



Back

WBo2

Products

Software

Help & Info.

Purchase

Lambda-16 (λ_{16}) - High Resolution AFR/ Lambda Value



This page describes λ_{16} . For WBo2 wideband firmware xx61 (and higher) the RS232 [2.0 frame](#) format is modified. The **Wideband ADC value** (bytes 6 and 7) is changed to be **Lambda-16** (abbreviated in normal text to **L16** or to λ_{16} in formatted text).

$\lambda_{16} \Leftrightarrow \lambda$ - Formula and Conversions

Lambda-16 is an unsigned 16 bit number representing lambda (λ). For simplicity and to preserve accuracy across the possible range of Lambda, Lambda-16 is a dual-slope transfer function covering the ranges :

1. Lambda = 0.5 \rightarrow 5.0 (normal usage range of unleaded AFR = 7.35 to AFR = 73.5)
2. Lambda = 5.0 \rightarrow free-air (useful for non-tuning wideband applications)

Lambda (λ) is converted to Lambda-16 (λ_{16}) as follows

```
If ( $\lambda < 5.0$ )
     $\lambda_{16} = (\lambda - 0.5) * 8192$ 
else
     $\lambda_{16} = 36864 + ((\lambda - 5.0) * 128)$ 
```

Lambda-16 is converted to Lambda as follows:

```
if ( $\lambda_{16} < 36864$ )
     $\lambda = (\lambda_{16} / 8192) + 0.5$ 
else
     $\lambda = 5.0 + ((\lambda_{16} - 36864) / 128)$ 
```

Note that **AFR** is directly related to λ , and λ_{16} , by

$$\begin{aligned} \text{AFR} &= \lambda * \text{AFR}_{\text{stoich}} \\ \text{AFR} &= ((\lambda_{16} / 8192) + 0.5) * \text{AFR}_{\text{stoich}} \quad (\text{for the useful vehicle tuning range}) \end{aligned}$$

Where **AFR_{stoich}** is the AFR value at stoich for the fuel used (14.7 for unleaded).

λ_{16} Precision

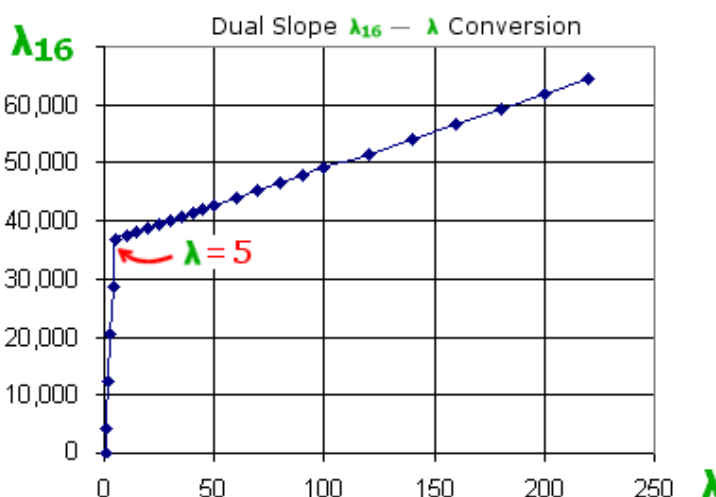
For lambda < 5.0 the granularity of Lambda derived from Lambda-16 is $(1/8192) = 0.000122$ so for Lambda between 0.500 and 5.000 it is represented very precisely to 3 decimal places.

For Lambda > 5.0 the granularity is $(1/128) = .0078$ so a 1 (or closer to 1.5) decimal place representation for Lambda is very precise.

The limits for the Lambda-16's representation of Lambda are 0.5 (L16 = 0) and Lambda = 224.0 (L16 = 65,535).

% Oxygen, λ and Wideband

Bosch have a (rough) formula for calculating λ from percent oxygen (**xO2**) - it only works in the lean region where % oxygen is positive, and it also assumes the H/C (Hydrogen to Carbon) ratio is 2.0. Here K is a constant and, depending on the Bosch document, is either 4.76 or 4.77 (it depends on what you define as the free-air oxygen concentration). Also **xO2** is a fraction, eg. 0.207 for free-air:



- $xO_2 = 3 * (\lambda - 1) / (1 + 3 * K * \lambda)$
- $\lambda = (xO_2 / 3 + 1) / (1 - K * xO_2)$

Note that **Ipx** (see below) is fairly linear when graphed against **xO2**. **Ipx** graphed against **λ** is very non-linear and they actually have a reciprocal relationship.

Go here for more information about [oxygen percentage](#).

Why λ₁₆?

The original *Tech Edge* wideband controller (the 2A0) worked with just one sensor family (the LSU 4.0/4.2). We didn't think of all future possibilities when we made some firmware design decisions. For RS232 logging we specified a [2.0 data frame](#) with two Lambda representations:

- **Ipx** = the sensor's **Normalized Pump Current** where 0 is the maximum **rich** value and 8192 is the **free-air** value (ie. Oxygen % = 20.7 and there are no additional hydrocarbons present). Ipx is limited to the range 0 to a slightly larger value than 8192. Ipx at stoich is a value around zero pump current (or close to 4096). The actual stoich Ipx depends on the sensor and to some extent the gas mix.
- **DAC-Count** = the 12 bit value of the currently programmed WBlin voltage sent to the controller's hardware DAC (Digital to Analogue Converter). For the default output values, the DAC-Count was 0 for AFR = 9.00 and 4095 for AFR = 19.0.

This created some future problems:

- If you use **Ipx** then non-linear tables and interpolation are, for many people, apparently difficult to program as it requires a non-linear lookup-up table and interpolation, to generate λ (or AFR).
- if the WBlin voltage was re-programmed then the **DAC count** changes too!
- Different sensors have slightly different Ipx vs. λ curves, which means that if you use the **Ipx** field and a fixed lookup table, then if the sensor type changes (eg. from LSU 4.0/4.2 to LSU 4.9 or to NTK) then the lookup table should also change.

We wanted to resolve these problem, which were not significant except for those customers who wanted the best possible accuracy our equipment was capable of (and who doesn't). So, we introduced Lambda-16 and put it in the DAC-Count field which was most likely to change anyway.



Page updated 24 Mar 11 ([link added](#))

Unique-visitor counter **3852** Statistics by www.digits.net

Page created 13 Apr 2007 | [Tell me about broken links](#)

[◀ Back](#) [WBo2](#) [🏠](#) [Contact](#) [Feedback](#) [Copyright ©](#) **Tech Edge**