

# **dSPACE Application Note - Operating lambda probes with RapidPro SC-EGOS module**

**Version 2.0**

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## About this solution

This application note shows how to work with the RapidPro lambda module SC-EGOS 2/1 (DS1634). Please notice that this document belongs to board revision 06 (DS1634-06) and newer. For former versions there exists an older application note (vs1.0). With that board revision a new type of lambda probe is supported (Bosch LSU-ADV type) and hence there are also some differences in operation mode of the module.

## Introduction

The RapidPro hardware is an extension to dSPACE prototyping systems and consists of three different unit types: the RapidPro SC Unit (signal conditioning unit), the RapidPro Power Unit (power stage unit), and the RapidPro Control Unit (intelligent I/O subsystem for dSPACE prototyping systems). With their compact and robust mechanical design, the units are ideally suited for in-vehicle use, and can also be used on test benches and in laboratories. The enclosure is designed so that you can either use the units separately or connect several of them to build a stack for use as one physical unit. Off-the-shelf hardware- and software-configurable signal conditioning (SC) and power stage (PS) modules can be mounted on the RapidPro units to set up individual systems that optimally fit the needs of a particular application. Customer-specific modules are available on request. The modular concept, using modules that are hardware- and software-configurable, means that all components can be reused, reconfigured, or extended, for example in later projects, with a minimum of effort.



**Figure 1 RapidPro triple Stack**

This application note gives instructions on putting a lambda probe into operation together with the RapidPro module SC-EGOS 2/1. The SC-EGOS 2/1 module supports Bosch linear lambda probes LSU4.2, LSU4.9 and LSU-ADV.

This document gives a short introduction to lambda probes, describes the module and explains its use on the basis of an example application.



**Figure 2 SC-EGOS 2/1 Module**

# Lambda Sensors

## Principle of a Lambda Probe

A lambda probe measures the remaining oxygen content in the exhaust gas so that the engine ECU can determine the amount of fuel required to ensure optimal exhaust gas values. The remaining oxygen content is expressed by the variable  $\lambda$ :

$$\lambda = \frac{\text{current\_air\_to\_fuel\_ratio}}{\text{stoichiometric\_air\_to\_fuel\_ratio}} = \frac{\text{current\_air\_to\_fuel\_ratio}}{14.7:1}$$

Complete combustion can be achieved only if the air-to-fuel ratio is 14.7 : 1 (for gasoline motor), thus  $\lambda = 1$ .

Rich air / fuel mixture  $\lambda < 1.0$

Lean air / fuel mixture  $\lambda > 1.0$

For significant results the lambda probe has to be operated at a specific temperature. The recommended working point depends on the probe type and can be found in the probes documentation.

## Narrowband Sensor

Also known as a two-step lambda oxygen sensor (Bosch notation: LSF or LSH).

The O<sub>2</sub> concentration is measured in the Nernst cell, which generates a voltage depending on the O<sub>2</sub> concentration.

This type of oxygen sensor can only output a rich-lean indication. The exact air/fuel ratio can not be estimated. When the air/fuel ratio is perfectly balanced, a conventional O<sub>2</sub> sensor produces a signal of about 0.45 volts (450 millivolts). When the fuel mixture goes rich, even just a little, the O<sub>2</sub> sensor's voltage output shoots up to its maximum output of close to 0.9 volts. Conversely, when the fuel mixture goes lean, the sensor's output voltage drops to 0.1 volts.

Every time the oxygen sensor's output jumps or drops, the engine ECU responds by decreasing or increasing the amount of fuel that is delivered. This rapid flip-flopping back and forth allows the feedback fuel control system to maintain a more-or-less balanced mixture, on average.

## Wideband Sensor

Also known as a linear lambda probe, air/fuel ratio sensor or UEGO (universal exhaust gas oxygen) sensor (Bosch notation: LSU or LSV).

With a two-step sensor, only 'Lambda > 1' and 'Lambda < 1' states can be detected. To achieve better exhaust values, the exact concentration of oxygen must be known. A linear lambda probe allows linear measurement of the oxygen concentration.

## Structure

The wideband sensor is a combination of a Nernst cell and a current driven oxygen pump cell. The Nernst cell works as described in the chapter about the narrowband sensor. With the current in the pump cell oxygen ions can be delivered or removed from the measuring cell. So an electronic circuit containing a feedback loop controls the oxygen pump current ( $I_p$ ) to keep the output of the electrochemical cell constant, so that the Nernst cell always detects  $\lambda=1$ . Deviations will be adjusted by the controller and the pump current. Therefore the intensity of the pump current is an indicator for the exact  $\lambda$  value.

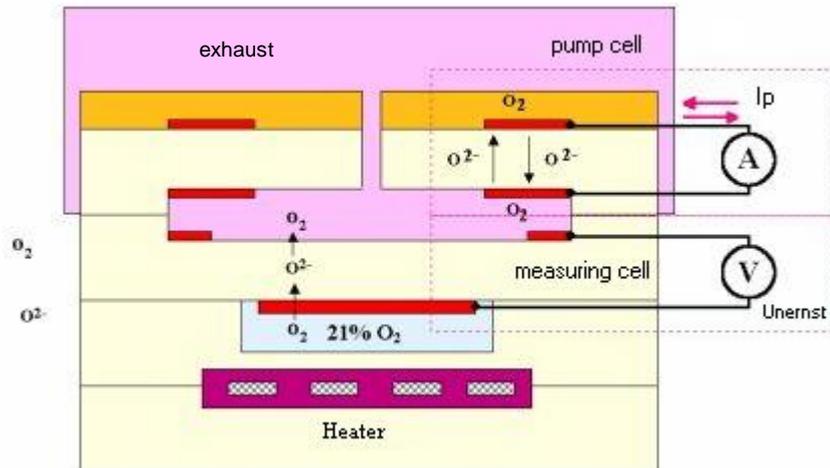


Figure 3 Principle structure of a linear lambda probe

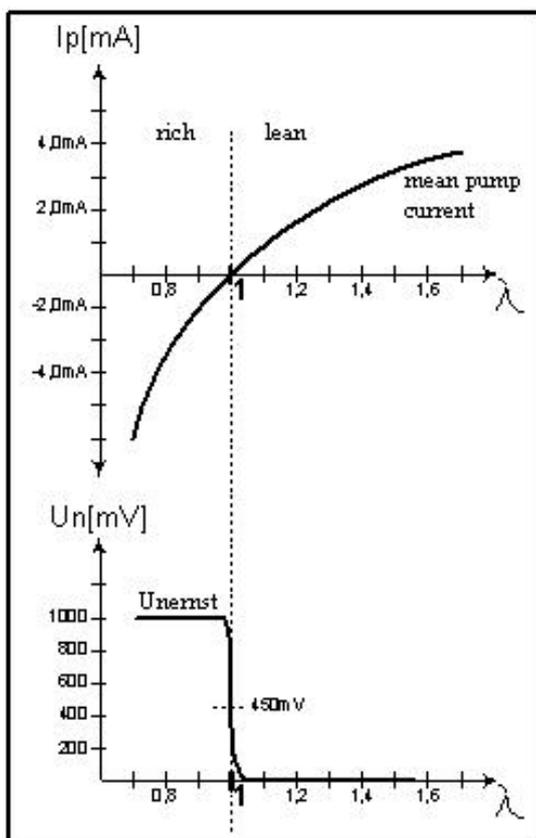


Figure 4 Example Correlation between pump current and lambda value

# SC-EGOS 2/1 Module

## Overview

The dSPACE RapidPro SC-EGOS 2/1 module (DS1634) is a two-channel exhaust gas oxygen sensor (EGOS) module for connecting Bosch LSU4.2, LSU4.9 and LSU ADV lambda probes.

It is based on two Bosch CJ125 ICs, which are used to control the connected lambda probes. Therefore two of the mentioned lambda probes can be connected.

The configuration of the SC-EGOS 2/1 module for using LSU4.2, LSU4.9 or LSU-ADV must be done by dSPACE.

A linear lambda probe of LSU4.2 / 4.9 type has six pins. The lambda probe of type LSU-ADV has only 5 pins (Trim resistor IA is missing). Two of the pins are used for the heater of the sensor. It is recommended to operate the lambda probe heater with the help of a RapidPro Power Unit. More details about heating up the lambda probes are given in a later chapter. The remaining four pins are signals  $U_N$ ,  $V_M$ ,  $I_A$ ,  $I_P$ .

### Module input = lambda probe output

EGOS_ $U_N$	-	Nernst voltage ( $U_{Nernst}$ )
EGOS_ $V_M$	-	virtual ground
EGOS_ $I_A$	-	adjustment current through trim resistor (not provided at LSU ADV probe)
EGOS_ $I_P$	-	pump current
EGOS_GND	-	module ground, must be applied only once per module

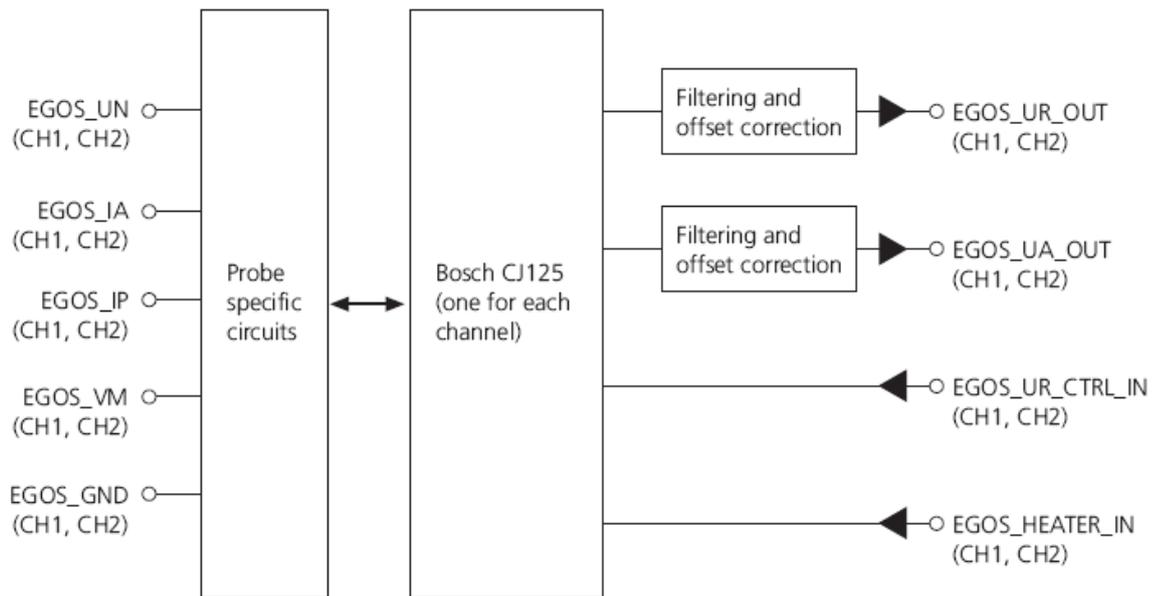
### Module output

EGOS_UR_out	-	$R_i$ - measurement output voltage
EGOS_UA_out	-	Lambda measurement output voltage

### Module control input

EGOS_CTRL_in	-	$R_i$ Measurement control input (for Lsu4.2 and 4.9) / Control of pump current (for LSU ADV)
EGOS_Heater_in	-	Heater Signal input (The control signal for the lambda heater is also provided to the CJ125 IC on the SC-EGOS module. This improves signal quality of the lambda signal).

For more detailed information about the different signals please refer to the 'RapidProInstConfigRef.pdf'. Please be aware that the signal EGOS\_CTRL\_IN formerly was denoted as EGOS\_UR\_CTRL\_IN. As of board revision DS1634-06 this signal has different functionality when using LSU4.2/4.9 or LSU-ADV probes (see later chapters).



**Figure 5 Input and Output signals of SC\_EGOS module**

#### **Routing of RapidPro system for usage with SC-EGOS 2/1 Module**

To be able to operate the SC-EGOS system in a RapidPro system with ControlUnit it is necessary to configure the RapidPro system with a special routing code. If a new rapidPro system with SC-EGOS module is delivered this is already considered. If you rearrange modules afterwards a new routing code might be necessary. In this case please contact dSPACE

## How to Use - Example Application

This chapter explains how to use a Bosch LSU lambda probe on the basis of an example application ('SC\_EGOS\_example.mdl'). Please notice, that in the example model channel 1 is configured for Bosch LSU ADV probe and channel 2 for LSU 4.2 probe type.

### Configuring the SC-EGOS module

As mentioned before the SC-EGOS module supports different types of lambda probes. This configuration can only be done by dSPACE. You can control the configured type with the help of ConfigurationDesk (see entry 'supported lambda probe') but you can not change it.

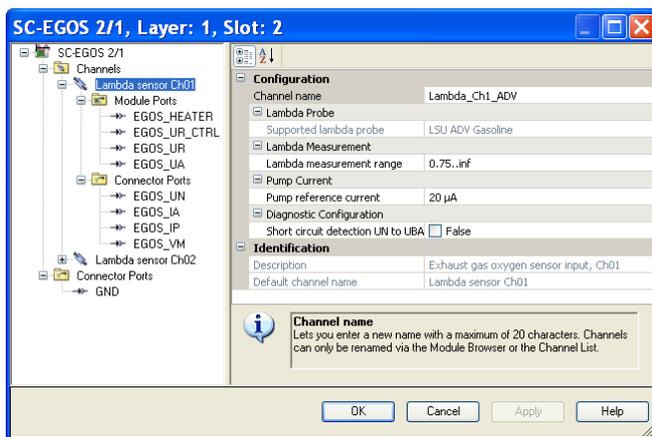


Figure 6 Configuration of channel 1 of the example model

Furthermore you can see and adjust the lambda measurement range and the pump reference current. Please refer to the probes documentation for the exact value of your probe.

### Heating the Lambda Probe

Bosch lambda sensors LSU4.2 / 4.9 / ADV have an integrated heater to maintain working temperature.

As explained above, the SC-EGOS 2/1 module can be used in a Signal Conditioning Unit or in a Control Unit. The current required for heating the lambda probe must be provided by an additional RapidPro Power Unit including power modules. For driving the sensor heater, a low side driver module (PS-LSD 6/1) or a high side driver module (PS-HSD 6/1) can be used.

If the heater needs more than 5 A, because of low ambience temperature or fast heat-up behavior, two channels of the power module must be used in parallel and synchronously. Therefore both channels of the power module have to be driven by the same PWM signal. Special routing must be performed by dSPACE for this. In this case please contact dSPACE.

The measured lambda values are only exact if the lambda probe is at the working point. Normally for the working point a value of resistance  $R_i$  and not a temperature value is given. The exact working point values can be found in the probes documentation.

The formulas for estimating Ri from EGOS\_UR can be found in the RapidProInstConfigRef.pdf:

- For LSU4.2:

$$R_i [\text{Ohm}] = \frac{\text{EGOS\_UR\_OUT} [\text{V}] - 0.294}{0.00775}$$

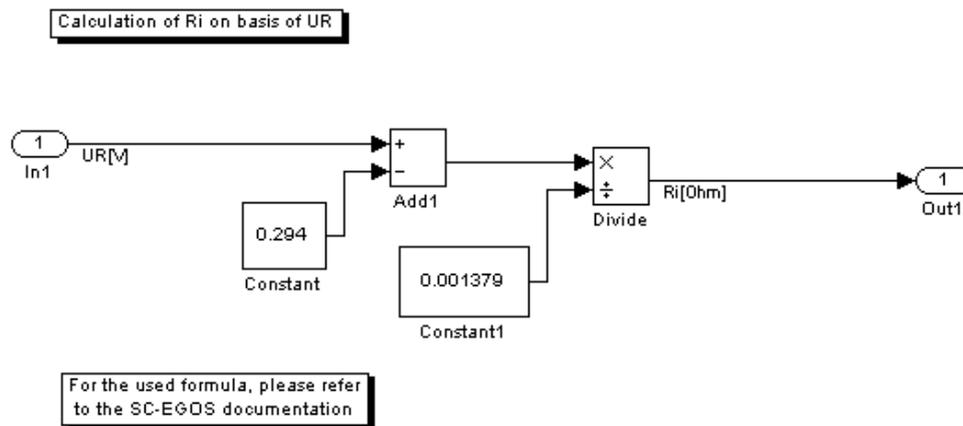
- For LSU4.9:

$$R_i [\text{Ohm}] = \frac{\text{EGOS\_UR\_OUT} [\text{V}] - 0.294}{0.00245}$$

- For LSU ADV:

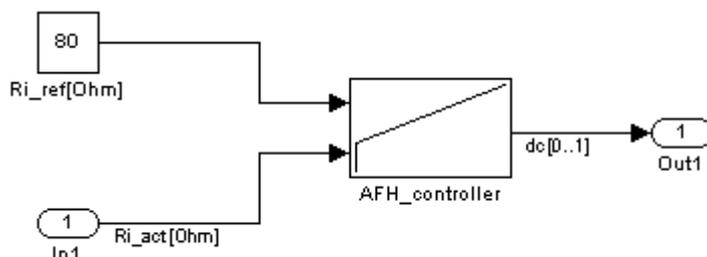
$$R_i [\text{Ohm}] = \frac{\text{EGOS\_UR\_OUT} [\text{V}] - 0.294}{0.001379}$$

They are used in the example model in subsystem 'Lambda\_Probe\_Ch1/LSU\_ADV\_Ri\_calc'



**Figure 7 Calculation of Ri [Ohm]**

In the model the working point is reached and held by the help of a PID-controller. Input value is the current value of Ri[Ohm] (estimated from EGOS\_UR) and output is the duty cycle for the heater channel. The controller parameters for the LSU 4.2 and LSU ADV implementation differ slightly. You have to find out the best parameters for your application. Please notice, that for LSU4.2/4.9 valid signals of EGOS\_UR are only achieved when EGOS\_Ctrl is activated (signal is low-active)(see also next chapter).

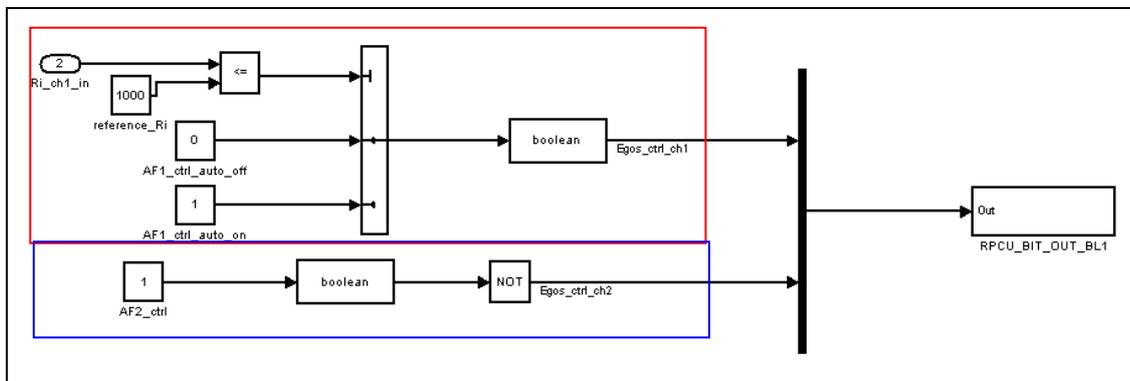


**Figure 8 Example PI-controller implementation for LSU4.2**

Input:  $R_i$  reference value,  $R_i$  actual value – Output: duty cycle for heater PWM

## How to use EGOS\_Ctrl signal

The signal EGOS\_Ctrl has different functionality when used for a LSU-ADV or LSU4.2/4.9 probe.



**Figure 9 Usage of EGOS\_ctrl signal**

*LSU ADV (upper part of figure, red frame):*

For LSU-ADV probes it is recommended to switch on the pump current not before a certain working temperature is reached. For this purpose when working with LSU-ADV probes the EGOS\_ctrl signal has the functionality of switching pump current  $I_p$  on and off. In the example model this is done temperature (means  $R_i$ ) depending. Therefore it is checked whether the current value of  $R_i$  is below a certain border (here 1000 Ohm). Only if this condition is fulfilled the EGOS\_Ctrl signal is set to '1' and hence the pump current is enabled. Without enabling the pump current no lambda measurement is possible.

*LSU 4.2/4.9 (lower part of figure, blue frame):*

For measuring the resistance  $R_i$  a high frequency measurement signal is superposed. This measurement signal can cause small disturbances on the measured signal EGOS\_UA. With the control signal EGOS\_Ctrl you are able to switch of this measurement signal. But when switching off the measurement frequency the signal EGOS\_UR is not valid and hence the heater controller has no information about the actual resistance  $R_i$ . A switching mechanism between measuring EGOS\_UA and EGOS\_UR could help solving this problem. In the example model no mechanism like that is implemented. Instead the measurement frequency is switched on permanently. Please notice, the polarity of the EGOS\_Ctrl signal:

Low level =  $R_i$  measurement on

High level =  $R_i$  measurement off

In the example model a constant '1' is given to the EGOS\_ctrl output, but via the 'not' block an inversion is reached, so that in the example model the measurement frequency is permanently switched on.

## How to determine the Pump current $I_p$ and lambda value

From measurement variable EGOS\_UA it is possible to determine the pump current  $I_p$ . The formulas for this math operation is given in the RapidProInstConfigref.pdf. In the example model in the figure below this is shown for a LSU-ADV probe. The parameters are depending on the probe type (gasoline or diesel) and the measurement range that could be configured in ConfigurationDesk.

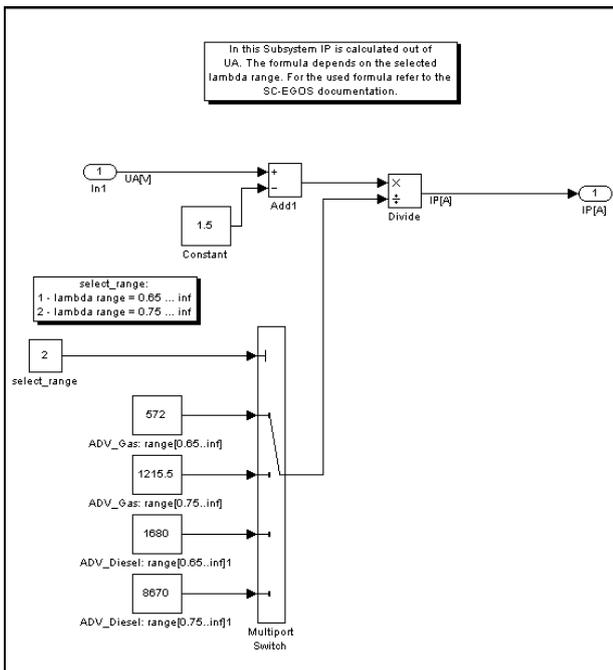


Figure 10 Determining pump current for LSU-ADV probe

The relation between pump current and lambda value results in a characteristic curve. As dSPACE can not provide this table data some dummy data is used in the example model. More information is given in the probes documentation or contact the probes manufacturer.

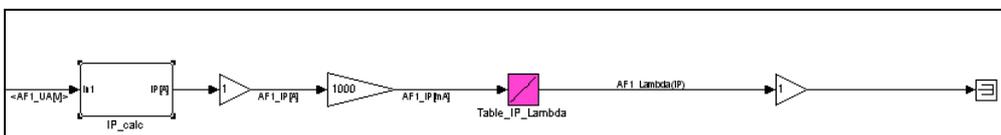


Figure 11 Determining lambda value

## How to Contact dSPACE Support

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- Via Start – Programs – dSPACE Tools (after installation of the dSPACE software)
- At <http://www.dSPACE.com/goto?supportwizard>  
You can always find the latest version of dSPACE Support Wizard here.

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