



Flex Fuel Composition Sensor

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

Note: This document provides standard technical requirements for the Flex Fuel Composition Sensor, which will be referred in this document as the Flex Fuel (Composition) Sensor (FFS).

1.1 Purpose. This specification establishes the component level requirements for FFS. This document shall be used in conjunction with and complement other requirements included in the Statement of Requirements (SOR).

1.2 Applicability. This specification applies only to Flexible Fuel Vehicles (FFV) operating on ethanol/gasoline blends. Refer GMW15311 for application requirements for the FFS.

1.3 Remarks. The primary function of FFS is to measure the ethanol percent in the fuel and provide a signal to the Engine Control Module (ECM).

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ASTM D4157	ISO 179/1eA	ISO 3167	SAE J1739
ASTM D4158	ISO 527-1/2	ISO 11469	SAE J1960
IEEE 1012	ISO 1043-1	ISO 16750-5	SAE J2044
IPC A-610E	ISO 1043-2	SAE J400	SAE J2886

2.2 GM Standards/Specifications.

9985784	GMW3191	GMW15272	GMW15841
GMW3059	GMW14234	GMW15311	GMW15862
GMW3097	GMW14872	GMW15570	GMW16331
GMW3103	GMW14911	GMW15760	GMW16600
GMW3172			

2.3 Additional References.

- CG2099: Flex Fuel Composition Sensor Validation Cross Reference Index (VCRI)
- GM8774 Platform to Powertrain Electrical Interface Specification: Enhanced Evaporative Emissions and Fuel Subsystem Technical Specification (SSTS)
- GM Fuel Systems Peer Review Checklist (ID)
- Part Number (PN) 13588130 electrical connector
- PN 15708574 deionized water
- Statement of Requirements (SOR)

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2.3.1 Fuels.

GMPT-4-002

GMPT-4-020

GMPT-6-007

GMPT-6-032

GMPT-4-008

GMPT-6-002

GMPT-6-031

GMPT-6-037

GMPT-4-019

GMPT-6-005

3 Requirements

3.1 System/Subsystem/Component/Part Definition.

3.1.1 Appearance. Not applicable.

3.1.2 Content.

3.1.2.1 Physical Content. The FFS consists of housing, cover, fuel inlet/outlet tube, Negative Temperature Coefficient (NTC) temperature sensor and Printed Circuit Board (PCB)/electronics. Refer to Figure 1.

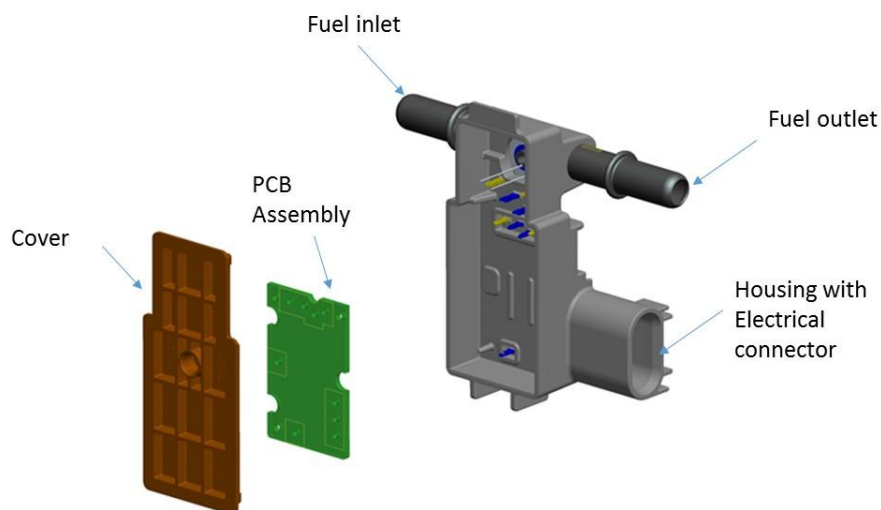


Figure 1: Flex Fuel Sensor Content

3.1.2.1.1 Sensor Pinout. The sensor shall be designed with the pinout shown in Figure 2.

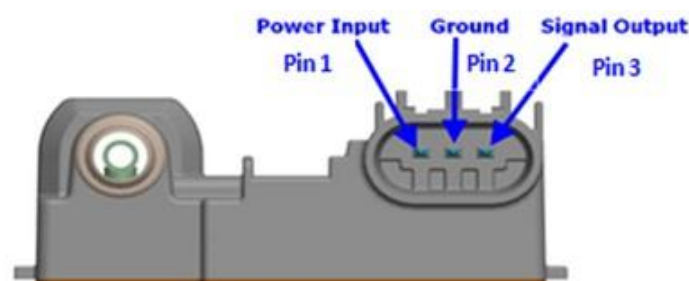


Figure 2: Flex Fuel Sensor Pinout

3.1.2.2 Functional Content. The FFS will be attached to the fuel supply line and, as the fuel flows through the sensor, will determine the ethanol content of the fuel. The output signal from the sensor will be delivered to the ECM. Subsequently, the ECM will adjust the base fueling equations to compensate for the percent ethanol in the fuel to maintain proper engine performance. Refer to Figure 3.

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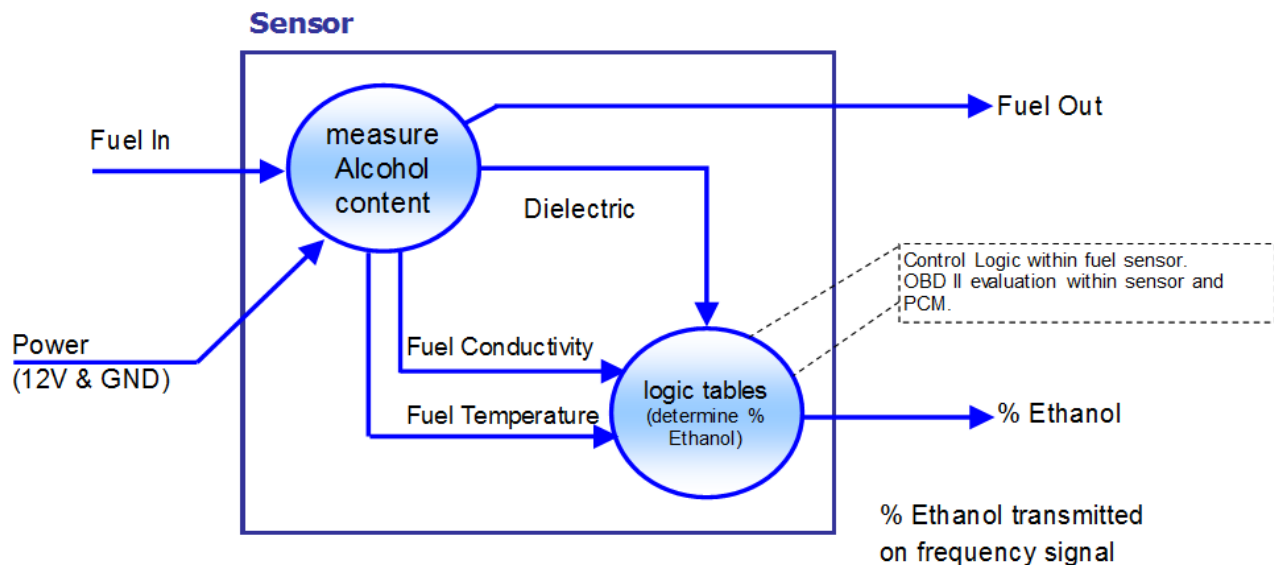
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3.1.2.2.1 FFS Signal and Accuracy. The software shall be designed such that the calculated composition is between 0% and 100%. The signal frequency range shall be 50 Hz, -0 Hz/+5 Hz (0% ethanol) to 150 Hz, -5 Hz/+0 Hz (100% ethanol). Refer to Figure 4. Regular operation of the sensor shall be as per ethanol content governed in each mark fuel. Accuracy of the signal be ± 5 Hz maximum for fuel temperature between -40 °C and 85 °C. Accuracy depends on fuel conductivity and temperature for a specific percent ethanol in fuel.



Note: GND = Ground, OBD II = On Board Diagnostics, Version II, PCM = Powertrain Control Module.

Figure 3: Flex Fuel Sensor Functional Diagram

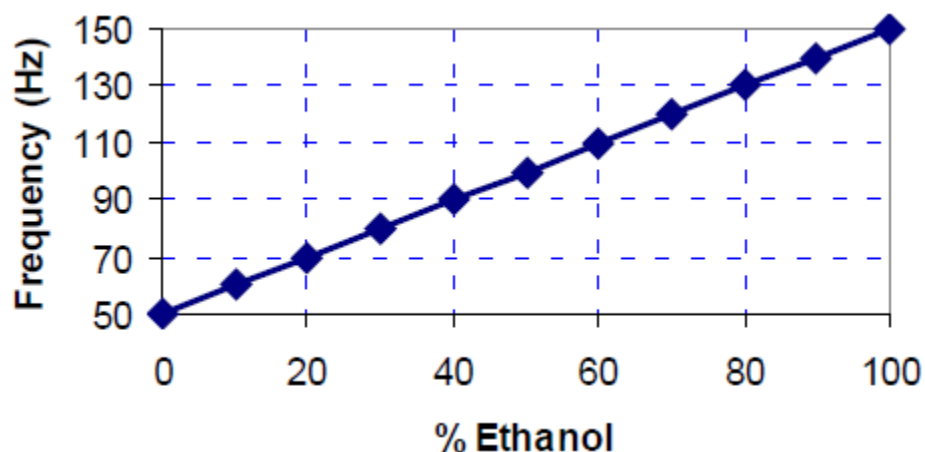


Figure 4: Flex Fuel Sensor – Frequency vs. Percent Ethanol

3.1.2.2.2 Ethanol Compensation Accuracy. Ethanol compensation accuracy of the sensor shall be $\pm 5\%$ of absolute volume.

3.1.2.2.3 Resolution of the Sensor. The FFS digital pulsed output signal shall have resolution of 0.1 Hz.

3.1.2.2.4 Error Code Frequency Tolerance. The FFS output error code frequency tolerance shall be ± 0.2 Hz.

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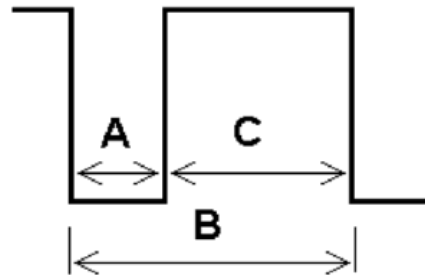
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3.1.2.2.5 FFS Response Time. From initial to 63% of final value, the sensor response time shall be < 1 s with 135 L/h fuel flow.

3.1.2.2.6 Sensor Power-Up Time. After key on, the FFS power up time (time to first available signal) shall be ≤ 120 ms. Refer to Figure 5.

3.1.2.2.7 Power to the Sensor. The sensor shall be designed to work with vehicle battery run/crank voltage of 6 V to 16 V.



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

Figure 5: FFS Power-Up Time

3.1.2.2.8 Temperature Sensor Signal. The temperature sensor signal during on time (low period of signal, A) shall be between 1 ms to 5.36 ms, which represents -40 °C to +140 °C temperature, refer to Table 1.

Note: The temperature sensor signal is not sent to ECM, but used only inside the FFS to calculate total pulse width B as outlined in Figure 5.

Table 1: Temperature Sensor Signal

Temperature (Degrees Celsius)	Low Period of Signal, A (milliseconds)
-40	1.00
-30	1.24
-20	1.48
0	1.97
10	2.21
20	2.45
30	2.70
40	2.94
50	3.18
60	3.42
70	3.67
80	3.91
90	4.15
100	4.39

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Temperature (Degrees Celsius)	Low Period of Signal, A (milliseconds)
110	4.64
120	4.88
125	5.00
130	5.12
140	5.36

3.1.2.2.9 Temperature Sensor Accuracy. The temperature sensor signal shall have $\pm 1^\circ\text{C}$ accuracy between -40°C and 85°C , and $\pm 2^\circ\text{C}$ accuracy between 85°C and 140°C .

3.1.2.2.10 On Board Diagnostics. The calculated composition of the fuel shall be updated every 100 ms, provided the frequency of the FFS signal can be reliably determined. If, for whatever reason, this value cannot be determined reliably, the frequency value (used by the FFS diagnostic) will be forced to 0.0, and the composition value will be held constant until such time that a valid frequency can be determined, or until a failure is detected by the diagnostic. If a failure of the frequency component of the signal is detected, then the fuel composition is to be set to KeE85I_Pct_FFS_CompDflt.

The frequency value shall continue to be updated even if a failure has been detected. This is required in order to enable the diagnostic to determine that a sensor fault may have cleared up and report a passed diagnostic. This process converts the FFS signal frequency (Hertz) into a fuel ethanol composition (percent).

Due to On Board Diagnostics, Version II (OBD II) requirements, a digital sensor requires allocating two out of range diagnostic bands, one each for the power and ground signals. These diagnostic bands are mandatory. It is not required that these two bands be of equal magnitude. To comprehend unexpected sources of variation, an additional 10 Hz dead band must be allocated to provide some additional protection against false diagnosis. Based on this, the sensor's output is allowed to range anywhere from 50 Hz to 150 Hz of its total range between the reference voltage and ground. Further, most ECMs have a tolerance of $\pm 1\%$ for digital inputs. Comprehending this allocation, the FFS shall be designed so that the sensor's output as measured where it enters the ECM, including all other system variation, never drops below 40 Hz or goes above 160 Hz unless a particular failure is present in the system. See Figure 6.

The sensor shall be designed so that nominal sensor output with E0 is 50 Hz, $-0\text{ Hz}/+5\text{ Hz}$. Similarly, the nominal sensor output with E100 shall be 150 Hz, $-5\text{ Hz}/+0\text{ Hz}$. For purposes of robustness against false diagnosis, the variation in measurement accuracy (at the ECM) of E0, must be such that the mean frequency minus four (4) sigma will not infringe into the out-of-range low diagnostic band. Similarly, the variation in measurement accuracy of E100 must be such that the mean frequency plus four (4) sigma will not infringe into the out-of-range high diagnostic band. The high out of range frequency should top out below 185 Hz. A signal above 185 Hz should signify that the fuel conductivity is out of range. This will cause the ECM to set a C-type code that the service technician can access to help diagnose drivability issues. When set, this code will lead the technician to replace the contaminated fuel. Refer to Table 2 for the diagnostics/error conditions.

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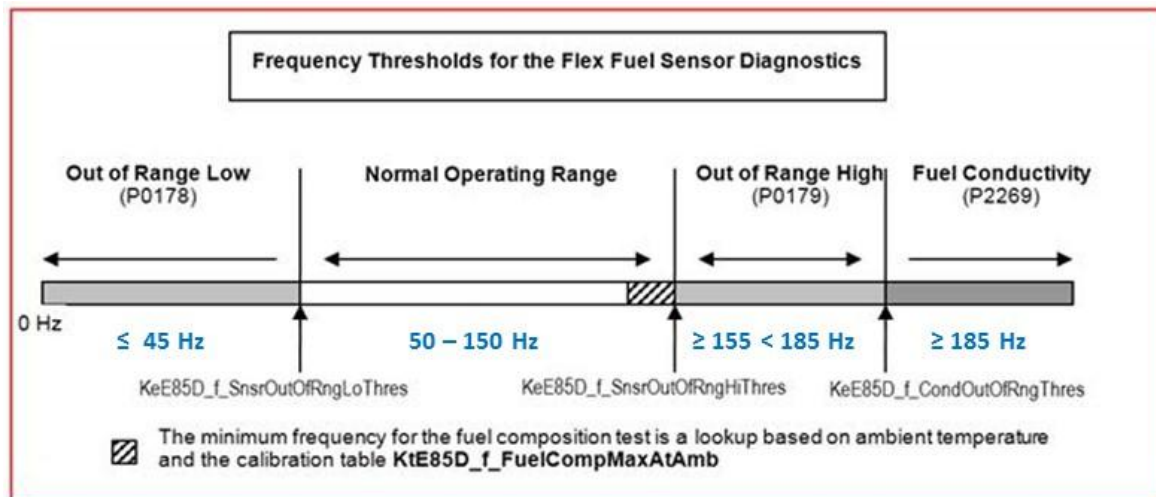


Figure 6: Frequency Thresholds

Table 2: Diagnostics/Error Conditions Operating Environment

Priority	Error Frequency (Hertz)	Error Condition
1	169	Software program Read Only Memory (ROM) checksum error (low pulse time set to 0.5 ms)
2	170	Data storage Electrically Erasable Programmable Read Only Memory (EEPROM) checksum error (low pulse time set to 0.5 ms)
3	172	Software program math or calculation error or a Random Access Memory (RAM) parity error: (Central Management Console (CMC) Error or RAM Parity)
4	173	Software program time out error: software program lost: (Watchdog Timer)
5	171	Sensor measurement cell shorted
6	175	Sensor measurement cell ground open (loss)
7	176	Negative Temperature Coefficient (NTC) Thermistor shorted error (low pulse time set to 0.5 ms)
8	177	NTC Thermistor open error (low pulse time set to 0.5 ms)
9	179	Temperature measurement outside table range error: Temperature < -40 °C or > 125 °C
10	180	Fuel dielectric (constant, Er) measurement outside table range error: Water in fuel
11	190	Fuel conductivity error (Bad Fuel): Fuel is electrically conductive > 1000 μS (microsiemens)

3.1.3 Ambient Environment. This section specifies the environmental conditions that the FFS will be exposed to during its lifetime.

3.1.3.1 Operating Environment. The FFS shall be capable of operating in the environments described in Table 3 without adverse effect to functional performance.

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Table 3: Operating Environment

Underbody	-40 °C to 90 °C
Relative Humidity	2% to 100%
Fuel Temperature	-40 °C to 90 °C
Barometric Pressure	56.9 kPa to 106.3 kPa. The system shall survive an atmospheric pressure of 10 kPa, not operated, during air shipment.
Precipitation	≤ 4.6 mm/minute
Grade	≤ 30%
Ozone	≤ 0.40 ppm
Altitude	-150 m to 4600 m

3.1.3.2 Robustness to Ozone. This requirement applies to parts made of polymer/elastomer compounds with external exposure. The parts shall not exhibit loss of function or service life following 568 h exposure to ozone (chamber) at 50 pphm at 38 °C per ASTM D4157 and ASTM D4158. After the test, parts shall not have surface cracks, crazing or discontinuities, when comparing pretest to posttest parts at 30x to 40x magnification.

3.1.3.3 Ultraviolet Radiation. Ultraviolet radiation, accelerated weathering, applies to incomplete vehicles only (e.g., cab chassis, cutaway G-Van, etc.) The exposed materials shall retain 75% of the original properties for tensile strength (ISO 527-1/2) and notched Charpy impact (ISO 179/1eA) after 2500 kJ/m² of accelerated exposure using xenon arc weathering apparatus as described in SAE J1960. Tensile bars shall be prepared using ISO 3167, 4 mm thick, Type A. Charpy impact bars shall be 80 mm × 10 mm × 4 mm, machined V notch, r = 0.25 mm. For complete vehicle applications, this requirement does not apply.

3.1.3.4 Corrosives – Chloride Exposure. Polymers exposed to the underbody and lower underhood atmosphere shall meet the requirements listed in GMW16600.

3.1.3.4.1 Resistance to Zinc Chloride. The sensor shall work without any performance degradation after testing as outlined in GMW16600.

3.1.3.4.2 Resistance to Calcium Chloride. The sensor shall work without any performance degradation after testing as outlined in GMW16600.

3.1.3.5 Types of Fuels. Table 4 includes fuels for which the FFS may be exposed. These fuels shall be considered in component design and analysis. Information regarding GMPT fuels can be obtained by contacting GMPT Materials Engineering. Test fuels shall be purchased from an approved supplier.

3.1.3.5.1 Fuel Soak. FFS shall not exhibit any degradation in performance after the sensor is soaked in fuels listed in Table 4 for 336 h at 65 °C.

Table 4: Types of Fuels

GMPT-6-002	Corrosive E-22
GMPT-6-005	90% Gasoline - 10% Ethanol
GMPT-6-007	85% Gasoline - 15% Methyl Tertiary Butyl Ether (MTBE)
GMPT-6-031	Corrosive E85
GMPT-6-032	Conductive E85
GMPT-4-008	General Purpose E25
GMPT-4-002	General Purpose - Summer E85
GMPT-4-019	Brazil E100 Cert Fuel

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GMPT-4-020	Brazil E100 Fuel for Calibration and Durability
GMPT-6-037	E100 Conductivity

3.1.4 Interfaces (of FFS to Other Subsystems and Vehicle). The interface and clearance requirements (3.1.4.1 through 3.1.4.5) may constrain or drive design of the sensor and, therefore, must be addressed during design and development.

3.1.4.1 Fuel Line Interface. The dimensional requirements of SAE J2044 shall be followed for inlet and outlet fuel ports at the sensor. Size of fuel lines shall be 9.525 mm (0.375 in).

3.1.4.2 Clearance Requirements. The following clearances shall be maintained as per GM Fuel Systems Peer Review Checklist (The supplier shall work with the GM responsible engineer to comprehend this requirement).

- Clearance to underbody
- Clearance to vehicle ground lines
- Clearance to tools and fixtures at GM assembly plants
- Clearance to fuel tank
- Clearance to other surrounding parts from the vehicle

3.1.4.3 Electrical Connector Interface. Electrical connectors that are classified, according to GMW3191, as Submersion Sealed and High Pressure Spray Protected only shall be used. Electrical connector interface on FFS shall be designed for connection to electrical connector PN 13588130.

3.1.4.3.1 FFS electrical connector and terminals design shall meet the requirements of GMW15841.

3.1.4.4 The sensor interface to the ECM shall meet requirements of GM8774, Enhanced Evaporative Emissions and Fuel Subsystem Technical Specification (SSTS).

3.1.4.5 Electrical Components. The supplier shall document all test parameters in GMW3172 plan template. GM Engineering approval shall be obtained before executing any tests. Electrical/Electronic components shall meet the validation requirements of GMW3172 using the codes:

- Electrical Loads: 6 V to 16 V (B)
- Mechanical Loads: Truck Sprung Masses, Elbow Load and Foot Load (H)
- Temperature Loads: -40 °C to 90 °C (D)
- Climatic Loads: 500 h (J)
- Chemical Loads: Exterior Area (F)
- Dust Protection: Dust-tight (6K)
- Water Protection: Seal - Continuous immersion in water (IP6K8)
- Water Protection: High pressure water spray cleaning (IP6K9K)

3.1.5 Usage Definition. Refer GMW15311 for FFS usage definition.

3.2 Product Characteristics. The required product characteristics for the FFS are identified in 3.2.1 through 3.2.34.

3.2.1 Test Setup Verification and Approval.

3.2.1.1 PCB Cross Section and Inspection. Prior to testing start, one (1) PCB inside FFS shall meet the cross section and inspection criteria for new parts listed in GMW3172.

3.2.1.2 Vibration Transmissibility Demonstration. Refer to Figure A1 in Appendix A for test flow. The sensor shall meet the criteria outlined in GMW3172 for vibration transmissibility demonstration.

3.2.1.3 Natural Frequency of NTC Sensor and PCB. The overhang of NTC temperature sensor bulb from PCB attachment point shall be minimized to protect the integrity of solder joints during vibration. Natural frequency at the NTC sensor bulb and PCB shall be ≥ 150 Hz. Test by applying 1G acceleration applied to the vibration table and recording the acceleration (G) at the NTC sensor bulb and PCB from 10 Hz to 1000 Hz in all three directions. In the charts, clearly mark natural frequency of each hardware.

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