Continental

FLEX-FUEL SENSOR GENERATION II
BRAZILIAN CALIBRATION SPECIFICATION

1.0 INTRODUCTION

This document contains the functional and environmental requirements for a Brazilian Flex Fuel Sensor (Br-FFS). The Br-FFS is intended for operation in the Brazilian market for vehicles operating on blends of gasohol and alcohol (where gasohol is defined as a blend of gasoline and anhydrous ethanol fuel; and alcohol is defined as hydrous ethanol fuel). The Br-FFS is a component in the Fuel Storage and Handling Subsystem. The Br-FFS will determine & report the percent total ethanol (anhydrous and hydrous) of the fuel.

1.1 BRAZILIAN FUEL BLENDS

Brazil supplies two types of fuel at fueling stations for a spark ignition engine vehicle: (1) gasohol and (2) alcohol. Gasohol is a blend of anhydrous ethanol fuel and gasoline. Anhydrous ethanol has a purity of 99.6% ethanol by volume and may contain a maximum of 0.4% water by volume. Alcohol is hydrous ethanol fuel. The hydrous ethanol purity range of 95.1 and 96.0% ethanol by volume and may contain a maximum of 4.9% water by volume (approximately 92.5 to 93.8% ethanol by mass and 7.4% water by mass). Alcohol fuel does not contain any gasoline. The Brazilian National Petroleum Agency (ANP) specifies these properties of an anhydrous ethanol fuel and hydrous ethanol fuel (Agência Nacional Do Petróleo, Gás Natural E Biocombustíveis. Resolução Anp Nº 7, De 9.2.2011 - Dou 10.2.2011 – Retificada Dou 14.4.2011, Rio de Janeiro, Brasil). Pure gasoline is not typically available to consumers in Brazil.

The concentration of anhydrous ethanol fuel in gasohol is dictated by the Brazilian government National Program of Alcohol (PROALCOOL) and is dependent on the annual sugarcane harvest. The concentration of anhydrous ethanol fuel may range from 20 to 25 volume percent. The gasohol is sometimes referred to as E22 (22% ethanol by volume) or E25 (25% ethanol by volume) based on previous mandated anhydrous ethanol fuel concentration in recent years.

In practice, numerous intermediate gasohol and alcohol blends could be generated from these two types of fuel sources. Table 1 shows the Br-FFS output for all potential fuel blends for gasohol and alcohol assuming an anhydrous ethanol concentration of 22.5 percent by volume (E22.5) and hydrous ethanol concentration of 95.1 percent by volume (E95). Additionally, Table 1 shows the Br-FFS output for fuel blends of gasoline/anhydrous ethanol less than 22.5 percent (note: these fuels would not be typically found in Brazil but are given to demonstrate the output of the sensor).

1.2 FUEL COMPOSITION VARIATION

The Brazilian calibration is highly robust but does require several basic assumptions of the fuel type and ethanol content. Since Brazilian gasohol may contain between 20 to 25 percent anhydrous ethanol, the sensor calibration assumes a content of 22.5 percent anhydrous ethanol by volume. This is done to minimize errors due to actual fuel blending practices and natural market fluctuations. By selecting a middle blend, deviation errors would be limited to two volume percent and decrease with increasing ethanol concentrations.

Continental

Table 1: Gasohol (E22.5) and Hydrous Ethanol (95.1%) Fuel Blends

Anhydrous Ethanol Content in Gasohol	Water Content in Gasohol	Hydrous Ethanol Content in Alcohol	Water Content in Alcohol
22.50%	0.09%	95.1%	4.9%

Blend Availability	% of "Gasohol"	% of "Alcohol"	% of Gasoline	% of Anhydrous Ethanol	% of Hydrous Ethanol	% of Water	Total Ethanol	Dielectric (ε) @ 25°c	Br-FFS Output (Hz)
Not Typically Available in Brazil	0	0	100	0.0	0.0	0.0	0.0	2.00	50.0
	0	0	95	5.0	0.0	0.0	5.0	3.12	55.0
	0	0	90	10.0	0.0	0.0	10.0	4.23	60.0
	0	0	85	15.0	0.0	0.0	15.0	5.35	65.0
	0	0	80	20.0	0.0	0.0	20.0	6.47	70.0
Typical Fuel Blend in Brazil	100	0	77.4	22.5	0.0	0.1	22.5	7.09	72.5
	90	10	69.7	20.3	9.5	0.6	29.8	9.07	79.8
	80	20	61.9	18.0	19.0	1.1	37.0	11.06	87.0
	70	30	54.2	15.8	28.5	1.5	44.3	13.05	94.3
	60	40	46.4	13.5	38.0	2.0	51.5	15.03	101.5
	50	50	38.7	11.3	47.6	2.5	58.8	17.02	108.8
	40	60	31.0	9.0	57.1	3.0	66.1	19.01	116.1
	30	70	23.2	6.8	66.6	3.5	73.3	20.99	123.3
	20	80	15.5	4.5	76.1	3.9	80.6	22.98	130.6
	10	90	7.7	2.3	85.6	4.4	87.8	24.97	137.8
	0	100	0.0	0.0	95.1	4.9	95.1	26.96	145.1

* All Data in Volume Percent

1.3 BRAZILIAN FLEX FUEL SENSOR CALIBRATION

The Br-FFS calibration is illustrated in Figure 1 for 25°C. The figure shows two segments separated by an inflection point. From 0.0 to 22.5 percent ethanol concentration, the Br-FFS assumes all ethanol content is derived from an anhydrous ethanol fuel. Greater than 22.5 percent ethanol concentration, the Br-FFS assumes all ethanol content is derived from hydrous ethanol fuel.

Please note the Br-FFS is not intended for markets where hydrous ethanol fuel is not consumed. If the Br-FFS is used to detect anhydrous fuel concentrations above 22.5 volume percent, the sensor accuracy will be diminished as the sensor will under predict the actual ethanol concentration. Vehicles exposed to anhydrous ethanol fuels should use the worldwide Flex Fuel Sensor only.

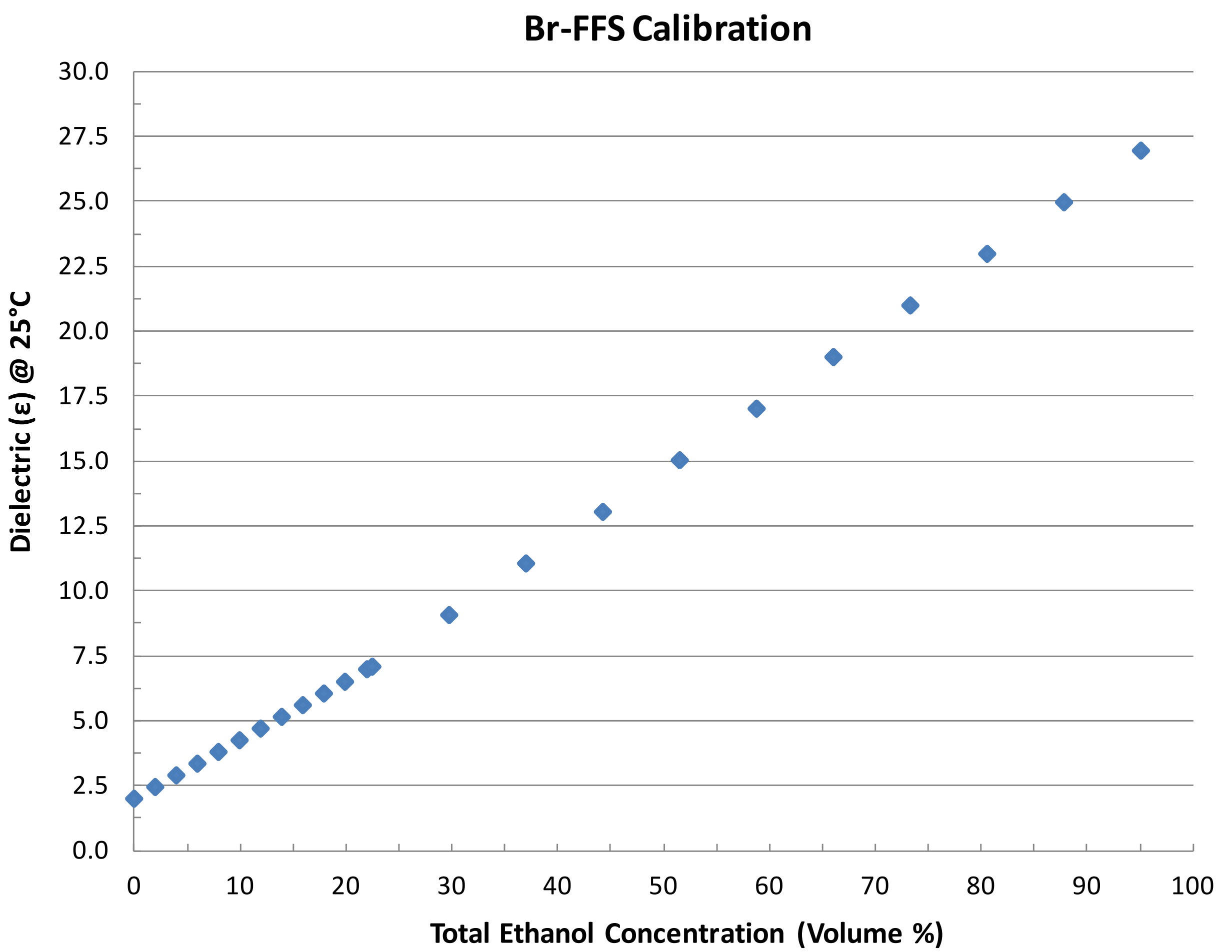


Figure 1: Calibration for Brazilian Gasohol and Alcohol Fuel Blends

2.0 SENSOR DESIGN

The following content describes the Br-FFS sensor working principles and design.

2.1 SENSOR DESCRIPTION

The Br-FFS is to be attached to the fuel supply line, and as the fuel flows through the Sensor, will determine the total ethanol (anhydrous plus hydrous) content of the fuel. The output signal from the Sensor will be delivered to the Engine Control Module (ECM) in the units of frequency (Hz). Materials and material treatment processes used in the manufacture of the Br-FFS are suitable for this purpose. The Br-FFS has the following attributes:

Continental

- can be mounted in line with the fuel line and attached to the vehicle underbody
- identified P/N, date code & supplier identification in the form of a permanent laser marking
- weight not to exceed 200 g
- does not require maintenance operations
- is an individual replaceable assembly
- standard tools are sufficient for use in service for removing the Sensor
- designed to operate at a maximum fuel flow of 400 L/hr
- designed to operate at a normal operating pressure of 700 kPa static flow
- extreme operating pressure of the Br-FFS shall not exceed 900 kPa
- maximum pressure drop across the Sensor shall be <3 kPa at 25ºC with fuel flow of 135 L/hr
- meets all performance requirements with fuel conductivity of 1000 micro-siemens per meter, or less at 25°C
- output resolution is 0.1 volume percent Ethanol (0.1 Hz).
- accuracy is ±5 volume percent absolute Ethanol error (±5 Hz) for fuel temperature range of -40°C to 95°C.

Figure 2: Exploded View of Sensor

2.2 SENSOR MEASUREMENT PRINCIPLE

The Flex Fuel-Sensor (Br-FFS) is an electronic device to measure the percentage of Ethanol and the temperature of the fuel before being delivered to the engine.

The following is the basis of the measurement technique:

- The relative permittivity of gasoline ($\varepsilon_r \approx 2$) differs from that of ethanol ($\varepsilon_r \approx 24.3$), due to the difference in molecular composition
- Ethanol and gasoline also have different conductivity

Using the sensor, the ethanol content of the fuel is a well defined function of its relative permittivity and conductivity, related to temperature.

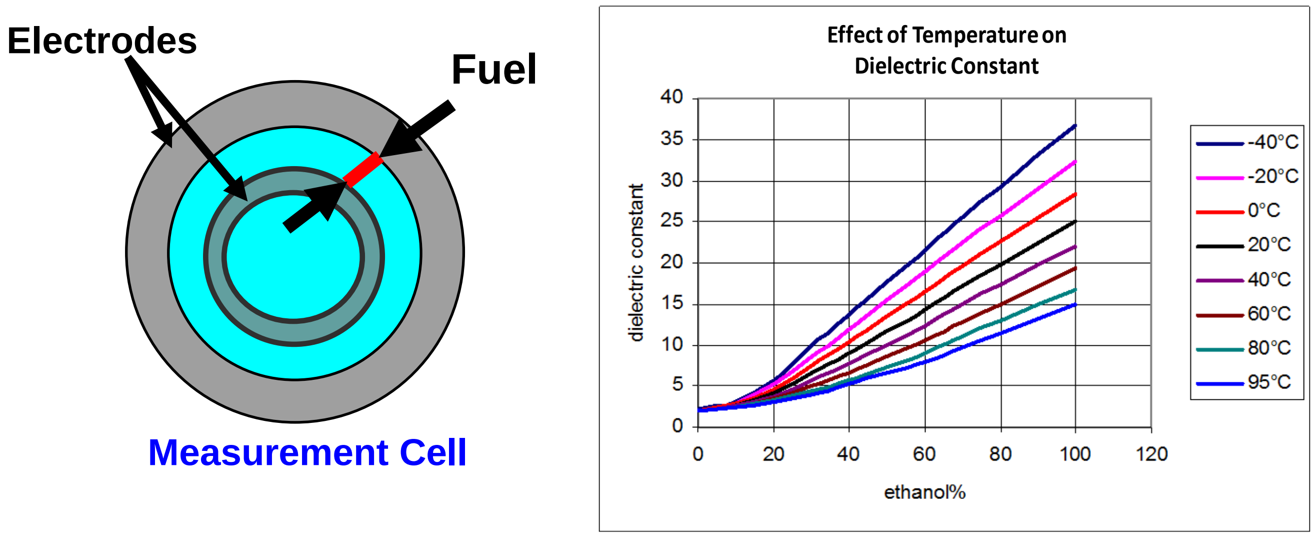


Figure 3: Cross Section View of Measurement Cell (Left).

Effect of Temperature on Dielectric (Right).

2.3 ELECTRONIC FUNCTION PRINCIPLE

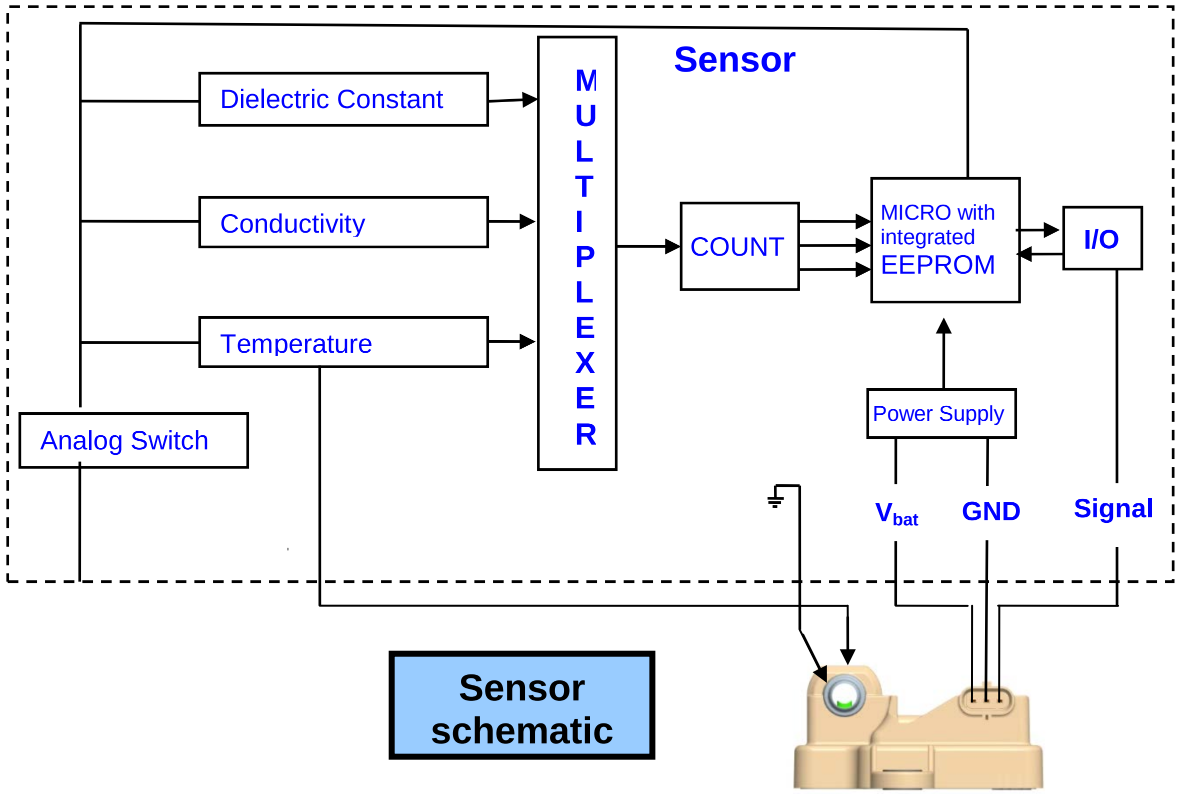
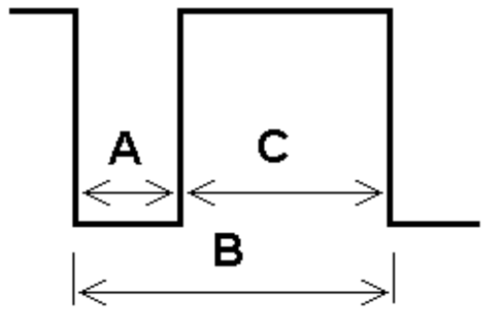


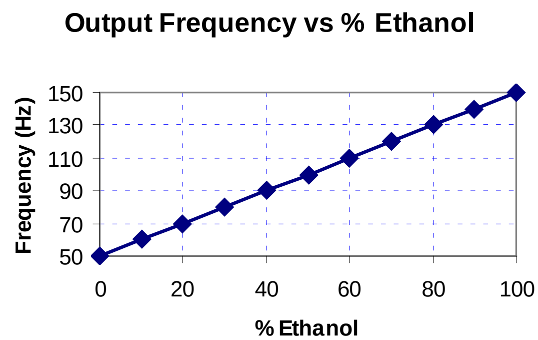
Figure 4: Sensor Schematic

2.4 SENSOR OUTPUT SIGNAL

A pulsed output signal – frequency (50 Hz - 150 Hz) corresponds to concentration of total volume percent ethanol (0 – 100%) within an ambient temperature range of -40°C to 125°C. Power-up time (time to first available signal) is less than 500 ms.

FLEX FUEL SENSOR OUTPUT SIGNAL PROFILE





A: time ON of cycle (temperature) T_{pulse}
B: total period of cycle (% Ethanol)
C: time OFF of cycle

- Temperature (°C) = ((T_{pulse}-1ms)*41.25°C/ms)-40°C
- Temperature = Low state of signal width: 1 ms corresponds to -40°C and 5 ms corresponds to +125°C
- Output low voltage: maximum 0.5V at a maximum 5mA load current
- Output high voltage: established by ECM pull-up. Sensor output is open-collector
- Output leakage: <100µA
- Output Signal nominal current draw is the average value over duty cycle of the output signal; the current load depends on the pull-up resistor, the pull-up voltage as well as the fuel temperature and the fuel content inside the measurements cell. Output Signal only draws current in the low signal state.

2.5 SPECIFICATION SUMMARY

#	Parameter		Value	Comment
1	Measuring Range		0 ... 100% ethanol*	Fuel temp < 90°C **
2	Output Signal (see information below)	Ethanol %	Signal Frequency : 50Hz to 150Hz Error signal : 170 – 190 Hz	See section 2.6 for error signal
		Temperature	Off time (Low Period of Signal) 1ms to 5ms = -40°C to +125°C	
3	Accuracy		± 5% v/v (absolute) ***	Fuel temp < 90°C **
4	Resolution		0.1 % v/v (absolute) Ethanol	Fuel temp < 90°C **
5	Power Supply		9 – 18 V	
6	Reverse Voltage Protection		-16 V	
7	I_{cc}		< 25 mA	
8	V_{OUT} Sink Current		11 mA maximum	Current limited, < 5mA is a guideline
9	V_{OUT} Voltage		3 – 18 V	Pull-up voltage
10	V_{OUT} error code frequency tolerance		±0.2 Hz	
11	Temperature Range	Environment	-40°C ... +125°C	Fuel temp < 90°C *
		Fuel	-40°C ... +90°C	
		Environmental tests	T_{max} = 85°C	When tested with fuel
12	Static Fuel Temperature accuracy		±1.0°C (-40°C to +90°C) ±2.0°C (90°C to +125°C)	
13	Response time		< 1 s	Output updated every ~225 ms
14	Max Fuel Pressure		13.5 bar (189 psi)	Burst pressure > 25 bar (360 psi)
15	Max Pressure Drop		< 7 kPa / 25°C / 26.3 g/s	
16	Max Flow		400 L/hr (80 g/s)	
17	Protection Range		IPX8	
18	Chemical Resistance		All fuel mixtures	
19	Vibration Strength		6 G_{RMS}	
20	Environment		Lead free solder	

* For use with Brazilian grade alcohol fuels as defined by the Brazilian National Petroleum Agency (ANP) (Agência Nacional Do Petróleo, Gás Natural E Biocombustíveis. Resolução Anp Nº 7, De 9.2.2011 - Dou 10.2.2011 – Retificada Dou 14.4.2011, Rio de Janeiro, Brasil)

** Sensor can be operated with fuels higher than 90ºC. However correct signal output can only be within performance specification at fuel temperatures <90ºC.

*** Sensor accuracy is a function of five factors (1) relative capacitive measurement accuracy; (2) temperature measurement accuracy; (3) dimensional accuracy of measurement cell; (4) software table interpolation; (5) calibration. The cumulative influence of these factors may result in a deviation of ±5% (by absolute volume) from actual ethanol concentration. The inaccuracy of the sensor is not expected to increase over product life. Sensor accuracy may be reduced with the presence of excessive, non-uniform fuel deposits in the measurement cell. Typical, uniform fuel deposits in the measurement cell would not affect sensor accuracy.

The addition of emulsified water contamination (a homogenous solution whereby excess water is absorbed by the gasohol or alcohol above the allowable specified limits) will decrease the accuracy of the sensor. The magnitude of the error is proportional to the amount of water contamination and the ethanol concentration. Error will be greatest at lower ethanol concentrations and lesser at higher ethanol concentrations.

Free water contamination (a heterogeneous solution whereby excess water is separated from the gasohol or alcohol) may be detected by the sensor resulting in a diagnostic error output code.

Ionic water contamination emulsified or free (homogenous or heterogeneous) may be detected by the sensor resulting in a diagnostic error output code.

2.6 DIAGNOSTICS

The software is designed such that when representing ethanol, the output is clamped between 0% and 100% ethanol. The signal frequency range is therefore limited to 50-150Hz (0% - 100% Ethanol). The composition of the fuel is updated every 225 ms. If for whatever reason, this value cannot be determined reliably, the frequency value is forced to an Error Code Frequency (170-190 Hz) until such time that a valid Ethanol content can be determined. The output frequency is continually updated.

Notes:

- Error codes between 170 Hz and 179 Hz are reserved for sensor internal failures and warrant sensor replacement.
- Error code 180 HZ indicates the fuel composition is outside the sensor measurement range (capacitance). This error code may suggest that free water is present in the fuel.
    - Recommended action: check/replace fuel and retest
- Error code 190 Hz indicates the fuel composition is outside of the sensor measurement range (conductivity). This error code may suggest that ionic water is present in the fuel.
    - Recommended action: check/replace fuel and retest
- Error code 171 Hz indicates the fuel composition is outside of the sensor measurement range. This error code may suggest that ionic water is present in the fuel.

Table 2 shows the effect of water contamination on the Br-FFS output using several fuel blends. These blends may be used to develop OBD strategy.

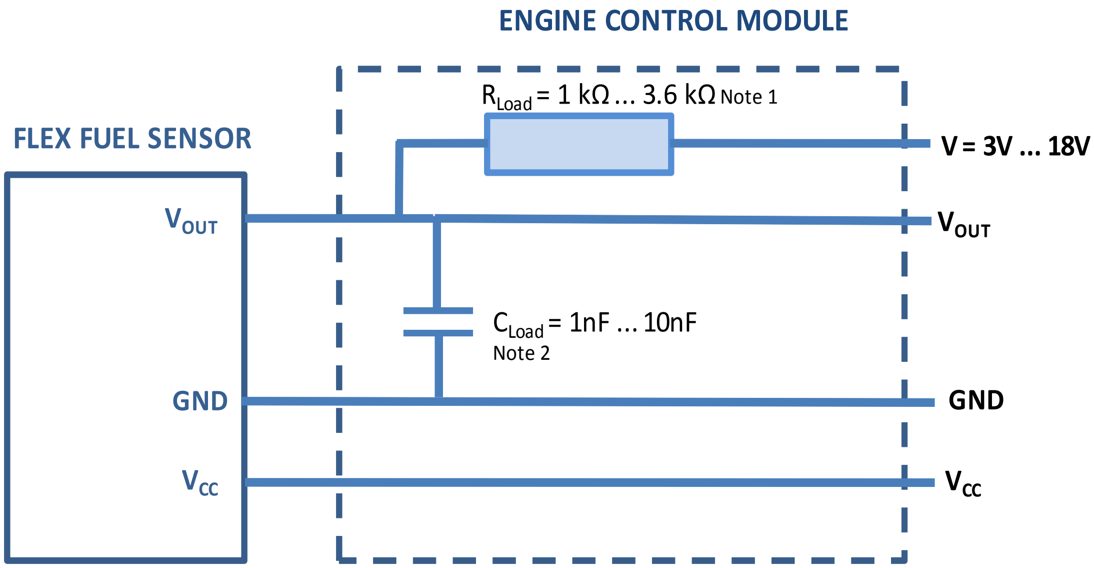
Continental

Table 2: Effect of Water Contamination on Sensor Output

Fuel Blends	Gasoline % (vol %)	Anhydrous Ethanol % (vol %)	Hydrous Ethanol % (vol %)	Normal Water % (vol %)	Adulterated Water %	Total Water %	Free Water Present	Brazil FFS Output (Hz)
Gasohol	77.5	22.5	0	0.1	0%	0.1	No	72.5
					+ 2%	2.1	No	75.4
					+ 4%	4.1	Yes*	180 / 81.3
50%:50% Gasohol & Alcohol	39	11	47.6	2.5	0%	2.5	No	108.9
					+ 2%	4.5	No	113.2
					+ 4%	6.5	No	119.2
Alcohol	0	0	95.1	4.9	0%	4.9	No	145.1
					+ 2%	6.9	No	150.0
					+ 4%	8.9	No	150.0

* Free water is present. Fuel tank will consist of two components: (1) Gasoline/Ethanol/Water blend and (2) Water. Hence two outputs are possible depending on which component sensor the sensor is exposed.

2.7 LOAD CIRCUIT



Note 1: R_{load} should be chosen to limit pull-up current to 5mA as a guide line. High values of pull-up resistor R_{load} will round the rising edge of the Output waveform. V_{OUT} is current limited to 11 mA.

Note 2: High values of capacitor C_{load} will round the rising edge of the output waveform.

Note 3: Pull-up voltage and resistor to be selected to limit the rise time of the output signal to 10% maximum of one cycle of the maximum output frequency (150Hz).

3.0 VALIDATION SPECIFICATION

The following section describes the methodology for evaluating the Br-FFS.

3.1 TEMPERATURE

The environmental conditions defined here are boundary conditions for the Br-FFS. The following paragraphs define the anticipated temperatures that the Br-FFS will be exposed to during its useful life.

3.1.1 Normal operating Environment

The Br-FFS shall operate as designed throughout its useful life for all normal operating conditions stated below:

A.	Ambient Air Temperature:	-40°C to +125°C
B.	Under-hood Air Temperature: (not engine mount)	-40°C to +125°C
C.	Fuel Temperature	-40°C to + 95°C
D.	Relative Humidity:	0 to 100% @ 38°C
E.	Barometric Pressure:	55 to 105 kPa

3.1.2 Non-Operating Storage Environment

The Br-FFS meets all normal performance requirements when returned to the operating environment after exposure to the following conditions:

A.	Extreme Ambient Temperature:	-40°C to 125°C	Indefinite duration
B.	Transport at Altitudes to:	13,700 meters	(un-pressurized)

3.2 ENVIRONMENTAL PROTECTION

The Br-FFS is capable of withstanding exposure to water and water based fluids during in service use as defined in the following paragraphs.

3.2.1 Water Test

The Br-FFS is designed to a water protection degree of IPX8 according to IEC 60529 nomenclature.

3.2.2 Under hood / Underbody Car Wash

Occurrence	70x
Wash duration:	60 s
Wash Flow Rate:	Car wash spray wand with 80 bars
Wash Fluid Temperature Range:	0°C to 20°C (ground water)

Wash Fluid Temperature Range: 50°C to 80°C (steam cleaner)

3.2.3 Resistance to Chemicals

The materials of Br-FFS were chosen to resist engine oil, brake fluid, transmission fluids and various chlorides.

REVISION HISTORY

05NOV13	Updated FFS Gen2 variant for rise time duty cycle 10% max, Output Signal current draw and V_{OUT} error code frequency tolerance ±0.2 Hz	Miller
16NOV13	Corrected 2.7 Load Circuit; Removed “Output is capable of driving a load of 1.2kΩ pulled up to 5V in the ECM” Pg 8	Miller
28FEB14	Corrected: load pull voltage to 3V to 18V diagram, page 12; Vout Sink Current to 11 mA maximum table line 8, page 9 and Note 1 page12; added < 5mA is a guideline table line 8, page 9.	Miller