Version	Comment	Released
1	Released for production.	2017-11-24
2	Added maximum supply voltage. Added accuracy information.	2018-08-11

Table of contents

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 (O_2) sensor in their products or projects. Adding accurate data, such as the oxygen content 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. If used with any other single-board microcontroller or computer, first ensure that it is pin and signal compatible.

2.2 - Sensors

All sensors of the type Bosch LSU 4.9 is compatible with the Bosch CJ125 lambda controller and compatible with this device. For accurate readings make sure you always connect it with the intended connector as this contains a laser calibrated resistor. If you want to purchase a compatible sensor we recommend the Bosch model *0 258 017 025*.

3 – Operation

3.1 – Connection Table

Pin LSU 4.9	Pin Lambda Shield	Function
1	1	Pump Current (IP)
2	2	Virtual Ground (VM)
3	3	Heater (H-)
4	4	Heater (H+)
5	5	Trim Resistor (IA)
6	6	Nernst Voltage (UN)

Maximum supply voltage: 15 VDC (Limited by voltage divider)

3.2 – Alternative Power Input

WARNING!

This feature is for expert users only. The power used to heat 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 (or compatible) board is directly connected to power input of the Lambda Shield. This can be used either to power the Arduino from the Lambda Shield. Or power the Lambda Shield (heater) from the Arduino. In either case the 5V is always common.

Please review the schematics for more information.

4 – Calculations

4.0 – Calibration and Accuracy

The CJ125 controller can be set in calibration mode by transmitting the SPI command (0x569D). This sets the analogue output for oxygen content to its optimal value. The oxygen content output is defined as CJ125_UA and is connected to analogue input 0. This voltage of 1.50V corresponds to a pump current of 0mA and a λ value of 1.00.

Monitoring the 10-bit ADC of the Arduino Uno, 1.50V corresponds to the ADC value of 307. Depending of the voltage powering the CJ125, it affects the accuracy. Either the voltage from the USB-bus or the regulated 5V from the Arduino. See section 3.2 on how to power the Arduino and CJ125 by the supply voltage of the Lambda Shield.

Note, it is normal that the calibration voltage measured by the Arduino ADC does not read the decimal value of 307. The voltage regulator of the Arduino has an accuracy of 1%, which means the voltage powering the CJ125 will also affect its voltage output.

Temperature is also a critical factor in terms of measurement accuracy and precision. The sensors zirconium dioxide membrane operates at a certain temperature, approximately 650°C. The CJ125 controller gives a temperature feedback for heat regulation purposes. The feedback voltage is defined as CJ125_UR and is connected to analogue input 1. In calibration mode, the target temperature (optimal temperature) voltage equivalent will be the output from the CJ125 controller.

Note, a lower voltage indicates a higher temperature. To prevent damage of the sensor when cold and wet, a condensation water phase during heating is necessary and described in full detail by Bosch in the Technical Product Information - *Y 258 E00 015e*.

4.1 – Calculating Pump Current (I_P)

I_P is the pump current running thru the sensor and measured by the CJ125 controller. This is the basic operation of a Lambda sensor. Based on the amount of available oxygen, the current changes. The sensors pump current can be approximated with the following formula according to Bosch Technical Product Information - *Y 258 E00 015e*. Where ADC is the CJ125_UA ADC value. In this example, we will calculate the typical calibration value of 307 which correspond to the λ value of 1.00.

$$ADC = 307$$

$$\mathrm{U_A} = \frac{\mathrm{ADC}}{1023} \cdot 5.0 = \frac{307}{1023} \cdot 5.0 = 1.5\ \mathrm{V}$$

$$\mathrm{I_P} = \frac{1000 \cdot (\mathrm{U_A} - 1.5)}{61.9 \cdot 17} = \frac{1000 \cdot (1.5 - 1.5)}{61.9 \cdot 17} = 0\ mA$$

4.2 – Calculating Oxygen Content (O_2)

The wideband sensor characteristics of oxygen content (O_2) and pump current (I_P) can be approximated with a simple linear equation. For high precision readings, nonlinear approximations are more suitable. Bosch Technical Product Information - *Y 258 E00 015e* contains some given measurement points.

% O_2	0.00	3.00	6.00	8.29	12.0	20.95
I_P	0.00	0.33	0.67	0.94	1.38	2.54

The linear equation gives:

$$O_2 = k \cdot I_P$$

$$k = \frac{20.95}{2.54}$$

Calculating oxygen content *of λ 1.00 from the I_P example gives:*

$$O_2 = k \cdot I_P = \frac{20.95}{2.54} \cdot 0 = 0\ \%$$

Note, the readings are affected by temperature, pressure and humidity.

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*.

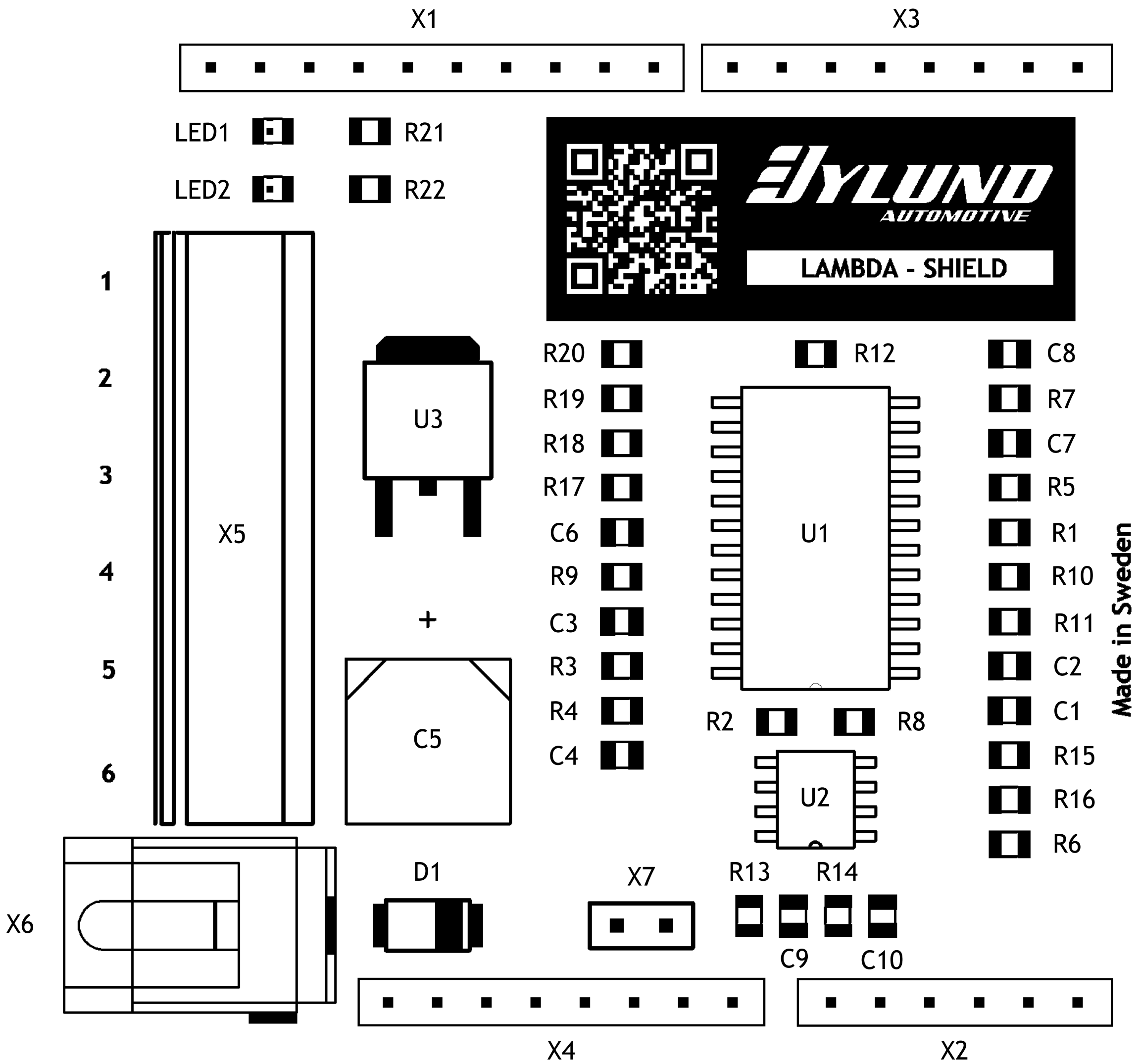
$$\lambda = \frac{\frac{O_2}{3} + 1}{1 - 4.77 \cdot O_2}$$

Calculating λ *value of 1.00 from the* I_P *and* O_2 *examples gives:*

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

5 – Components

5.1 - Component Positions



5.2 - Component List (BOM)

PCBA Component	Description
D1	Diode DO-214AC (2A)
C1, C3, C6, C8, C9, C10	100nF Capacitor C0805
C2	2.2nF Capacitor C0805
C5	220μF Capacitor
C7	1nF Capacitor C0805
C4	1μF Capacitor C0805
R1, R4	10k Resistor R0805
R16	49k9 Resistor R0805
R9	4k7 Resistor R0805
R2, R8, R13, R14, R15, R17, R18, R19, R20	100k Resistor R0805
R3, R6	50R Resistor R0805
R5	6k8 Resistor R0805
R7	31k6 Resistor R0805
R10	470k Resistor R0805
R12	301R Resistor R0805
R11	61R9 Resistor R0805
R21, R22	150R Resistor R0805
U3	MOSFET Transistor
U1[1]	CJ125 Lambda Controller
U2	MOSFET Driver
X1	Stackable header 10-pin
X2	Stackable header 6-pin
X3, X4	Stackable header 8-pin
X7	Jumper Header 2-pin
X5	MKDSN 1,5/6-5,08
X6[2]	DC Power Jack
LED1, LED2	Green LED 0805

[1]. Bosch CJ125 part no. 1 267 379 259.
[2]. 2.5mm / 6.4mm DC Jack.

5.3 — Schematics