Toyota A/F Ratio Sensor + Planar A/F Sensor Review

Air Fuel Ratio sensors are commonly termed Wide Range Ratio A/F sensors, Wide Band O² sensors, Air Fuel (A/F) Ratio sensors or Wide Range Air Fuel (WRAF) sensors.
An increasing number of vehicle manufacturers are now adopting the Air Fuel Ratio sensor to their newer vehicles.

Air Fuel Ratio sensor applications are of two types used in Toyota vehicle applications:

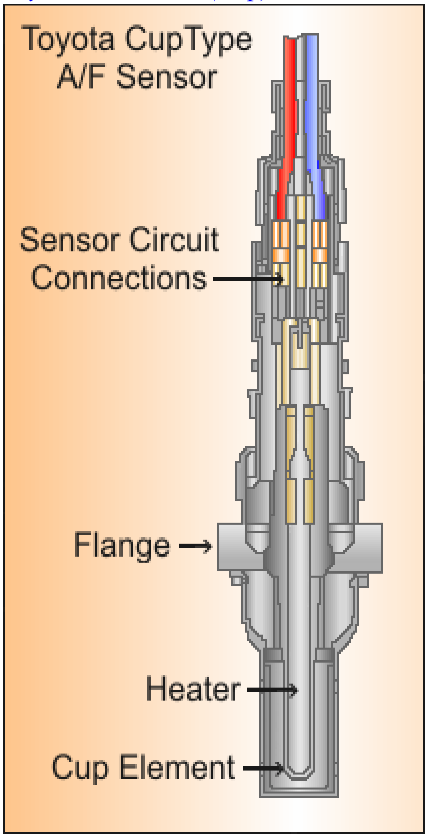
- Wide Band A/F Ratio Planar sensor (cup type)
- Wide Band A/F Planar sensor (integrated heater element type)

Unlike the conventional O² sensor construction, the A/F Ratio sensor contains additional elements to enable the ECU/PCM to provide a more rapid and wider correctional range to the fuel correction to maintain the stoichiometry point.

Toyota A/F Ratio sensor signal data and system monitoring is specific and unlike that of Toyota vehicles using the conventional narrow band O² sensor.

Toyota Air Fuel Ratio Sensor – Planar (cup type)

Toyota A/F Sensor (Cup) Schematic



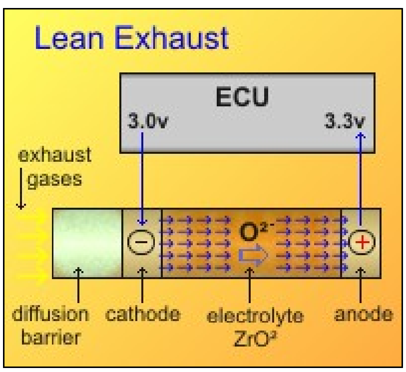
The Air Fuel Ratio (A/F) sensor appears similar to the narrow band oxygen sensor, (O^2 sensor), but it is constructed differently and has different operating characteristics.

The A/F Ratio sensor is a wide band sensor because of its ability to detect air fuel ratios over a greater range than that of a conventional O^2 sensor.

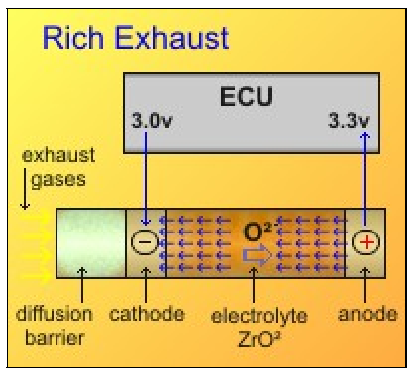
The accuracy from the A/F Ratio signal enables the ECU to have greater control of fuel monitoring, resulting in reduced vehicle tail pipe emissions.

The A/F Ratio sensor requires greater temperature application, (650°C), compared to the conventional O^2 sensor temperature requirement of 400°C.

The A/F Ratio sensor changes its current (amperage) in relation to the amount of oxygen left after combustion in the vehicle exhaust gas stream.
A detection circuit incorporated in the ECU allows for changes in the strength of the current flow and outputs a current signal relatively proportional to exhaust content.



O^2 Ion Transfer Schematic1



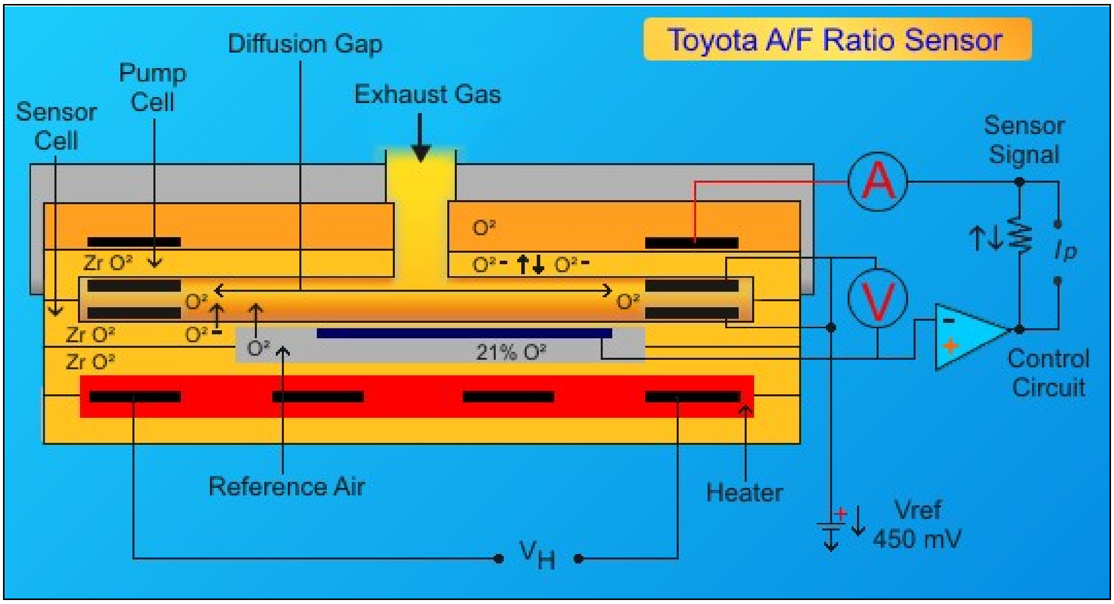
O^2 Ion Transfer Schematic 2

Unlike the conventional O^2 sensor, the A/F Ratio sensor signal does not make abrupt signal changes when the air fuel mixture turns lean or rich.

This makes the A/F Ratio sensor better suited for the low emissions standards required by vehicle manufacturers in their production of new vehicles.

Toyota Air Fuel Ratio Sensor Operation

The A/F Ratio sensor outwardly appears of similar construction to the conventional oxygen sensor. However, internal elements and operation are different than that of the conventional O^2 sensor.



The A/F Ratio sensor protected nose cone houses a dual sensor element. The protected ceramic coated cell combines a laminated sensing element layer with an 'oxygen pump' cell, separated by a 'diffusion gap'.

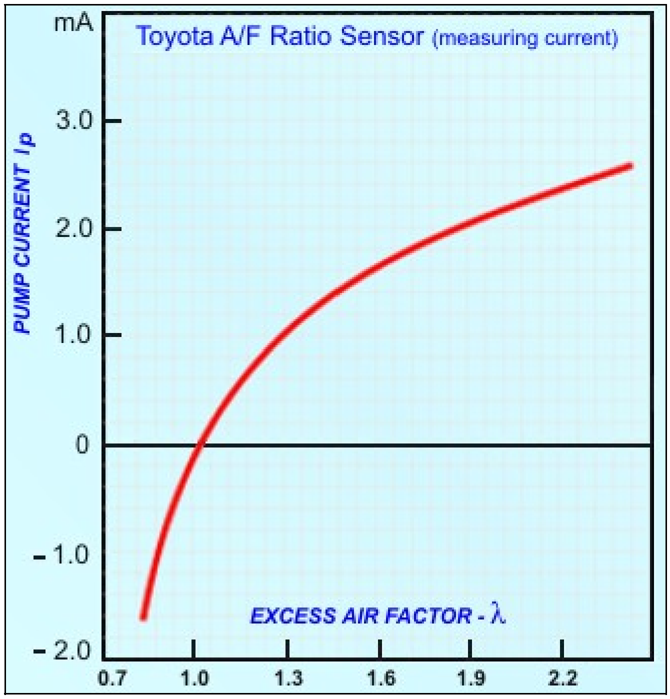
Engine exhaust gases permeate through vents in the protective outer A/F Ratio sensor nose cone. Oxygen is diffused through the ceramic substrate containing the sensor element ZrO^2 layer and the reaction causes the Nernst pump cell to generate a voltage. The oxygen pump compares the change in voltage to the control voltage from the ECU and balances one against the other to maintain an internal O^2 ion balance.

This alters the current flow through the sensor, creating either a negative or positive current signal that indicates the exact air fuel ratio. If the current signal increases, (positive current signal), the fuel mixture becomes leaner, conversely, if the signal is a negative current signal, the fuel mixture becomes richer. When the correct air fuel ratio (14.7:1) is attained, current flow stops and the current signal ceases in either direction.

The ECU sends a controlled reference voltage (3.30 volts) to the A/F Ratio sensor and monitors the A/F Ratio sensor output current signal from a paired wired set.
The ECU detection circuit monitors the strength and change of current flow of the sensor element i.e. High or Low. The current change indicates the exact air fuel ratio of the engine.

Sensor current flow is relatively small, being approximately 0.02 amperes. The ECU converts the sensor signal into data values that can be read by your Hanatech scanner.

A/F Ratio Sensor Measured Current Graph



Note:

The A/F Ratio Sensor is a **CURRENT GENERATOR** [fixed voltage output]

A conventional O² sensor is a **VOLTAGE GENERATOR** [no current output]

The A/F Ratio sensor incorporates a heater element to help enable the sensor to reach operating temperature rapidly. A/F Ratio sensors operate at a much higher temperature than that of a conventional O² sensor.

Typically the A/F Ratio sensor operating temperature required is approximately 650°C compared to that of 400°C for a conventional O² sensor.

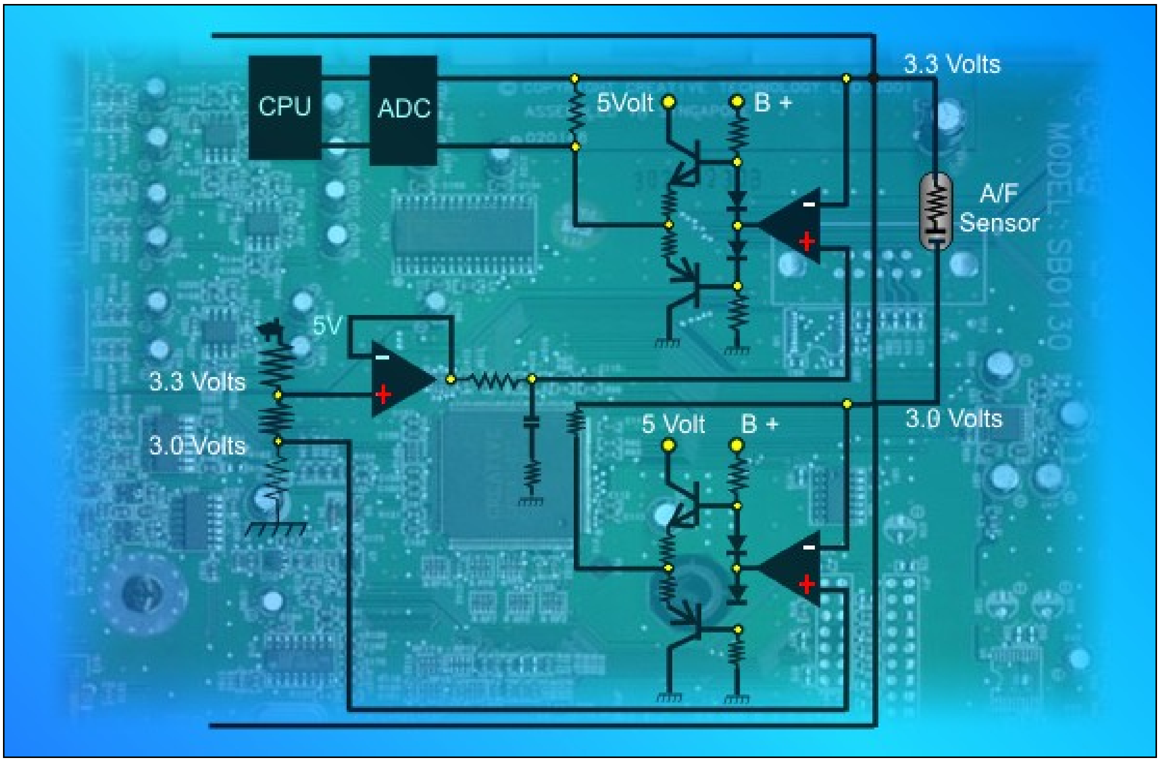
The amperage of the conventional heater relay for the O² sensor is approximately 2 amperes, where as the A/F Ratio sensor heater relay can be as high as 8 amperes. The high heater relay amperage is needed for the additional heating of the A/F Ratio sensor heater element.

Engines using dual circuit A/F Ratio sensors are controlled by the A/F Ratio sensor relay. Operation of the A/F Sensor relay is simultaneous with the switch on of the EFI system relay.

The A/F Ratio sensor heater circuit is of a duty ratio controlled width modulated (PMW) design.

The ECU continually monitors the heater circuit and if a circuit malfunction occurs, A/F Ratio sensor operation will not be operational during most driving modes and the ECU will record the failure

ECU Control Detection Circuit Schematic



ECU Internal Detection circuitry Schematic

The ECU creates a 0.30 voltage differential across the A/F Ratio sensor electrodes. The potential difference of 0.30 volt is fixed. The ECU internal circuitry generates a current in order to maintain the fixed voltage.

The ECU sends a reference voltage of 3.30 volt to the A/F Ratio sensor and the returned sensor signal is processed by the ECU. The processed data can be displayed on a scanner as an A/F ratio value, a fuel trim value and a voltage value.

The Hanatech scanner will display voltage data as shown in the table below.

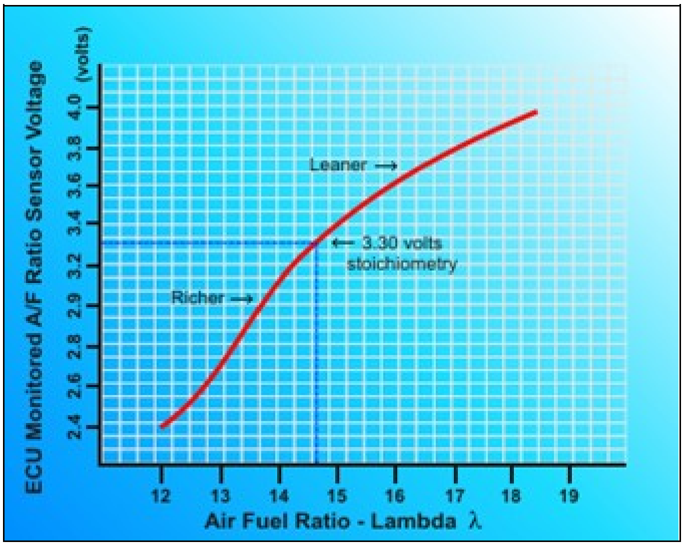
Exhaust O² Content	**Current Flow**	**Voltage Signal**	**Air Fuel Mixture**
Low O²	Negative direction	below 3.30 volts	RICH
Stoichiometry	Zero current	3.30 volts	14.7: [Lambda = 1]
High O²	Positive direction	above 3.30 volts	LEAN

Hanatech Scanner Toyota Planar Air Fuel Ratio Sensor Voltage Data Reference Table

As can be seen by the voltage data table, the Toyota A/F Ratio sensor reaction is opposite to that of a conventional O² sensor.

Conventional O² Sensor - [high voltage = richer mixture and low voltage = leaner mixture]

ECU Detection Monitor Voltage Graph



If the ECU detection monitor output voltage is **above** 3.30 volts, a **lean** mixture is indicated.

If the voltage is **below** 3.30 volts, a **rich** mixture is indicated.

The Hanatech scanner displays the voltages accordingly.

If the scanner is displaying a voltage of 3.30 volts, this represents stoichiometry.

Note:
If you find any A/F Ratio sensor DTC's logged in the scanner data, it is important to refer to each of the set DTC's descriptions and setting criteria before proceeding with the diagnostic.

Toyota A/F Ratio sensors have a specific 3 range set and criteria setting for DTC's that are logged using preprogrammed 2 trip detection logic, (2nd Generation A/F Sensor – 1 trip detection logic for heater circuit).

- Sensor range and performance malfunction.
- Sensor response malfunctions.
- A/Ratio sensor heater circuit incorrect operation.

P1130, P1150 - Circuit/Range Performance Malfunction (A/F Sensor output voltage)

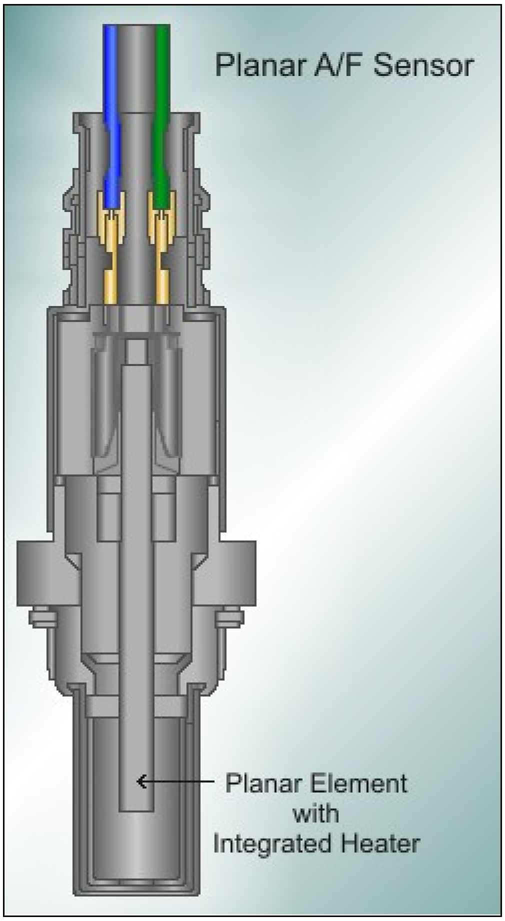
P1133, P1153 - Circuit Response Malfunction (A/F Sensor response rate)

P1135, P1155 – A/F Sensor Monitor (A/F Sensor circuit current)

An additional DTC **PO125** – Coolant Temperature Insufficient for Closed Loop Operation - can also set if the current is too high or too low for the A/F Ratio sensor element is detected. If the monitored current is too high, the ECU will switch the circuit off.

Toyota Planar A/F Sensor - (2nd Generation)

Toyota Planar A/F Sensor Schematic



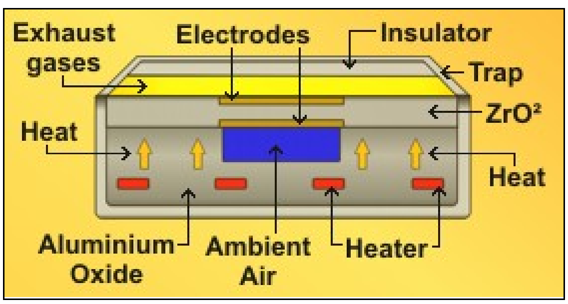
The Planar A/F sensor is an improved version of the earlier cup type Air Fuel Ratio sensor

The new type sensor is not interchangeable with the earlier cup type element A/F Ratio sensor.

Improvement in heater element design by integrating the element into the sensing element, allows for the sensor to reach operating temperature much quicker than that of the cup type A/F Ratio Sensor.

This allows the ECU to enter into in 'Closed Loop' earlier, thereby reducing cold start emissions

The Planar A/F sensor has the same signal characteristics and detection range as the earlier A/F Ratio sensor.



Toyota Planar Element Schematic

Like the conventional O² sensor and the A/F Ratio sensor, the Planar sensor has atmospheric air on one side of the ZrO² layer and exhaust gases on the other side.

The aluminum oxide layer serves to conduct heat directly to the ZrO² element providing rapid warm up

Toyota sensor heater element resistance specifications:

- Planar A/F sensor heater resistance -1.8Ω -3.4Ω @ 20C°
- A/F Ratio sensor cup type heater resistance - 0.8Ω - 1.4Ω @ 20°C
- Conventional O² sensor - 11.0Ω - 16.0Ω @ 20°C

Toyota A/F Ratio Sensor Voltage to Air Fuel Ratio Reference

Toyota uses a scaled down voltage for the Air Fuel Ratio sensor as seen on your Hanatech scanner by a factor of 5 i.e. a 'divide by 5' modification has been applied to the to the voltage output as seen on the factory scanner.

Some Generic OBDII scan tools display the Air Fuel Ratio sensor voltage as 0 volt to 1 volt. When comparing the viewed sensor voltage data between your Hanatech scanner and generic scanners, please be aware of the Toyota 'divide by 5' modification.

Voltage – Air Fuel Ratio Reference Table

Hanatech Scanners	Generic OBDII Scanners	**Air Fuel Ratio**
2.50 volts	0.50 volt	12.5:1
3.00 volts	0.60 volt	14.0:1
3.30 volts	0.66 volt	**14.7:1**
3.50 volts	0.70 volt	15.5:1
4.00 volts	0.80 volt	18.5:1

The two types of Toyota Planar Air Fuel Ratio sensors are not interchangeable. To visually differentiate between the two, measure the the complete body length of the sensors.

The Planar (cup type) type is approximately 95mm in length while the Planar A/F sensor is approximately is approximately 82mm in length.

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