Wiring Component Design Guidelines

SAE/USCAR-12 Revision 3
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WIRING COMPONENT DESIGN GUIDELINES

Scope:

This document gives general guidelines to be used during the connector design stage. Various guidelines may not apply in all situations. Therefore, sound engineering judgment must be used in their application. Consider these guidelines as the basis for connector and wiring DFMEA's. Items in this document are grouped by DFMEA functional requirements. Groups are as follows:

A. Electrical Continuity
B. Electrical Isolation/Sealing
C. Device Assembly
D. Harness Assembly
E. Vehicle Assembly
F. Materials
G. Serviceability
H. Environmental Requirements
I. High Voltage (≥ 60V) Application Requirements

References:

SAE/USCAR-2 – Performance Specification for Automotive Electrical Connector Systems
SAE/USCAR-20 – Field Correlated Life Test Supplement to SAE/USCAR-2
SAE/USCAR-25 – Electrical Connector Assembly Ergonomic Design Criteria
SAE/USCAR-37 – High Voltage Connector Performance Supplement to SAE/USCAR-2
USCAR/EWCAP-001 – Blade Chart (see USCAR/EWCAP website)
USCAR/EWCAP-002 – 1.5mm Female Cavity (see USCAR/EWCAP website)
SAE J1344 – Marking of Plastic Material
SAE J1742 – Connections for High Voltage On-Board Road Vehicle Electrical Wiring Harnesses – Test Methods and General Performance Requirements
SAE J1766 – Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing
ISO 20653 (DIN 40 050) – Road vehicles – Degrees of protection (IP-Code) – Protection of electrical equipment against foreign objects, water and access (Also persons)
GADSL – Global Automotive Declarable Substance List
IMDS – Automotive Industry Material Data System

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A. ELECTRICAL CONTINUITY

1. Connector and terminal system designs must meet the appropriate requirements per SAE/USCAR-2 (i.e. temp class, vibration, and sealing, etc.) (Reference SAE/USCAR-21).

2. During the initial design of each new connector and terminal family, complete a layout study of the mated assembly showing minimum/maximum terminal insertion, seal compression tolerance stack-ups, and worst case connector-to-connector alignment at the point of initial terminal contact. This guideline ensures that connector lock over-travel and minimum terminal engagement length requirements are met. The supplier retains this information and makes it available to the OEM or tier supplier upon request.

3. Take connector and terminal misalignment during all stages of engage/disengage into account. Account for cocking of the fully mated connector due to wire bundle longitudinal and lateral stress. Provide for a minimum 1.0mm terminal engagement beyond the male terminal coined edge in all possible positions.

4. Design terminals, with identified surfaces or edges to prevent stamping burrs (i.e. interface mating and external surfaces).

5. Verify that all lubricants, cleaners, and mold release agents used in the manufacture of terminals and connectors are not harmful to the electrical and mechanical performance for the life of the connection system. Must be validated to SAE/USCAR-2 and 37 if applicable.

6. Design the terminal so that it retains any pre-staged lubricant (if specified) in the contact area during all stages of shipping and processing through final assembly into the vehicle.

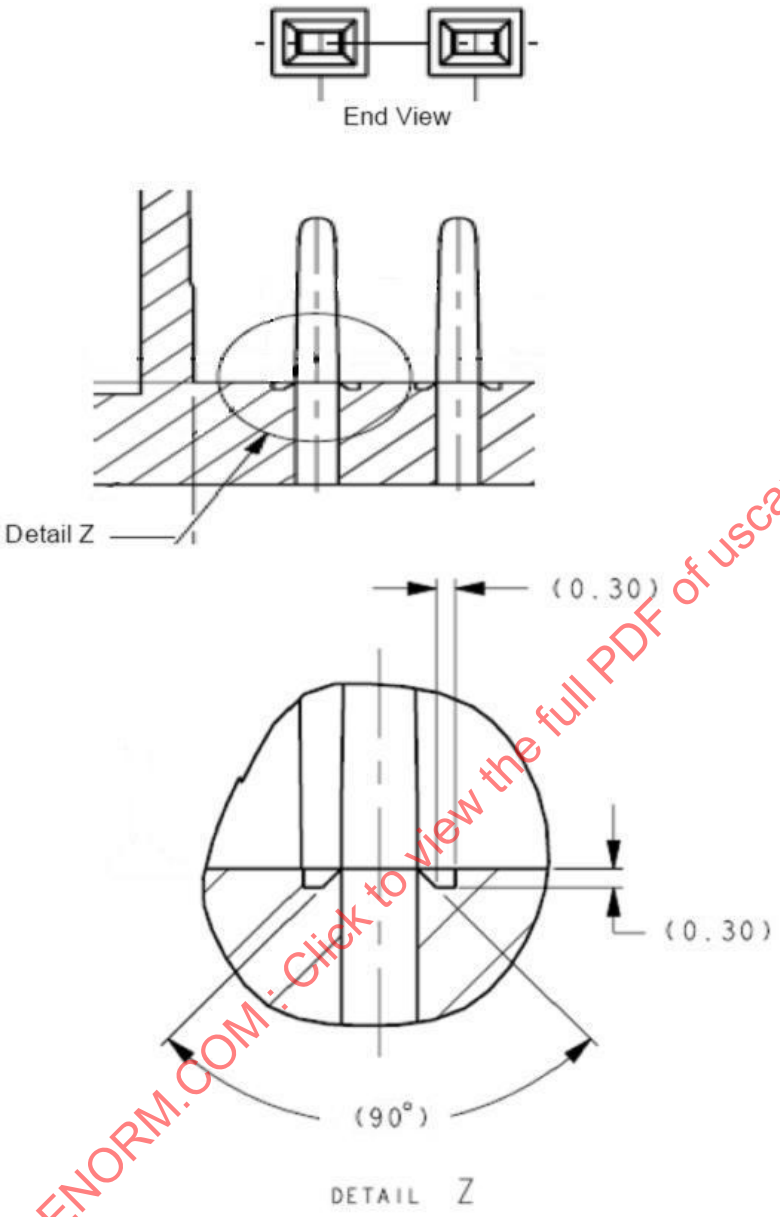
B. ELECTRICAL ISOLATION/SEALING

1. Conduct product validation testing using mating part samples that are production intent, whenever possible. Document any modifications (i.e. sealing holes) made to a mating housing (header) in the test report and share this information with the component manufacturer.

2. In cases where power and ground are in the same connector and the existence of the opposite potentials is known during the initial design, locate the (+) and (–) pins as far from each other within the pin field as practical. Plastic isolating walls to increase the creepage distance may be used as an alternative. (For A.C., locate the power circuits as far from each other within the pin field as practical).

   For any connectors, where EMC requirements is an issue (e.g. high voltage applications), you must locate the power and ground adjacent to each other, but must have an isolation wall between them.

To avoid tracking from pin to pin, in a connector, (as an example) the following configuration can be used at the base of the male terminal: See figure B 2



Prevent conductive material tracking, dimensions in mm

Figure B 2

3. Design the connector, so that the wire seal is unaffected by wire bending and handling (a strain relief feature is an option). Allow for plugs to be inserted in individual terminal cavity openings in the cap after the end cap is installed. Provide for positive retention of seal plugs if used. Another alternative is an end cap with integral hard plugs that are removed according to circuit loading. The last alternative is flashing over cavities in the connector.

4. Design the individual cable seals from moving along the wire and away from the terminal during assembly and handling.

5. Peripheral seals shall be designed as part of the female connector and must have a shroud to completely protect the peripheral seal to avoid accidental removal or damage prior to vehicle assembly.

6. Design to prevent “bunching” rollover or excessive movement of the peripheral seal during mating and un-mating of connectors. Design connectors with a seal retaining feature.

7. When using a multiple rib peripheral seal, design so that shroud length and size incorporates full utilization of all functional ribs in the worst-case dimensional stack-ups, as qualified.

8. Design terminals and connectors so that there is at least 1 mm of plastic coverage between the back of the terminal and the back of the connector

9. Keep mold parting lines, steel match lines, and part decorations off of the sealing surfaces of the seals and the plastic connector housing. ..

10. Design protective cover for unused (option delete) connectors with positive retention to the covered connector and maintain sealing capability as required.

11. Sealed Connectors validated under SAE/USCAR-2 may or may not be subjected to high pressure spray testing. Consider additional validation testing when connector/cable seals are directly exposed to moving vehicle induced wind, road/wheel splash or spray. The connector may require a rear splash cover to withstand the high pressure spray test.

12. Consider the pressure differential developed within connectors as the device is heated and quenched by road splash. A good practice is to not allow standing water/fluid to collect on the seal during vehicle operation which could be drawn into the connector as the device cools. All new cable seals shall include a feature that promotes water drainage and minimize water from pooling between the cable and the connector housing.

13. For sealed connectors, isolate connectors and terminals from contamination emanating from within the component side of the connection (i.e. brake fluid, engine coolant, transmission fluid, etc.)

14. All sealing methods must be designed for two (2) terminal insertions and one (1) terminal extraction from the connector cavity without compromising the sealing properties.

15. Cautionary note: Silicone seals typically contain a siloxane that will outgas (evaporate) over time. When siloxane gas is exposed to electrical arcing (like a brush style motor or electromechanical relay), grains of silicon oxide will form and deposit in the general region, especially sealed devices. Potential solutions include heat curing the seals in an air circulating oven or using non-silicone materials like flouro-polymers (without siloxane).

C. DEVICE ASSEMBLY

1. Verify that the device assembly still meets all functional requirements after worst case processing (temperature and chemical exposure) of the device or module.

2. The device housing shall not have flash, or mismatch of mold parting lines on critical surfaces (i.e. lock ramps and sealing surfaces that would prevent connector to connector, or connector to device latching or sealing).

D. HARNESS ASSEMBLY

1. Chart wire range and insulation diameter range on all terminal drawings. .Also, for shielded wire show range of shield sizes. Provide crimp dimensions for all applicable cable types and sizes either on the drawing or as a separate document. Make this information readily available to the harness supplier.

2. Fully disclose terminal materials (alloy/temper) on all drawings supplied to end users for crimp analysis.

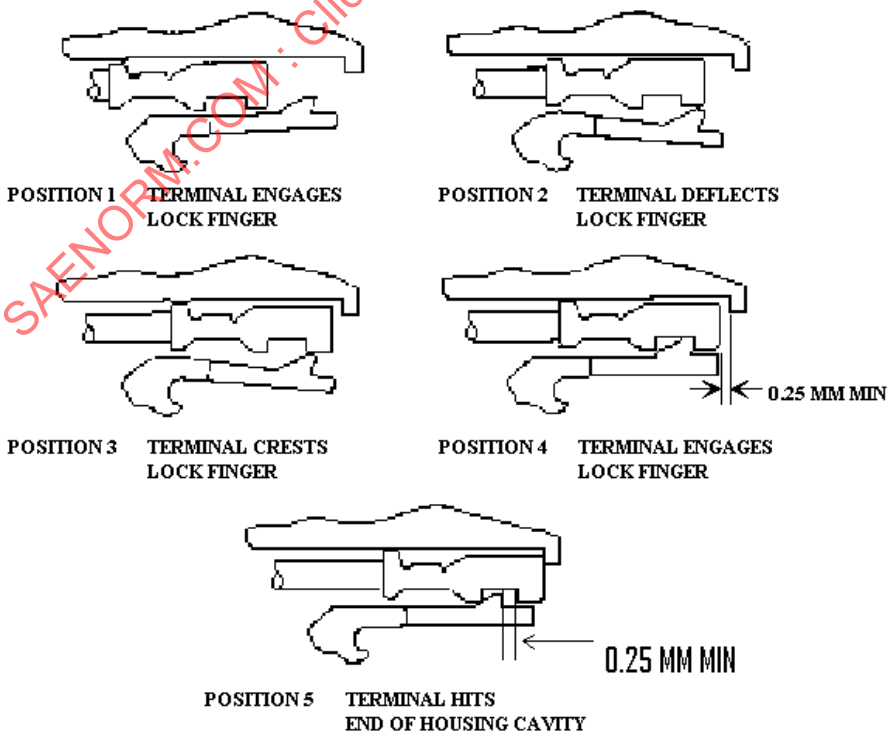
3. Specify the approved wire outer diameter ranges on all connector assembly drawings and cable seal drawings.

4. Make seal a contrasting color to the connector housing.
The TPA/PLR, whenever possible, should be a contrasting color to the connector housing.

5. Design seals with features that will prevent them from sticking to each other before assembly.

6. Design the rear surface of the connector housing with lead-ins for rear seals.

7. Provide at least 0.25mm over travel of terminal which leaves clearance between the terminal lock surface and the cooperating terminal cavity locking finger retention surface. This is measured with the terminal against its forward stop and with the locking finger swung to a position where its retention surface most closely approaches the terminal lock surface.



8. Design all connectors with lead-ins on all mating surfaces. A chamfer or radii is allowed as long as it doesn't defeat keyways (polarization).

9. Design connectors with a feature to detect and/or correct partially seated terminals. This requires the use of: a TPA (which detects and corrects), a ISL (which detects, but not corrects), a PLR (which detects, but not corrects), or a FBT (which detects, but not corrects)(A ring-out system needs to be implemented with FBT to detect partially seated terminals).

10. Design the cavity with a terminal forward stop feature or alternative means to prevent terminals from pushing through during assembly and handling. The stop feature needs to be part of the initial connector housing, not in the front loaded TPA /PLR.

11. Avoid sharp projections on terminals which may cut operators' hands or damage mat seals.

12. Provide access for the harness fixture continuity probe in the connector housing assembly. Provide access for the probe through the front of the connector. Design the connector and probe so that contact is not made with the terminal mating surface. As an example, use pogo pin designs as shown on drawing EWCAP-002.

13. Design the terminal and connector to prevent mis-orientation. (Note: not all terminals require a polarization feature.) For designs that require polarization, design the terminal:

    a. With an external terminal orientation insertion feature which is visually obvious.
    b. To prevent full insertion of an incorrectly oriented terminal into the connector housing such that at least the terminal insulation grip fully protrudes from the rear of the connector housing. (If a mat seal with a rear cap is used, the terminal insulation grip must be visible).

TERMINALS

14. Design the female and male terminal with sufficient lead-in. (See EWCAP-001 for male blade details).

15. Rear carrier strips are preferred on terminals with wire grips. Header blades may be side carried, end carried or on a bandolier.

16. Design terminals to avoid snagging at harness assembly plants. (i.e. protected tangs, etc.).

17. Design the female terminal with a shape (or configuration) to protect the electrical contact(s).

18. Design terminal retention features using: a) plastic lock fingers, or b) protected tangs (single tang, no dual tangs allowed on new designs).

19. Terminals with precious metal plating shall have a visible indicator.

20. Overstress protection of the female contact beams shall be included in the design, to minimize damage from probing with oversize males and inserting males at acute angles.

21. Plated terminals are preferred, with limited applications unplated due to specific requirements. Thickness, method of plating, type of material, etc. must be defined for each application and specified on the drawing. Male to female contact surfaces, including shorting clips, must be compatible (electrically, mechanically, and metallurgically).

22. Pure silver plated terminals, must have anti-tarnish protection.

SECONDARY TERMINAL LOCKS (TPA's, ISL's, PLR's and FBT's).

23. All connector designs must include a secondary terminal lock, whether it's a TPA, ISL, PLR, or FBT(Flex Beam):

    a) The TPA must not be capable of being fully inserted unless all terminals are fully seated and in their correct orientation. It may also correct partially seated terminals. TPA's are a separate piece and must resist insertion if one or more terminals are not fully seated.
    b) An ISL shall provide an additional means of retaining the terminal within the terminal cavity and shall perform this function independently of the primary lock. The ISL must not be capable of being fully inserted unless all terminals are fully seated in their correct orientation. The ISL may be a separate piece, or may be hinged.
    c) The PLR backs up the plastic lock finger (primary lock) and may detect partially seated terminals. The PLR is typically a separate piece.
    d) The FBT uses a rigid ramp, in place of a flexible lock arm, to provide the terminal primary lock. A flexible, integrated Primary Lock Reinforcement pushes the terminal against the rigid lock, thus insuring maximum terminal retention. A FBT detects partially seated terminals (A ring-out system needs to be implemented with a FBT to detect partially seated terminals). The FBT is an integral part of the connector housing.

24. Design secondary locks with ergonomically friendly surfaces for harness assembly.

25. Design the secondary lock with a snap fit. Make the design to be removable without damage or the use of special tools.

26. Make the design of the secondary lock, to meet the values shown in SAE/USCAR-2, table 5.4.1.4.

27. Avoid polarization of the secondary lock. If the secondary lock provides connector to connector keying, then polarization of the secondary lock is mandatory..

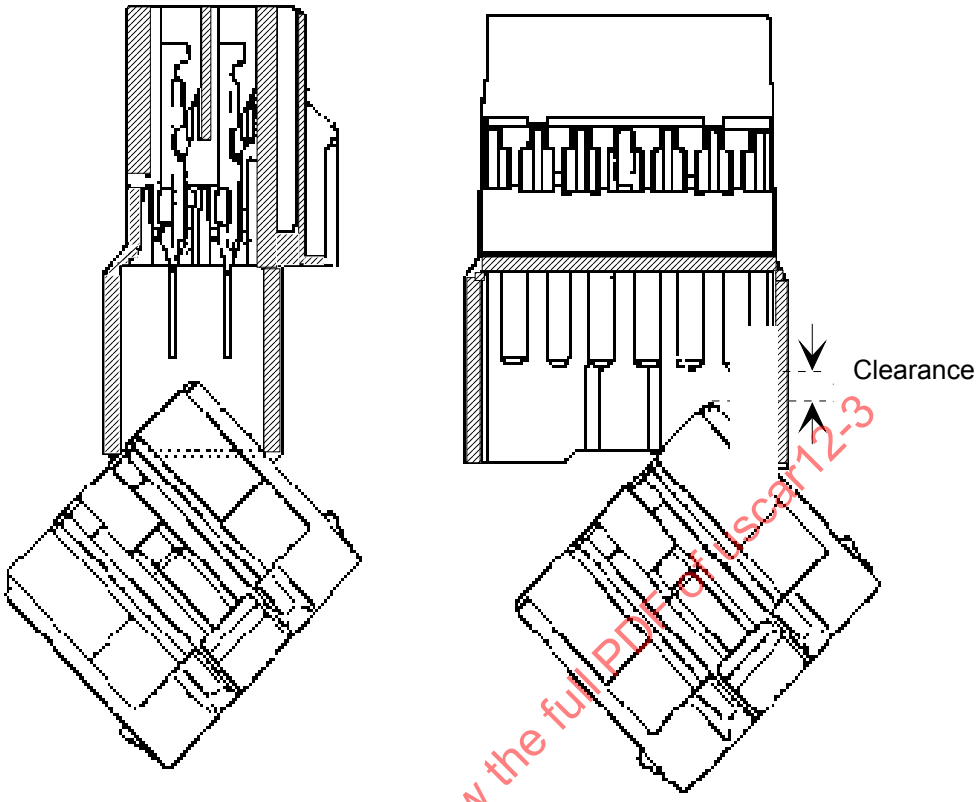
28. Make the secondary lock, whenever possible, a contrasting color to the connector housing.

E. VEHICLE ASSEMBLY

1. Design all in-line connector systems with standard clip mounting provisions (tooling inserts) for a slide-on clip for sheet metal mounting. Consider direct connects (female connector) for clip provisions for future in-line applications. Provide for a positive retention feature for all un-used connectors (i.e. option delete). The retaining feature may be on the cap or on the connector body.

2. Provide for multiple polarizations with a recommended minimum of four (design cannot allow miss-mating) in the design. Design tooling to support the potential of additional polarizations. Design polarizations to be visually distinguishable. See color chart in the USCAR Drawing Guidelines.

3. Design the connector shroud to provide proper alignment of the mating connectors before terminal engagement. This provides good terminal alignment. Design the female housing so there is clearance to the male terminals during worst case mis-insertion angle (see sketch below), to provide "scoop proofing". A combination of CAD, SLA and prototype part studies may be required to demonstrate fulfillment of this guideline. Besides good keying (polarization feature), the shroud walls must be robust enough to minimize flex and not allow defeat of the connector keying. This requires care in selecting wall thickness, based on material type. Warpage of the shroud walls must also be considered in the design for maintaining proper connector to connector alignment. All of these design features must be considered in order to meet the acceptance criteria in SAE/USCAR-2, section 5.4.4.4.



4. Design terminal blades per: EWCAP-001 drawing, but be aware that the width of the blades varies, between in-line and header (fixed) applications

5. Quantify and provide (on demand) the insertion efforts of the connection system, fully populated with all applicable terminals.

6. For all mating connection systems SAE/USCAR-25.must be considered.

7. Twist-lock mating connection systems should be avoided for ergonomic reasons..

8. Include a radius as large as possible on all exposed connector edges to prevent injury and/or discomfort during handling and assembly.

9. Multi-cavity connectors with large pin fields may require protective measures to prevent damage prior to assembly in the vehicle assembly plant, (e.g. plastic walls between terminal rows).

10. Bolt assist connectors should be avoided. If a bolt must be used, call out the recommended torque and/or the torque specification on the assembly drawing of any connector using a fastener (i.e. a nut, bolt, bushing, etc.).

11. Design the functional features (i.e. connector to connector latches, shrouds and external keyways) of the connector assemblies to be robust or protected by the connector construction to withstand the normal packaging, shipping, and handling of the product. Avoid snag points.

12. Design connector halves with terminals so that there is no buzz, squeak, or rattle in either the mated or unmated condition.

CONNECTOR LOCKING FEATURE

13. Design the connector locking feature with anti-snag and release protection to prevent inadvertent unlocking or permanent deformation during storage and shipping or after assembly in the vehicle.

14. Incorporate overstress protection in the design of the connector locking feature.

15. Design the locking feature to provide visual, audible, and tactile feedback.

16. Design the connector housing lock to avoid a false indication of lockup.

17. Design the flexible lock member to be on the female connector half. Never put the latch on the device.

18. Design connector to connector plastic locks with a minimum of 0.25mm over travel following full engagement.

19. A desirable design feature for mechanical assist (lever or slide) connectors is to have no electrical continuity when the connector is in the pre-lock position. Also, the lever shouldn't move when the connector is positioned in the pre-lock position. In this way, it provides an opportunity at vehicle assembly to detect connectors which have not had the mechanical assists initially actuated since there will be no electrical continuity. However, such a design consideration may mean that the overall travel provided by the mechanical assist must be increased and it may cause the size of the connector to increase. Therefore, although it is listed here as a preferred design feature, adherence to this design consideration is at the discretion of the OEM, dependent upon their specific application needs/packaging requirements.

CONNECTOR POSITION ASSURANCE (CPA)

20. Provide for CPA capability in the design of the connector housing. Include a CPA or secondary latch in the design of mechanical assist connectors (slide, lever, etc.) Bolt together designs do not require a CPA.

21. Design the CPA so that it cannot be engaged until the connector is completely mated.

22. Design the CPA so that it is capable of being preloaded on the connector housing. Loose piece CPA's are not allowed.

23. Make the CPA of a contrasting color to the connector housing.

24. The CPA shall provide readily identifiable visual feedback of closure. The CPA shall also provide tactile feedback of proper closure.

25. The CPA shall be designed to prevent from activating the connector lock and disconnecting the connector halves when it is positioned in its final position.

F. MATERIALS

1. Yellow is reserved for airbag and restraint systems. Orange is reserved for high voltage systems (60V to 600V) (see SAE/USCAR-37).

2. Certify that any used combination of regrind and raw material meets the plastic manufacturer's specification. Also certify that the "as molded" parts are not degraded beyond acceptable material limits.

3. Select materials to meet the specified requirements. Materials selected shall not be harmful to health, environment, etc.

G. SERVICEABILITY

1. Use the standard terminal cavity identification schemes shown in Appendix A, on all connector housings. Space permitting, make the numbers no less than 1.5mm high. If not possible to number each cavity, you must number each row at the beginning and end of a row.

2. Identify plastic parts with material identification symbols per SAE J1344. (Space permitting).

3. Ensure that the terminal lock finger design does not reach its elastic limit when stressed to maximum open position. This may be accomplished by designing in an internal wall or stop.

4. Ensure that the connector latch feature(lock finger) does not reach its elastic limit when stressed to the maximum deflection.

5. Design the terminal and connector system so that terminals and the connector can be removed without the use of “special tools”. (Nothing other than typical terminal picks).

6. Design wire routing guides (rear covers, or wire dress covers) to be capable of disassembly for service without functional damage to connector housing.

7. Design the connector locking feature so that it is ergonomically accessible and easily operated. Opening the connector lock shall not require the use of any tools, unless specified by the design objective for a special application (e.g. high voltage connector).

8. Avoid impeding of access to the connector lock by the location of any of the components attached to the connector housing (i.e., strain relief, locator, wire guides), except the secondary lock (CPA).

H. ENVIRONMENTAL REQUIREMENTS

1. GADSL- covers declarable substances that are expected to be present in a material or part that remains in a vehicle at point of sale.

2. IMDS- data system where all materials used for car manufacture are archived and maintained.

I. HIGH VOLTAGE (≥ 60V) APPLICATION REQUIREMENTS

The following may be system level requirements (not part of connector design requirements):

The system must not be powered up until HV connections are engaged to prevent a hazard to health and safety, and damage to the terminal from arcing. Also, the system must be powered down before connections can be disengaged to prevent a hazard to health and safety, and damage to the terminal from arcing.

HV connections must have serviceable fuse when required, and is dependent on the system design by the OEM.

The following are HV connector design requirements:

1. Terminal Tip Protection from electric shock (ISO 20653) (DIN 40 050). This refers to finger touch accessibility. (IP2xB). (Dependent on OEM system requirements)

2. If a HVIL (High Voltage Inter Lock) connector is required, the HVIL connector must be capable of disconnecting the high voltage power through the interface before the HV (High Voltage) connector halves are separated. A five(5) second delay is required to Disengage the HV connector after disconnecting the HVIL connector.

3. HV connector color will be orange. Allowance for miscellaneous external components like seal retainers to be colors other than orange.

4. HV connector may require EMC shield.

5. HV connector system may require capability of crimping EMC braided cables.
6. Mated HV connectors should not come apart during crash (SAE J1766).
7. The HV connector must be designed to use common service center tools.
8. HV connectors may require independent terminal cavities and independent seals, for Isolation capability.

PREPARED BY
EWCAP (ELECTRICAL WIRING COMPONENT APPLICATIONS PARTNERSHIP)

APPENDIX A
CAVITY NUMBERING GUIDELINES

These guidelines are intended to provide a standard system for designating connector cavities. This is not an all inclusive list or a substitute for common sense. It is to be used as a supplement to existing good design practices and standards.

1. Position the female connector with the locking or latching member pointed upward.

2. The rear of the connector (wire end) faces you.

3. A. For square or rectangular cavity spacings, start with number one, in the upper left corner and progress to the right. When the upper level is filled, continue the sequence on the next level starting at the left and so on.

   B. For circular or oval cavity patterns, start with number one in the uppermost cavity under the center of the locking/latching member. Continue the numbering in a clockwise direction, working toward the center of the connector.

   NOTE: If the center of the lock/latch member falls between two cavities of equal distance and height, start with the cavity to the right of the center of the lock/latch. Always start with the uppermost cavity.

4. Number the mating connector/part to the above connector so that cavity numbers match up (1-1, 2-2, etc.) when connected.

5. Where spacing allows connector make permanent terminal cavity identification visible from the rear of the connector.

6. If numbers can't be physically fit on the connector housing, they must be identified on the component drawing.

- Several examples reflecting this procedure are shown on the following pages.

GUIDELINE EXAMPLES

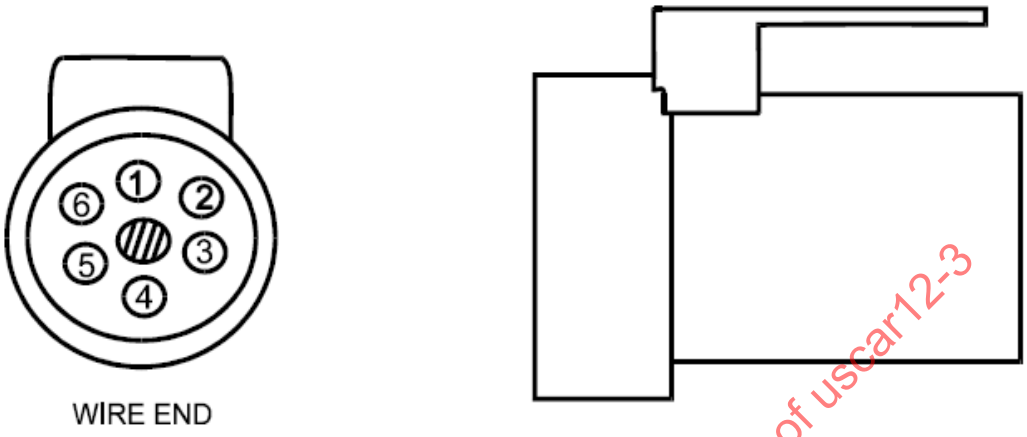


FIGURE #1

This example incorporates the guidelines for case 3(b), where the cavities are equally spaced and the first cavity is under the center of the latch.

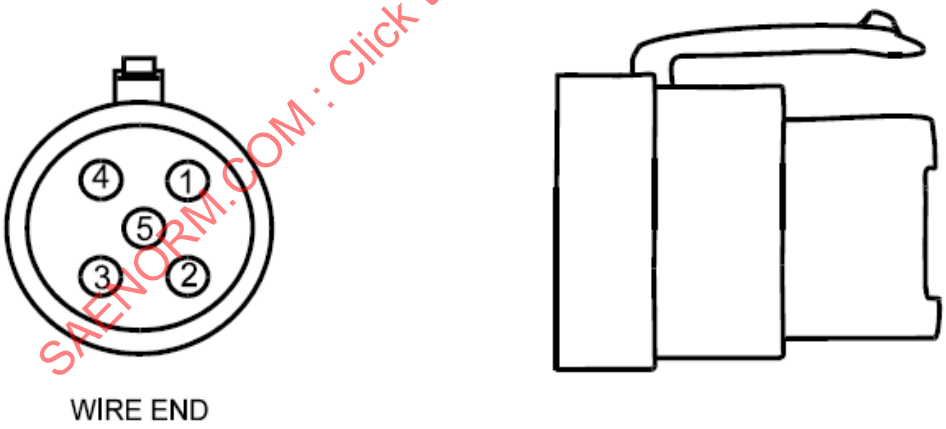


FIGURE #2

This example incorporates the guidelines for the noted case of 3(b), where two cavities are equally distant from the center of the latch.

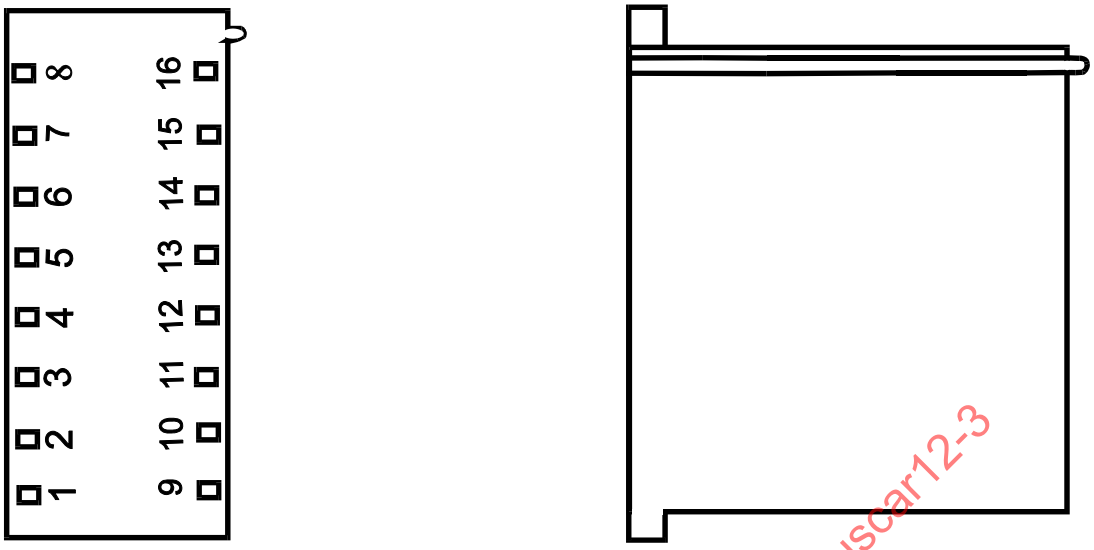


FIGURE #3

This example incorporates the guidelines for case 3(a).

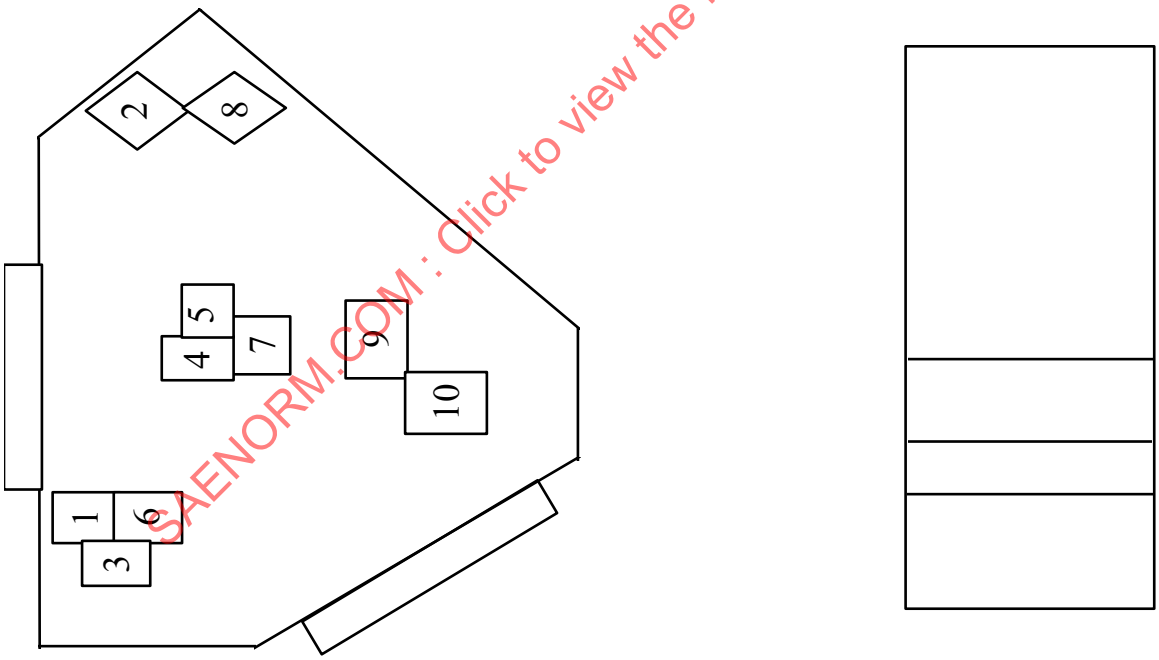
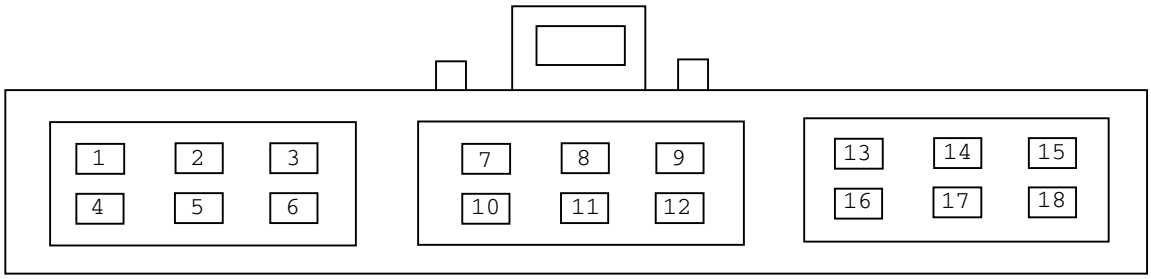


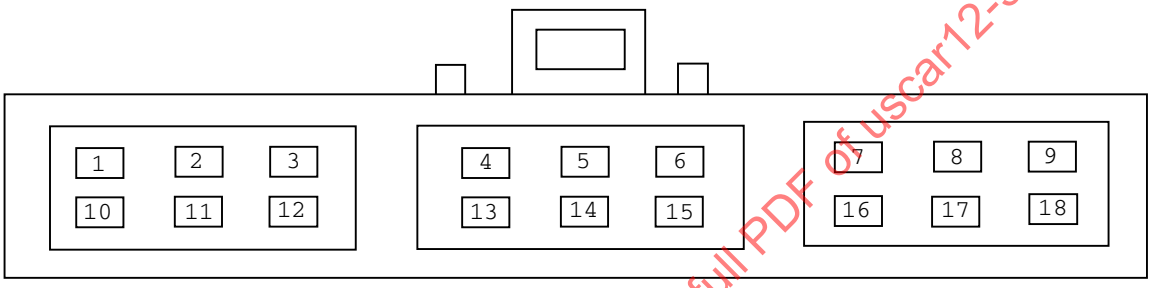
FIGURE #4

This example has two locking features, and the cavities are irregularly spaced. The guidelines could not be applied in this case. The cavities were numbered by personal preference.



(A)

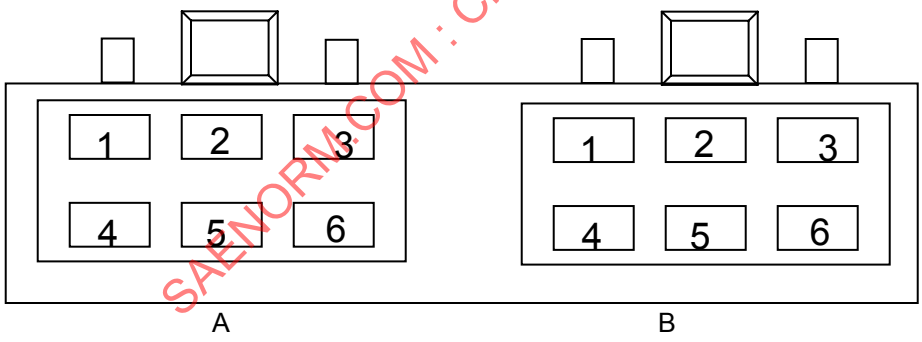
WIRE END



(B)

WIRE END

Multiple terminal fields with single mating connector



(C)

WIRE END

Multiple terminal fields with multiple mating connectors

These examples show the cavity numbering convention for a connector system with multiple terminal fields. Three acceptable numbering schemes are shown.