Technical Manual	NOx Shield	6 000 000 017

Version	Comment	Released
1	First release.	2021-01-23

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1 - Disclaimer

This device is designed for educational use. It is intended to be used by students, hobbyists and professionals. This device and the accompanying software are provided as is and should never be used in any circumstance where it is left unattended or could jeopardize the safety of an individual or property.

The purpose of this device is to give students, hobbyists and professionals the possibility to learn how to implement a high-resolution wideband oxygen and nitrogen oxides (O_2 NO_X) sensor in their products or projects. Adding accurate data, such as the content of nitrogen oxides in a closed loop control environment will assist in developing more efficient and environmentally friendly combustion-based solutions. All the necessary software examples to get started is available on our GitHub page.

2 – Compatibility

2.1 – Boards

This device or shield is designed and verified to be used with the Arduino Uno (Rev 3), Arduino Uno WIFI (Rev 2), Arduino Mega 2560 (Rev 3). If used with any other single-board microcontroller or computer, first ensure that it is pin and signal compatible.

2.2 – Sensors

All NOx sensors of the SAE J1939 type of Bosch EGS-NX2 are compatible with this device. As it is compatible with SAE J1939 it may be compatible with other devices. If you want to purchase a compatible 12V sensor, we recommend the Bosch model 0 281 007 891. If you want to purchase a compatible 24V sensor, we recommend the Bosch model 0 281 007 156.

2.2 – Apps

This device or shield is compatible with the Lambda Shield app available on the Apple App Store and Google Play Store. For use with the Lambda Shield app, it requires the Arduino Uno WIFI (Rev 2). The required Arduino software is available on our GitHub page.

3 – Operation

3.1 – Connection Table

Pin EGS-NX2	Pin NOx Shield	Function
1	1	Supply Voltage
2	2	Ground
3	3	CAN Low (SAE J1939)
4	4	CAN High (SAE J1939)
5	5	Address Configuration

Maximum supply voltage:　　　　　12 / 24 VDC (See 3.2)

3.2 – Alternative Power Input

WARNING!

This feature is for expert users only. The voltage used to power the sensor can cause your Arduino (or compatible) board to break, overheat and even catch on fire. Never connect more than one power source at any time when using this feature.

By using a jumper on X7, the power input from the Arduino board is directly connected to power input of the NOx Shield. This can be used either to power the Arduino from the NOx Shield or power the NOx Shield sensor from the Arduino. In either case the 5V is always common.

Maximum supply voltage:　　　　　15-20 VDC - Limited by the Arduino. Without X7 populated, the maximum supply voltage is 24 VDC.

Always review the schematics and the specification of your Arduino board and sensor before connecting a power supply.

<div style="text-align:center">4 – Calculations</div>

4.1 – SAE J1939 CAN Frame

Data from the NOx sensors are transmitted to the NOx Shield and Arduino by the Controller Area Network (CAN) in the SAE J1939 format. The recommended sensors operate on a fixed baud rate of 250 kbps, but it may differ if you use other sensors.

Example CAN-bus messages from NOx sensor:

Address*	CAN ID (29-bit)	Data 0	Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7
High	0x18F00F52	0x7F	0x0F	0x74	0xF6	0x55	0x1F	0x1F	0x1F
Low	0x18F00E51								

*. Referring to the address configuration, pin 5 on the screw terminal. See schematics.

For the sensor to operate it requires pre-heating to have passed the dew point temperature threshold. A temperature sensor on the CAN-bus giving this information can be simulated with the following CAN-broadcast.

Example CAN-bus messages to NOx sensor:

CAN ID (29-bit)	Data 0	Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7
0x18FEDF00	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF	0x55

4.2 – Calculating Nitrogen Oxides Content (NOx)

The nitrogen oxides content (NOx) is stored in data byte 0 (Data 0) and 1 (Data 1) of the CAN-bus messages received from the NOx sensor. Using these two bytes we can calculate the nitrogen oxides content as ppm using the following formula with the example data from section 4.1.

Prepare raw data:
$$SPN_{3226} = Data_1 \ll 8 + Data_0 = 0xF7F = 3967$$

Convert raw data:
$$NO_X = SPN_{3226} \times 0.05 - 200 = 3967 \times 0.05 - 200 = -2\ PPM$$

4.2 – Calculating Oxygen Content (O₂)

The oxygen content (O₂) is stored in data byte 2 (Data 2) and 3 (Data 3) of the CAN-bus messages received from the NOx sensor. Using these two bytes we can calculate the oxygen content as % using the following formula with the example data from section 4.1.

Prepare raw data:
$$SPN_{3227} = Data_3 \ll 8 + Data_2 = 0xF674 = 63092$$

Convert raw data:
$$O_2 = SPN_{3227} \times 0.000514 - 12 = 63092 \times 0.000514 - 12 = 20\%$$

4.3 – Calculating Lambda Value (λ)

Once the oxygen content (O_2) of the gas is known the lambda value can be calculated by a simple formula described in Bosch Technical Product Information - Y 258 E00 015e.

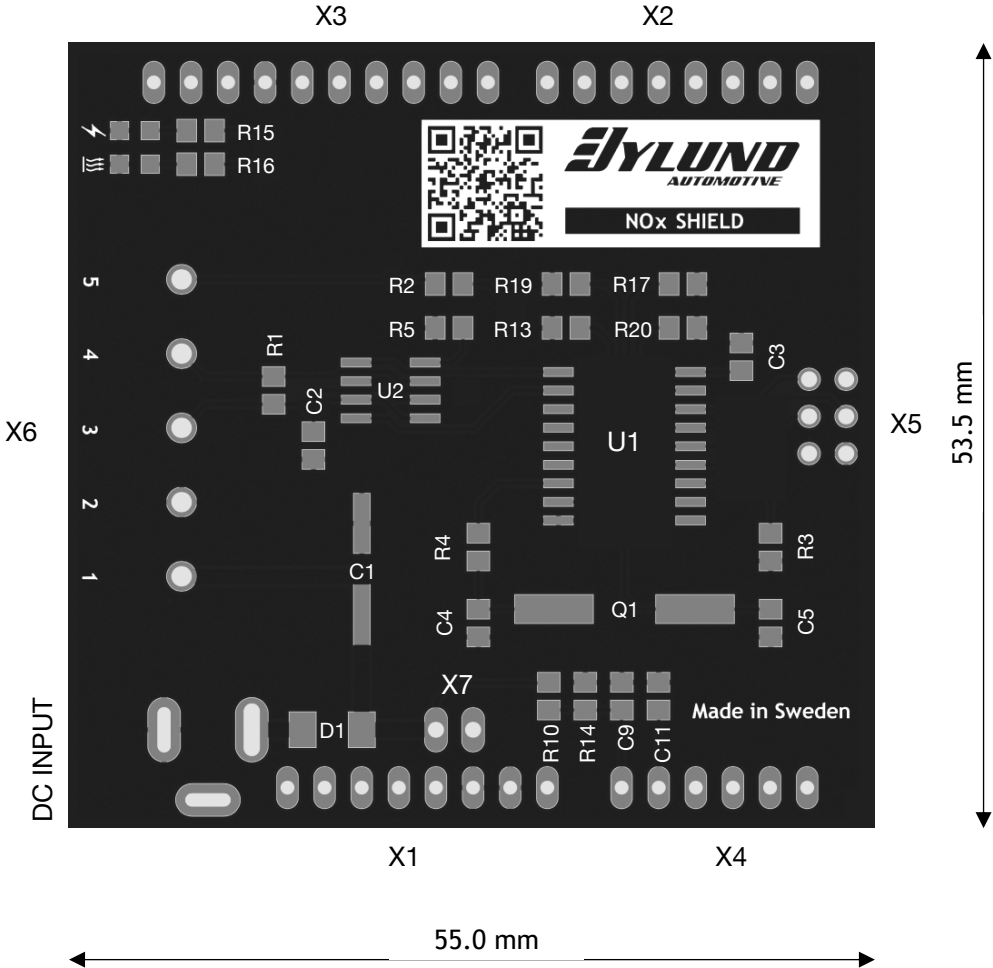$$\lambda = \frac{\frac{O_2}{3} + 1}{1 - 4.77 \cdot O_2}$$

Calculating λ value of 1.00 from O_2 (0%) gives:

$$\lambda = \frac{\frac{O_2}{3} + 1}{1 - 4.77 \cdot O_2} = \frac{\frac{0}{3} + 1}{1 - 4.77 \cdot 0} = \frac{1}{1} = 1.00$$

Note, calculating lambda values for very lean gases is not relevant. Instead use O_2 content.

5 – Components

5.1 – Component Positions

5.2 – Component List (BOM)

PCBA Component	Description
D1	Diode DO-214AC (2A)
C2, C3, C9, C11	100nF Capacitor C0805
C4, C5	22pF Capacitor C0805
C1	220μF Capacitor
R2, R14	10k Resistor R0805
R5	4k7 Resistor R0805
R3, R10, R13, R17, R19, R20	100k Resistor R0805
R1	60R Resistor R0805
R4	1k Resistor R0805
R15, R16	150R Resistor R0805
Q1	16MHz Crystal
U1	MCP2515 CAN Controller
U2	MCP2551 CAN Tranceiver
X1, X2	Header 8-pin
X3	Header 10-pin
X4	Header 6-pin
X5	Socket 6-pin
X6	Screw Terminal 6-pin
X7	Header 2-pin
DC INPUT[1]	DC Power Jack
LED1, LED2	Green LED 0805

[1]. 2.5mm / 5.5mm DC Jack.

5.3 – Schematics
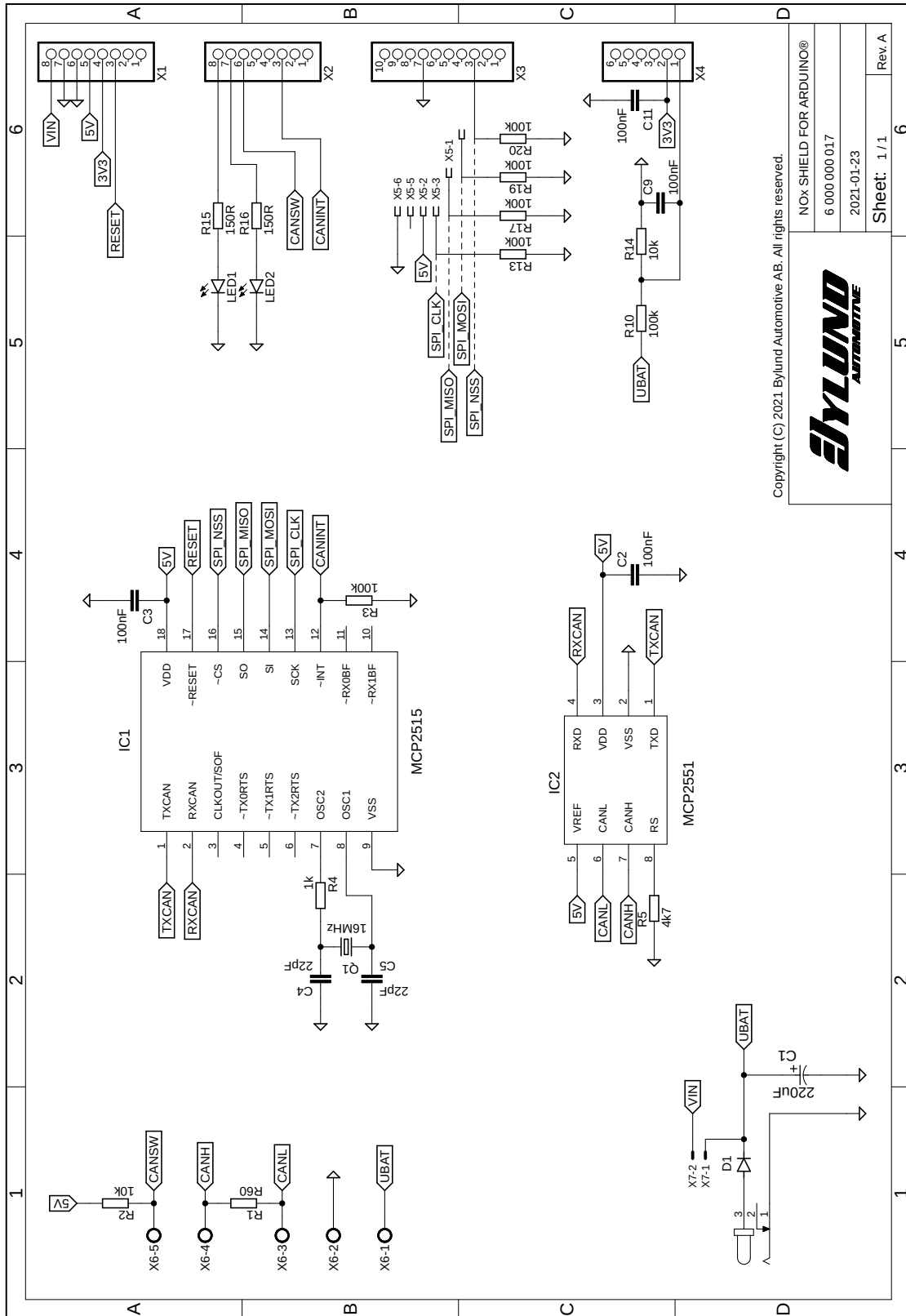
NOx SHIELD FOR ARDUINO®

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