INSTALLATION INSTRUCTIONS FOR THE

BES SERIES
BATTERY SAFETY ELECTROLYTE SENSOR

3019-5864
Issue A

1.0 GENERAL INFORMATION

The Battery Safety Electrolyte Sensor (BES) is an automotive-grade sensor designed for early detection of venting and thermal runaway in lithium-ion batteries. 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.

2.0 USE OF THE BES SENSOR

The Honeywell Battery Electrolyte Sensor is designed to provide an alarm signal in the event of a Li-ion battery vent or thermal runaway. The BES outputs several critical outputs, including a thermal event alarm, ambient temperature, and a scalar value that quantifies the amount of gas released during a thermal event, relative to the baseline gas levels present within the battery pack.

3.0 CALIBRATION/COMPENSATION

The Battery Electrolyte Sensor uses a patented algorithm that is agnostic to battery cell chemistry, form, and state of charge. By quantifying the background gas levels on start-up and accounting for slow changes within the pack, the BES can detect a sudden characteristic release of Li-ion battery gases that would be seen during a cell vent or thermal runaway scenario.

4.0 INSTALLATION

Mount the sensor using two mounting bushings and two grade 8.8 M5 bolts. The mounting tabs accommodate various bolt head styles, such as hex, socket head cap, and hex flange bolt head. Torque mounting bolts to 6 Nm ±1 Nm. See Figure 1 for physical dimensions.

In the event of a single-cell Li-ion battery vent, a large volume of gas is released into the pack. The BES detects the characteristic, sudden presence of electrolyte vapors (and other battery cell byproducts, such as hydrogen and carbon monoxide) to alert the Battery Management System (BMS) of a dangerous condition. Because the BES relies on the detection of gases released from the cell, Honeywell recommends installing the BES inside of a sealed battery pack near the external vent for optimal functionality.

The BES is designed with 4-pin connector conforming to USCAR 120-S-004-1-Z02. Pin 1 must be connected to the 12 V or 24 V battery and remain powered at all times in order to provide an alarm in the event of a battery cell vent or thermal runaway.

A list of mating connectors is maintained on the USCAR website (https://uscar.org/part-list/).

5.0 GASES DETECTED

The Honeywell BES can detect the release of a majority of typical gases from a Li-ion battery, including, but not limited to:

- Ethylene Carbonate (EC)
- Dimethyl Carbonate (DMC)
- Diethyl Carbonate (DEC)
- Ethyl Methyl Carbonate (EMC)
- Propylene Carbonate (PC)
- Hydrogen (H_2)
- Carbon Dioxide (CO)
- Hydrocarbons (CxHx)

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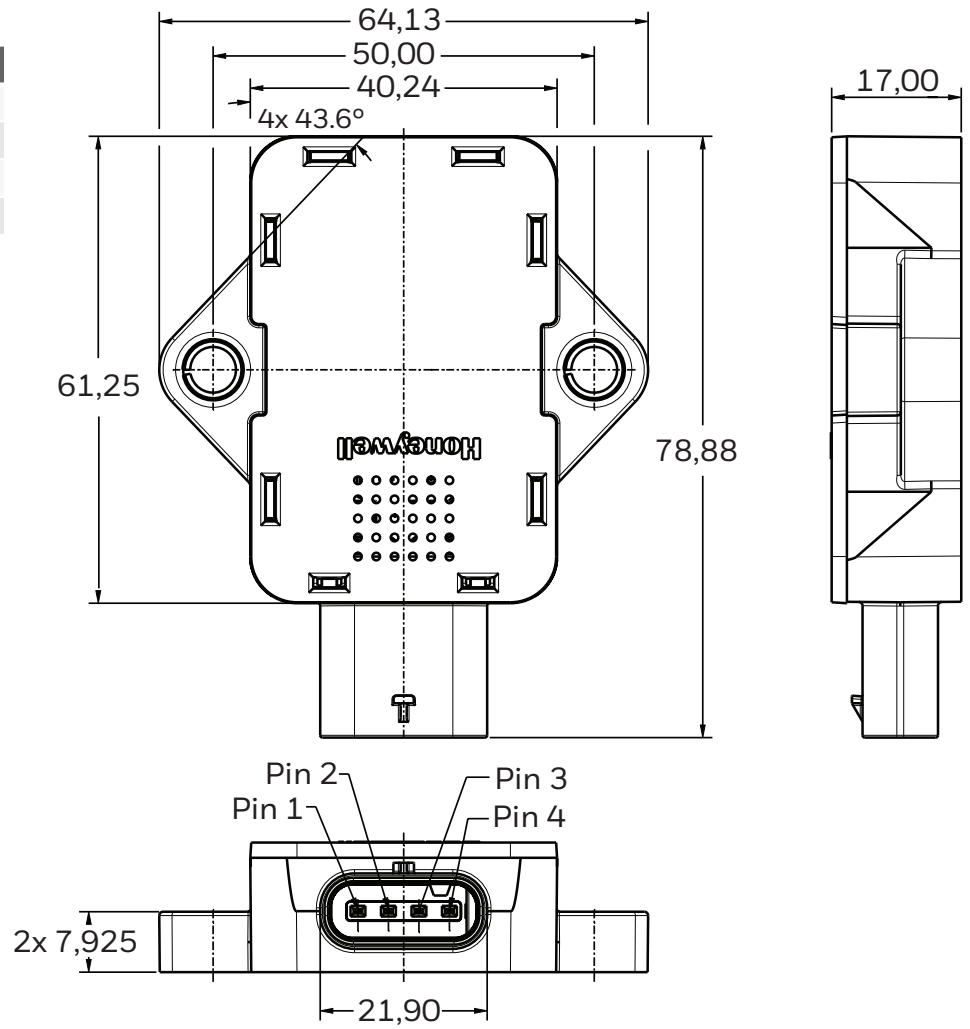
Figure 1. Dimensions

PINOUT	DESCRIPTION
PIN 1	Power Input
PIN 2	Ground
PIN 3	CAN H
PIN 4	CAN L



6.0 CONNECTING THE BES TO A CAN NETWORK

6.1 THE PHYSICAL LAYER

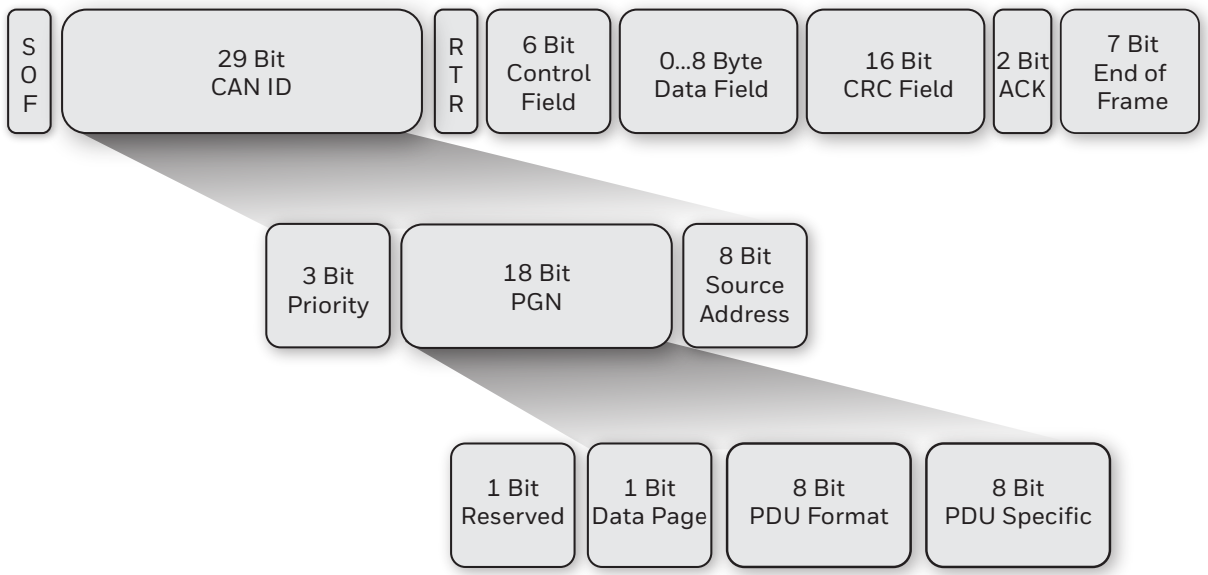
The Honeywell BES is designed to be installed on a CAN Bus Network conforming to SAE J1939 Standards for CAN 2.0B (Ref: J1939-11, -14, & -15). This includes, but is not limited to, the following guidelines:

- Ensure a daisy chain configuration for the CAN bus with 120 Ω termination resistors at both ends
- Avoid star network configurations
- Do not connect multiple sensors with different CAN baud rates to the same CAN bus
- If multiple BES sensors are connected to the same network, ensure that each sensor has a unique address, either as purchased from Honeywell, or via the Address Claim procedure described below

6.2 THE DATA LAYER

The data layer of the BES is based on SAE J1939-21, with all message formats being in Classical Extended Frame Format (CEFF), with a 29-Bit ID as shown below.

Figure 2. SAE J1939 CAN2.0B Message Format (CEFF)



6.3 BES STATE MESSAGE

When the BES is in NORMAL mode, it will send a broadcast message on the CAN network indicating its current state, temperature, and scalar value output.

The "State" value indicates whether a battery venting or thermal runaway condition is detected (0x04), a nominal or normal operating condition (0x03), in the middle of its 75 s warm-up period (0x02), or if an internal error has occurred in the sensor (0x01). An error state will be accompanied by a DTC message indicating the reason for the error.

The "Temperature" value is the sensor processor temperature, so it is typical for the value to be slightly higher than ambient, and is useful for detecting very high temperature changes consistent with thermal runaway.

The "Scalar" value is a numeric representation of the amount of gas present within the pack. Any value greater than 1.0 for greater than 3 seconds will cause the BES State to change to 0x04 (Alarm). For more details on the BES Algorithm, see datasheet.

TABLE 1. PDU 0XFF01/65281

Frame Format	29-Bit ID						Data (8 Bytes)							
Field	**P**	**EDP**	**DP**	**PF**	**PS**	**SA**	**State**	**Deg C**	**Low Byte**	**High Byte**	**Not Used**			
Number of 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	0x00	0x00	0x00	0x00

29-BIT ID	
Message	**Description**
EDP/DP=0	J1939 standard data page
PF = 0xFF	Broadcast Message
PS=0x01	Destination Address (Address of 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

Temperature (°C)	
Temperature (C) = (int8_t) * °C	
SCALAR Value=(int16_t) SCALAR/100	
Typical warm-up	-2.00
Clean air	0.00
Thermal runaway alarm	>1.00
High level of gas	>4.00

Example:

Broadcast Normal Operation at 23°C (0x17h=23) and 0.28 Scalar (0x001C = 28), No Alarms

ID	DATA
0x08FF01E4	03 17 1C 00 00 00 00 00

6.4 DIAGNOSTIC TROUBLE CODE MESSAGES

In the event of a sensor fault or out of tolerance conditions, the BES sensor will broadcast the following messages indicating the Diagnostic Trouble Code (DTC).

TABLE 2. SENSOR DIAGNOSTIC OUTPUT | PDU 0xFECA/65226

Frame Format	29-Bit ID		Data (8 Bytes)										
Field	**P**	**EDP**	**DP**	**PF**	**PS**	**Light**	**Flash**	**DTC**			**Occ**	**NA**	**NA**
Number of bits	3	1	1	8	8	8	8	8	8	8	8	8	8
CAN Message	0x08			0xFE	0xCA	0x04	0x0C	0x71	0xE2	0xFF	0x03	0xFF	0xFF

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

Example:

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

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

No data is transmitted with this message, all 8 bytes are set to 0xFF.

DM3 (J1939-73 Standard) | PDU 0xFECC/65228

Frame Format	29-Bit ID						Data (8 Bytes)						
Field	**P**	**EDP**	**DP**	**PF**	**PS**	**SA**							
Number of bits	3	1	1	8	8	8	8	8	8	8	8	8	8
CAN Message	0x18			0xFE	0xD3	0xE4	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)

7.0 BES WAKE-UP BEHAVIOR

The Honeywell BES sensor features two modes, NORMAL and ECO.

7.1 NORMAL MODE

NORMAL mode is intended for when the vehicle ignition is ON, or when the high voltage battery is being charged. When the BES is in NORMAL Mode (default), the CAN transceiver within the sensor is active and transmits the BES State message every 1000 ms, as well as any active DTC codes that may be present.

7.2 ECO MODE

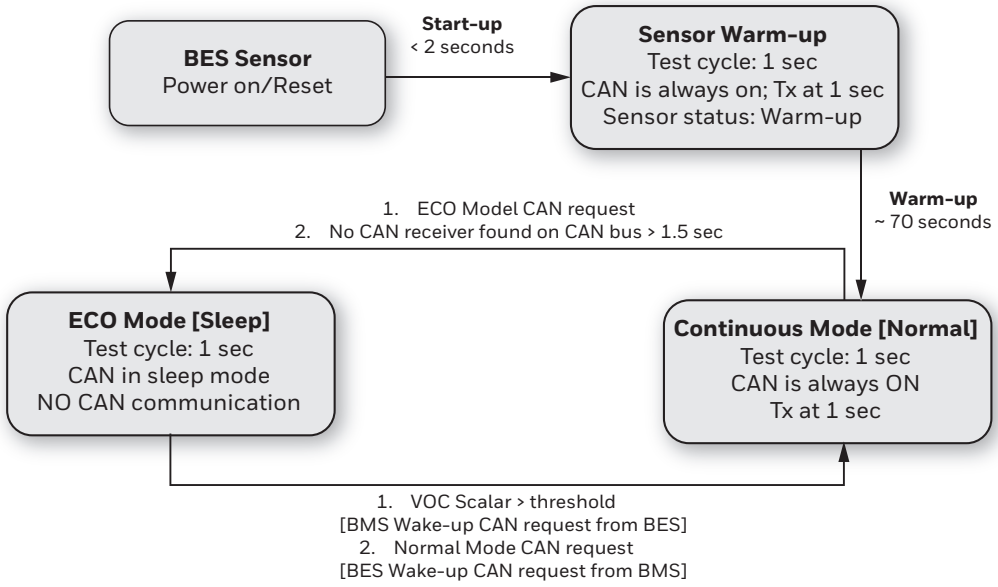
ECO mode is intended for when the vehicle is turned off. It features lower power consumption by disabling CAN communications. When the BES is in ECO Mode, the CAN transceiver is set to an Rx Only mode, no communications are transmitted on the CAN bus.

During ECO Mode, the BES continues to monitor the gas levels within the pack. If a battery vent condition is detected, the BES will automatically change back to NORMAL mode, with the BES State message indicating a battery venting or thermal runaway condition was detected (0x04).

7.3 VEHICLE REQUIREMENTS

For the BES Wake-up scheme to properly function, the Network Controller (BMS or other CAN bus hub) must support a Wake-Up Pattern (WUP) per ISO 11898-2:2016. Per the standard, the format of the BES State message (as discussed in Section 6.3) constitutes a WUP and will cause WUP-enabled transceivers in Rx Only mode to exit standby mode.

Figure 3. BES Mode State Machine



7.4 TRANSITIONING BETWEEN STATES (ECO AND NORMAL MODE)

In order to command the BES to different states, the CAN Network Controller must send a P2P message to the BES to indicate the desired mode. When in NORMAL mode, a single P2P message can be sent to transition the BES into ECO mode. This should preferably be one of the last messages transmitted by the Network Controller prior to the network going to sleep.

P2P Message Example: 0 x 19 EF E4 F6 01 02 (Transition to ECO Mode)

Once in ECO mode, the BES is in Rx Only mode. The BES CAN Transceiver is in standby mode, and will wake up upon receiving a Wake-Up Pattern (WUP) on the network, per ISO 11898-2:2016. Because of the timing requirements, any valid CAN J1939 message transmitted at 250 kbps or 500 kbps constitutes a WUP, so whenever the BES detects network traffic, it will wake up and be ready to receive the P2P message to transition back to NORMAL mode. If no network traffic is present prior to the BES P2P message transmission, the message will need to be transmitted twice to change state.

P2P Message Example: 0 x 19 EF E4 F6 01 01 (Transition to NORMAL Mode)

TABLE 3. PDU 0xEF00/61184

Frame Format	29-BIT ID						Data (2 Bytes)	
Field	P	EDP	DP	PF	PS	SA	ID	CMD
Number of bits	3	1	1	8	8	8	8	8
CAN Message	0x18			0xEF	0xE4	0x01	0x01	0x00

29-BIT ID	
Message	Description
EDP/DP=0	J1939 standard data page
PF=0xEF	Point-to-Point Message
PS=0xE4	Destination Address (Address of BES Sensor)
SA=0x01	Source Address (Address of Controller)

ID	
Temperature (C) = (int8_t) * Deg C	
CMD: Determines Operating Mode	
NORMAL Mode	0x01
ECO Mode	0x02
No Change	0x00

Example:

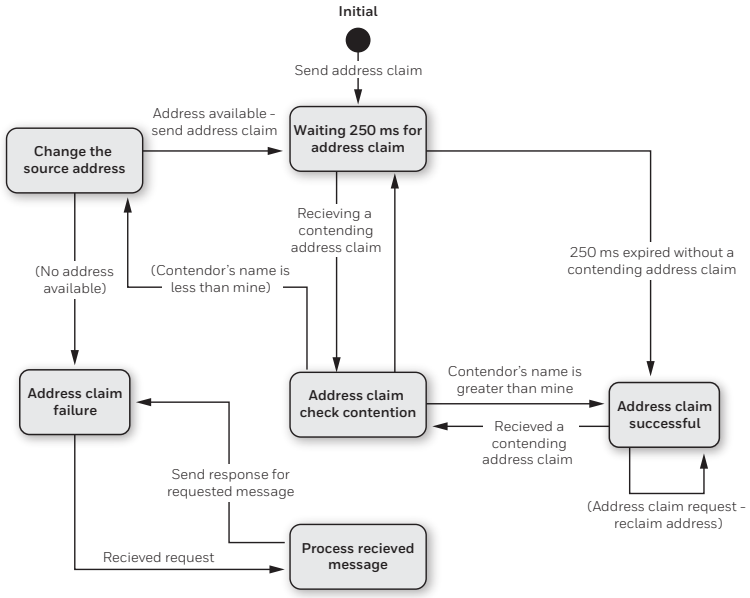
Network Controller (address 0x01) requests BES to enter ECO Mode

ID	DATA
0x18EFE4F6	01 02

8.0 CHANGING THE BES ADDRESS

The Honeywell BES sensor features two modes, NORMAL and ECO.

Figure 4. Address Claim State Machine



8.1. ADDRESS CLAIM - ARBITRATION

Once power is applied, the BES sensor will automatically begin the process of claiming the address set at the factory (for BES-131-111-001, this address is 0xE4). If no other devices on the network claim the same address, the claim is successful and the address set. If there is an address conflict, an arbitration process begins, as shown in Figure 4. The arbitrary address will be taken in the following order (default, 0x80, 0x81, 0x82, etc.). This feature helps resolve conflicts and is useful for temporary installations. However, for permanent networks with multiple BES sensors, it is recommended that the system integrator uses different default addresses by selecting different part numbers or follows the Commanded Address procedure below in section 8.3. This ensures each sensor has its own dedicated address instead of relying on random address selection.

8.2 ADDRESS CLAIM – COMMANDED ADDRESS

The Commanded Address message is used to instruct the BES with a certain NAME to assume the address as commanded. This procedure is useful, for instance, for bridges, diagnostics and scan tools.

The BES receiving the Commanded Address message can respond in two ways:

The BES accepts the new address and starts the address claim procedure.

The BES ignores the message and sends no response.

The Commanded Address message requires 9 bytes of data which necessitates using the BAM (Broadcast Announce Mode) of the Transport Protocol (as described in SAE J1939/21). First a connection initiation packet to be sent to the global address and Data transfer packets to be sent to BES Sensor.

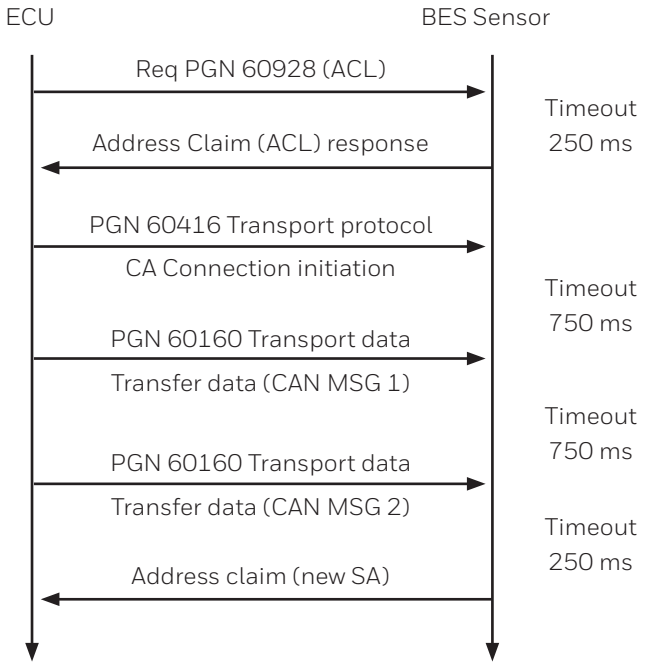
The process of commanding the BES to a new address is as follows:

1. Network Controller (VCU, BMS, or similar) requests ECU 64-bit name from Source Address (SA).
2. ECU responds with unique 64-bit name. This name is saved for Address Claim (ACL).
3. Transport Protocol is initiated to allow for large data transfer (PGN 60416).
4. Two-part message sent indicating 64-bit BES name and new SA.
5. BES responds from new SA with 64-bit name.

When identifying the sensor, the 64-bit name follows the following format:

NAME of Command Address Target		
1-3.1	21 bits	IDN - Identity Number
3.6-4	11 bits	MFG - Manufacturer Code
5.1	3 bits	ECU_I - ECU Instance
5.4	5 bits	FNC_I - Function Instance
6	8 bits	FNC - Function
7.1	1 bit	RES - Reserved
7.2	7 bits	VS - Vehicle System
8.1	4 bits	VS_I - Vehicle System Instance
8.5	3 bits	IG - Industry Group
8.8	1 bit	AAC - Arbitrary Address Capable

Figure 5. Address Claim (ACL) Message Timing



For the BES, the 21-bit IDN includes the week and serial number of the sensor, as shown below:

IDN – Identity Number (21 bits)	
Week	**Serial No.**
6-bits	15-bits

Message Formats

Below are the message formats for claiming an address.

Broadcast message from controller, requesting 64-bit NAME as response from all ECUs

TABLE 4. Request for Address Claimed (J1939-81 Standard) | PDU 0xEA00 / 59904									
Frame Format	**29-BIT ID**						**Data (3 Bytes)**		
Field	**P**	**EDP**	**DP**	**PF**	**PS**	**SA**	**SA**	**ID**	**CMD**
Number of bits	3	1	1	8	8	8	8	8	8
Message	0x18			0xEA	0xFF	0xF6*	0x00	0xEE	0x00

*Address of Network Controller

Broadcast message from ECU, responding with 64-bit NAME from original source address (0xE4).

TABLE 5. ACL (J1939-81 Standard) | PDU 0xEE00 / 60928

Frame Format	29-BIT ID						Data (8 Bytes)									
Field	P	EDP	DP	PF	PS	SA	Name									
							IDN	MFG	ECU_I	FNC_I	FNC	RES	VS	VS_I	IG	AAC
Number of bits	3	1	1	8	8	8	21	11	3	5	8	1	7	4	3	1
Message	0x18			0xEE	0xFF	0xE4	0x3E007	0x95	0x4	0x00	0x02	0x0	0x00	0x4	0x0	0x1

Broadcast message from controller to set network into Commanded Address connection.

CA Connection Initiation (J1939-81 Standard) | PDU 0xEC00 / 60416

Frame Format	29-BIT ID						Data (8 Bytes)							
Field	P	EDP	DP	PF	PS	SA	CA Connection Initiation							
Number of bits	3	1	1	8	8	8	8	8	8	8	8	8	8	8
Message	0x18			0xEE	0xFF	0xE4	0x20	0x09	0x00	0x02	0xFF	0xD8	0xFE	0x00

2-part Message providing 9-bytes of data (ECU name and new Source Address).

Transport Data – Message 1 (J1939-81 Standard) | PDU 0xEB00 / 60160

Frame Format	29-BIT ID						Data (8 Bytes)							
Field	P	EDP	DP	PF	PS	SA	Msg ID	Name (bytes 0 – 6)						
Number of bits	3	1	1	8	8	8	8	8	8	8	8	8	8	8
Message	0x18			0xEB	0xFF	0xF6	0x01	0x3E	0x00	0x71	0x2B	0x00	0x04	0x00

Transport Data – Message 2 (J1939-81 Standard) | PDU 0xEB00 / 60160

Frame Format	29-BIT ID						Data (8 Bytes)							
Field	P	EDP	DP	PF	PS	SA	Msg ID	NAME (byte 7)	New SA	Reserved				
Number of bits	3	1	1	8	8	8	8	8	8	8	8	8	8	8
Message	0x18			0xEE	0xFF	0xE4	0x20	0x09	0x00	0x02	0xFF	0xD8	0xFE	0x00

Confirmation broadcast from ECU from new Source Address with 64-bit name.

ACL (J1939-81 Standard) | PDU 0xEE00 / 60928

Frame Format	29-BIT ID						Data (8 Bytes)									
Field	P	EDP	DP	PF	PS	SA	Name									
							IDN	MFG	ECU_I	FNC_I	FNC	RES	VS	VS_I	IG	AAC
Number of bits	3	1	1	8	8	8	21	11	3	5	8	1	7	4	3	1
Message	0x18			0xEE	0xFF	0x80	0x3E007	0x95	0x4	0x00	0x02	0x0	0x00	0x4	0x0	0x1

Example:

Time (sec)	ID	Name	Dir	DLC	Data
4.271209	18EAFFF6x	RQST	Tx	3	00 EE 00
4.375204	18EEFFE4x	ACL	Rx	8	3E 00 71 2B 00 04 00 81
5.318138	1CECFFF6x	TPCM	Tx	8	20 09 00 02 FF D8 FE 00
5.418874	1CEBFFF6x	TPDT	Tx	8	01 3E 00 71 2B 00 04 00
5.568898	1CEBFFF6x	TPDT	Tx	8	02 81 80 FF FF FF FF FF
5.840592	18EEFF80x	ACL	Rx	8	3E 00 71 2B 00 04 00 81

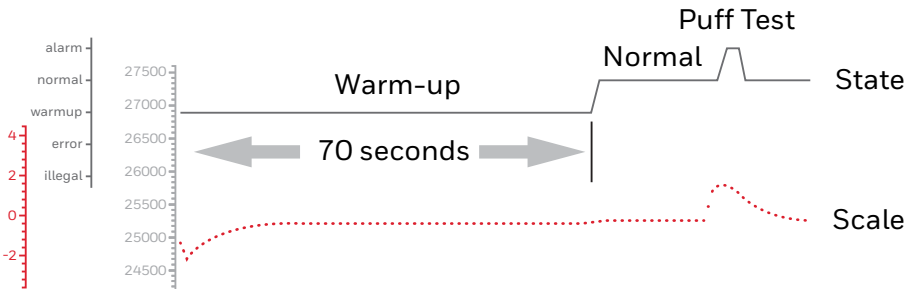
9.0 FUNCTIONAL TEST PROCEDURE

Objective: To verify the proper function and communication of the BES sensor within a CAN Network

Test Steps:

1. Connect the sensor to either a 12 Vdc or 24 Vdc power source, as required by the BES configuration
2. Initiate CAN communication
   a. Sensor will begin by claiming address
   b. BES State message will be broadcast once per second
3. CAN Data Acquisition Message
   - Check the state of the system
     - If State is "WARM-UP" (0x02), continue to wait for a total of 75 seconds for warm-up period to conclude
     - If State is "NORMAL" (0x03), begin functional testing
4. Perform Functional Test
   - Place approximately 50 mL of isopropyl alcohol (IPA) into a plastic bottle
   - Position the opening of the bottle near the BES gas port
   - Apply pressure to the bottle, such that the vapor inside the bottle is ejected towards the BES
     - **NOTE: Ensure that liquid IPA does not spill onto the sensor**
   - Wait for 4 seconds for BES response
   - Review CAN data. State should transition to "ALARM" (0x03) and Scalar value should increase to >1.0

Figure 5. Successful execution of the Puff test and accurate data acquisition and processing



10.0 ADDITIONAL SENSOR INSTALLATION NOTES

A. The BES sensor is a highly sensitive device that utilizes a metal oxide sensor for gas detection. The sensor has siloxane protection and has been evaluated to 15 years of life in a 570 ppb siloxane environment (OMTS, D4, D5 siloxanes). These chemicals are often a component of epoxies, glues, and adhesives. These chemicals could be outgassed during baking/curing. Despite the filter, a combination of small molecule siloxanes (D3 and smaller) at large quantities and elevated temperature (greater than 70°C) for extended periods can poison the sensor and reduce sensitivity to electrolyte vapors. The sensor will continue to respond to hydrogen (H_2).

B. Oxygen is required for the gas detection mechanism to work properly. The BES will not detect gases in a vacuum or inert atmosphere.

C. The BES sensor has been evaluated for an operating temperature range of -40°C to 85°C.

D. BES sensors are not repairable. The BES is designed for one-time use.

E. Faulty products should be returned to the manufacturer via the RMA process.

WARRANTY/REMEDY

Honeywell warrants goods of its manufacture as being free of defective materials and faulty workmanship during the applicable warranty period. The Honeywell standard product warranty applies unless agreed to otherwise by Honeywell in writing; please refer to your order acknowledgment or consult your local sales office for specific warranty details. If warranted goods are returned to Honeywell during the period of coverage, Honeywell will repair or replace, at its option, without charge those items that Honeywell, in its sole discretion, finds defective. **The foregoing is buyer's sole remedy and is in lieu of all other warranties, expressed or implied, including those of merchantability and fitness for a particular purpose. In no event shall Honeywell be liable for consequential, special, or indirect damages.**

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

⚠WARNING MISUSE OF DOCUMENTATION

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