SAE The Engineering Society For Advancing Mobility Land Sea Air and Space® INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

# SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J1773

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Submitted for recognition as an American National Standard

## (R) SAE Electric Vehicle Inductively Coupled Charging

***Foreword—***This is a Recommended Practice and in no manner should be interpreted as a standard of the SAE. This proposal should not be interpreted as an endorsement of inductive charging by the SAE. This document contains 44 pages, including this page, and should not be used as a design tool if any of the pages are missing. Portions of this document may be revised to keep pace with experience and technological advances.

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***1. Scope—***This SAE Recommended Practice establishes the minimum interface compatibility requirements for electric vehicle (EV) inductively coupled charging for North America.

This part of the specification is applicable to manually connected inductive charging for Levels 1 and 2 power transfer. Requirements for Level 3 compatibility are contained in Appendix B. Recommended software interface messaging requirements are contained in Appendix A.

This type of inductively coupled charging is generally intended for transferring power at frequencies significantly higher than power line frequencies. This part of the specification is not applicable to inductive coupling schemes that employ automatic connection methods or that are intended for transferring power at power line frequencies.

**1.1 General Inductive Charging System Description—**The basic principle behind inductive charging is that the two halves of the inductive coupling interface are the primary and secondary of a two-part transformer. When the charge coupler (i.e., the primary) is inserted in the vehicle inlet (i.e., the secondary), power can be transferred magnetically with complete electrical isolation just as it occurs in a standard transformer. The number of turns (windings) on the secondary is “matched” to the vehicle’s battery pack voltage so that the same charger can charge any vehicle.

The charger converts utility power to high frequency AC (HFAC) power (130 kHz to 360 kHz). The high frequency operation is utilized to reduce the size and mass of the on-vehicle portion of the transformer. The vehicle inlet is the power inlet on the vehicle which receives the HFAC from the charger. The HFAC is converted into DC to charge the batteries. An on-vehicle charge controller continuously monitors the state of the batteries during charging and controls the charger output power level via an IR communications link between the vehicle inlet and the charger (the charger’s communications interface is physically imbedded in the charge coupler). The charge controller signals the charger to stop charging when it determines that the batteries are completely charged or a fault is detected during the charging process.

The following steps correspond with the diagram in Figure 1, and describe the closed-loop charging system.

a. Vehicle charge controller determines desired current into batteries. **
b. Vehicle charge controller transmits charger output power request to charger via an IR communications interface. **
c. Charger controls input current from utility based on charger output power request from vehicle charge controller. **
d. Charger converts 60 Hz utility power to HFAC power.
e. HFAC power is magnetically coupled from the coupler (primary) to the vehicle inlet (secondary).
f. HFAC power is rectified/filtered to DC to charge the vehicle batteries.
g. Process repeats until the vehicle charge controller determines the batteries are fully charged. **

NOTE—Items with ** indicate control loop.

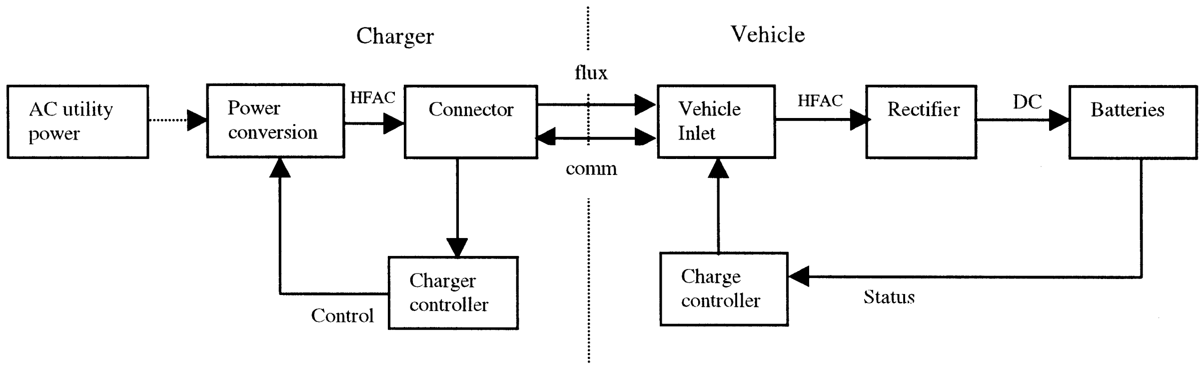



FIGURE 1—TYPICAL CLOSED-LOOP CHARGING SYSTEM.

## *2. References*

**2.1 Applicable Publications—**The following publications form a part of this document to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J551-2—Test Limits and Methods of Measurement of Radio Disturbance Characteristics of Vehicles, Motorboats, and Spark-Ignited Engine-Driven Devices
SAE J551-5—Performance levels and Methods of Measurement of Magnetic and Electric Field Strength from Electric Vehicles, Broadband, 9 kHz to 30 MHz
SAE 1211—Recommended Environmental Practices for Electronic Equipment Design
SAE J1850—Class B Data Communications Network Interface
SAE J2178—Class B Data Communication Network Messages
SAE J2293—Energy Transfer System for Electric Vehicles

2.1.2 FEDERAL COMMUNICATIONS COMMISSION (FCC)—Available from U.S. Government Printing Office, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954.

CFR 47—Code of Federal Regulations, Title 47, Parts 15B, 18C
CFR 40—Code of Federal Regulations, Title 40, Part 600, Subchapter Q

2.1.3 UNDERWRITERS LABORATORIES, INC.—Available from Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 94—Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
UL 2202—Electric Vehicle (EV) Charging System Equipment

**2.2 Related Publications**

2.2.1 NFPA PUBLICATION—Available from the National Fire Protective Association, Batterymarch Park, Quincy, MA 02269.

NFPA-70-1999—National Electric Code (NEC), - Article 625

2.2.2 CANADIAN ELECTRIC STANDARDS—Available from: Canadian Standards Association, 170 Rexdale Blvd., Rexdale, Ontario, Canada M9W 1R3

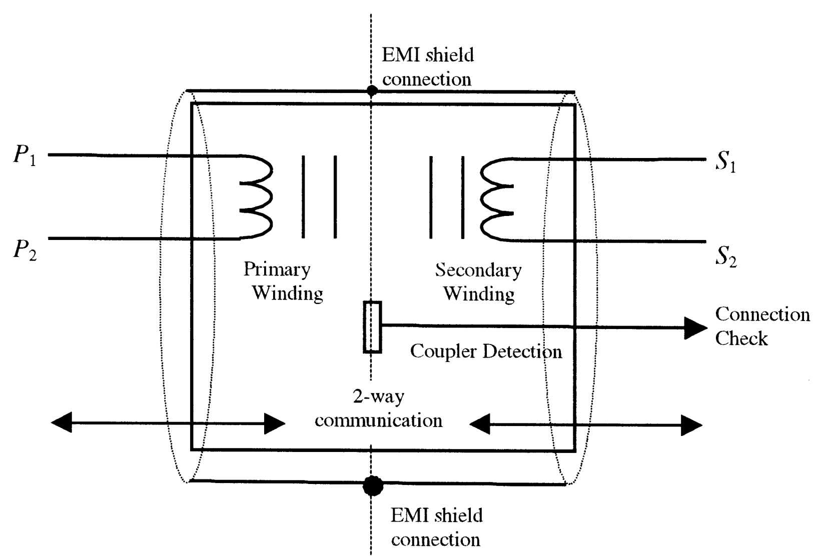
Canadian Electric Code*CEC Part 1, Section 86

## *3. Definitions*

**3.1 Electric Vehicle (EV)—**An automotive type vehicle, intended for highway use, powered by an electric motor that draws current from an on-vehicle energy storage device, such as a battery, which is rechargeable from an off-vehicle source, such as residential or public electric service. For the purpose of this document the definition of automobile in the United States Code of Federal Regulations Title 40, Part 600 Subchapter Q is used. Specifically, an automobile means:

a. Any four-wheeled vehicle propelled by a combustion engine using onboard fuel or by an electric motor drawing current from a rechargeable storage battery or other portable energy devices (rechargeable using energy from a source off the vehicle such as residential electric service),
b. Which is manufactured primarily for use on public streets, roads, or highways,
c. Which is rated at not more than 3855.6 kg (8500 lb) gross vehicle weight, which has a curb weight of not more than 2721.6 kg (6000 lb), and which has a basic vehicle frontal area of not more than 4.18 $m^2$ (45 $ft^2$).

**3.2 Inductive Coupling—**A mating inductive vehicle inlet and inductive connector set. See Figure 2.




$P_1$, $P_2$: primary connections
$S_1$, $S_2$: secondary connections
Connection check: signal verifying coupler fully inserted into charge port

FIGURE 2—TYPICAL INDUCTIVE COUPLING.

**3.3 Inductive Connector—**The male part of the inductive coupling. The inductive connector is that part of an inductive charger, which is manually inserted into a mating inductive vehicle inlet. The inductive connector contains the primary windings, ferrite to complete the magnetic path, and a communications interface to the vehicle.

**3.4 Inductive Vehicle Inlet—**The female part of the inductive coupling. The inductive vehicle inlet is that part of the electric vehicle, which mates with the inductive connector. The inductive vehicle inlet contains the secondary windings, ferrite to complete the magnetic path, and a communications interface to the charger.

**3.5 Two-Part Transformer—**A transformer whose primary and secondary windings are located in separate devices designed to be physically separable from one another and which are galvanically isolated as in a double-wound transformer. Efficient energy transfer can occur when the two halves of the transformer are properly aligned.

**3.6 Level 1 Charging—**A charging method that allows an electric vehicle to be charged by having its charger connected to the most common grounded receptacle (NEMA-5-15R). The maximum power supplied for Level 1 charging shall conform to the values shown in Table 1.

**TABLE 1—CHARGE LEVEL SPECIFICATIONS (NORTH AMERICA)**

| Charge Method | Nominal Supply Voltage | Max Current (Amps-continuous) | Branch Circuit Breaker Rating (Amps) | Continuous Input Power (reference) |
|---|---|---|---|---|
| Level 1 | 120 VAC, 1-phase | 12 A | 15 A | 1.44 kW |
| Level 2 | 208 to 240 VAC, 1-phase | 32 A | 40 A | 6.66 to 7.68 kW |
| Level 3 | 208 to 600 VAC, 3-phase | 400 A | As required | > 7.68 kW |

**3.7 Level 2 Charging—**A charging method that utilizes dedicated electric vehicle supply equipment in either private or public locations. The maximum power supplied for Level 2 charging shall conform to the values shown in Table 1.

**3.8 Level 3 Charging—**A charging method that utilizes dedicated electric vehicle supply equipment in either private or public locations. The maximum power supplied for Level 3 charging shall conform to the values shown in Table 1.

***4. Inductive Charging Interface Requirements—***The following paragraphs describe the technical requirements for the inductive interface.

**4.1 Power Transfer**

4.1.1 AVERAGE OUTPUT VOLTAGE RANGE—The allowable range for the average voltage at the output of the secondary-side rectifier, $V_O$, of the vehicle inlet shall be from 10 V/turn to 107.5 V/turn.

4.1.2 MAXIMUM AVERAGE OUTPUT CURRENT AS A FUNCTION OF AVERAGE OUTPUT VOLTAGE—The maximum value for the average current output, $I_o$, from the secondary-side rectifier shall be the lesser of (a) 100 A-turns, or (b) the current calculated by the division of 90% of the maximum Level 2 input power (7.68 kW) by the average output voltage, as shown in Figure 3, where 90% is the charger system efficiency.

4.1.3 POWER TRANSFER FREQUENCY RANGE—The fundamental operating frequency for power transfer shall range from 130 kHz to 360 kHz for maximum continuous input power levels up to 7.68 kW.

4.1.4 MAXIMUM ALLOWABLE AVERAGE OUTPUT CURRENT VERSUS FREQUENCY—The maximum average output current shall be 100 A-turns (e.g., 25 A for a four turn secondary) at the minimum frequency of 130 kHz. The allowable limit for the average output current, $I_O$, for an average output voltage range of 69.1 V/turn to 107.5 V/turn, is plotted as a function of the power transfer fundamental operating frequency in Figure 4 (lower curve).

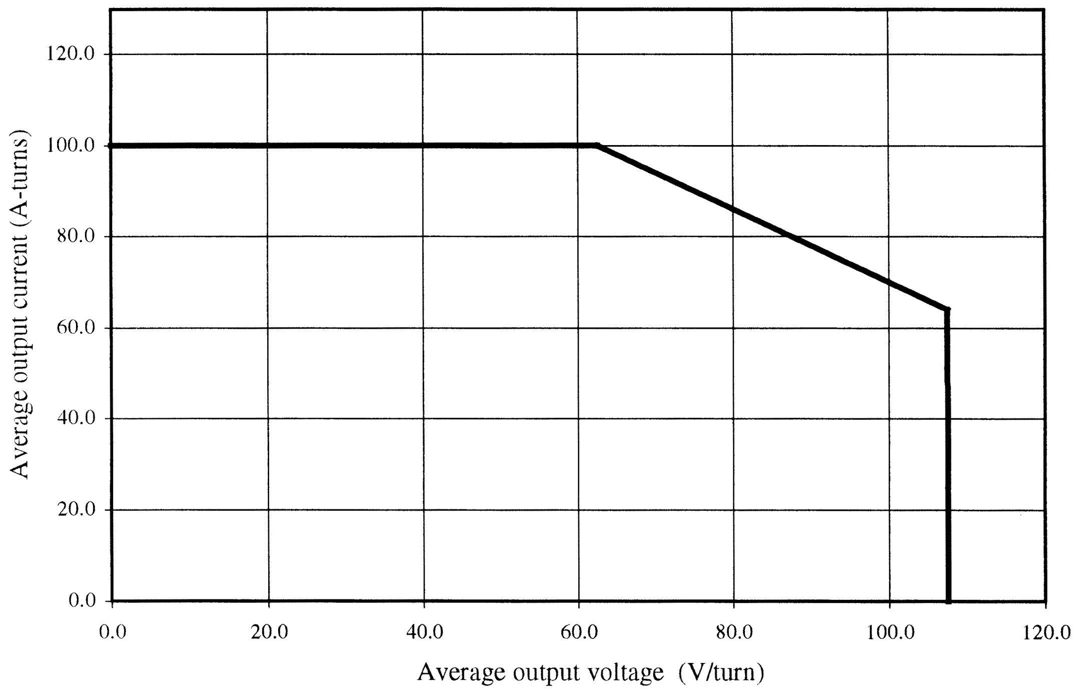



FIGURE 3—MAXIMUM AVERAGE OUTPUT CURRENT, $I_O$, AS A FUNCTION OF AVERAGE OUPUT VOLTAGE, $V_O$

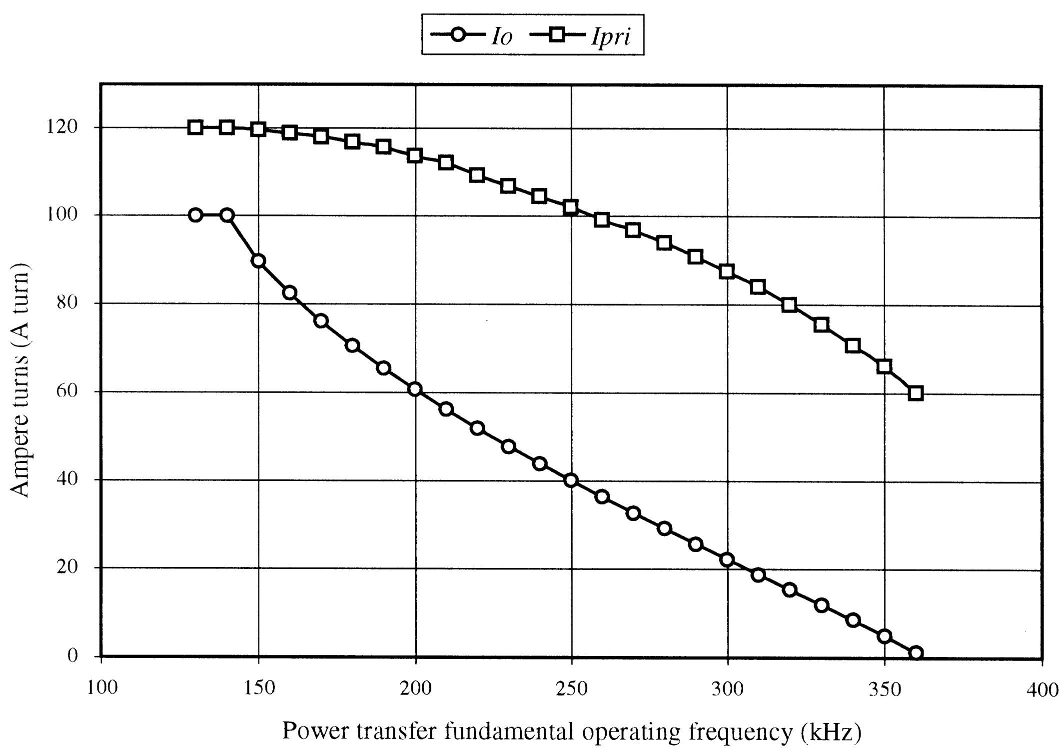
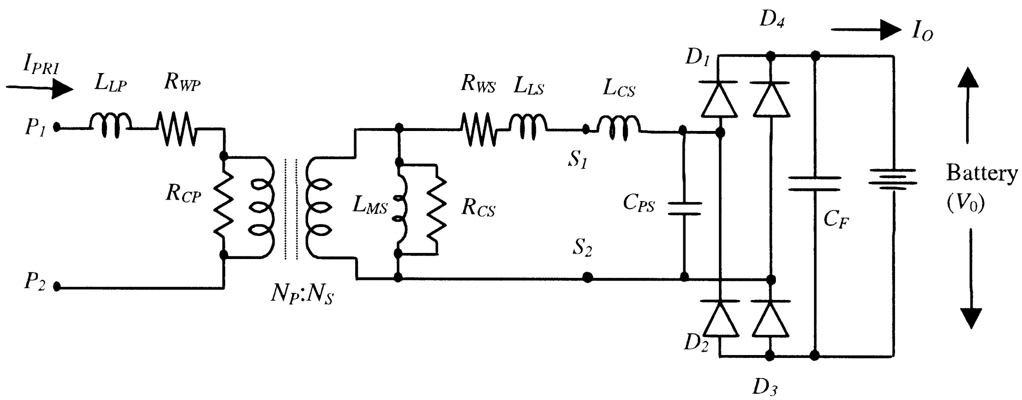



FIGURE 4—MAXIMUM ALLOWABLE INLET CURRENTS

4.1.5 MAXIMUM ALLOWABLE RMS INPUT CURRENT VERSUS FREQUENCY—The maximum allowable RMS primary current shall be 120 A-turns (e.g., 30 A for a four turn primary) at the minimum frequency of 130 kHz. The allowable limit for the RMS input current, $I_{pri}$, as a function of the power transfer fundamental operating frequency is shown by the upper curve in Figure 4.

4.1.6 EQUIVALENT CIRCUIT PARAMETERS AT CHARGE COUPLING INTERFACE—The inductive interface equivalent circuit diagram is shown in Figure 5. The interface parameters shall conform to the requirements of Table 2.




| | | | |
|---|---|---|---|
| $P_1$, $P_2$ | primary connections | $L_{MS}$ | magnetizing inductance |
| $L_{LP}$ | connector leakage inductance | $R_{CS}$ | ferrite core loss resistance |
| $R_{WP}$ | connector winding resistance | $R_{WS}$ | winding resistance |
| $R_{CP}$ | ferrite core loss resistance | $L_{LS}$ | inlet leakage inductance |
| $N_P$ | primary turns | $L_{CS}$ | secondary cable leakage inductance |
| | | $C_{PS}$ | parallel capacitor |
| | | $S_1$, $S_2$ | output connections |
| | | $D_{1-4}$ | rectifier diodes |
| | | $C_F$ | output filter capacitor |
| | | $N_s$ | secondary turns |

FIGURE 5—INDUCTIVE INTERFACE EQUIVALENT CIRCUIT

**TABLE 2—ALLOWABLE RANGE OF EQUIVALENT CIRCUIT PARAMETERS FOR A NORMALIZED TRANSFORMER (SINGLE TURN PRIMARY AND SINGLE TURN SECONDARY)**

| Parameter | $L_{MS}$ | $L_{LP} + L_{LS} + L_{CS}$ | $C_{PS}$ | $R_{WP}$ | $P_{RWP}$ | $R_{CP}$ | $P_{RCP}$ | $R_{CS}$ | $V_O$ | $I_O$ | $R_{WS}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (unit) | (µH/turn$^2$) | (µH/turn$^2$) | (nF turn$^2$) | (mΩ/turn$^2$) | (W) | (kΩ/turn$^2$) | (W) | (kΩ/turn$^2$) | (V/turn) | (A-turn) | (mΩ/turn$^2$) |
| Minimum | 2.37 | | 608 | | | | | | 10 | 0 | |
| Typical | 2.63 | 0.031-0.219 | 640 | 0.625 | | 2.5 | | 0.125 | | | 0.938 |
| Maximum | 3.75 | 0.25 | 704 | | 10 | | 5 | | 107.5 | 100 | |

## 4.2 Heat Transfer

4.2.1 EXCESS INDUCTIVE CONNECTOR POWER DISSIPATION—The inductive interface cooling system shall have the capability to dissipate 15 W maximum added to the interface by the inductive connector during charging.

4.2.2 INDUCTIVE CONNECTOR TOUCH TEMPERATURE—The maximum surface temperatures shall comply with UL 2202, Electric Vehicle (EV) Charging System Equipment.

**4.3 Communications—**The inductive charging interface shall contain an IR link between the vehicle and the charger. The communications interface physical layer shall be compatible with SAE J2293. Conformance to this requirement shall be determined by demonstrating the ability of the physical layer to pass SAE J1850-compliant messages across the inductive interface.

4.3.1 IR COMMUNICATIONS METRICS—See Table 3.

**TABLE 3—IR COMMUNICATIONS METRICS**

| | IR System Value |
|---|---|
| **SAE J1850 Parameters** | |
| Direction | bi-directional, half duplex |
| Baud Rate | 10. 4 kbits/s |
| Bit Encoding | VPW |
| Communication protocol between inlet and charger | encoded SAE J1850 (see Figure 6) |
| **Communication Metrics** | |
| Transmit Frequency | 880 nm |
| Modulation Type | on-off keying |
| On/Off Power ratio | ≥30 dBm |
| Max Duty Cycle | 80% “Active” @ 4 kHz |
| Min Duty Cycle | 0% |
| Max “Active” On Time | 500 µs |
| **SAE J1850 Metrics** | |
| Max Node Voltage Offset | 0.25 V |
| Network Time Constant | 5.2 µs |
| Transceiver loading | 1 unit load |
| Noise Rejection | ≤8 µs |
| **Steady-State Performance Metrics** | |
| IR Radiant intensity measured | 2.3 mW/Sr |
| Voltage Output | $V_{ol}$ and $V_{oh}$ per SAE J1850 |
| Voltage Input | $V_{il}$ and $V_{ih}$ per SAE J1850 |
| **Transient Performance Metrics** | |
| Transmitter Turn On Delay | 1.0 µs ± 0.5 µs |
| Receiver Turn On Delay | 7.0 µs ± 2.0 µs |
| Total System Delay | 10.5 µs (max) |

NOTE 1—The IR transmit power level shall be measured at the surface, on both sides of the inductive connector, directly above the transceiver interface.

NOTE 2—It is highly recommended that the communications interface be implemented as a dedicated link due to the potential for SAE J1850 bitwise arbitration problems when the interface is used in a multi-node communications system.

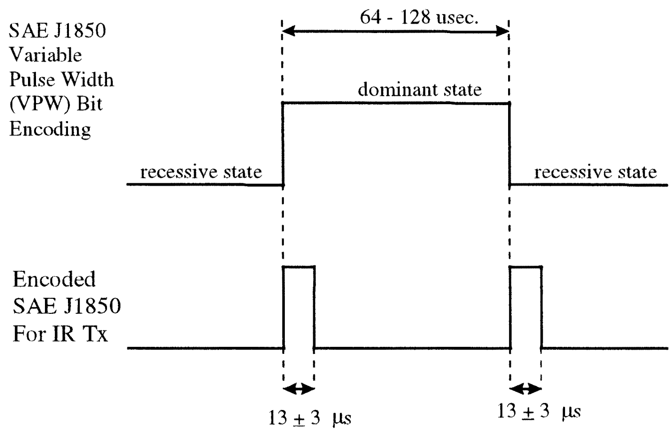



FIGURE 6—SAE J1850 ENCODING FOR IR TRANSMISSION

## 4.4 Physical Compatibility

4.4.1 INDUCTIVE CONNECTOR

*4.4.1.1 Critical Dimensions*—See Figures 7 and 8.

*4.4.1.2 Orientation*—The operation of the inductive connector shall be independent of the orientation when inserted into the vehicle inlet.

*4.4.1.3 Connection Present Magnet Location*—The inductive connector shall contain two magnets at the locations specified in Figure 8. These magnets may be used by the vehicle to detect the presence of the inductive connector when it is fully inserted into the vehicle inlet.

*4.4.1.4 Connection Present Magnet Strength*—The magnetic field strength of the coupler connection detection magnets shall be 60 millitesla minimum when measured at the surface of the connector directly above the magnet location.

*4.4.1.5 Tactile Feel Indents*—There shall be indents on both sides of the inductive connector at the locations specified in Figure 7. These indents may be used by the vehicle to provide positive tactile feedback to the user when the inductive connector is fully inserted into the vehicle inlet.

*4.4.1.6 EMI Shield Contact Zone Location*—There shall be a conductive contact area encircling the inductive connector as specified in Figure 7. This contact area shall be used to connect the charger ground to the vehicle chassis ground for purposes of EMI shielding when the inductive connector is fully inserted into the vehicle inlet.

*4.4.1.7 EMI Shield Contact Zone Impedance*—The resistance between the external surface of the EMI shield contact zone and charger ground shall be less than 0.5 Ω.

*4.4.1.8 IR Transceiver Interface Location*—The inductive connector may contain one IR transceiver interface at the locations specified in Figure 8 to meet the IR communications requirements. This transceiver interface shall be used for IR communications between the charger and vehicle inlet when the inductive connector is fully inserted into the vehicle inlet.

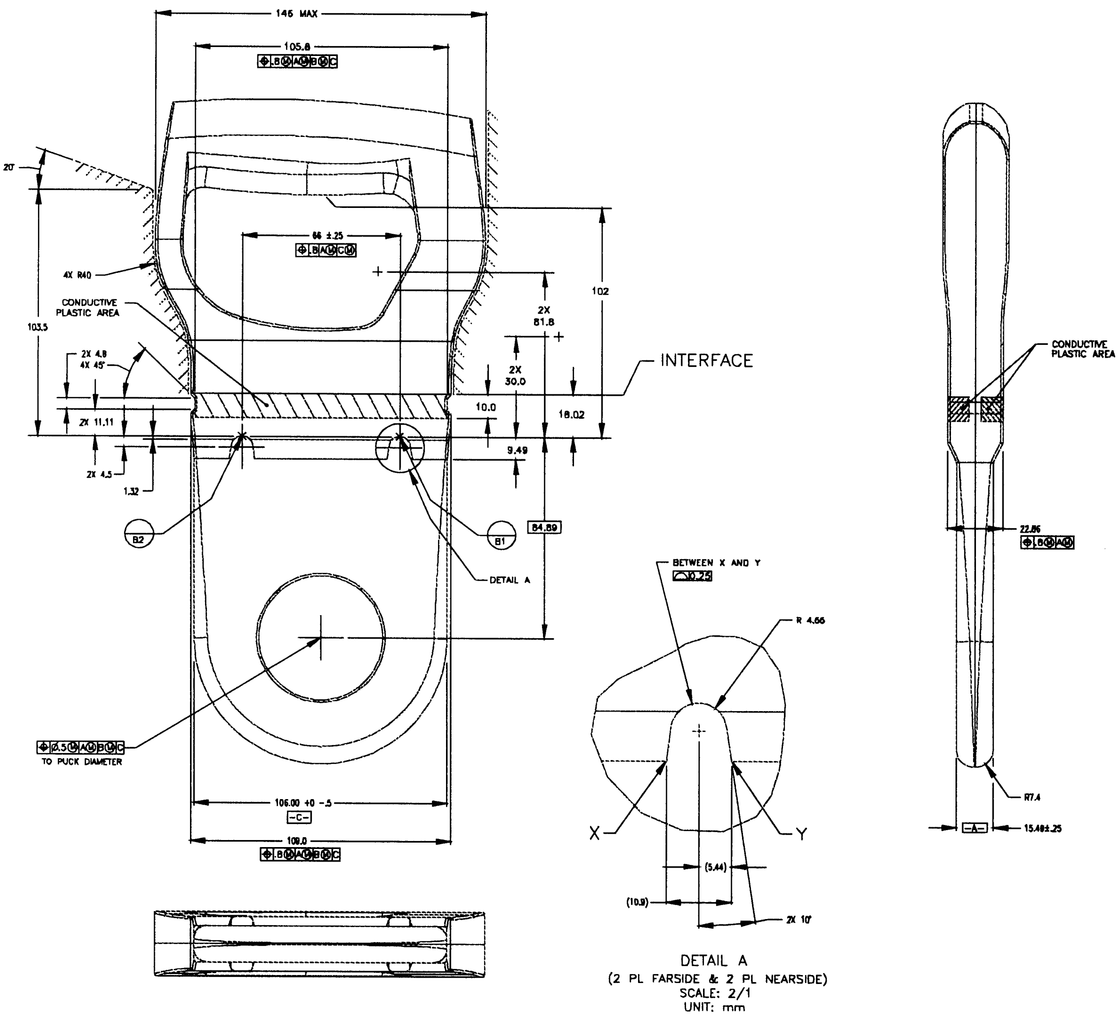



FIGURE 7—INDUCTIVE CONNECTOR CRITICAL DIMENSIONS

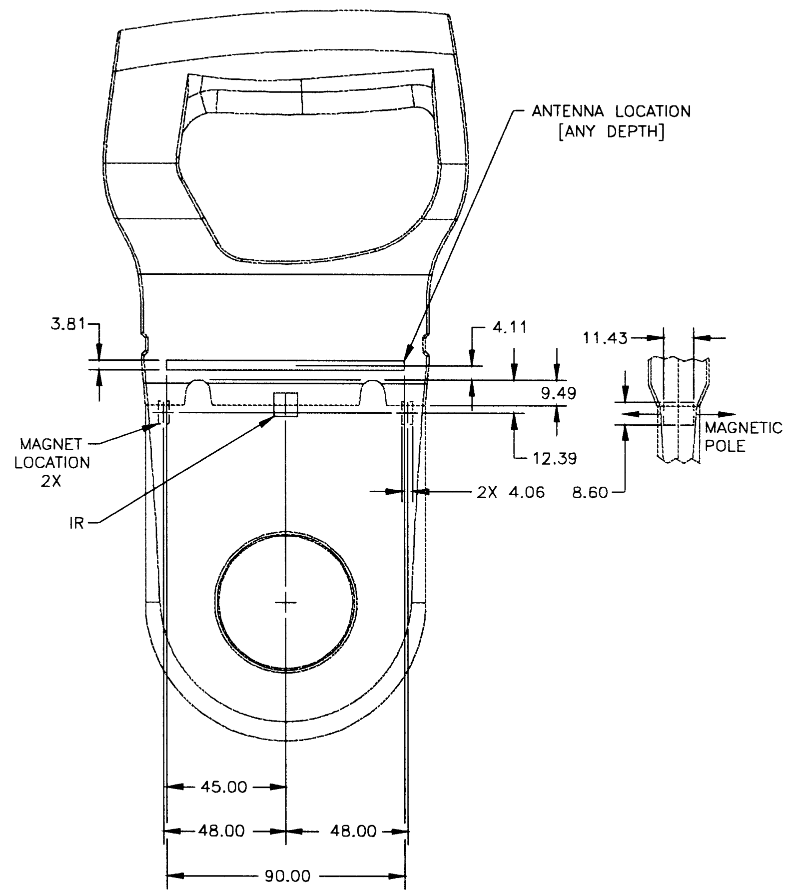



FIGURE 8—INDUCTIVE CONNECTOR CRITICAL DIMENSIONS

*4.4.1.9* *Stop Receptacle Locations*—The inductive connector shall include stop receptacles at the locations specified in Figure 7. These stop receptacles may be used to align the inductive connector when it is fully inserted into the vehicle inlet.

4.4.2 INDUCTIVE VEHICLE INLET

*4.4.2.1* *Critical Dimensions*—See Figure 9.

NOTE—Use of an adapter to mate a standard size inductive connector to a non-standard size inductive vehicle inlets shall be allowed provided all other requirements are met.

*4.4.2.2* *Alignment*—The inductive vehicle inlet shall provide a means for alignment of the inductive connector during insertion. Alignment of the inductive connector ferrite with the vehicle inlet ferrite center post shall be within 1.0 mm of true position when the inductive connector is fully inserted into the vehicle inlet.

*4.4.2.3* *EMI Shield Contact Zone Location*—There shall be a conductive contact area inside the vehicle inlet receptacle as specified in Figure 7. This contact area shall be used to connect the vehicle chassis ground to the charger ground for purposes of EMI shielding when the inductive connector is fully inserted into the vehicle inlet.

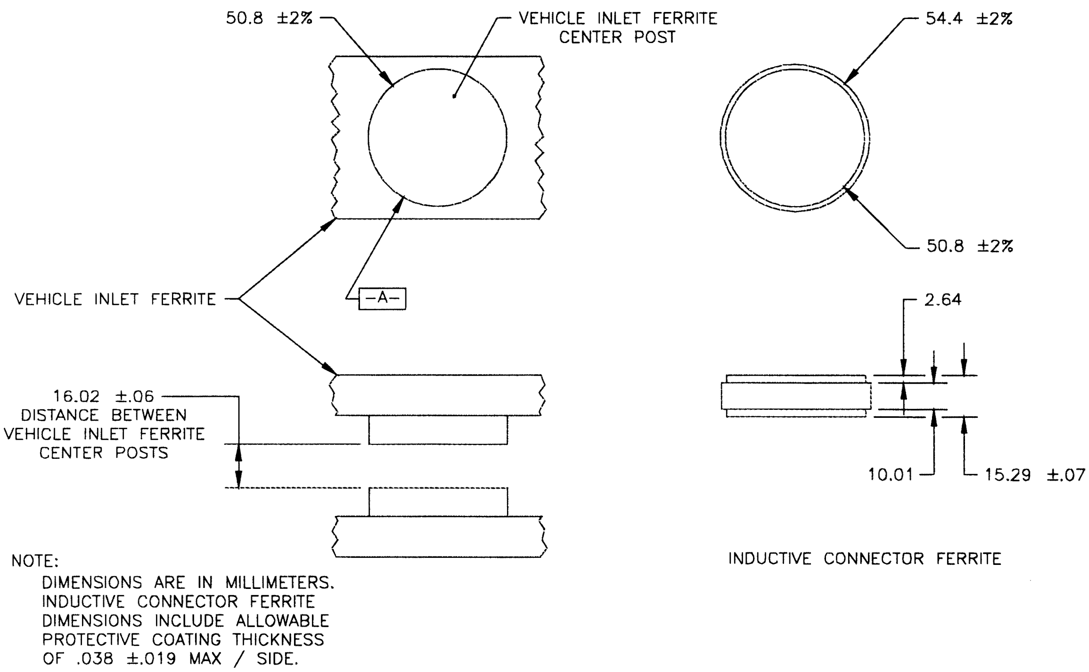



FIGURE 9—INDUCTIVE VEHICLE INLET CRITICAL DIMENSIONS

4.4.2.4 *Grounding of EMI Shield Contact Zone*—The EMI shield contact zone shall be grounded to the vehicle chassis.

4.4.2.5 *IR Transceiver Alignment*—The IR transceiver in the vehicle inlet shall be aligned within ±10 degrees of the IR transceiver in the inductive connector when the inductive connector is fully inserted into the vehicle inlet.

**4.5 Electromagnetic Emissions—**The interface shall comply with the requirements of 4.4.1.7 (EMI Shield Contact Zone Impedance) and 4.4.2.4 (Grounding of EMI Shield Contact Zone).

NOTE—The inductive interface is a component of a larger inductive charging system. The following EMI/EMC requirements are intended to apply to inductive charging systems manufactured for and used in the U.S. For systems intended to be used outside of the U.S., manufacturers shall comply with all local EMI/EMC regulations. Vehicle manufacturers may apply additional requirements.

4.5.1 SAE CHARGING SYSTEM REQUIREMENTS—When tested as an operational inductive charging system passing power to an appropriate load, the electromagnetic emissions shall, at a minimum, comply with SAE J551-2 and J551-5.

4.5.2 FCC CHARGING SYSTEM REQUIREMENTS—When tested as an operational inductive charging system passing power to an appropriate load, the charging system shall comply with the requirements of FCC CFR 47 Part 18C RE and Part 15B CE using Class B limits.

## *5. Application Requirements*

**5.1 Environment—**The inductive inlet will meet the performance requirements due to weather and environmental exposure as defined by the individual automotive manufacturers. As a minimum, the inductive connector shall meet the performance requirements as listed in SAE J1211.

5.1.1 PERFORMANCE REQUIREMENTS

*5.1.1.1 External Touch Temperature*—The maximum external touch temperature of the inductive connector shall not be greater than 60 °C when the ambient temperature is 40 °C. The design process shall take into consideration material types and solar loading (Reference UL 2202).

*5.1.1.2 Operational and Storage Temperature*—The inductive connector shall be designed to withstand continuous ambient temperatures in the range of –30 °C to +50 °C during normal operation. For storage, the inductive connector shall be designed to withstand continuous ambient temperatures in the range of –50 °C to +80 °C.

*5.1.1.3 External Contaminants*—The inductive connector shall be unaffected by automotive lubricants, solvents, and fuels (Reference SAE J1211, 4.4 Immersion and Splash).

*5.1.1.4 Vibration*—The inductive inlet shall be tested to the following minimum conditions:

a. Amplitude = 2.54 mm p-p displacement limit
b. Frequency = 5 to 200 Hz and back to 5 Hz
c. Sweep Type = Linear
d. Time per Sweep = 2 min
e. Axis = Vertical axis of the device as mounted on the vehicle.
f. Test Duration = 18 h

*5.1.1.5 Pass Criteria*—After completion of the test, there shall be no observed rotation, displacement, cracking, or rupture of parts of the device which would result in failure of any other test requirements within this document. Cracking or rupture of the parts of the device that affect the mounting shall constitute a failure.

*5.1.1.6 Material*—The inductive connector material shall meet the flammability requirements of UL 94-HB or better.

*5.1.1.7 Fluid Egress*—The inductive inlet shall provide for the egress of fluids.

**5.2 Charger Requirements**

5.2.1 POWER LEVEL COMPATIBILITY—See Appendix B for more detail of these requirements.

**5.3 Vehicle Requirements**

5.3.1 POWER LEVEL COMPATIBILITY—See Appendix B for more detail of these requirements.

## *6. Notes*

**6.1 Marginal Indicia—**The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE ELECTRIC VEHICLE CHARGING SYSTEMS

## APPENDIX A

## SOFTWARE INTERFACE

***A.1 Scope***—This appendix describes requirements for a standard inductive charging software interface. Note that while certain required and optional messages have been defined for each software state, this proposal does not preclude the possibility that additional optional messages may be defined by individual manufacturers and used as part of the software interface provided that (a) the minimum requirements in this document continue to be met, and (b) no additional requirements are imposed on existing systems.

For manufacturers considering adding optional messages to the software interface, it is recommended that total bus loading not exceed 80% — allocated equally as 40% maximum contribution by the charger and 40% maximum contribution by the vehicle — on a dedicated charging communications link. In general, total bus loading should be reduced even further if there are additional active nodes on the same bus as the charger controller and the vehicle charging controller.

***A.2 Software States***—There are four software states that apply equally to both the vehicle and the charger: Wakeup, Initialization, Operate, and Sleep. In the Wakeup state, the vehicle and charger attempt to establish a communications link. In the Initialization state, the vehicle and charger exchange initialization information including any information necessary to determine whether it is safe for the charger to transfer power to the vehicle. In the Operate state, the vehicle may request the charger to transfer power for charging or support purposes. In the Sleep state, the current charging session is ended and communications between the vehicle and charger are discontinued. See Figure A1.

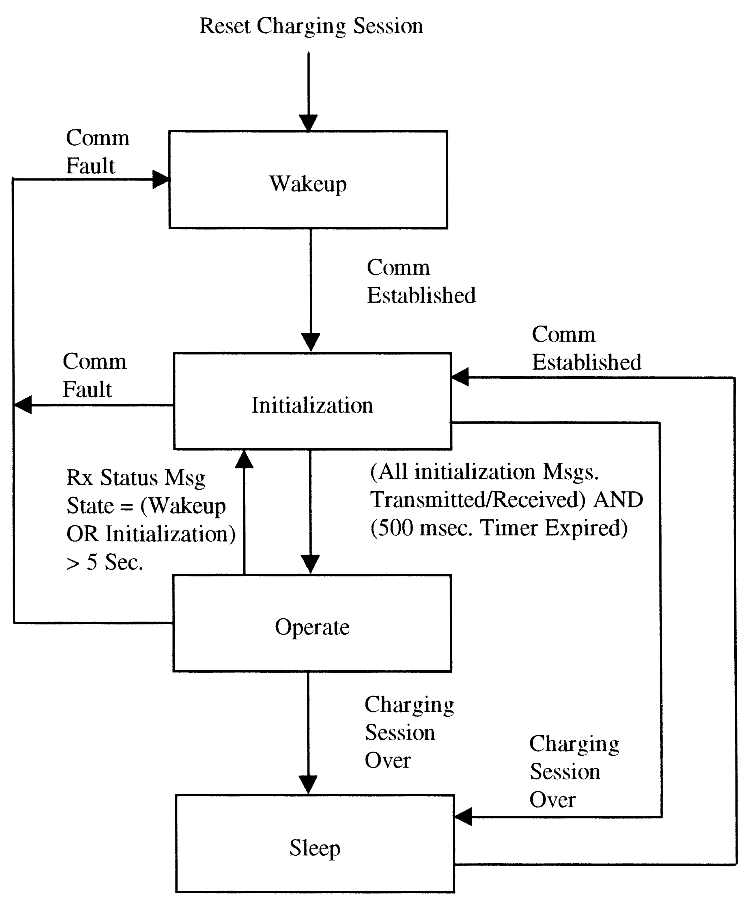



FIGURE A1—INDUCTIVE CHARGING SOFTWARE STATE TRANSITION DIAGRAM

Note that the "Fault state" referenced later in this document is considered a "substate" of the Wakeup, Initialization, and Operate states.

**A.2.1 Wakeup State—**The Wakeup state is the first state entered at the beginning of a charging session. If a communications fault is detected during a charging session, the software that has detected the communications fault will automatically reenter the Wakeup state to reestablish communications so that charging may continue.

A charging session may be initiated by either the vehicle or the charger. The vehicle initiates a charging session by transmitting Vehicle Status Messages to the charger at regular intervals. The charger initiates a charging session by transmitting Charger Status Messages to the vehicle at regular intervals.

Required and optional messages sent between the vehicle and the charger during the Wakeup state are listed in Tables A1 and A2. Message format and content are discussed in a later section of this document.

**TABLE A1—VEHICLE-TO-CHARGER MESSAGES—INITIALIZATION STATE**

| Vehicle-to-Charger Messages | Comments |
|---|---|
| Vehicle Status Msg | Required |
| Bus Wakeup Msg | Optional |

**TABLE A2—CHARGER-TO-VEHICLE MESSAGES—INITIALIZATION STATE**

| Charger-to-Vehicle Messages | Comments |
|---|---|
| Charger Status Msg | Required |
| Bus Wakeup Msg | Optional |

When the charger receives a Vehicle Status Message, it shall automatically transition to the Initialization state. When the vehicle receives a Charger Status Message, it shall automatically transition to the Initialization state.

NOTE—Some existing chargers and vehicles may initially transmit an optional Bus Wakeup Message until communications have been established between the vehicle and charger. Once communications have been established, the vehicle and charger will then begin transmitting status messages.

**A.2.2 Initialization State—**The Initialization state is entered once communications have been established with the vehicle (or reestablished following a loss of communications). During the Initialization state, the vehicle and charger exchange initialization information including any information necessary to determine whether power transfer may safely occur. Neither the vehicle nor the charger shall transition to the Operate state until (a) all required Initialization messages have been transmitted and received, and (b) a 500 ms timer begun at the entrance to the Initialization state has expired. (The 500 ms timer is intended to ensure that sufficient time has elapsed for the charger to receive the Vehicle Power Capability Message which is required for Level 3 charging.) Note that some of the messages that may be exchanged during the Initialization state are required while other messages are considered optional.

Required and optional messages sent between the vehicle and the charger during the Initialization state are listed in Tables A3 and A4. Message format and content are discussed in a later section of this document.

**TABLE A3—VEHICLE-TO-CHARGER MESSAGES—INITIALIZATION STATE**

| Vehicle-to-Charger Messages | Comments |
|---|---|
| Vehicle Status Msg | Required |
| Vehicle Power Capability Msg | Required for Level 3 charging, optional for Level 2 and Level 1 charging |

**TABLE A4—CHARGER-TO-VEHICLE MESSAGES—INITIALIZATION STATE**

| Charger-to-Vehicle Messages | Comments |
|---|---|
| Charger Status Msg | Required |
| Charger Power Capability Msg | Required |
| Charger Software ID Msg | Optional |

**A.2.3 Operate State—**The vehicle may enter the Operate state only after it has received all the required Initialization state messages from the charger. The charger shall enter the Operate state only after it has received all the required Initialization state messages from the vehicle.

The primary purpose of the Operate state is for the vehicle to request power from the charger, however both the vehicle and the charger may be in the Operate state without actual power transfer occurring. Power transfer will only occur while the charger is receiving regular Charger Power Request Messages with non-zero power requests from the vehicle. During the Operate state, the vehicle and the charger shall exchange messages periodically. Note that some of the messages that may be exchanged during the Operate state are required while other messages are considered optional.

Required and optional messages sent between the vehicle and the charger during the Operate state are listed in Tables A5 and A6. Message format and content are discussed in a later section of this document.

**TABLE A5—VEHICLE-TO-CHARGER MESSAGES—OPERATE STATE**

| Vehicle-to-Charger Messages | Comments |
|---|---|
| Vehicle Status Msg | Required |
| Charger Power Request Msg | Required for power transfer |
| User State Of Charge Msg | Optional |
| Time To Complete Msg | Optional |
| Bus Sleep Msg | Required to transition to Sleep state |

**TABLE A6—CHARGER-TO-VEHICLE MESSAGES**

| Charger-to-Vehicle Messages | Comments |
|---|---|
| Charger Status Msg | Required |
| Restricted Maximum Power Msg | Required when charger output power is restricted, otherwise optional (MAY BE DELETED!) |
| Charger Power Capability Msg. | Optional |
| Charger Software ID Msg. | Optional |

If the charger detects that the vehicle state in the Vehicle Status Message has been in either the Wakeup or Initialization states for more than 5 s, the charger shall automatically transition back to the Initialization state. If the vehicle detects that the charger state in the Charger Status Message has been in either the Wakeup or Initialization states for more than 5 s, the vehicle shall automatically transition back to the Initialization state.

When the charger receives a Bus Sleep Message, it shall automatically transition to the Sleep state. The vehicle shall automatically transition to the Sleep state after sending one or more Bus Sleep Messages to the charger.

**A.2.4 Sleep State—**The vehicle and the charger enter the Sleep state upon termination of the current charging session. A charging session should normally only be terminated by the vehicle (although there are some unusual situations, such as loss of power to the charger, where the charging session is effectively terminated by the charger). The charger shall enter the Sleep state after receiving a Bus Sleep Message from the vehicle. The vehicle shall enter the Sleep state after transmitting one or more Bus Sleep Messages to the charger.

During the Sleep state, the charger should not transmit any messages to the vehicle unless the charger wishes to initiate a new charging session (e.g., as in a remote or time-delayed request to initiate charging). In addition, the vehicle should not transmit any messages to the charger unless the vehicle wishes to initiate a new charging session. If the charger receives a Vehicle Status Message during the Sleep state, it shall assume that a new charging session has been initiated and shall automatically enter the Initialization state. If the vehicle receives a Charger Status Message during the Sleep state, it shall assume that a new charging session has been initiated and shall automatically enter the Initialization state.

### *A.3 Message Structure*

**A.3.1 General—**Charging message structure shall conform to SAE J1850 and GM Class 2 message structures (see Figure A2). Each message is 5 to 12 bytes long. The first 4 bytes of each message are required header bytes followed by 0 to 7 data bytes. The last byte is a required CRC byte.

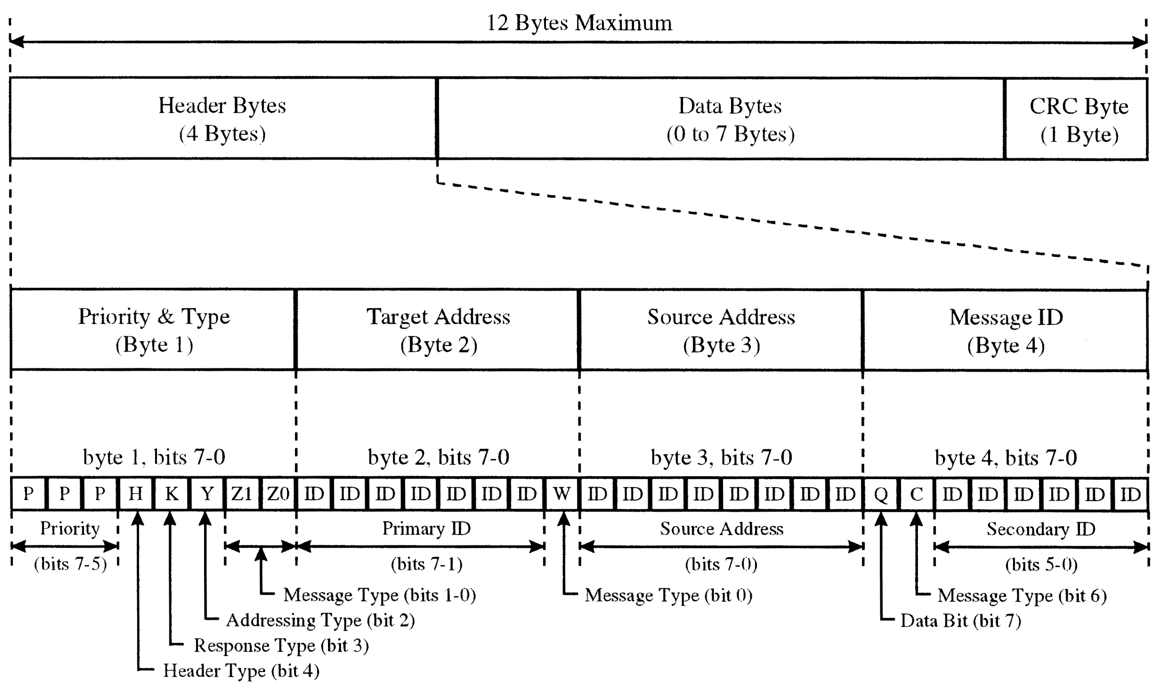



FIGURE A2—CHARGING MESSAGE STRUCTURE

**A.3.2 Priority Bits—**Bits 7-5 of header byte 1 are message priority bits used in bitwise arbitration of messages on the SAE J1850 bus. '000' is the highest priority and '111' is the lowest priority.

**A.3.3 Header Type Bit—**Bit 4 of header byte 1 is the header type bit and is used to select between the SAE J1850 3-byte header (H = 0) and the single byte header (H = 1). Since the charging messages conform to the SAE J1850 3-byte header, this bit must always be set to '0'.

NOTE—The 4th byte of the charging message structure (the secondary ID byte) is an extension of the SAE J1850 3-byte header format for this application.

**A.3.4 Response Type Bit—**Bit 3 of header byte 1 is the response type bit and is used to select between the SAE J1850 In-Frame Response Required (K = 0) and In-Frame Response Not Allowed (K = 1). Since in-frame responses are not allowed for the charging messages, this bit must always be set to '1'.

**A.3.5 Addressing Type Bit—**Bit 2 of header byte 1 is the addressing type bit and is used to select between the SAE J1850 functional addressing (Y = 0) and physical addressing (Y = 1). Since the charging messages all use functional addressing, this bit must always be set to ‘0’.

**A.3.6 Message Type Bits—**Bits 1-0 of header byte 1, bit 0 of header byte 2 and bit 6 of header byte 4 form a 4-bit message type field. This field is used to select between the SAE J2178 message types (see Table A7). The message type bit values for each charging message are message-dependent.

**TABLE A7—MESSAGE TYPE BITS**

| Z1 Bit value | Z0 Bit value | W Bit Value | C Bit value | Message Type Abbreviation | Message Type Description |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | LOAD | Command Load Parameter Value |
| 0 | 0 | 0 | 1 | MOD | Command Modify Parameter Value |
| 0 | 0 | 1 | 0 | RPT | Report Parameter Value |
| 0 | 0 | 1 | 1 | RPTF | Report Parameter Failsoft |
| 0 | 1 | 0 | 0 | REQ | Request Parameter Value |
| 0 | 1 | 0 | 1 | ACK | Acknowledge |
| 0 | 1 | 1 | 0 | RQCV | Request Commanded Parameter Value |
| 0 | 1 | 1 | 1 | QUE | Query Parameter Monitors |

NOTE—Currently only message types “LOAD” and “RPT” are used in this application.

**A.3.7 Primary ID Bits—**Bits 7-1 of header byte 2 are the primary ID bits and in combination with the message type bit ‘W’ (bit 0 of header byte 2) are used to select a functional target address (see Table A8).

**TABLE A8—PRIMARY ID BITS**

| Primary ID | Target Address |
|---|---|
| $72 | Charging System Cmd Msg |
| $73 | Charging System Status Msg |
| $FE | Broadcast Message |

NOTE—Bit 0 of the primary ID is the ‘W’ bit of the message type. A ‘W’ bit value of ‘0’ indicates a “command” message type and a ‘W’ bit value of ‘1’ indicates a “status” message type.

**A.3.8 Source Address Bits—**Bits 7-0 of header byte 3 are the source address bits and are used to identify the functional address of the sender (see Table A9).

**TABLE A9—SOURCE ADDRESS BITS**

| Source Address | Functional Address |
|---|---|
| $72 | On-Vehicle Charge Controller |
| $F2 | Charger |

**A.3.9 Data Bit—**Bit 7 of header byte 4 is a data bit and may be used for 1-bit boolean data in LOAD, MOD, RPT and RPTF message types. When the Q bit is not defined for a particular message, the Q bit shall be set to ‘0’.

**A.3.10 Secondary ID Bits—**Bits 5-0 of header byte 4 are the secondary ID bits and in combination with the data bit ‘Q’ (bit 7 of header byte 4) and message type bit ‘C’ (bit 6 of header byte 4) are used as a message ID. Each charging message has a unique message ID.

**A.3.11 Data Bytes—**Following the first 4 header bytes, each message may include from 0 to 7 data bytes. Data byte definitions are message-dependent.

**A.3.12 CRC Byte—**The last byte of each transmitted and received message is always a Cyclic Redundancy Check (CRC) byte. CRC generation and checking is automatically performed by the SAE J1850 interface hardware.

## *A.4 Message Definitions*

### A.4.1 Vehicle-to-Charger Messages

A.4.1.1 BUS WAKEUP MESSAGE—Optional (Network Control Message)

Header Bytes: $88 - $FE - $72 - $82
Priority: 4
Message Type: ‘0000’ (LOAD)
Target Address: $FE (Broadcast)
Source Address: $72 (On-Vehicle Charge Controller)
Data Bit: 1 (True)
Message ID: $82
Nominal Periodic Rate: 250 ms
Data Bytes: None

NOTE—The Vehicle Status Message has replaced the Bus Wakeup Message as the primary means for the vehicle to wake up the charger, however the Bus Wakeup Message is still used by some existing vehicles to perform the charger wakeup function.

A.4.1.2 BUS SLEEP MESSAGE—Required (Network Control Message)

Header Bytes: $88 - $FE - $72 - $84
Priority: 4
Message Type: ‘0000’ (LOAD)
Target Address: $FE (Broadcast)
Source Address: $72 (On-Vehicle Charge Controller)
Data Bit: ‘1’ (True)
Message ID: $84
Nominal Periodic Rate: 100 ms
Data Bytes: None

A.4.1.3 Vehicle Status Message—Required

Header Bytes: $88 - $73 - $72 - $21
Priority: 4
Message Type: '0010' (RPT)
Target Address: $73 (Charging System)
Source Address: $72 (On-Vehicle Charge Controller)
Data Bit: Not Defined (Set to '0')
Message ID: $21
Nominal Periodic Rate: 100 ms
Data Byte 1 (Byte 5):
- Bit 7: Battery Full
  - 0 = False, 1 = True
- Bit 6: High Power Charging Complete
  - 0 = False, 1 = True
- Bit 5: Spare (Set to '0')
- Bits 4-3: Power Usage Mode
  - 00 = No Power Transfer
  - 01 = Charging
  - 10 = Battery Equalization
  - 11 = Support
- Bit 2: Ventilation Required During Charging
  - 0 = False, 1 = True
- Bits 1-0: Vehicle State
  - 00 = Wakeup
  - 01 = Initialization
  - 10 = Operate
  - 11 = Fault

NOTE 1—High Power Charging Complete (bit 6) is not applicable for Level 2 (6.6 KW) or Level 1 (1.5 KW) charging.

NOTE 2—Vehicle high power charging capability is implicit in the Vehicle Power Capability Message.

A.4.1.4 Charger Power Request Message—Required for power transfer

Header Bytes: $68 - $72 - $72 - $20
Priority: 3
Message Type: '0000' (LOAD)
Target Address: $72 (Charging System)
Source Address: $72 (On-Vehicle Charge Controller)
Data Bit: Not Defined (Set to '0')
Message ID: $20
Nominal Periodic Rate: 100 ms (During Power Transfer)
Data Byte 1 (Byte 5): Requested % of Max Charger Output Pwr Cap (MSByte)
Data Byte 2 (Byte 6): Requested % of Max Charger Output Pwr Cap (LSByte)
- Range: 0 - 100%
- Resolution: 100/65 535%

A.4.1.5 USER STATE OF CHARGE MESSAGE—Optional

Header Bytes: $A8 - $73 - $72 - $22
Priority: 5
Message Type: '0010' (RPT)
Target Address: $73 (Charging System)
Source Address: $72 (On-Vehicle Charge Controller)
Data Bit: Not Defined (Set to '0')
Message ID: $22
Nominal Periodic Rate: 2 s
Data Byte 1 (Byte 5): Battery Pack % State of Charge
Range: 0 - 100%
Resolution: 1%

NOTE—Battery pack state-of-charge data greater than 100% shall be ignored.

A.4.1.6 TIME TO COMPLETE MESSAGE—Optional

Header Bytes: $A8 - $73 - $72 - $26
Priority: 5
Message Type: '0010' (RPT)
Target Address: $73 (Charging System)
Source Address: $72 (On-Vehicle Charge Controller)
Data Bit: Not Defined (Set to '0')
Message ID: $26
Nominal Periodic Rate: 2 s
Data Byte 1 (Byte 5): Time Remaining Until Charging Complete (MSByte)
Data Byte 2 (Byte 6): Time Remaining Until Charging Complete (LSByte)
Range: 0.00 - 100.00 h
Resolution: 0.01 h

NOTE—Time to complete data shall be interpreted as applicable to the level of charging currently in progress according to the following priority: (a) high power (> 6.6 KW) charging, (b) medium/low power (≤6.6 KW) charging, (c) battery equalization.

A.4.1.7 VEHICLE POWER CAPABILITY MESSAGE—Required for Level 3 charging, optional for Level 2 and Level 1 charging

Header Bytes: $A8 - $73 - $72 - $28
Priority: 5
Message Type: '0010' (RPT)
Target Address: $73 (Charging System)
Source Address: $72 (On-Vehicle Charge Controller)
Data Bit: Not Defined (Set to '0')
Message ID: $28
Nominal Periodic Rate: 100 ms
Data Byte 1 (Byte 5): Vehicle Charging Power Capability (MSByte)
Data Byte 2 (Byte 6): Vehicle Charging Power Capability (LSByte)
Range: 0 - 655 350 W
Resolution: 10 W

NOTE—The Vehicle Power Capability Message is part of the proposed software requirements for ensuring power level compatibility between the charger and the vehicle.

**A.4.2 Charger-to-Vehicle Messages**

A.4.2.1 BUS WAKEUP MESSAGE—Optional (Network Control Message)

Header Bytes: $88 - $FE - $F2 - $82
Priority: 4
Message Type: ‘0000’ (LOAD)
Target Address: $FE (Broadcast)
Source Address: $F2 (Charger)
Data Bit: 1 (True)
Message ID: $82
Nominal Periodic Rate: 250 ms
Data Bytes: None

NOTE—The Charger Status Message has replaced the Bus Wakeup Message as the primary means for the charger to wake up the vehicle, however the Bus Wakeup Message is still used by some existing chargers to perform the vehicle wakeup function.

A.4.2.2 CHARGER STATUS MESSAGE—Required

Header Bytes: $88 - $73 - $F2 - $23
Priority: 4
Message Type: ‘0010’ (RPT)
Target Address: $73 (Charging System)
Source Address: $F2 (Charger)
Data Bit: Not Defined (Set to ‘0’)
Message ID: $23
Nominal Periodic Rate: 500 ms
Data Byte 1 (Byte 5):
- Bit 7: Power Transfer Not Allowed
  - 0 = Max charger output power capability does not exceed vehicle power capability
  - 1 = Max charger output power capability exceeds vehicle power capability
- Bit 6: Ventilation Fault
  - 0 = False, 1 = True
- Bit 5: Communications Fault
  - 0 = False, 1 = True
- Bit 4: Charger Fault
  - 0 = False, 1 = True
- Bit 3: Overtemperature Fault
  - 0 = False, 1 = True
- Bit 2: Ventilation Ready
  - 0 = False, 1 = True
- Bits 1-0: Charger State
  - 00 = Wakeup
  - 01 = Initialization
  - 10 = Operate
  - 11 = Fault

NOTE 1—Ventilation Fault (bit 6) is not required if a different paddle configuration is required for chargers which effectively provide ventilation for vehicles which have batteries that require ventilation during charging.

NOTE 2—Communications Fault (bit 5) is only valid after charging session communications have been established.

NOTE 3—Charger Fault (bit 4) indicates a charger hardware or software fault, not a communications fault or overtemperature fault.

NOTE 4—Ventilation Ready (bit 2) is not required if a different paddle configuration is required for chargers which effectively provide ventilation for vehicles which have batteries that require ventilation during charging.

A.4.2.3 CHARGER POWER CAPABILITY MESSAGE—Required

Header Bytes: $A8 - $73 - $F2 - $24
Priority: 5
Message Type: ‘0010’ (RPT)
Target Address: $73 (Charging System)
Source Address: $F2 (Charger)
Data Bit: Not Defined (Set to ‘0’)
Message ID: $24
Nominal Periodic Rate: 2 s
Data Byte 1 (Byte 5): Max. Charger Output Power Capability (MSByte)
Data Byte 2 (Byte 6): Max. Charger Output Power Capability (LSByte)
Data Byte 3 (Byte 5): Min. Charger Output Power Capability (MSByte)
Data Byte 4 (Byte 6): Min. Charger Output Power Capability (LSByte)

Range: 0 - 655 350 W
Resolution: 10 W

A.4.2.4 SOFTWARE ID MESSAGE—Optional

Header Bytes: $A8 - $73 - $F2 - $27
Priority: 5
Message Type: ‘0010’ (RPT)
Target Address: $73 (Charging System)
Source Address: $F2 (Charger)
Data Bit: Not Defined (Set to ‘0’)
Message ID: $27
Nominal Periodic Rate: 2 s
Data Byte 1 (Byte 5):
- Bits 7-4: First Digit/Character of Software Part Number in Hex Format
- Bits 3-0: Second Digit/Character of Software Part Number in Hex Format

Data Byte 2 (Byte 6):
- Bits 7-4: Third Digit/Character of Software Part Number in Hex Format
- Bits 3-0: Fourth Digit/Character of Software Part Number in Hex Format

Data Byte 3 (Byte 7):
- Bits 7-4: Fifth Digit/Character of Software Part Number in Hex Format
- Bits 3-0: Sixth Digit/Character of Software Part Number in Hex Format

Data Byte 4 (Byte 8):
- Bits 7-4: Seventh Digit/Character of Software Part Number in Hex Format
- Bits 3-0: Eighth Digit/Character of Software Part Number in Hex Format

NOTE—If the software part number is less than 8 characters long, leading zeroes (not spaces) should be used.

A.4.2.5 RESTRICTED MAXIMUM POWER MESSAGE—Required when charger output power is restricted, otherwise optional (MAY BE DELETED!)

Header Bytes: $A8 - $73 - $F2 - $29
Priority: 5
Message Type: '0010' (RPT)
Target Address: $73 (Charging System)
Source Address: $F2 (Charger)
Data Bit: Not Defined (Set to '0')
Message ID: $29
Nominal Periodic Rate: 2 s (When Charger Output Power Is Restricted)
Data Byte 1 (Byte 5): Max Charger Output Power Limit

Range: 0 - 100%
Resolution: 100/255%

## *A.5 Fault Detection and Handling*

**A.5.1 Communication Faults—**When the vehicle does not receive a Charger Status Message within 2.5 times the specified periodic message transmission rate, the vehicle shall transition to the Wakeup state. Optionally, if the vehicle does not receive any other required messages from the charger within 2.5 times the specified periodic message transmission rates, the vehicle may transition to the Wakeup state.

When the charger does not receive a required message from the vehicle within 2.5 times the specified periodic message transmission rate, the charger shall set Communications Fault to True in the Charger Status Message and transition to the Wakeup state.

Note that loss of other messages may also trigger communication faults at the manufacturer's discretion.

**A.5.2 Vehicle Faults—**When the vehicle detects any charging-related fault during charging including faults reported by the charger, it shall immediately discontinue sending Charger Power Request Messages. If the vehicle detects any vehicle fault other than a communications fault during charging, it shall set the Vehicle State to either Fault or Wakeup in the Vehicle Status Message. Note that the "Fault state" is considered a "substate" of the Wakeup, Initialization, and Operate states.

When the charger receives a Vehicle Status Message with Vehicle State = Fault, the charger shall automatically disable power transfer.

**A.5.3 Charger Faults—**When the charger detects a charger fault other than a communications fault during a charging session, the charger shall set the appropriate fault bits in the Charger Status Message, set Charger State to Fault in the Charger Status Message and automatically disable power transfer. Note that the "Fault state" is considered a "substate" of the Wakeup, Initialization, and Operate states.

When the vehicle receives a Charger Status Message with fault bits set and/or Charger State to Fault, the vehicle may choose to terminate the current charging session. In this case, the vehicle should transmit one or more Bus Sleep Messages to the charger and enter the Sleep state.

***A.6 Message Summary***—See Table A10.

**TABLE A10—MESSAGE SUMMARY**

| Message | Format (Hex) | Comments |
|---|---|---|
| **Vehicle-to-Charger:** | | |
| Bus Wakeup | 88-FE-72-82-crc | Optional |
| Bus Sleep | 88-FE-72-84-crc | Required to transition to Sleep state |
| Vehicle Status | 88-73-72-21-xx-crc | Required |
| Charger Power Request | 68-72-72-20-xx-xx-crc | Required to transfer power |
| User State-of-Charge | A8-73-72-22-xx-crc | Optional |
| Time To Complete | A8-73-72-26-xx-xx-crc | Optional |
| Vehicle Power Capability | A8-73-72-28-xx-xx-crc | Required for Level 3, Optional for Levels 1 and 2 |
| **Charger-to-Vehicle:** | | |
| Bus Wakeup | 88-FE-F2-82-crc | Optional |
| Charger Status | 88-73-F2-23-xx-crc | Required |
| Charger Power Capability | A8-73-F2-24-xx-xx-xx-xx-crc | Required |
| Software ID | A8-73-F2-27-xx-xx-xx-xx-crc | Optional |
| Restricted Max Power | A8-73-F2-29-xx-crc | Required if power restricted, otherwise optional (MAY BE DELETED!) |

***A.7 Glossary***

**A.7.1 Battery Equalization—**Battery charging at very low power levels intended to equalize the cell voltages within the battery pack and thus extend battery life and vehicle range.

**A.7.2 Charging Session—**The period of time beginning when communications are first established between the charger and the vehicle and ending when communications between the charger and the vehicle are intentionally terminated and the charger and vehicle enter Sleep state, e.g., when the vehicle's batteries have been fully charged.

**A.7.3 Level 1 Charging—**In North America, refers to battery charging systems operating at maximum input power levels of approximately 1.44 kW and below.

**A.7.4 Level 2 Charging—**In North America, refers to battery charging systems operating at maximum input power levels of approximately 7.68 kW.

**A.7.5 Level 3 Charging—**In North America, refers to battery charging systems operating at maximum input power levels significantly greater than approximately 7.68 kW.

**A.7.6 Support—**Refers to power transfer from the charger to the vehicle for the sole purpose of providing power for non-charging functions on the vehicle, e.g., air conditioning, etc.

## APPENDIX B

## LEVEL 3 COMPATIBILITY

***B.1 Scope***—There is a functional requirement for independent hardware communication of the vehicle inlet power rating to the charger via a TBD mechanism. The purpose of this interface is for a Level 3 (high power) charger to recognize the power level of the charge port and automatically reconfigure itself to match (or at least not exceed) the rating of the charge port for safety reasons. This mechanism must be independent from the normal SAE J1850 data communications interface between the vehicle and the charger in order to avoid safety critical software in the charger and the resulting UL investigation of said software. The general technical assumption for the aforementioned interface has been an "IR beacon" interface proposed by GM engineers as a high level suggestion some months ago.

The purpose of this appendix is to describe a general system design implied by these assumptions. The proposed system design fulfills the requirements for an independent hardware and software mechanism in the charger to "match" the charger power level to the charge port power level. As will be shown, this design is not trivial or inexpensive, hence alternative options are discussed.

The inductive charging interface for Level 3 charging shall contain an IR link between the vehicle and the charger. The communications interface physical layer shall be compatible with SAE J2293. Conformance to this requirement shall be determined by demonstrating the ability of the physical layer to pass SAE J1850-compliant messages across the inductive interface.

***B.2 Level 3 Power Compatibility System Design***—Figure B1 shows a block diagram for the proposed Level 3 inductive charging power compatibility system.

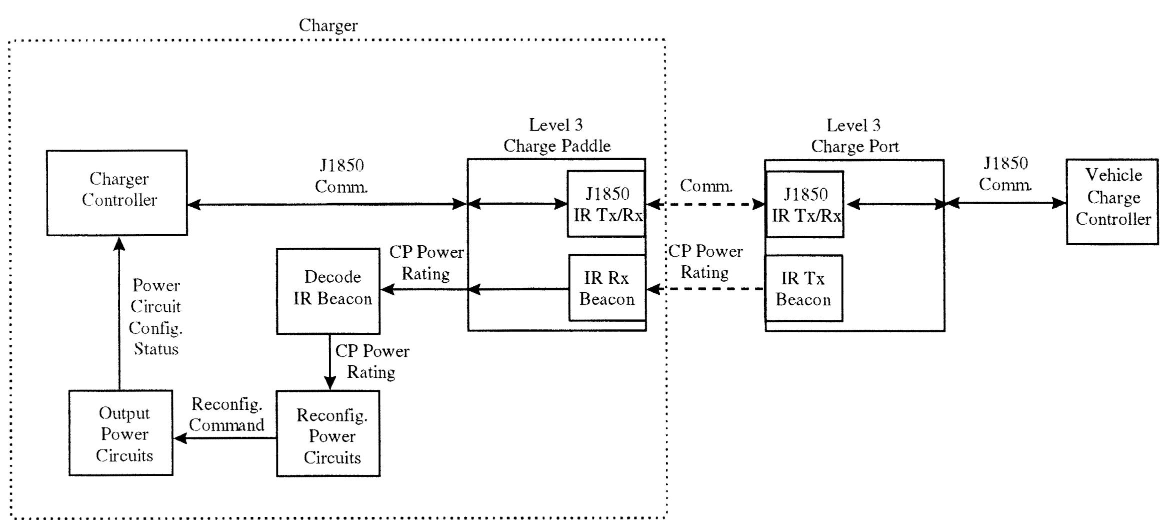



FIGURE B1—INDUCTIVE CHARGING SYSTEM LEVEL 3 COMPATIBLE DESIGN DIAGRAM

**B.2.1 Hardware Power Level Comparison Requirements—**The hardware path for communication of the charge port (CP) power rating to the charger is as follows: an “IR beacon” signal containing the encoded CP power rating is sent via an IR transmitter in the CP. The “IR beacon” signal is received by an IR receiver in the charge paddle and passed to a decoding circuit. The decoded CP power rating is passed to a circuit that determines the necessary reconfiguration of the charger power circuits such that the maximum charger output power will not exceed the CP power rating. If it is not possible to reconfigure the charger output power circuits such that the maximum charger output power will not exceed the CP power rating, the reconfiguration circuit shall disable the charger output power circuits. The current status and configuration of the charger output power circuits (including whether the charger output power circuits have been disabled) is made available to the charger controller software for comparison with the CP power rating transmitted by the vehicle charge controller via the SAE J1850 bus.

**B.2.2 Software Power Level Comparison Requirements—**The software path for communication of the charge port (CP) power rating to the charger is via the SAE J1850 communications bus. The CP power rating shall be preprogrammed into the vehicle charge controller and transmitted to the charger controller via the SAE J1850 communications bus. The charger controller shall read the charger output power configuration status from the charger output power circuits and transmit the maximum charger output power to the vehicle charge controller via the SAE J1850 communications bus.

***B.3 Charger Controller Requirements—***If the maximum charger output power does not exceed the CP power rating received via the SAE J1850 communications bus, the charger controller will allow power transfer from the charger to the vehicle. If the maximum charger output exceeds the CP power rating received via the SAE J1850 communications bus (or the charger output power circuits have been disabled by the IR beacon decoding circuits), the charger controller shall not allow power transfer from the charger to the vehicle.

***B.4 Vehicle Charge Controller Requirements—***If the maximum charger output power received via the SAE J1850 communications bus does not exceed the CP power rating preprogramed into the vehicle charge controller software, the vehicle charge controller may request power from the charger. If the maximum charger output power received via the SAE J1850 communications bus exceeds the CP power rating preprogramed into the vehicle charge controller software, the vehicle charge controller shall terminate the charging session without requesting power from the charger.

## APPENDIX C

## COMPATIBILITY WITH EXISTING SYSTEMS

***C.1 Scope***—Inductive charging system manufacturers are currently in the process of transitioning from an RF to an IR communications system. The industry will have completed its transition to a standard IR only communications system by 2003. Until this transition is complete, inductive charger manufacturers may choose to support both RF and IR communications systems in order to be compatible with both types of systems.

There are three key elements of this compatibility to fielded systems that shall be adhered to if future manufacturers decide to support inductive charging systems fielded prior to 2003. These elements are (a) the use of an RF communication system, (b) the use of an adapter to ensure physical compatibility of standard inductive connectors with vehicle inlets manufactured prior to the latest edition of this document, and (c) the use of RF antennas placed in the inductive connector.

***C.2 Communications Metrics***—See Table C1.

**TABLE C1—COMMUNICATIONS METRICS**

| | RF System Value |
|---|---|
| **SAE J1850 Parameters** | |
| Direction | bi-directional, half duplex |
| Baud Rate | 10. 4 k bits/s |
| Bit Encoding | VPW |
| Communication protocol between inlet and charger | SAE J1850 |
| **Communication Metrics** | |
| Transmit Frequency | 915 MHz ± 1.0 MHz |
| Receiver Bandwidth | 200 MHz |
| Receiver Sensitivity | –20 dBm |
| Modulation Type | on-off keying |
| RF Envelope Rise Time | <100 ns (10% to 90%) |
| RF Envelope Fall Time | <100 ns (90% to 10%) |
| Transmitter Output | +9 dBm minimum |
| On/Off Power ratio | >30 dBm |
| Max Duty Cycle | 80% “Active at 4 kHz |
| Min. Duty Cycle | 0% |
| **Steady-State Performance Metrics** | |
| Voltage Output | $V_{ol}$ and $V_{oh}$ per SAE J1850 |
| Voltage Input | $V_{il}$ and $V_{ih}$ per SAE J1850 |
| **Transient Performance Metrics** | |
| Transmitter Turn On Delay | <1 µs |
| Transmitter Turn Off Delay | <1.5 µs |
| Receiver Turn On Delay | <3.5 µs |
| Receiver Turn Off Delay | <6.5 µs |
| Turn On Delay | <6.5 µs |

NOTE 1—The RF transmit power level shall be measured at the surface on both sides of the inductive connector directly above the antenna.

NOTE 2—It is highly recommended that the communications interface be implemented as a dedicated link due to the potential for SAE J1850 bitwise arbitration problems when the interface is used in a multi-node communications system.

***C.3 RF Antenna Location—***The inductive connector may contain one antenna at the location specified in Figure C1 to meet the RF communications requirements. This antenna shall be used for RF communications between the charger and vehicle inlet when the inductive connector is fully inserted into the vehicle inlet.

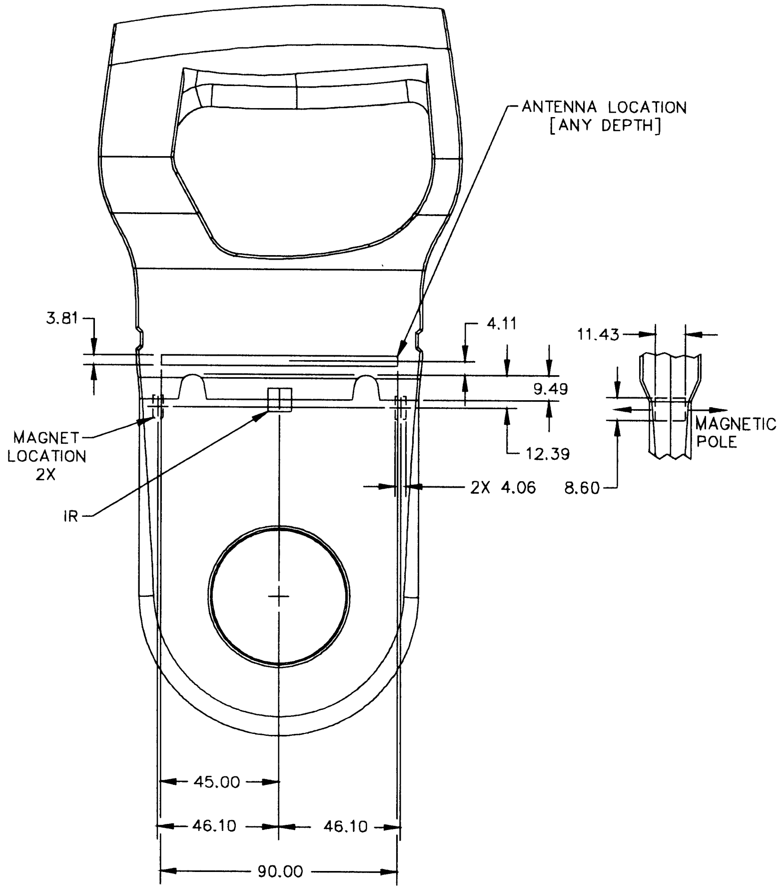



FIGURE C1—INDUCTIVE CONNECTOR CRITICAL DIMENSIONS.

NOTE—Use of an adapter to mate a standard size inductive connector to a non-standard size inductive vehicle inlet shall be allowed provided all other requirements are met.

***C.4 FCC Charging System Requirements for RF Systems—***If an RF communication system is used employing the characteristics described in Section C.2, the system shall comply with FCC CFR 47 Parts 15B RE, Class B limits. This requirement shall be in addition to FCC requirements described in 4.5.2.

***C.5 Inductive Connector Physical Compatibility—***Currently fielded systems make use of an inductive connector and vehicle inlet compliant with version 1995-01 of SAE J1773. The dimensions of that connector and inlet are different from those described in this updated edition. It should be noted that the old-style (non-standard) connector is not physically compatible with the new standard vehicle inlet described in this document. However, the new standard connector is compatible with old-style (non-standard) inlets by the use of an adapter (see Section C.3).

## APPENDIX D

## 138 mm COUPLER

***D.1*** ***Scope—***Inductive charging system manufacturers are currently in the process of transitioning from (a) an RF to an IR communications system and (b) from a coupler 138 mm in width to a coupler 106 mm in width. The industry will have completed its transition to a standard coupler with a width if 106 mm containing only an IR only communications system by 2003. Until this transition is complete, inductive charger manufacturers may choose to build and support the wider coupler containing an RF communications system. This system is described in the January 1995 issue of SAE J1773.

In order to set forth a body of requirements in this latest issue of SAE J1773, included in this Appendix are the physical requirements for the 138 mm coupler and inlet. These dimensional requirements originally appeared in the January 1995 issue of SAE J1773. Requirements for the RF communication system are contained in Appendix C of this document.

The following paragraphs itemize the physical requirements for the 138 mm inductive connector, including the location of connection present magnets and the RF antenna, the dimensions of the ferrite core contained within the inductive connector, and the dimensions of the vehicle inlet designed to accept the 138 mm connector.

All other requirements contained in the body of this document, i.e., maximum primary and secondary currents, allowable frequency range of operation, equivalent circuit parameters, etc., shall apply to the inductive connector described in this Appendix.

***D.2*** ***Coupler Dimensions—***Figures D1 and D2 describe the physical characteristics of the 138 mm coupler.

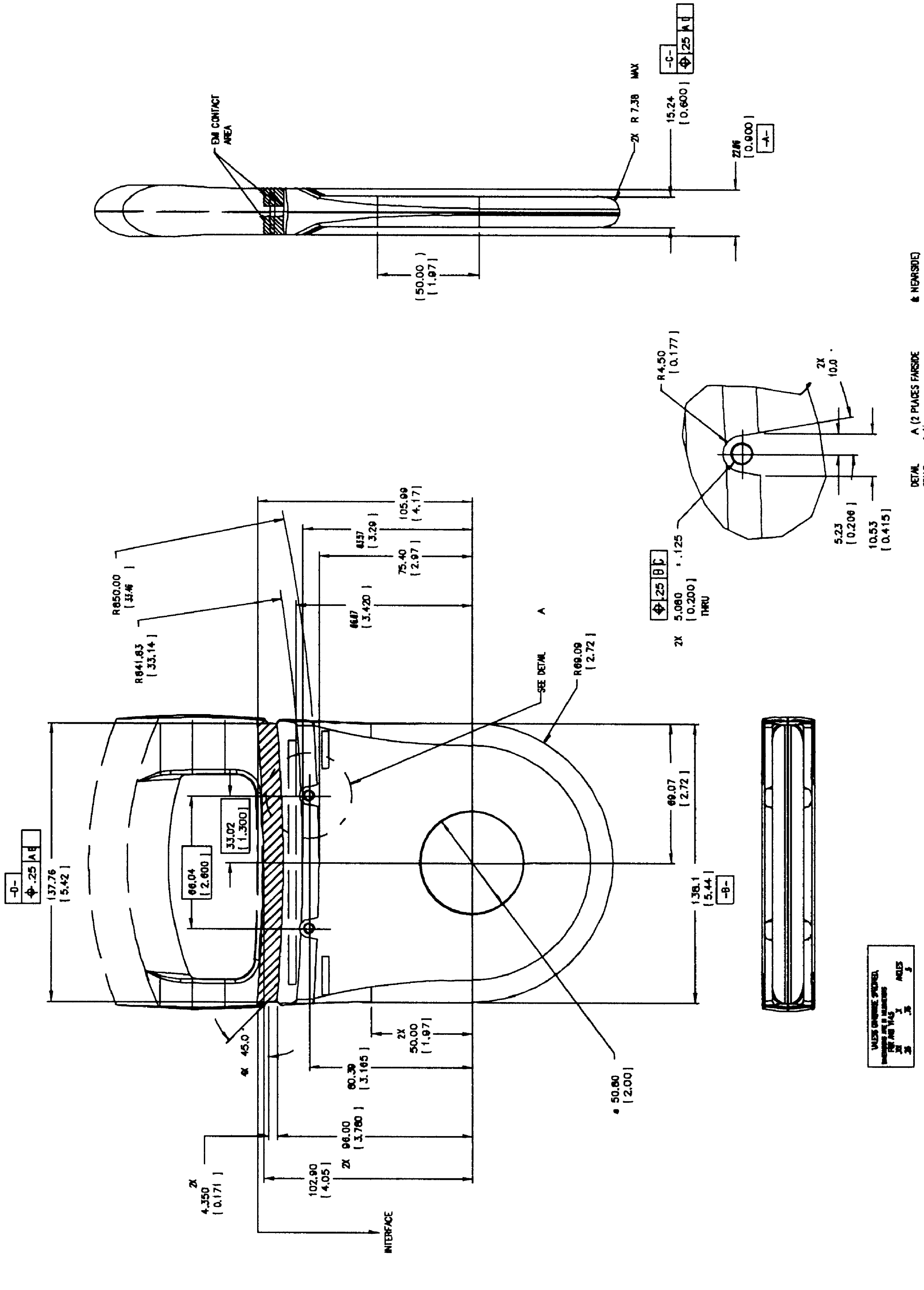


FIGURE D1—DIMENSIONS OF 138 mm COUPLER

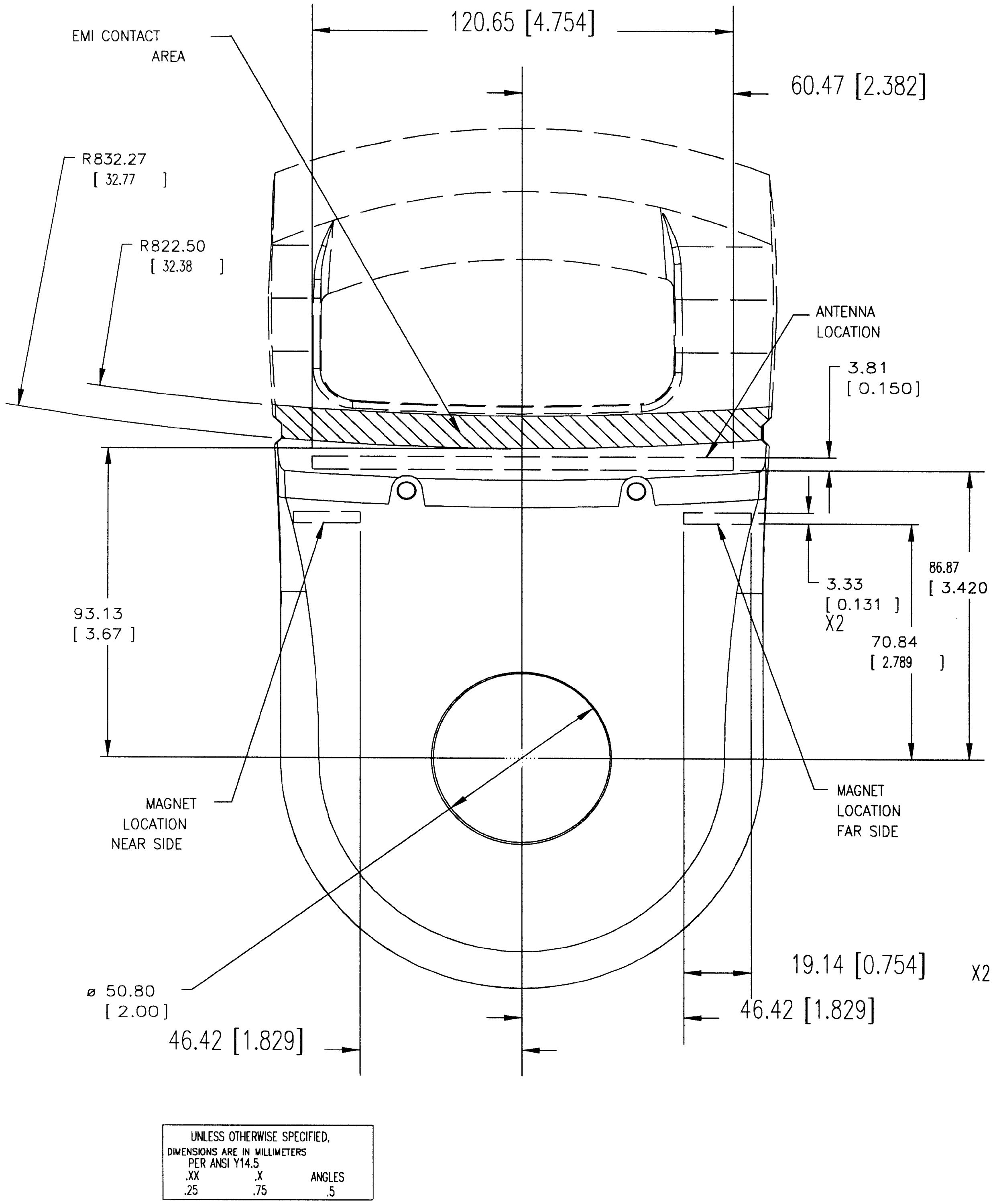



FIGURE D2—DIMENSIONS OF RF ANTENNA PLACEMENT WITHIN 138 mm COUPLER

***D.3 Inlet Core Dimensions*—**See Figure D3.

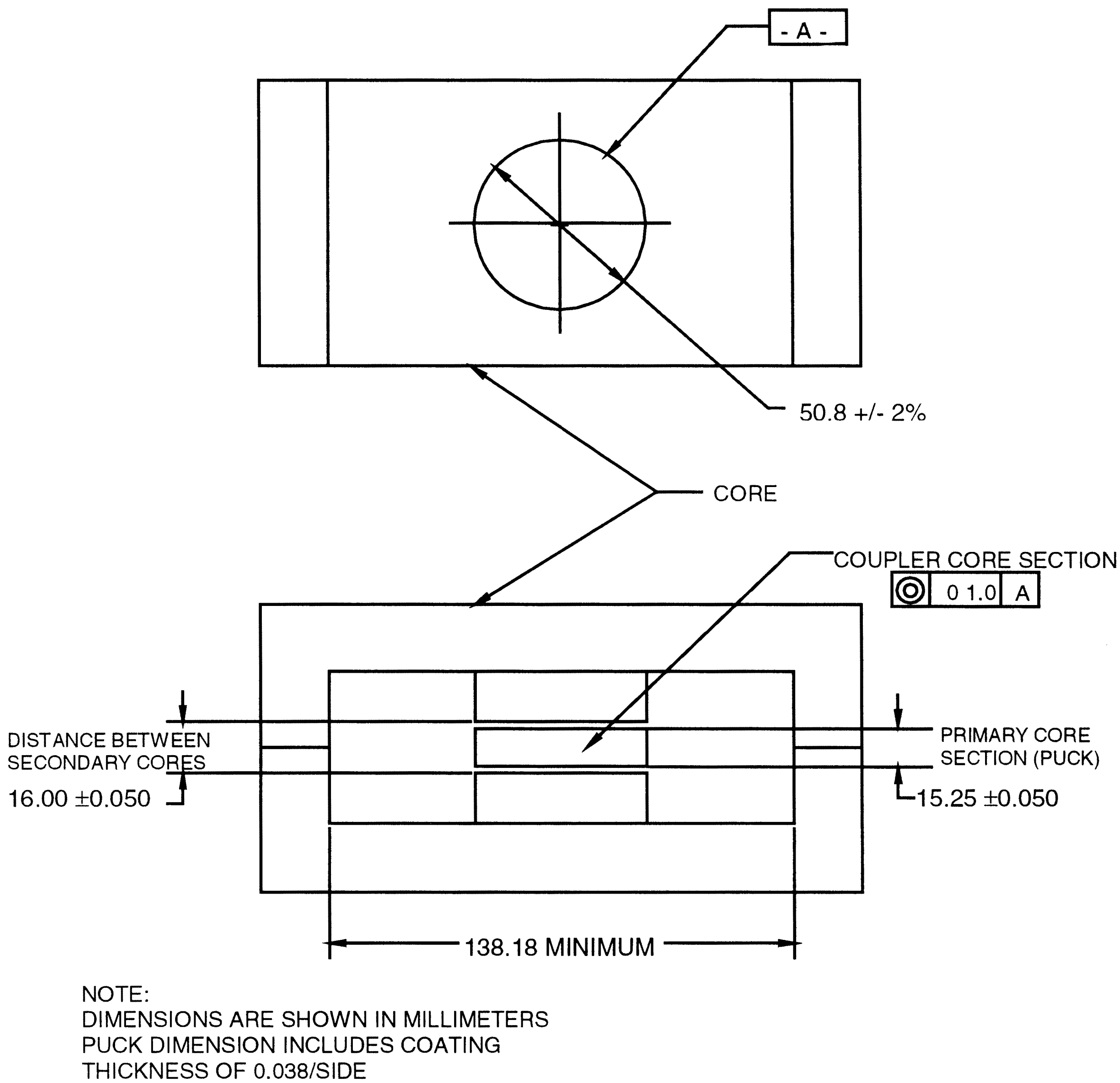



FIGURE D3—VEHICLE INLET CORE DIMENSIONS FOR USE WITH 138 MM COUPLER

**Rationale—**Not applicable.

**Relationship of SAE Standard to ISO Standard—**Not applicable.

**Application—**This SAE Recommended Practice establishes the minimum interface compatibility requirements for electric vehicle (EV) inductively coupled charging for North America.

This part of the specification is applicable to manually connected inductive charging for Levels 1 and 2 power transfer. Requirements for Level 3 compatibility are contained in Appendix B. Recommended software interface messaging requirements are contained in Appendix A.

This type of inductively coupled charging is generally intended for transferring power at frequencies significantly higher than power line frequencies. This part of the specification is not applicable to inductive coupling schemes that employ automatic connection methods or that are intended for transferring power at power line frequencies.

**Reference Section**

SAE J551-2—Test Limits and Methods of Measurement of Radio Disturbance Characteristics of Vehicles, Motorboats, and Spark-Ignited Engine-Driven Devices

SAE J551-5—Performance levels and Methods of Measurement of Magnetic and Electric Field Strength from Electric Vehicles, Broadband, 9 kHz to 30 MHz

SAE 1211—Recommended Environmental Practices for Electronic Equipment Design

SAE J1850—Class B Data Communications Network Interface

SAE J2178—Class B Data Communication Network Messages

SAE J2293—Energy Transfer System for Electric Vehicles

CFR 47 Code of Federal Regulations, Title 47, Parts 15B, 18C

CFR 40—Code of Federal Regulations, Title 40, Part 600, Subchapter Q

UL 94—Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

UL 2202—Electric Vehicle (EV) Charging System Equipment

NFPA-70-1999—National Electric Code (NEC), - Article 625

Canadian Electric Code*CEC Part 1, Section 86

**Developed by the SAE Electric Vehicle Charging Systems Committee**