BES SERIES

006023
Issue 2

Battery Safety Electrolyte Sensor

First Vent Detection | Patented Rate of Change Algorithm | Automotive Grade

DESCRIPTION

The Battery Safety Electrolyte Sensor (BES) is an automotive-grade sensor designed for early detection of venting and thermal runaway in battery systems. Utilizing an advanced and patented rate of change algorithm, the BES detects battery electrolyte vapor commonly released during the initial venting phase called First Vent, as well as hydrogen and carbon monoxide gases released during a thermal runaway event.

The ability to detect the First Vent provides an essential early warning for potential thermal runaway incidents in Lithium-Ion battery packs. This proactive early detection facilitates timely and appropriate mitigation measures, significantly reducing the risk of thermal runaway. BES employs a patented advanced rate of change algorithm designed to identify significant changes in the concentration of target gases within a sealed battery pack. This innovative method effectively reduces the occurrence of false negatives that may be seen with conventional ppm-based sensors, which focus on precise target gas threshold monitoring. The algorithm is tuned to prevent false positives, improving the end-user experience. Furthermore, the algorithm is supported by more than 12 years of rigorous research and validated through seven years of practical field deployment.

This extensive experience not only enhances the reliability of the detection algorithm but also underscores its effectiveness in real-world applications. BES enhances the safety and reliability of automotive battery systems.

EARLY DETECTION OF THERMAL RUNAWAY FOR ELECTRIC VEHICLES

Sensing

- Battery electrolytes
- Hydrogen
- Carbon monoxide
- Humidity (customizable upon request)
- Pressure (customizable upon request)
- Temperature

OUTPUT

BES provides three types of output via CAN message:

- Scalar value indicating volume of gas released by the Li-ion battery cell(s)
- Ambient temperature value
- Alarm flag indicating thermal event

NOTE: BES is designed for single use only. It must be replaced after exposure to a thermal event.

OPERATING MODES

The sensor functions in the following operating modes selectable via CAN command:

- **ECO Mode:** In ECO mode, CAN communication is disabled which reduces power consumption by 60 %. In the event of an alarm condition, the sensor will automatically return to NORMAL mode and send alarm signals to the BMS
- **NORMAL Mode:** In NORMAL mode, the sensor provides full functionality with CAN communication enabled

APPLICATIONS

Sealed lithium-ion battery packs or modules used in electric, hybrid vehicles and other on-road applications

FEATURES

- Responsive to battery electrolyte vapor released during the first vent (before thermal runaway)
- Responsive to hydrogen gas released during thermal runaway
- Responsive to carbon monoxide gas released during thermal runaway
- Patented rate of change algorithm to mitigate false negatives
- Resistant to siloxane poisoning
- Compatible with all Lithium-ion battery chemistries and cell types
- Automotive product with CAN 2.0B output with diagnostic features
- Tested for performance life of 15 years

VALUE TO CUSTOMERS

- **Enhanced asset protection:** Battery electrolyte vapor monitoring provides early warning of thermal events, enabling thermal runaway prevention and asset preservation
- **Reliable battery health monitoring:** BES responds to multiple gases that are typically released during thermal runaway, therefore increasing detection reliability and reduces false negatives
- **Ease of integration:** The rate of change algorithm eliminates the need for precise target gas threshold testing and validation. As a result, it significantly reduces integration costs and timeline

PORTFOLIO

The BES Series joins the Battery Monitoring Suite. To view the entire product portfolio, click here.

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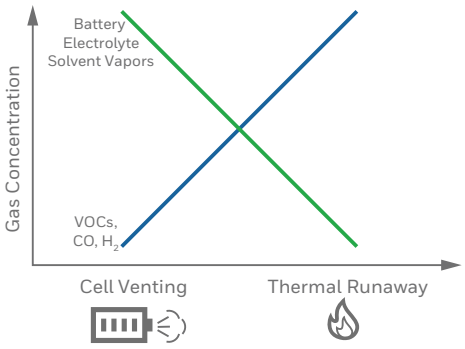


PRINCIPLE OF OPERATION

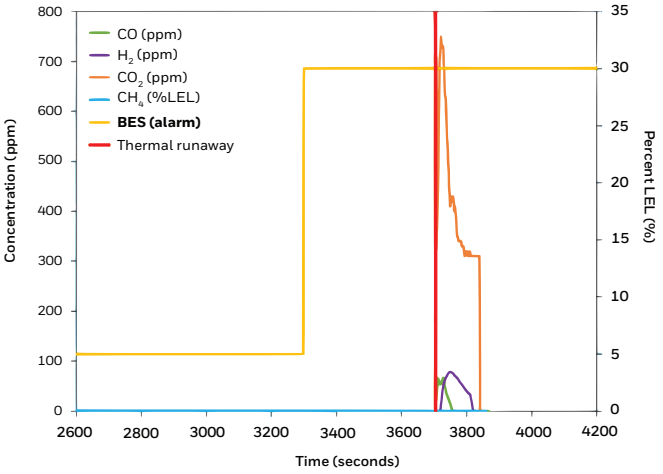
During a thermal runaway event, various gases are released. In the early stage, the cell vents a high concentration of electrolyte vapor. This includes gases such as Ethylene carbonate (EC), Diethyl carbonate (DEC), Ethyl Methyl carbonate (EMC) and Dimethyl carbonate (DMC) etc.

As the event progresses to an explosion, there is an increase in H_2 and CO. The BES Series sensor is equipped with a siloxane-resistant metal oxide semiconductor sensor that is highly sensitive towards electrolyte vapors, H_2 and CO. Due to its sensitivity to multiple target gases, the BES sensor ensures reliable and early detection compared to traditional gas sensors.

The BES sensor is equipped with a patented built-in rate of change algorithm, which triggers an alarm upon the detection of any of the target gases. This feature ensures quick and precise response to gas presence, enhancing safety and monitoring efficiency.

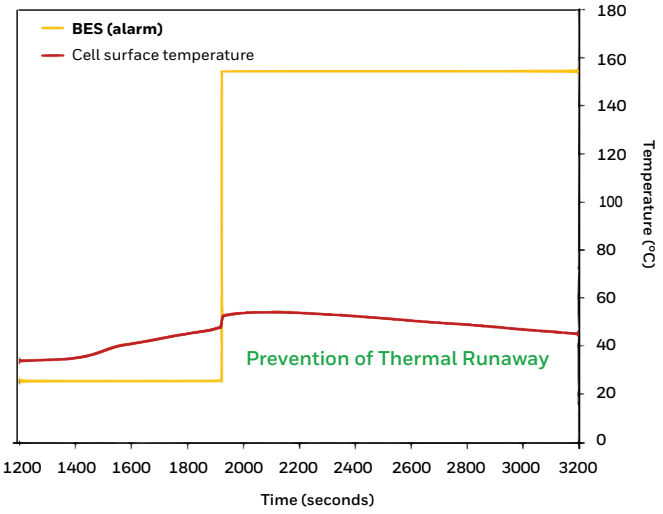
PPM based gas sensors may drift over a period increasing the risk of missing critical warning of thermal events. The BES rate of change algorithm approach addresses this concern as precise ppm monitoring is not required, ensuring early and reliable alerts.

Test A: Early detection of thermal runaway with the Honeywell BES sensor rate of change algorithm compared to other ppm-based gas sensors



- In this test a pouch cell is overcharged at 2C rate to induce thermal runaway or explosion
- BES sensor alarms ~7 minutes before thermal runaway
- H_2, CO, CO_2 and CH_4 gas sensors showed ppm response only during the cell explosion/thermal runaway

Test B: BES sensor enabling prevention of thermal runaway by removing abuse factor



- In this test a pouch cell is abused by overcharging at 2C rate. Once the BES alarm is triggered, the charging is turned off
- Cell cools down and thermal runaway is prevented
- BES detected thermal runaway early enough to enable the prevention of thermal runaway by removing the source of abuse

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TABLE 1. KEY SPECIFICATIONS		
Characteristic	**Parameter**	
Performance		
Gas sensed	Electrolytes vapors[1], H_2, CO	
Temperature measurement	-40°C to 125°C	
Pressure measurement [2]	60 kPa to 165 kPa	
Response time	<5 seconds	
Startup time	<2 seconds	
Algorithm initialization time	<75 seconds	
Severity of gas detected	-2.00 = typical warm-up condition 0.00 = clean air 1.00 = alarm trigger >4.00 = typical high level of gas	
Vibration	5.9 Grms, 10 Hz to 2000 Hz	
Safety rating	QM grade	
MTTF/MTBF	1.3 million hours / 150.86 years	
Location of sensor	Sensor can be installed anywhere in battery pack, provided sensing port is unobstructed	
Electrical		
Supply voltage	Nominal: 12 Vdc, Range: 8 Vdc to 16 Vdc	
Over voltage	Maximum of 26 V for 60 s	
Reverse voltage	Maximum of 20 V	
Current consumption	1. In ECO mode, 9 mA typical 2. In NORMAL mode, 20 mA typical	
Environmental		
Operating temperature	-40°C to 85°C	
Storage temperature	-40°C to 85°C	
Humidity	0 to 90 %RH	
Siloxane poisoning	15 years of life in 570 ppb siloxane exposure	
ROHS, Reach	Yes	
CAN Bus		
Protocol	SAE J1939 CAN 2.0B	
Baud rate	250/500 Kbps	
Short circuit protection	Yes	
Broadcast rate	1 second	
CAN Bus Parameters	**Minimum**	**Maximum**
CAN H/L voltage range (V)	-45	45
Dominant differential output (V)	1.5	3
Recessive differential output (V)	-0.12	0.012
Mechanical		
Connector	USCAR 120-S-004-1-Z02 (Keying Option A) Mating Connector: Molex® 349004120	
Mounting	M5 GRADE 8.8 BOLT (X2), recommended mounting torque is 6 Nm ±1 Nm	
Weight	40 g max.	
Dimensions	78,88 mm × 64,13 mm × 17,00 mm	
Housing Material	VALOX DR48 17 % GF	
Flammability	UL 94 V-0	
Ingress Protection	IP3X	

1. EC, PC, DEC, DMC and other electrolytes used in lithium-ion cell
2. Not in standard offering. Available upon demand

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Figure 1. Product Dimensions

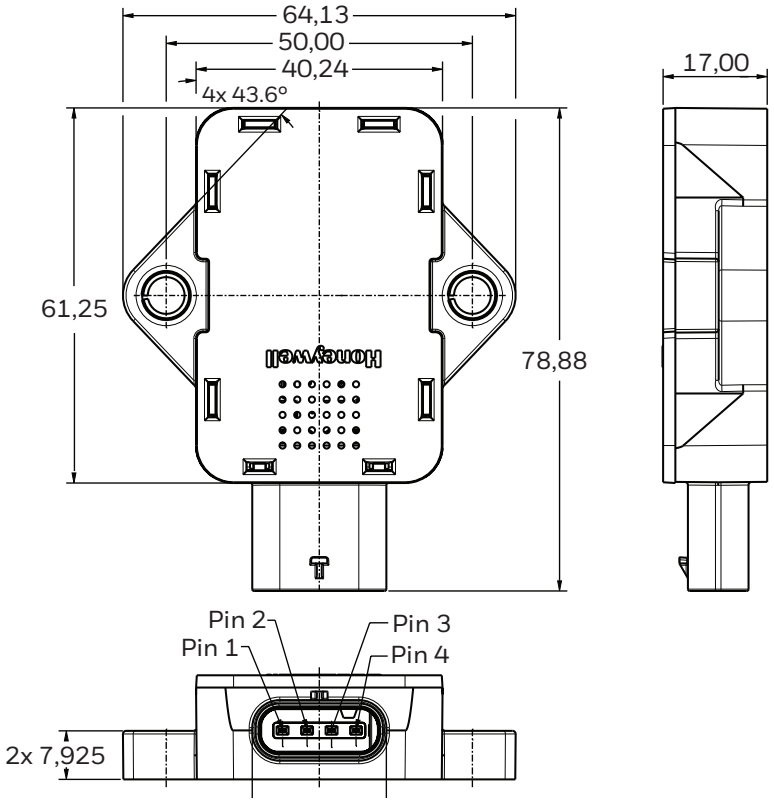

TABLE 2. PIN OUT

Pin	Description
1	Power input
2	Ground
3	CAN H
4	CAN L

NOTE: BES is designed for single use only. It must be replaced after exposure to a thermal event.

Figure 2. Product Nomenclature

BES - 1 3 1 - 1 1 1 - 001

SENSOR TYPE
BES – Electrolyte Vapor

ELECTRICAL POWER
1 – 12 Vdc (8 Vdc to 16 Vdc)

SEALING
3 – IP30

CONNECTOR
1 – USCAR 120-S-004-1-Z02 (keying option A)

RESERVED FOR FUTURE USE

CAN ADDRESS
1 – 0xE4
2 – 0xE5
3 – 0xE6
4 – 0xE7
5 – 0xE8
6 – 0xE9

OUTPUT
1 – CAN 2.0B (Baud Rate 250 kbps)
2 – CAN 2.0B (Baud Rate 500 kbps)

REDUNDANCY
1 – None

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SENSOR STATE FORMAT | PDU 0XFF01/65281

Frame Format	29-BIT ID						DATA (8 BYTES)							
									Scalar					
Field	P	EDP	DP	PF	PS	SA	State	Deg C	Low Byte	High Byte	Not Used			
# Bits	3	1	1	8	8	8	8	8	8	8	8	8	8	8
CAN Message	0x08			0xFF	0x01	0xE4	0x03	0x17	0x1C	0x00	0xFF	0xFF	0xFF	0xFF

29 BIT ID	
Message	**Description**
EDP/DP=0	J1939 standard data page
PF = 0xEF	Peer-to-peer message
PS = 0x01	Destination address (address of the controller)
SA = 0xE4	Source address (address of BES sensor)

STATE: REPRESENTS THE STATE OF SENSOR	
Message	**Description**
Error	0x01
Warmup	0x02
Normal	0x03
Alarm	0x04

Deg C	
Temperature (C) = (int8_t) * Deg C	
Value=(int16_t) Scalar/100	
Typical warm up	-2.00
Clean Air	0.00
Thermal runaway alarm	>1.00
High level of electrolytes	>4.00

Example
Broadcast Normal Operation at 23°C (0x17h=23) and 0.28 Scalar (0x001C = 28)

SENSOR OPERATING MODE | PDU 0xEF00/61184

Frame Format	29-BIT ID						DATA (2 BYTES)	
Field	P	EDP	DP	PF	PS	SA	ID	CMD
# Bits	3	1	1	8	8	8	8	8
CAN Message	0x19			0xEF	0xE4	0xF6	0x01	0x00

ID	
ID	ID for operating mode is 0x01
CMD: Determines operating mode	
NORMAL Mode	0x01
ECO Mode	0x02
No Change	0x00

SENSOR DIAGNOSTIC OUTPUT | PDU 0xFECA/65226

Frame Format	29-BIT ID						DATA (8 BYTES)							
Field	P	EDP	DP	PF	PS	SA	Light	Flash	DTC			Occ	NA	NA
# Bits	3	1	1	8	8	8	8	8	8	8	8	8	8	8
CAN Message	0x18			0xFE	0xCA	0xE4	0x04	0x0C	0x71	0xE2	0xFF	0x03	0xFF	0xFF

This message is broadcasted every 1 second while DTC is active

Diagnostic Messages	
Severity	Protect=0, Warning=1, Stop=2, Malfunction=3
Light	0=Off, 1=On, 2=Error, 3=Any
Flash	0=slow, 1=fast, 3=no flash
DTC	0x7E000 - 0x7FFFF refer to fault codes
FMI	most severe=0, 0x1F = not available: ref J1939-73
Occurrence	1-127

Example
BES Sensor CRC Error (Light=1, Flash = 3, Severity = 1, DTC=0x7E271, FMI = 0x1F, occurrence = 3)

Example	
ID	18FECAE4x
Data	04 0C 71 E2 FF 03 FF FF

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The DM3 message is used to clear stored and active DTCs.

DM3 (J1939-73 Standard) | PDU 0xFECC / 65228														
Frame Format	**29-BIT ID**						**DATA (8 BYTES)**							
Field	**P**	**EDP**	**DP**	**PF**	**PS**	**SA**								
# Bits	3	1	1	8	8	8	8	8	8	8	8	8	8	8
CAN Message	0x18			0xFE	0xD3	0xE4	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF

DTC FAULT CODES				
DTC	**Severity**	**Light**	**Flash**	**Description**
0x7E100	**Stop Now**	ON	No	App firmware missing
0x7E101	**Replace**	ON	FAST	App CRC check failed
0x7E110	**Stop Now**	ON	No	Config file missing
0x7E111	**Replace**	ON	FAST	Config CRC check failed
0x7E120	**Replace**	ON	No	Build file missing
0x7E121	**Replace**	ON	FAST	Build CRC check failed
0x7E242	**Warning**	OFF	No	Watchdog
0x7E250	**Warning**	OFF	No	Temperature too hot (greater than 85°C)
0x7E251	**Warning**	OFF	No	Temperature too cold (less than -40°C)
0x7E270	**Warning**	OFF	No	Gas sensor error
0x7E271	**Warning**	OFF	No	Gas sensor CRC
0x7E272	**Warning**	OFF	No	Gas sensor out of range
0x7E280	**Warning**	OFF	No	Event duration too long (alarm greater than 1 hour)

TABLE 3. EMC TEST SPECIFICATIONS		
Test	**Standard**	**Procedure**
CISPR 25 Conducted RF Emissions - Voltage	CISPR25	Section 6.2, Class 3
CISPR 25 Conducted RF Emissions -Current	CISPR25	Section 6.3, Class 3
CISPR 25 Radiated Emissions	CISPR25	Section 6.4, Class 3
Transient Conducted Emission	ISO 7637-2	Section 6.2
Bulk Current Injection (BCI) Test	ISO 11452-4	Frequency range: 1 MHz to 400 MHz, Test Level 200 mA
RF Radiated Immunity - ALSE	ISO 11452-2	Frequency range: 200 MHz to 1 GHz, Test Level 150 V/m 1 GHz to 6 Ghz, Test Level 100 V/m
RF Radiated Immunity - Stripline	ISO 11452-5	Frequency range: 10 kHz to 400 MHz, Test Level: 200 V/m
Electrostatic Discharge	ISO 10605	Unpowered direct contact discharge: ±6 kV Unpowered air discharge: ±15 kV Powered-up direct contact discharge: ±8 kV Powered-up air discharge: ±15 kV Network: 330 pF / 330 Ω

TABLE 4. ELECTRICAL TEST SPECIFICATIONS		
Test	**Standard**	**Procedure**
Long Duration Overvoltage	ISO 16750-2	Section 4.3.1.2 - Jumpstart
Transient Overvoltage	ISO 16750-2	Section 4.3.2
Superimposed Alternating Voltage	ISO 16750-2	Section 4.4, Levels 3 and 4
Slow Decrease / Increase of Supply Voltage	ISO 16750-2	Section 4.5
Momentary Drop in Supply Voltage	ISO 16750-2	Section 4.6.1
Reset Behavior at Voltage Drop	ISO 16750-2	Section 4.6.2
Reverse Voltage	ISO 16750-2	Section 4.7, Test case 2
Open Circuit	ISO 16750-2	Section 4.9
Short Circuit Protection	ISO 16750-2	Section 4.10.2
Insulation Resistance	ISO 16750-2	Section 4.11 ,10 MΩ at 500 Vdc

TABLE 5. ENVIRONMENTAL TEST SPECIFICATIONS		
Test	**Standard**	**Procedure**
Low Temperature Operating	ISO 16750-4	Section 5.1.1, T_{MIN}: -40°C
High Temperature Operating	ISO 16750-4	Section 5.1.2, T_{MAX}: 85°C
Thermal Step	ISO 16750-4	Section 5.2, Temp Range: -40 to 85°C
Thermal Cycle	ISO 16750-4	Section 5.3, Temp Range: -40 to 85°C
Humid Heat, Cyclic	ISO 16750-4	Section 5.6, Test 1 and 3
Damp Heat, Steady-State	ISO 16750-4	Section 5.7
Atmospheric Pressure	ISO 16750-4	Section 5.12, -100 m to 5000 m
Random Vibration	ISO 16750-3	Section 4.1 Test VII, Commercial Vehicles
Mechanical Shock	ISO 16750-3	Section 4.2, Shock Profile II
Handling Drop	ISO 16750-3	Section 4.3, 1 m drop
Withstand Voltage	ISO 16750-2	Section 4.12, 500 Vrms, 60 Hz for 60 s

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DO NOT USE these products as safety or emergency stop devices or in any other application where failure of the product could result in personal injury.

Failure to comply with these instructions could result in death or serious injury.

⚠WARNING MISUSE OF DOCUMENTATION

- The information presented in this product sheet is for reference only. Do not use this document as a product installation guide.
- Complete installation, operation, and maintenance information is provided in the instructions supplied with each product.

Failure to comply with these instructions could result in death or serious injury.

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