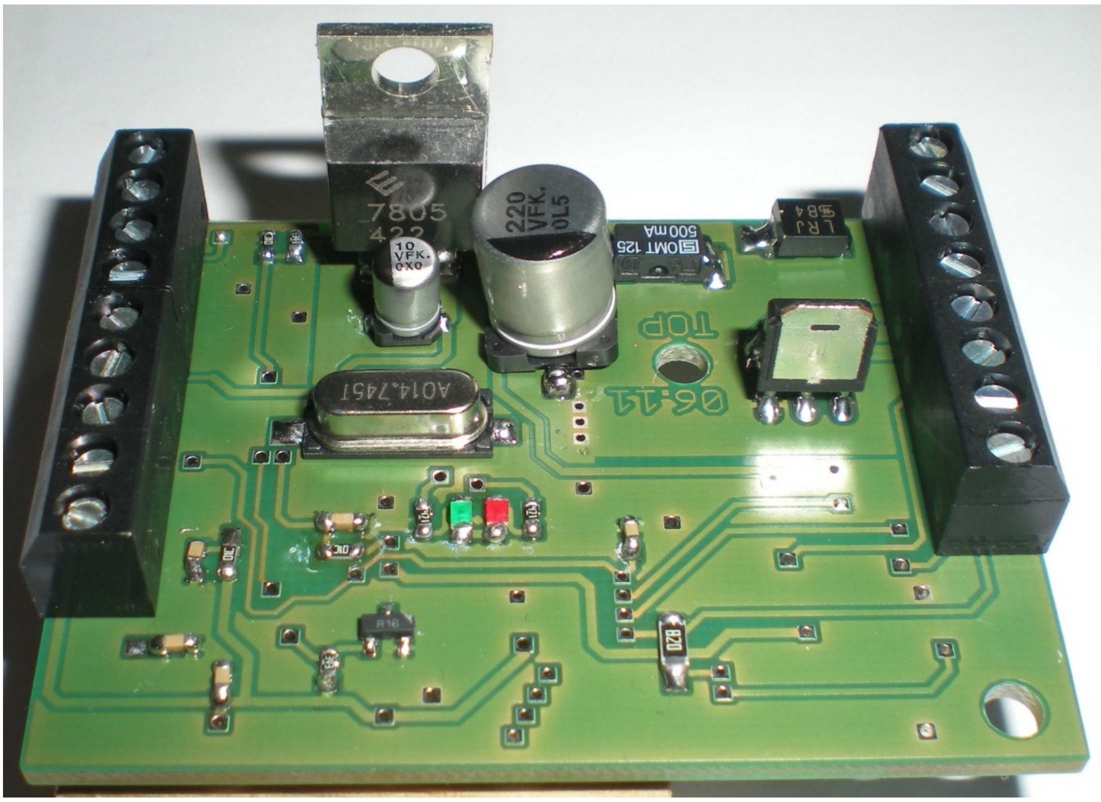
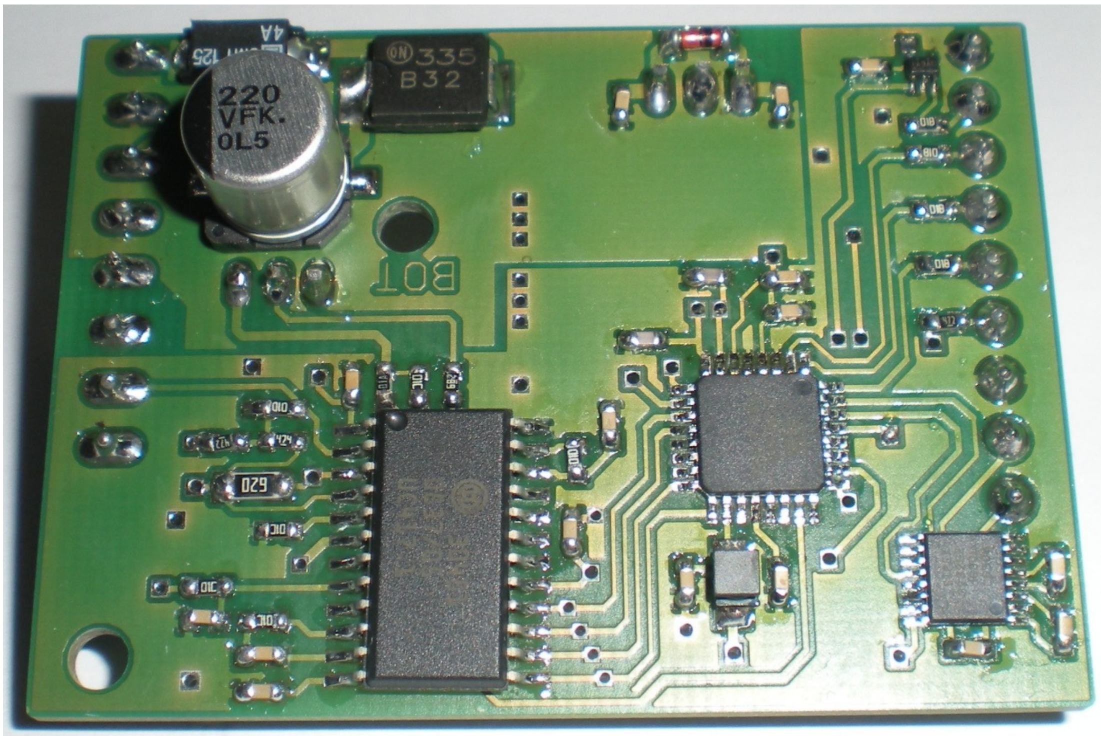
Wideband Lambdasensor Interface with Bosch CJ125

V3.1





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2 Introduction

The interface is based on the Bosch IC CJ125 and is developed for use with a Bosch LSU4.2 or LSU4.9 wideband Lambdaprobe.

Due to continuous development and improvement of circuitry and design in this third generation very little dimensions and high functionality can be achieved.
In this first revision the functionality of software and harware are improved again and are adapted to practical requirements.
The dimensions of the complete circuit board are now 41mm x 57mm.

This circuit contains all necessary function to control a wideband Lambdaprobe.
There are no further controllers or components needed.
Operation without external controller is now possible.

This device is still a prototype which is tested in laboratory environment only.
Distortions in industrial environment as well as EMC-effects are not examined.

3 Functions and operating the circuit

The circuit was developed to measure the oxygen-content of combustion-exhaust gases and calculate the Lambdavalue.
There are two different ranges:

1. Rich range
2. Lean range

If the exhaust gas is “lean” there is molecular oxygen in it. That means there was more oxygen for combustion than needed.
That range is interesting for Diesel-engines and heating systems (i.e. wood pellet or oil-fired heatings) because these devices do not function correct in rich areas.

The rich range is characterized by not burning all the fuel which is available. In the exhaust gas there are unburned fuel fractions existing.
For Otto-engines there is a slight power improvement in the rich area. For turbocharged engines a rich mixture is used to cool down damageable components (turbochargers, pistons and valves).

Due to the increased use of wideband Lambdaprobes in the automotive industry the price sank the last years. The use in heating systems and surveillance purpose is getting more interesting.

3.1 Connector configuration and electrical specifications

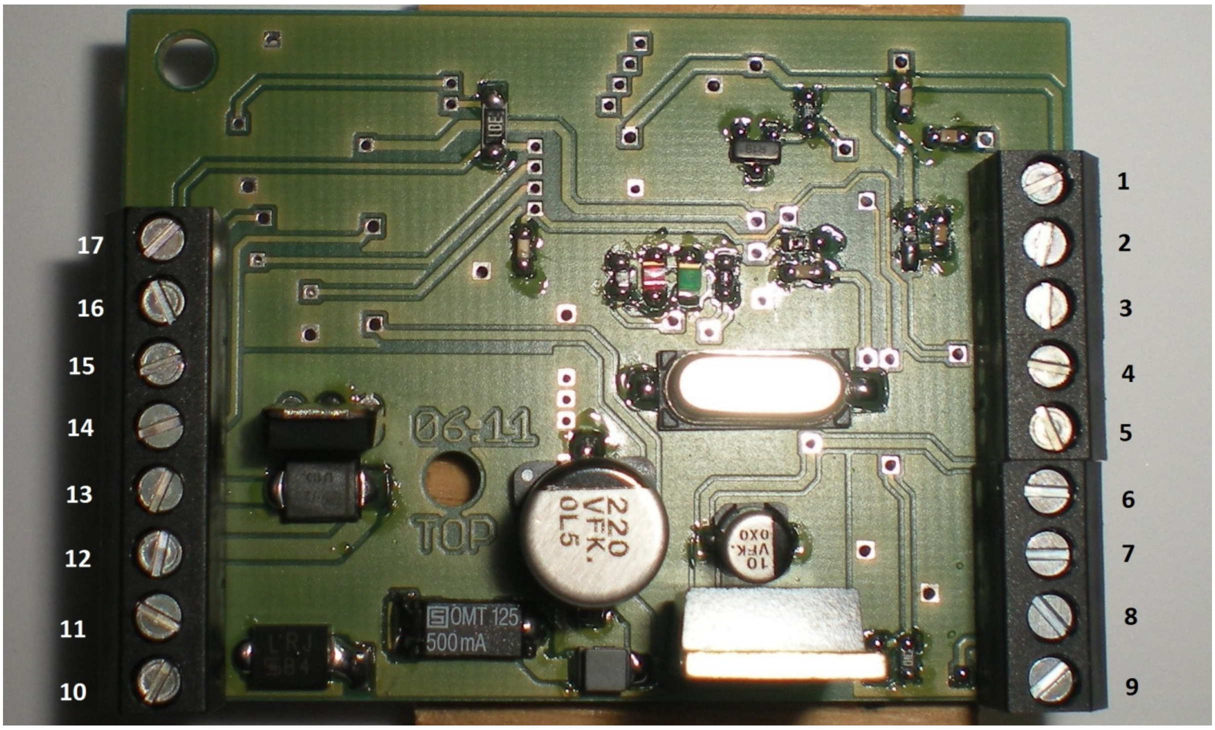

Figure 1: Connector configuration

Caution: Voltages are absolute maximum values!

Connector	**Function**	**Min. Voltage**	**Max. Voltage**
Interface			
1	TxD (RS232)	-12V	12V
2	RxD (RS232)	-12V	12V
3	Ground		0V
4	λ-Value (raw)	0V	5V
5	Error-Out (Out)	0V	5V
6	Start measure (In)	0V	5V
7	Calibrate (In)	0V	5V
8	λ-Value (linear)	0V	5V
9	Ground		0V

Powersupply			
10	+12V		28V
11	Ground		0V
Lambdaprobe			
12	Heater+UBatt (H+; grey)	0V	28V
13	Heater – (H-; white)	0V	28V
14	Pumpcurrent(APE; red)	0V	28V
15	Trimm-Resistor (RT; green)	0V	28V
16	Nernstvoltage(RE+; black)	0V	28V
17	Virtual Ground(IPN; yellow)	0V	28V

Table 1: Connector configuration and electrical specifications

3.2 Powersupply

The powersupply is connected to connector 10 and 11 and hast o fulfill the following specifications:

- stable voltage between 11.0V and 14.0V
- current up to 4A
- immune to current peaks

The heater of the Lambdaprobe is controlled by a slow PWM. This causes current peaks of up to 3.6A.

Figure 2 shows the current consumption at operating temperature with the probe at fresh air. Supply voltage is 12.0V from a Lead-Acid battery.

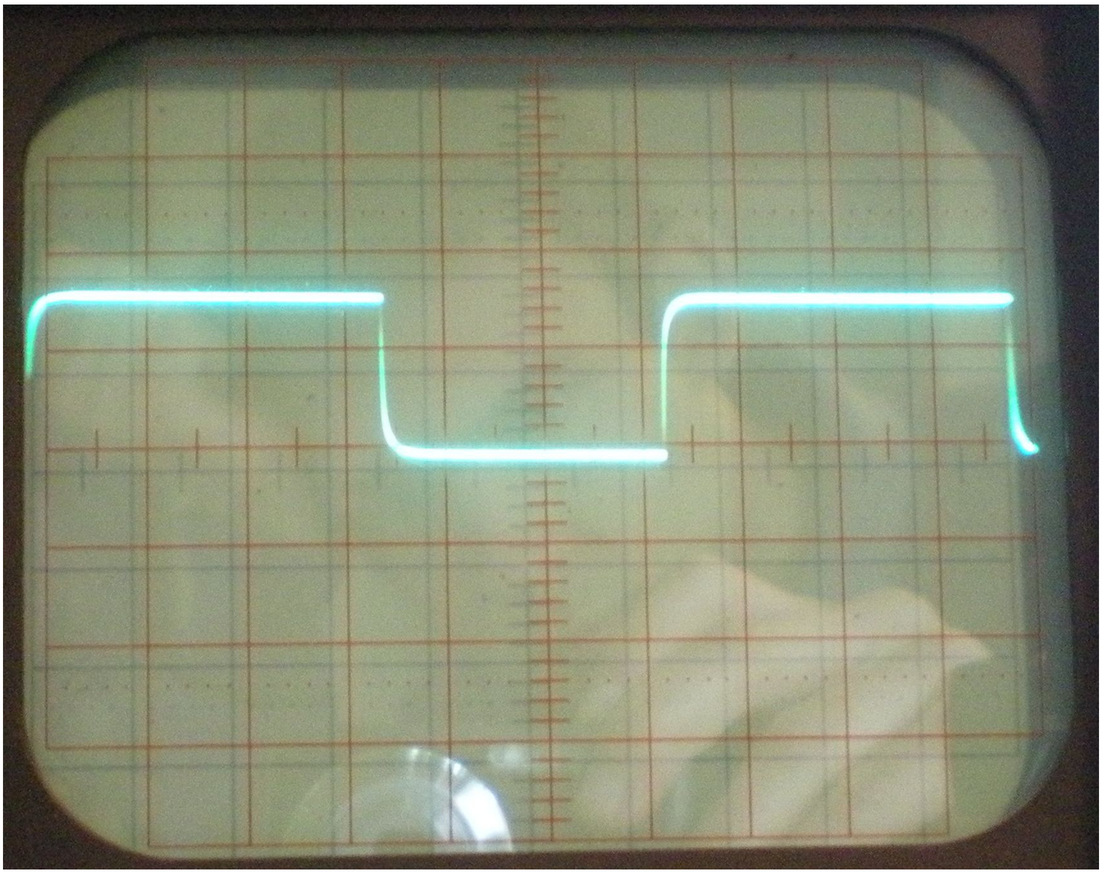

Figure 2: x-Axis: 5ms/Div; y-Axis: 2,4A/Div

Current consumption at stand-by mode with disabled heater is 70mA.

3.3 Status LEDs

The LEDs are signaling following conditions:

LED	Blinking frequency	Function
Green	constang	Stand-by mode
Green	fast (5Hz)	Heating up the probe
Green	slow (1Hz)	Operating temp. reached, measurement started
Red	slow (1Hz)	General failure (use RS232 for identification)
Red and green	fast (5Hz)	Fail-save mode

Table 2: Status LEDs

4 Connecting the circuit board

4.1 Connecting the Lambdaprobe

The Lambdaprobe is connected like in Table 1 mentioned.

Make sure that the probe is only used with its original plug. In the plug there is a individual calibration resistor integrated which is unique for each Lambdaprobe. Without this plug the Lambdaprobe can't be used!

Please make a proper installation sure. Interchanging or not connecting the wires leads to a not functioning circuit. In special cases it can cause severe damage to the Lambdaprobe due to overheating the ceramics element.

4.2 Connecting the analog interface

The analog interface offers the option of using the probe without external controller. Beside an error output (TTL) and an „start“ input an input for the calibration mode is now available too.

The analog interface consists of following connectors:

Pin	Function		Voltagerange
4	λ-Value (raw)	Analog-output	0.5 – 4.8V
5	Error_out	TTL-output	0 – 5V
6	Start	TTL-input	0.5 – 4.8V
7	Calibrate	TTL-input	0 – 5V
8	λ-Value (linear)	Analog-output	0 – 4V

Table 3: Analog interface

Pin 4 „λ-Value (raw)“ provides a value which can be directly converted into the oxygen content. This pin is directly connected to the CJ125 and has a very short reaction time. Converting the value is complex.

Pin 8 „λ-Value (linear)“ provides a linearized voltage for the Lambdavalue. Following versions are available::

- LSU4.2: λ 0.7 – 1.3 (Calibrated to λ=1,00)
- LSU4.2 λ1.0 – 2.0 (Calibrated to λ=1,37)
- LSU4.9 λ1.0 – 2.0 (Calibrated to λ=1,38)

The voltage is linear, λ=1.0 equals 0,0V and λ=2,0 equals 4,0V.

Pin 5 „Error_out“ is normally at „low-level“ (0V). If a failure occours the level changes to high-level (5V). Which kind of failure is present has to be read out via RS232 interface.

Pin 6 „Start“ can be used to start the measurement by pulling it to low-level (0V). The measurement can be started by the analog interface as well as by the digital interface.
The pin is pulled to high-level by a pull-up resistor.

Pin 7 „Calibrate“ can be used to change into the calibration mode. The linearized Lambda-output goes to its reference Lambdavalue and a calibration value is put out by digital interface.
Calibration can only be used while the probe is cold. Calibrating while operating the probe can give back wrong values.
The electronic calibrates itself at start-up. Normally a calibration is not needed.

All connectors are protectd by resistors against shortcircuit them.

4.3 Connecting the digital interface

The digital interface provides all diagnostic features of the used CJ125 and provides a full overview about all operating conditions.

Refreshing interval of the data can be chosen to 1Hz or 5Hz. To convert the data in a Excel-compatible format a adequate mode is included.
The data are provided in the following form:

```
Lambda: 250
Ref: 252
Bat: 505
Status: 32
CJ: 255
```

Excel-compatible mode:

```
250;252;505;32;255
```

The exact functions are explained in the according chapters.

The digital interface has following connectors:

Connector	Function		Voltagerange
1	TXD	RS232-Output	-12...+12V
2	RXD	RS232-Input	-12...+12V

Table 4: Digital interface

For direct connection to a PC or RS232-USB-Converter no level-converter is needed.

5 Functions of the digital interface

With the digital interface there are much more functions as the analog one provides. Its recommended to use the digital interface at least as an add-on to the analog interface.

5.1 Setting up the interface

To receive all data correctly and to send commands following settings have to be used:

Baudrate	115200 Baud
Databits	8
Stopbits	1
Parity	None
Handshake	None

Table 5: UART-Settings

Refreshing rate is up to 5Hz.

5.2 Decoding data pakets

5.2.1 „Lambda“

The first row contains the infomation about the current pumpcurrent in the probe. With this pumpcurrent the exact Lambdavalue can be calculated:

$$I_p = \frac{Lambda \times 5000mV}{1023 \times 62\Omega \times V}$$

V stands for the amplification. Is the probe in a lean atmosphere V is set to 17 while in rich atmospheres V is 8.

5.2.2 „Ref“

„Ref“ stands for the voltage at the build-in reference voltage. The voltage is 1.22V ± 1%. The operating voltage can be in wide range (4.75 to 5.25V) and is used as reference for the ADC.

With the reference the exact ADC reference voltage can be calculated.

$$U_{Referenz} = \frac{5{,}0V}{1023V} \times Ref$$

Ideal „Ref“ value is 250.

5.2.3 „Bat“

„Bat“ stands for the digitalized supply voltage. The voltage is divided by a voltage-divider (39 kΩ to 10 kΩ).

$$U_{Bat} = \frac{5{,}0V \times 4{,}9}{1023} \times Bat$$

Is the „Bat“ voltage below 440 (=10.5V) or above 670 (=16.0V) the measure is canceled and the circuit changes to stand-by mode to protect itself and the probe.

5.2.4 „Status“

In the „Status“ register all general operating conditions and failures are listed. The system is the same as in the register „CJ“.

The register is read in the binary format and looks like this (MSB first):

Status.7							Status.0
Calibration mode	Watchdog	System ready	SPI failure	Ubat high	Ubat low	Probe overtemp.	CJ-failure

Table 6: Decoding "Status"

Decoding:

- Calibrationm.: The circuit is in the calibration mode. The shown values does not equal to the really existing ones!
- Watchdog: Internal program failure – the circuit needs to be restarted.
- System ready: Value „Lambda“ is now useable. Operating temperature is reached.
- SPI Failure: Failure in internal communications.
- Ubat high: Powersupply voltage too high (> 16.0V)
- Ubat low: Powersupply voltage too low (< 10.5V)
- CJ-Failure: Internal failure in the CJ125. Reference „CJ“.

5.2.5 „CJ“

The variable „CJ“ contains the value of the CJ125 diagnosis register and has to be translated into a binary format. For analysing this table can be used:

CJF.7							CJF.0
DIAHG	DIAHD	IA/IP	IA/IP	UN	UN	VM	VM

Table 7: Failure Table "CJ"

With this table or with the datasheet of the CJ125 the binary format can be translated into clear text:

Error-Bits	DIAHG/DIAHD	IA/IP, UN, VM
0 0	Shortcircuit to Ground	Shortcircuit to Ground
0 1	Heater disconnected	Supply voltage low
1 0	Shortcircuit to UBat	Shortcircuit to UBat
1 1	No Error	No Error

Table 8: Clear Text Table "CJ"

If the value for “CJ” equals 255 no error is read out and the circuit is ready for operation.

After reading the diagnosis register it is deleted. If there is an error the heater of the probe is disabled to prevent it from over temperature. Additional to that the pin “Error_out” is pulled to high-level.

If there is a failure the pumpcurrent through the probe and the measurement of the resistance of the Nernstcell is stopped. The voltages and values read for the Lambdavalue are not correct while the error is still present.

Especially with older probes there can be many failures read while heating the probe up to operating temperature. Normally they disappear if operating temperature is reached.

If there are too many failures while heating up the probe should be changed.

5.3 Transmitting commands

Following commands are supported:

Befehl	Funktion
C	Calibration Mode
N	Normal Mode
H	Start Measuring
D	Stop Measuring
F	Fast connection (5Hz)
S	Slow connection (1Hz)
T	Clear Text Mode
E	".csv" Mode (Excel compatible)

Table 9: Command Reference

Description:

C	“Calibration Mode”	The CJ125 is changed into a calibration mode. Read the following chapter for more information.
N	„Normal Mode“	CJ125 is changed into normal measure mode
H	„Start Measuring“	Heating up the probe is started. Ca. 30 sec. later the probe is ready.
D	„Stop Measuring“	The heater is stopped.
F	„Fast connection“	Every second 5 fresh datasets are transmitted.
S	"Slow connection"	Every second one dataset is transmitted (standard setting)
T	"Clear Text"	Datasets are transmitted in clear text (Chapter 4.3)
E	"Excel-Mode"	Datasets are transmitted in „.csv“ compatible format..

The commands have to be transmitted in ASCII-Code and are case sensitive. Each command has to be terminated with a “carriage return” (ASCII character 13).

6 Calibrating the circuit

If the command „C“ is sent to to the board the CJ125 changes into a calibration mode.

In this mode on the output "λ-Value (raw)" a voltage is present which stands for a Lambdavalue of 1,00 (around 1.5V). The output "λ-Value (linear)" is driven to the calibration point too (Chapter 4.2).

The circuit is self calibrating on each power-up. That has only to be repeated if the measuring runs several hours (more than 24 hours).

7 Calculating the oxygen content

The combination of LSU4.2 and CJ125 reaches in the area around Lambda = 1 its highest accuracy.

At Lambda = 1.70 the probe has a measuring error of ±0.05 which can rise up to ±0.15 due to aging effects.

At Lamdba = 1.009 this measuring error is only ±0.006 and after 2,000 hours of operation ±0.008.

To calculate the oxygen content in the exhaust gas you have to generate a calibration curve with the values from the LSU4.2 or LSU4.9 datasheet:

O_2 cont.	0.0%	3.0%	6.0%	8.29%	12.0%	20.9%
Pumpcurrent	0.00mA	0.34mA	0.68mA	0.95mA	1.40mA	2.55mA

Table 10: Value table oxygen content/pumpcurrent

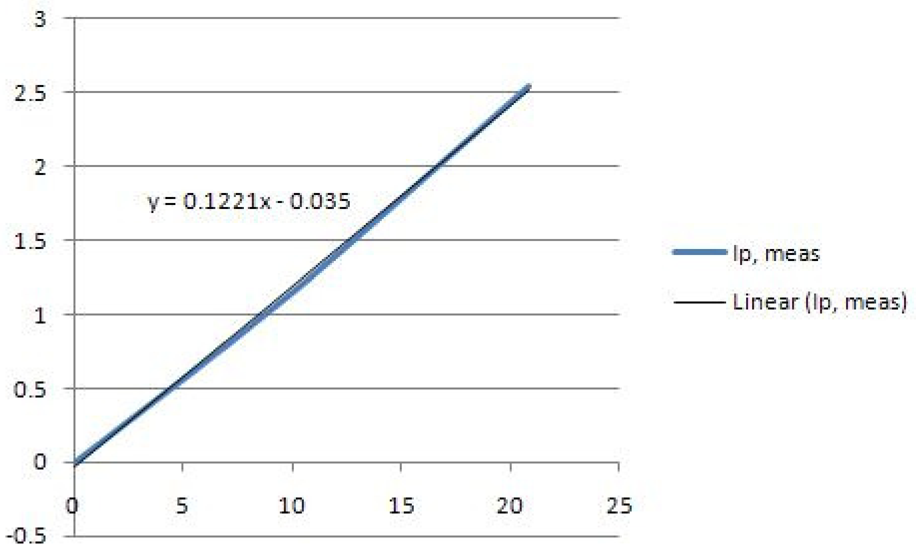

Figure 3: Oxygen concentration / Pumpcurrent

The oxygen concentration is directly proportional to the current which flows through the pumpcell.
This current is measured by the CJ125 via a shunt-resistor. The voltage drop over the resistor is amplified and measured.

The relation between current and voltage is explained in chapter 5.2.1.

To calculate the oxygen content the following equation can be used (Bosch LSU4.2 only!):

$$O_2 = \frac{I_p + 0{,}035}{0{,}1221}$$

For the rich area and the Lambdaprobe LSU4.9 there are different calibration values.

To get more accurate measurements a special gas for calibration can be used (e.g. from “Linde Gase” in Germany).