General Specification for an Electronic Brake Pad Wear Sensor for Brake Pad Life Monitor Estimation Algorithm

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.

1.1 Purpose. This document provides the standard technical requirements for a Brake Pad Wear Sensor (BPWS). This specification applies to three (3) state (minimum) resistor based sensors to be used in conjunction with the Brake Pad Life Monitor Algorithm. Sensor design shall meet all requirements in this specification, unless noted. Any requirements that may differ or be specific to a certain design will be defined in this specification. This document is supported by the vehicle program supplement Statement of Requirements (SOR) Appendix C2 that provides program-specific requirements related to the sensor and harness. Examples of vehicle program requirements are:

1.1.1 Sensor Design Variants.

- Part numbers and usage.
- Sensor assembly design: sense head dimensions, wire exit, harness length, grommet count and location, clips and clip accommodations, abrasive and temperature protection.

1.1.2 Packaging.

- Sensor packaging in caliper.
- Harness wire routing.
- Program-specific temperature and environmental requirements.

Note: The GM engineer will provide Appendix C2 in the SOR package.

1.2 Applicability. This BPWS standard applies to any program featuring the accompanying Brake Pad Life Monitor Algorithm.

1.2.1 Routing Requirements. Individual platform suspension, knuckle, axle, driveline, and bearing configuration define the BPWS assembly, and cable routing requirements.

1.2.2 Exceptions for Cordless Sensors. The requirements for the sensor cable specified in this document are not applicable for cordless sensors.

1.3 Remarks. The BPWS provides discrete threshold indications of brake pad height through use of a resistor based circuit exhibiting three (3) voltage levels (referred to as “states”) dependent on wear status of the circuit contained on the interior of the sensor head. The Brake Life Pad Monitor Algorithm requires two (2) hardware sensors, one per axle. Refer to Appendix C2 for program-specific requirements detailing sensor location for both front and rear axle.

The first state, State 1, of pad wear is represented by the foremost node of the circuit having a zero equivalent resistance circuit value. Varying directly with brake pad height, the sensor head height is depleted through direct frictional contact with the brake rotor. The first wear threshold is achieved when sensor head depletion causes this foremost node of the circuit to achieve an open state of operation, and thus redirecting the energy of the circuit to the secondary circuit contained in the sensor head.

The activation of this secondary circuit, State 2, represents the second state of pad wear and has an equivalent resistance value of 1300 Ω. Still varying directly with the brake pad height, the sensor head height continues to be depleted until this secondary circuit achieves an open state of operation.

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For the Diagnostics Solution depicted in Figure 1, once the pad wear level has achieved this last level of depletion, the circuit now at State 3, exhibits a 4870 Ω equivalent resistance value and the sensor head may continue to be depleted, however, there are no additional changes to the equivalent resistance value of the sensor head contained circuit.

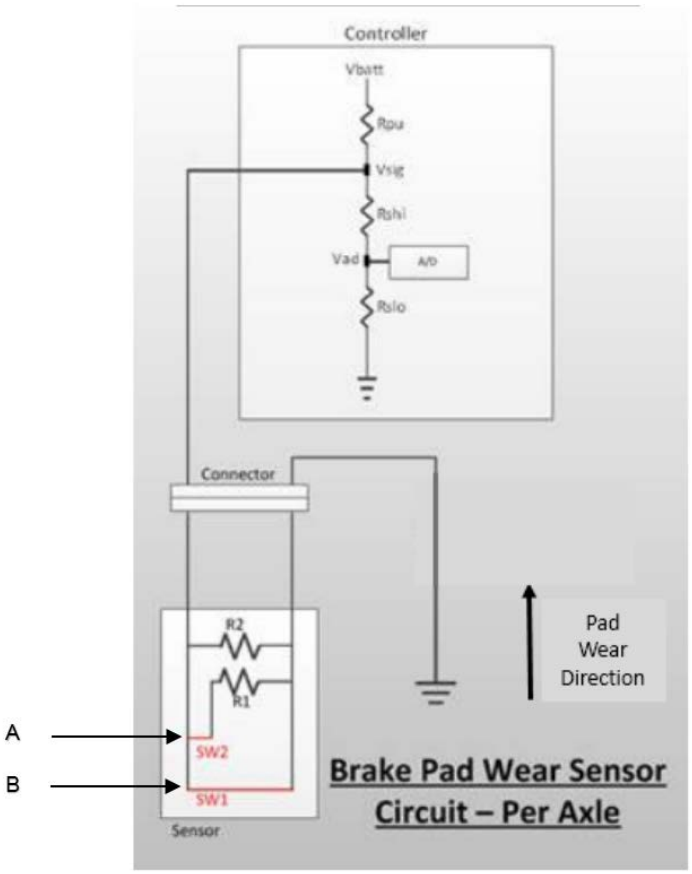


Figure 1: Electrical Circuit Diagram, Diagnostics

Diagnostic strategy and corresponding resistor values depicted in Figure 1, at R1 and R2 (where applicable), to be agreed upon by General Motors Electrical Design Release Engineer (DRE). The resistor values are dependent on the sense circuitry hardware's resistor values, the sense circuitry analog to digital converter reference voltage, and system voltage sense resistor values.

Sensor-sense electrical hardware combinations are subject to approval by electrical simulation analysis by General Motors.

Diagnostic driven configuration of BPWS System Circuit is depicted in Figure 1.

1.4 Order of Precedence. The referenced documents of the exact issue (or a later issue) shown, form a part of this specification to the extent specified herein. In the event of a conflict between the documents referenced herein and the contents of the specification, the contents of the specification shall be considered a superceding requirement except where noted. Nothing in this specification, however, supercedes applicable laws and regulations unless specific exemption has been obtained.

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2 References

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

2.1 External Standards/Specifications.

AIAG FMEA-4	IPC-7912	ISO 11469	UL 1581
AIAG PPAP-4	IPC-9261	ISO 14572	USCAR21
AIAG SPC-3	ISO 6722	SAE J1128	

2.2 GM Standards/Specifications.

GMW3059	GMW14394	GMW15189	GMW15862
GMW3091	GMW14573	GMW15272	GMW16377
GMW3097	GMW14700	GMW15386	GMW16449
GMW3103	GMW14794	GMW15626	GMW16600
GMW3172	GMW14872	GMW15702	
GMW3191	GMW14980	GMW15839	
GMW14089	GMW15105	GMW15841	

2.3 Additional References.

- Automotive Industry Action Group (AIAG), Southfield, Michigan (www.aiag.org)
- CG4096 Brake Pad Wear Sensor SOR Appendix G2 Validation Cross Reference Index (VCRI)
- Component Technical Specification (CTS)
- GM1738 (part of the GM specific requirements in the GM9000 series and located through https://gmsupplypower.covisint.com)
- GM Best Practices:

a. ELEC86-80 - Front Wheel Speed Sensor Harness Routing Practice Body Frame Integral (BFI) **Note 1**

b. ELEC86-101 - Protection Guidelines for Wire Harness Assemblies

c. ELEC86-90 - Practice to Prevent Fretting Corrosion in Electrical Automotive Connectors

d. ELEC86-71 - Selection of Wire for use in Vehicle Wiring System, in Consideration of Temperature Class, Wall Thickness, Material Type, Construction, and Size

ELEC86-69 - Practice for Packaging Electrical Components to Prevent Water Intrusion in the Connection System (Globally Approved)

e. ELEC86-64 - Vehicle Interface Guidelines for Wiring and Connector Attachments (Globally Approved)

f. ELEC86-46 - Proper Routing Separation Between Power and Signal Circuits for Electromagnetic Compatibility (EMC)

g. ELEC86-44 - Global Best Practice/Procedure for Conducting a Wire Harness Assessment (WHA)

h. ELEC86-41 - Connector Positioning Assurance (CPA) Description and Application Considerations

i. ELEC86-39 - Wire Design Guidelines for a Dynamic or Flexing Environment

j. ELEC86-38 - Wire Harness Twisting, Shielding, and Connector Pin Assignment Requirements for EMI Protection

k. ELEC86-27 - Selection and Application Practice for Universal Attachment Clips Used to Secure Wire Harness Assemblies (Globally Approved)

l. ELEC86-20 - Wheel Wiring System Harness Routing for Vehicle; System includes WSS, Semi Active Damping System (SADS) Dampeners and Brake Pad Sensor **Note 1**

Note: Provided for DRE Reference and for internal to GM use only. The supplier shall work with the GM Design Responsible Engineer to comprehend these requirements.

Note 1: Connector placement variation due to serviceability requirements, validation testing will confirm performance.

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- GM Drawing 13576801, See also KOSTAL Kontakt Systeme (connection systems) (www.kostal.com/kks/en/), or equivalent
- GM Brake Caliper Assembly Drawing
- Statement of Requirements (SOR), Appendix C2
- United States Council for Automotive Research (USCAR) Electrical Wiring Component Applications Partnership (EWCAP), (http://www.uscar.org/guest/teams/10/Electrical-Wiring-Component-Applications-Partnership (EWCAP))

a. EWCAP 001: Terminal Blades All

b. EWCAP 005-7: Clip Slot Bases and Sheet Metal

c. EWCAP 120-S-002-1-Z02: Connector Catalog - Supplier Tooled Parts

3 Requirements

Note: “Shall” denotes a binding provision to be met by the product or process. “Will” denotes requirements associated with the development of the product or external elements, rather than for the product itself. “May” is similar to “Will”, but less definite in occurrence. Shall be treated as a “Will” for the purpose of design and validation. “Withstand” pertains to all functions of the BPWS during and after exposure to the defined condition without inadvertent actuation of its outputs.

3.1 System/Subsystem/Component/Part Definition. A BPWS consists of a sensor head, cable, jacketed and/or sleeve protected wiring, fasteners (i.e., clips or rubber grommets), and an electrical connector. The sensor head is an over-molded assembly that contains a resistor network on a copper wire frame, or other circuit based technology. The sleeved or jacketed cable may also contain resistors for additional diagnostic purposes. Figure 2 shows a graphical representation of a generic BPWS design, and is not intended to represent any specific BPWS design.



Figure 2: Typical BPWS Assembly (Note: Over-Mold Features Not Pictured)

3.1.1 Appearance.

3.1.1.1 Visual Appearance. The surfaces of the BPWS shall be free from seam flash, scratches, sink marks, pin holes, nicks, knit lines, blisters, tears, cracking, scuffing, voids, contaminates or any other surface irregularities.

3.1.1.2 Finish. The BPWS shall have smooth corners and edges for all exposed surfaces.

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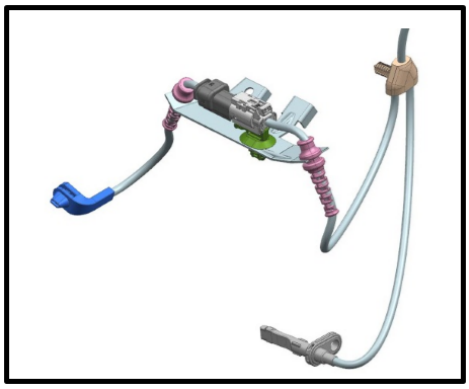
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3.1.1.3 Color. The color shall be black or grey as determined by the program specific DRE. GM Mating connector shall be dark grey.

3.1.2 Content. The required physical and functional content for the BPWS are identified in 3.1.2.1 thru 3.1.2.2.1.

3.1.2.1 Physical Content. This BPWS is a single component, comprising the sensor body, electric cable or wiring, possible attachment clips or fasteners, and GM mating connector. For examples, refer to Appendix D Figures D1 and D2. For serviceability purposes, the BPWS may interface with a jumper harness routing solution common to the Wheel Speed Sensor (WSS) wiring assembly for the given corner module (refer to Figure 3 and Appendix E, Section E1 and Figure E1). The BPWS and WSS circuits shall be electrically isolated and will not share a common connector interface. The exact sensor interfacing assembly design shall be defined by the designated vehicle application engineer, and harness length may vary according to program specific packaging requirements. For additional reference, see Appendix E, Table E1, listing a summary of Best Practices (the supplier shall work with the GM DRE to comprehend this requirement) related to the BPWS circuit routing design. (The supplier shall work with the GM DRE to comprehend this requirement.)



Note to GM DRE: Connector orientation to be agreed upon by Power and Signal Distribution System (PSDS).

Figure 3: Recommended Sensor Interface

3.1.2.2 Functional Content. The BPWS shall provide a signal to be transmitted by the sensor cable to the system electronic control unit, and be capable of performing the following functions:

- As agreed upon by the Program DRE, circuitry which enables control module sensing diagnostics will be used to detect the following failures for each wear state:

a. Sensor Short to Ground.

b. Open Circuit.

c. Erratic Signal.

- R1 shall be defined at a value of 1.78 kΩ ± 1%.
- R2 shall be defined at a value of 4.87 kΩ ± 1%.
- The sensor shall be designed such that point of transition to the specified R1 value shall occur at 5.3 mm ± 0.15 mm of friction material remaining when the sensor is mounted to the pad assembly unless otherwise specified.
- The sensor shall be designed such that point of transition to the specified R2 value shall occur at 3.4 mm ± 0.15 mm of friction material remaining when the sensor is mounted to the pad assembly unless otherwise specified.

Note: Refer to Figure 1 for overview.

The general characteristic of the pad height to BPWS equivalent resistance is shown graphically in Figure 4.

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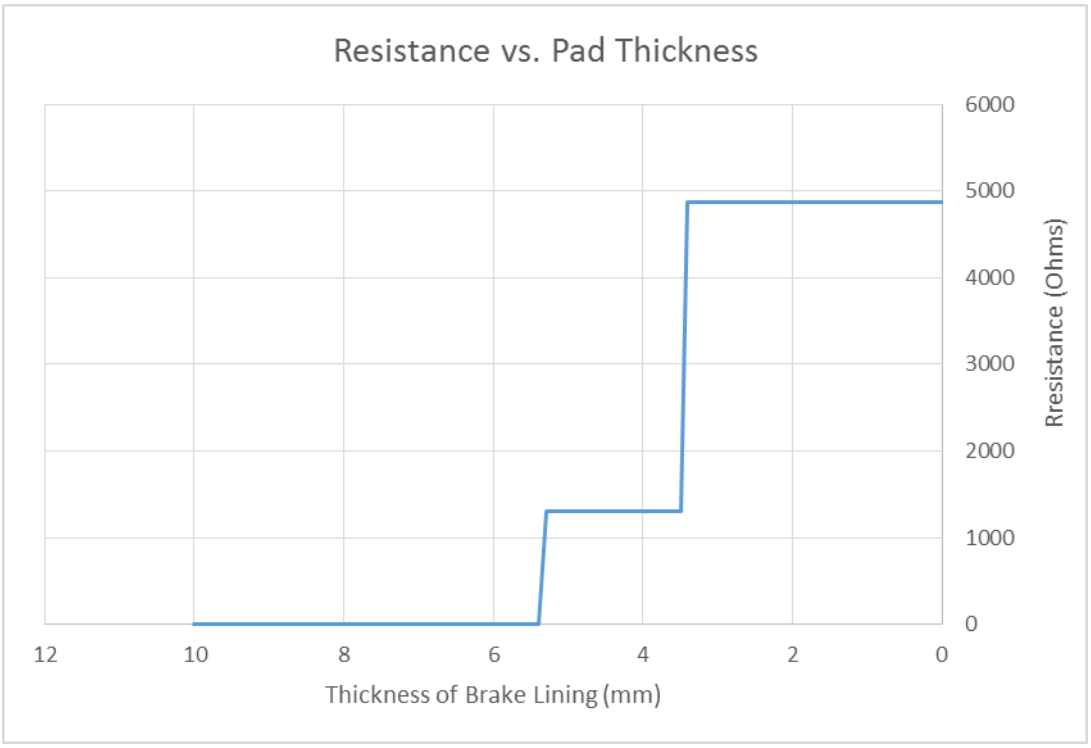


Figure 4: Typical BPWS Output (Example)

Also, Figure 5 depicts a sample implementation in the form of the wire frame type.

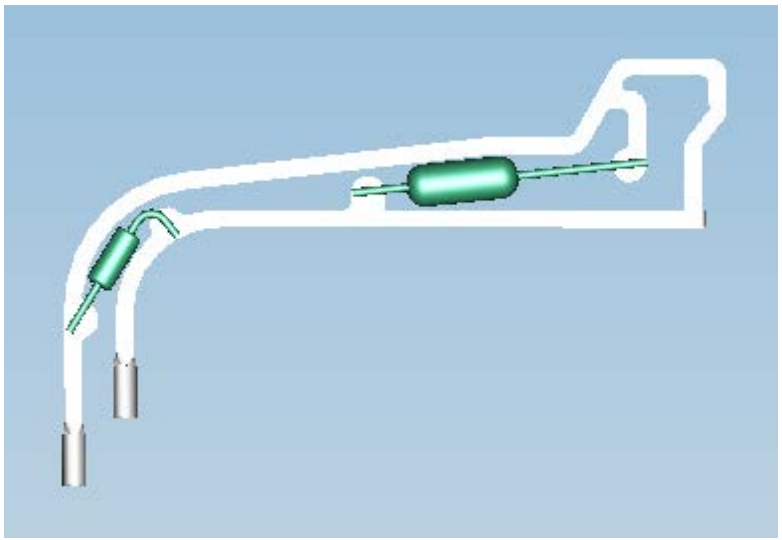


Figure 5: Sample, Two Resistor Wire Frame Type

3.1.2.2.1 Sensing Integrated Circuit (IC) Use. A BPWS sensing IC will not reside in the sensor head. The BPWS sensing IC will reside in a host control module to be determined by the Electrical DRE.

3.1.3 Ambient Environment. The components shall withstand all reasonable combinations of these conditions under such usage that includes, but are not limited to those defined in GMW3172.

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3.1.4 Interfaces. The BPWS interfaces diagram and descriptions are included in Appendix B, Figure B1 and Table B1.

3.1.4.1 Sensor Mounting. The GM BPWS vehicle harness connector will mount to the vehicle (i.e., knuckle, caliper, etc.) equipped with anti-rotation clip interface shown in Figure 3.

The BPWS mating connector shall interface with GM connector on vehicle WSS and BPWS combined jumper harness, or vehicle harness, which contains anti-rotation clip on connector for mounting. Other clips (to caliper for example) shall be determined required by the Electrical DRE.

3.1.5 Usage Definition.

3.1.5.1 Power On/Off Cycles. The number of power on/off cycles for the BPWS over the 15 year, target life. This will be defined in GMW3172.

3.1.5.2 Power-on Time. The total power-on time for the BPWS over the 15 year, target life will be defined in GMW3172.

3.2 Product Characteristics. The requirements for the BPWS are identified in 3.2.1 thru 3.2.5.

3.2.1 Performance Requirements. The verifiable technical requirements for the BPWS assembly are identified in 3.2.1.1 thru 3.2.1.23.

3.2.1.1 Sensor Assembly. For the product characteristics on a sensor assembly drawing, see the program specific technical specification.

3.2.1.2 Over-molded Material.

- The BPWS over-molded material shall be Phenolic based compound.
- The over-molded material shall be pore/void free.
- The over-molded material shall meet all requirements as stated in GMW15702.
- The sensor head and connector may use the same over-molded material.
- Any apparent wire strain in routed position, as determined by the Vehicle Program Engineering Team shall be protected using a trumpet grommet. Trumpet grommet or jacketed cable material shall meet anti-abrasion properties (needle cycles of ≥ 20 000) and shall perform over temperature ranges in a Class C environment. Figure 6 provides a trumpet grommet sample.

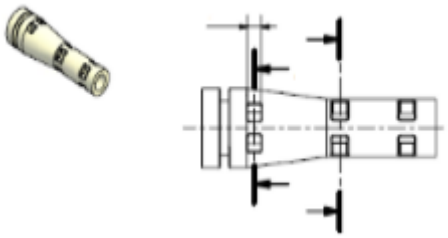


Figure 6: Sample Trumpet Grommet Geometry

3.2.1.3 Electromagnetic Compatibility. The BPWS shall meet the requirements and test procedures according to GMW3172 in the new state (prior to exposing resistive elements during the wear process).

3.2.1.4 Operating Temperature. At a minimum, the harness segment of the BPWS shall be functional in the entire ambient temperature range of -40 °C to 150 °C and for sustained excursions of 200 °C for up to 30 minutes.

The area of the BPWS sensor head that engages the caliper (retention to the pad and the circuit operation) shall be fully functional given the following temperature exposure limits from the rotor and pads:

- **Rotor Temperature:** Continuous exposure up to 350 °C, 2 minute excursions to 500 °C. Maximum 50 excursions per sensor life.

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- **Brake Pad:** Continuous exposure up to 250 °C, 2 minute excursions to 370 °C. Maximum 50 excursions per sensor life.

3.2.1.5 Handling. The BPWS as a standalone component shall remain functional when dropped to a concrete surface from a height of 2 m.

The BPWS cable shall maintain continuity with the sensor and not crack or separate from the over-molded material when pulled with a force of 150 N minimum.

3.2.1.6 Insulation Breakdown. The BPWS harness shall show no sign of insulation breakdown when exposed to 200 V. Reference 4.3.1.19.

3.2.1.7 Pothole Shock. When mounted in the vehicle, or in an applicable fixture, the BPWS assembly shall withstand repeated vibration shocks of 980 m/s^2 (100 G) in 11 ms duration, per GMW3172.

3.2.1.8 Gravel Impingement. The BPWS assembly shall withstand the gravel impingement encountered in the vehicle usage environment, as described in 4.3.1.26.

3.2.1.9 Articulation. The BPWS assembly shall function as designed and shall not interfere with any vehicle parts and other potential obstacles that may prevent it from proper function at all vehicle conditions of steering linkage position, suspension travel, and wheel alignment. Refer to GMW15105.

3.2.1.10 Overmold and Mounting Insert Retention. Where a bracket is applicable to the vehicle application, the BPWS mounting interface shall show no sign of movement or rotation in the over-molded material when an axial force of 270 N maximum or a torque of 11 N·m maximum is applied in any direction.

Overmolds shall meet the following axial pull force requirements:

- Sensor head to sleeved wires: 60 N.
- Single wire + sleeve to grommet: 25 N.
- Sheathed cable to grommet: 100 N.
- Sheathed cable to wire dress cover: 60 N.

3.2.1.11 Input Interface Protection. According to GMW3172.

3.2.1.12 Output Interface Protection. According to GMW3172.

3.2.1.13 Mechanical Interface. The BPWS head design shall include retaining clip, or other fastening interface on the sensor head, sample geometry provided in Figure 7. The clip shall be designed to meet the insertion and retention requirements, as specified in this section.

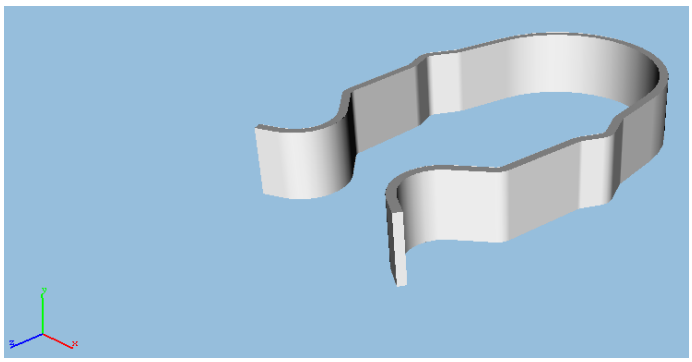


Figure 7: Spring Clip Sample Implementation

3.2.1.13.1 Figure 8 depicts a sample fastening solution, clip type, where backing plate interface clip is seated in sensor head.

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Figure 8: Sample, Spring Clip Seated in Sensor Head

3.2.1.13.2 The BPWS head retaining clip will interface to a cutout on the pad lining and backing plate on the caliper assembly. Retention force of the sensor head to the cutout area shall be in the range of 30 N to 80 N. Figure 9 provides a representation of the cutout. Insertion force of the sensor head to the cutout area shall be in the range of 20 N to 50 N.

Notch Dimension A	Notch Dimension B	Notch Dimension C	Notch Dimension D	Notch Dimension E
2.30-2.60 (after paint)	11.8-12.0 (after paint)	8.7-8.9 (after paint)	6.9-7.1 (after paint)	6.5-6.9 (after paint)

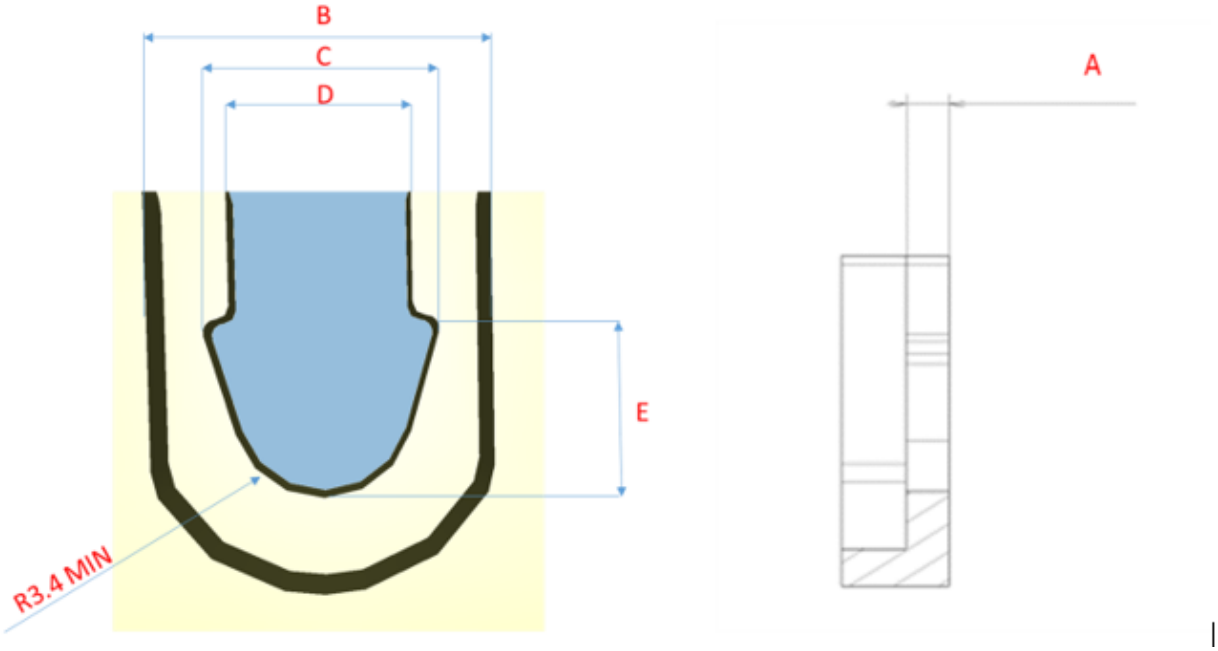


Figure 9: Pad/Backing Plate Cutout Geometry

3.2.1.13.3 The BPWS shall meet all requirements stipulated in the GM brake caliper assembly drawing. Contact GM Engineering before tooling kickoff to obtain the latest interface requirement drawing. Figure 10 depicts a sample, backing plate and brake pad, sensor accommodation.

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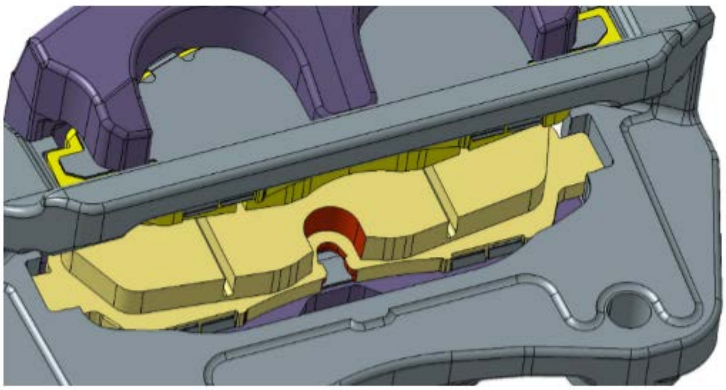


Figure 10: Backing Plate/Brake Pad Accommodation

3.2.1.14 Connector Requirements. The body side mating connector GM Mating Connector Part Number 13583195, or equivalent, shall meet all requirements as detailed in GMW3191 and GMW15841, also refer to EWCAP 120-S-002-1-Z02. The sensor pigtail GM connector is defined in GM drawing 13576801 or equivalent, as GM Connector Part Number 13583196 or equivalent, keying option A, sample depiction in Figure 11.

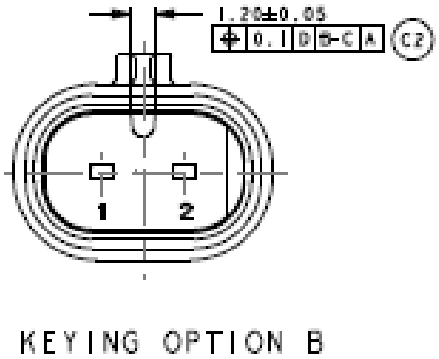


Figure 11: GM Mating Connector on Sensor Harness, Figure B1 with Circuit Identification

Both the sensor sealed mating connector and GM connector shall include over-molded material, onto the wire, wire sleeve or cable jacket, as determined necessary to meet requirements of this specification. Select connector per GMW3191, type T4V4S3 (high performance connector). Permissible materials must meet the performance requirements of this specification and ISO 14572.

The connector shall be seated using an integral Connector Positioning Assurance (CPA).

Refer to GM Drawing 13576801, for GM sealed and over-mold capable sensor GM connector part number 13583196, or equivalent, Class T4/V4 Keyway A (Grey). Figures 12 and 13 depict the GM connector, GM Part Number 13583196, or equivalent.

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