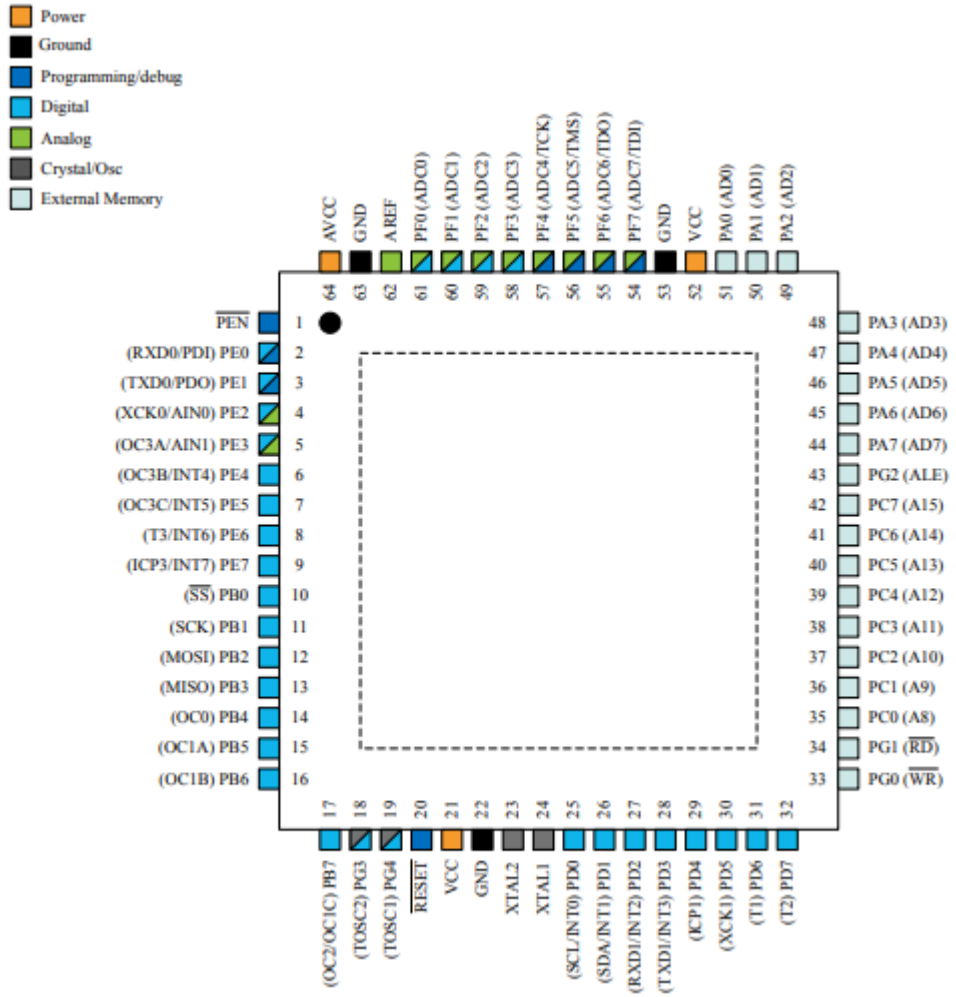
ATmega328P

Pin	Type	Description
VCC	Power in	+3.3V or +5V
GND	Ground	
PBx	bi-directional	input & output
PCx	bi-directional	input & output
PC6 / RESET	input	reset input
PDx	bi-directional	input & output
AVCC	Power in	supply voltage for a/d converter
AREF	analog reference	analog reference pin for a/d converter
ADCx	input	analog inputs

ATtiny412

Pin	Type	Description
VDD	Power Input	
GND	Ground	
PAx	bi-directional	GPIO with a/d
PA3/EXTCLK	bi-directional	GPIO with option to take external clock source
PA0/RESET/UPDI	bi-directional	by default it's the dedicated debug pin (UPDI) that's used to program the chip. It can also be configured as RESET or used as a regular GPIO

ATmega128A



S90

Pin	Type	Description
VCC	Power Supply	+5V
PWM	Input	PWM
GND	Power Supply	

BN055

Pin	Function	Description
VDD	Power Supply (3.3V to 5V)	Powers the BNO055 sensor.
GND	Ground	Ground connection for the sensor.
SCL	I2C Clock (or SCL for I2C)	I2C clock line for communication.
SDA	I2C Data (or SDA for I2C)	I2C data line for communication.
INT	Interrupt (Optional)	Digital output pin for interrupt signaling. Can be used to notify the microcontroller of events.
RST	Reset Pin	Used to reset the sensor. When pulled low, it resets the BNO055 module.
MOSI	Master Out Slave In (SPI Data)	Data input to the BNO055 when using SPI communication.
MISO	Master In Slave Out (SPI Data)	Data output from the BNO055 when using SPI communication.
SCK	SPI Clock	Clock signal for SPI communication.
CS	Chip Select	Used to select the BNO055 when using SPI. When low, SPI communication is enabled.

DC Motor

Pin	Type	Description
VCC	Power Supply	+12V
GND	Power Supply	

Power Budget

Controller

Component	Quantity	Max Intensity (mA)	Tension (V)	Power (mW)
NRF24L01	1	12.3	3.3	36.9
TFT LCD	1	-	3.3 / 5	720
ATmega328	1	15	5	75

Car

Component	Quantity	Max Intensity (mA)	Tension (V)	Power (mW)
DC motor	2	2000	12	48000
NRF24L01	1	12.3	3.3	36.9
ATmega328	1	15	5	75

Sensors

Lidar Module

Component	Quantity	Max Intensity (mA)	Tension (V)	Power (mW)
ATMEGA128	1	20	5	100
YDLIDAR X2	1	380	5	1900
SG90	3	700	5	10500
BNO055	1	12	3.3	40

Climate Module:

Component	Quantity	Max Intensity (mA)	Tension (V)	Power (mW)
ATtiny412	1	6	5	30
BME280	1	0.0007	3.3	0.0023
SDS011	1	80	5	400

Geiger Module:

Component	Quantity	Max Intensity (mA)	Tension (V)	Power (mW)
ATtiny412	1	6	5	30
Geiger	1	30	5	150

Gas Module:

Component	Quantity	Max Intensity (mA)	Tension (V)	Power (mW)
ATtiny214	4	6	5	30
MH-Z19	1	50	5	250
AO 03	1	10	3.3	50
AD8552M	1	60	3.3	198
MiCS-6814	1	32	2.4	76.8

Bonus

- Improve lidar rendering with algorithms
- Add automatizations
- Make a Geiger Counter module
- Include MiCS sensor for pollutants in Gases module