AVT inc

In-Vehicle Computer Networks

An Overview

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Objectives:

- Brief history of computers, networks, and gov't
- Introduce concepts.
- Introduce network types, names, users.

Provide an overview of where the industry is now and where it might be going.

Two tacts:

- History and very top level view
- Nitty gritty technical details

History is brief, how it got here, why is the government involved

In The Beginning . . .

- **Automotive electronics make an appearance**
  - **Microprocessors appear.**
  - **Sensor and Control applications.**
  - **Non-entertainment applications.**
- **Engine computer**
  - **Primarily to improve emissions.**
  - **Connected only to the sensors near it.**
  - **Diagnostic connection to special equipment.**
- **Drive train computer(s)**
  - **Engine and transmission.**
  - **Improve emissions and enhance performance.**
  - **Individual processors, only connected to the sensors near it.**
  - **Minimal interaction between processors.**
  - **Individual diagnostic connections to special equipment.**

Electronics in early cars consisted of AM/FM radio.

Then 8-tracks, then cassette.

First real microprocessors were engine controllers.

Primarily designed to improve emissions.

Originally they supplemented the existing engine technology.

Early Data Comm's and 'Networks'

- **GM - ALDL**
  - **Assembly Line Diagnostic Link. Also known as 8192 UART.**
  - **Still in use.**
- **Chrysler - SCI**
  - **Serial Communications Interface (Motorola SCI port), 62.5 kbps.**
  - **A dedicated high-speed link.**
  - **Between an engine controller and off-board test equipment.**
- **Chrysler - CCD**
  - **Chrysler Collision Detection. 7812.5 bps**
  - **Still in use.**
- **Ford - ACB / ACP**
  - **Audio Control Bus or Protocol**
  - **Remote control of entertainment equipment.**
- **There are / were others . . .**

Early data links were for off-board diagnostic equipment.

Diagnostic equipment was specialized and only for one module type.

ALDL eventually grew to become a networking standard.

All of these buses used UART technology.

CCD was first real attempt at a network, including a messaging strategy.

There were / are others. Refer to slide #7, J2056.

On-Board Diagnostics Phase 2 (OBD-II)

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- **Increased processing power, enhanced algorithms, and improved control**
- **A desire to utilize the new capabilities**
- **EPA and CARB**
  - » **EPA - Environmental Protection Agency**
    - – Cite: 40 CFR Part 86 Section 86.094
    - – Note that these requirements are minimum functionality issues.
  - » **CARB - California Air Resources Board**
    - – California Code of Regulations (CCR) Title 13 Section 1968.1
    - – Changes made in both CFR and CCR so that they are compatible. (Eliminate contentions, jurisdiction, and precedence issues.)
  - » **To paraphrase the law . . .**
    - – If thou maketh a car or light truck for sale in this country (m.y. 1996 and later) then:
    - – The vehicle shall have a J1962 diagnostic connector in it.
    - – The connector shall support at least one of three approved communications standards.
    - – The vehicle shall properly respond to (at least) the mandated diagnostic queries and commands.

Emissions control was a primary objective.

As processing power and memory improved so did control algorithms as well as control and sensor technology.

EPA and CARB wanted to make use of these new capabilities.

Emissions control and testing was a one-time stationary event. e.g. tailpipe testing.

Two levels of testing: corporate (CAFE) and individual (tailpipe).

They desired to move it to be an individual responsibility. e.g. the car should monitor itself.

Thus want every car to have some type of standardized diagnostic interface, hence OBD-II.

On-Board Diagnostics Phase 2 (OBD-II)

- **OBD-II Network Standards**
  - **J1850 VPW**
    - Adopted by GM; also known as Class 2.
    - Adopted by Chrysler (known as J1850).
    - Some references to VPW mode heard about in regards to Toyota (and Honda ?).
    - 10.4 kbps, single wire.
  - **J1850 PWM**
    - Adopted by Ford; also known as Standard Corporate Protocol (SCP).
    - Also seen in some Mazda products.
    - Some references to PWM mode heard about in regards to Mitsubishi.
    - 41.6 kbps, two wire balanced signal.
  - **ISO 9141 and ISO 9141-2 (also known as ISO 9141 CARB)**
    - Seen in some Chrysler and Mazda products.
    - Seems to be more common in Europe.
    - 10.4 kbps, single wire.

OBD-II purpose was/is to make it easy for testing and inspection stations to establish communications with the vehicle and query it for information regarding its performance.

Stored trouble codes, snapshot data, clearing trouble codes, queries, responses, security.

Additional technical details about these networks at the end of this presentation.

On-Board Diagnostics Phase 2 (OBD-II)

- **OBD-II Network Standards**
  - » **The three network protocols are totally incompatible**
  - » **Common characteristics**
    - – The network standards describe primarily the physical and data link layers
    - – The application layer is referenced, usually for specific messages.
    - – For more detail about the application and other layers, refer to: J1979, J2012, J2178 (three parts), and J2190.
  - » **Details on J1850 and ISO on slides #16 and #17**

None of the OBD-II network standards are compatible.

Referenced standards:

J1979 is a required.

All others are recommended practices.

They provide framework for growth,

meet manufacturer proprietary requirements,

and meet minimum OBD-II requirements.

Other Network Standards

- **Refer to J2056/2 Survey of Known Protocols**
  - Last updated April 1993.
- **Non - OBD Networks**
  - » **Keyword Protocol 2000 (ISO 14230, three parts)**
    - Uses the same physical layer as ISO 9141.
    - Standard addresses physical, data link, and application layers.
  - » **CAN - Controller Area Network**
    - Developed by Robert Bosch GmbH.
    - Been around since the late 80's.
    - Addresses data link and application layers.
    - Does not address physical layer or speed parameters.
    - Multiple versions: 1.0, 2.0A, and 2.0B.
    - Has been adopted as a basis for several national (SAE) and international standards (ISO).
    - ISO 11898 (High Speed) and ISO 11519 (Low Speed).

There are lots of other standards, these are not OBD-II.

But they are some form of networking.

We will only cover those that are somehow connected to vehicle applications.

Other Network Standards

- **Class 2**
  - GM standard using the J1850 VPW implementation.
  - True Class 2 implementation and design is actually physical layer and data link layer independent.
  - Note that this protocol is a "Superset" of the minimum required OBD-II.
  - J1850 VPW version: 10.4 kbps and 41.6 kbps (in special diagnostic mode).
- **Single Wire CAN**
  - The new standard at GM to replace J1850 VPW.
  - Physical layer is a single wire CAN implementation.
  - Class 2 messaging strategy most likely to remain unchanged. (My guess.)
  - SAE draft standard: J2411.
  - 25.0 kbps and 80.0 kbps (in special diagnostic mode).
- **SCP**
  - Standard Corporate Protocol.
  - Ford's messaging strategy implemented using J1850 PWM.
  - Note that this protocol is a "Superset" of the minimum required OBD-II.

Note the baud rates for Class 2 based on

J1850 VPW

SWC

Other Network Standards

- **DeviceNet**
  - A CAN network designed for industrial machine control.
  - CiA - CAN in Automation.
- **J1939**
  - A CAN network for heavy trucks and buses.
  - References CAN version 2.0B.
  - Baud rate: 250 kbps.
  - Two wire balanced signal.
- **J1708**
  - Promoted for use in heavy truck and bus applications.
  - The bus structure is, essentially, EIA-RS-485.
  - Baud rate: 9600 bps.
- **TTP - Time Triggered Protocol**
  - Developed and promoted by Technical University of Vienna.
  - Designed for Class C network applications.
  - Motorola has announced support.

J1939

Consists of multiple parts.

The specification is rather rigid.

Other Network Standards

- **ITS Data Bus**
  - Intelligent Transportation Systems Data Bus (IDB).
  - PC's and other peripherals involved.
  - Used to tie together ITS, information, entertainment, and other computer and peripheral equipment.
  - Intel, Microsoft, GM, and Ford are very active here.
  - Standards under development include: J2355, J2366, J2367, and J2368.
  - Information sources: http://www.itsa.org
    http://www.itsa.org/usstandcat.nsf
- **PC type networks**
  - USB - Universal Serial Bus; possible companion to IDB.
  - FireWire - IEEE1394; possible use in IDB-M (multimedia).
- **and there are more**
  - Old ones, new ones, . . .

Others

Reference the J-spec. on slide #7.

Crystal Ball

- **What's been heard and who'll be using what**
  - **GM**
    - Single Wire CAN.
    - Predicted for model year 2000.
    - To replace J1850 VPW.
  - **Ford**
    - CAN bus.
    - Predicted within 3 years.
    - To replace J1850 PWM.
  - **Chrysler**
    - Still migrating toward J1850 VPW.
    - Little further information available.

What are each using now.

What are they moving towards.

Architecture

- **Now On-The-Road**
  - » **Processors galore**
    - – Engine, transmission, ABS, air bag, driver door, passenger door, body control, cell phone, entertainment system, information system, ...
    - – Processors may be networked, but only by function.
    - – Data may be shared, but only within a single network.
    - – Control may be distributed, but only within a single network.
  - » **Multiple but Isolated networks**
    - – Network #1: Safety
      (e.g. CAN - ABS, air bag, ...).
    - – Network #2: Emissions, diagnostics, comfort
      (e.g. J1850 - engine, body, ... controllers)
    - – Little to no connection/interaction between networks.

Number of microprocessors and microcontrollers.

Not talking about entertainment equipment.

How the various units do or do not communicate.

Stress: there are various networks, they are **not** connected.

Architecture

- **Coming Down the Pike**
  - » **Multiple and Connected networks**
    - Network #1: Safety
      (e.g. CAN - ABS, air bag, ...).
    - Network #2: Emissions, diagnostics, comfort
      (e.g. J1850 - engine, body, ... controllers)
    - Network #3: Entertainment, information, ...
      (e.g. IDB - stereo, cell phone, driver information, ...)
    - All networks tied together via gateways / firewalls.
    - Information sharing among and between networks.
    - Test equipment may be more generic in nature.
    - Single point communications to external test equipment.
    - Single point access to all vehicle network(s) and all connected modules.

Even more processors, power, and memory.

Even more control and sensor functions.

Even more capabilities.

Stress: Networks are to be connected together.

Use of network bridges or gateways.

Architecture

» **Expectations and Predictions (?)**

– GM:

Plans to replace J1850 VPW with Single Wire CAN (SWC)
by model year 2000.
Has already built an IDB gateway for the Cadillac demonstrator.
Has stated they are
"ready to put IDB gateways in any GM car worldwide by model year 2000."

– Ford:

Plans to use CAN as the basic vehicle bus within the next 3 years.
(to replace J1850 PWM).
Plans to use IDB for convenience.
Plan to develop their own gateway.

– Chrysler:

Supports IDB.
Developed a Jeep demonstrator.
Plans to develop their own gateway.

Who has done what.

Who is heading in what direction.

What I know about who is planning on doing what.

Additional Information

- **Device database on our web site**
  - http://www2.ari.net/avt-inc/devices.htm
- **Evaluation Engineering magazine**
  - Two articles about J1850 and ISO 9141.
  - January and March of 1998.
  - http://www.nelsonpub.com/ee/

The database is J1850 device specific.

Evaluation Engineering article are ‘supposed’ to be archived on their web site.

Technical Details

- **J1850 VPW (Variable Pulse Width)**
  - Symbols are defined in J1850 specification.
  - Nominal 10.4 kbps.
  - Single wire with ground reference.
  - Bus idles low (ground potential).
  - Bus high is +7v, +3.5v decision threshold.
  - Bus high is dominant. Zero bits are dominant. (Bus high is not zero !)
  - GM does not use IFRs. Chrysler uses a few.
  - Messages limited to 12 bytes including CRC and IFR bytes.
  - Carrier Sense Multiple Access with Non-Destructive Arbitration (CSMA/NDA).
- **J1850 PWM (Pulse Width Modulation)**
  - Symbols are defined in J1850 specification.
  - 41.6 kbps.
  - Two wire differential signal (ground referenced).
  - Bus high is +5v. (There is a dominant state.)
  - Ford implementation requires IFRs.
  - Messages limited to 12 bytes including CRC and IFR bytes.
  - CSMA/NDA.

Note that J1850 is different from UART based communications.

J1850 uses defined symbols to delineate a complete message.

UART based protocols rely on timing issues to convey this type of information. There is symbol ambiguity in UART systems.

Technical Details

- **ISO 9141-2**
  - UART based.
  - 10.4 kbps.
  - K-line required, ground referenced.
  - K-line only used for normal communications.
  - *L-line only required on tester, ground referenced.*
  - *L-line is only used for initialization.*
  - K-line idles high.
  - K-line high is Vbatt.
  - K-line low is dominant.
  - Diagnostic messages are limited to 12 bytes including CRC byte.
- **Keyword Protocol 2000**
  - Physical and data link same as ISO 9141.
  - Baud rate is 1.2 to 10.4 kbps.
  - Messages may contain up to 255 bytes in the data field.

These are wired ‘OR’ circuits.

Timing is the critical element and controls bus operations.

The KWP 2000 message maximum length is ~259 bytes, header+data+CRC.

The K-line is bi-directional.

The L-line, if used, is uni-directional.

KWP 2000 is not an OBD-II protocol. Does not have to support the OBD-II messaging strategy.

Contact information

- **Advanced Vehicle Technologies, Inc.**
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  - **web site: http://www2.ari.net/avt-inc/**
- **SAE**
  - **SAE and ISO specifications.**
  - **http://www.sae.org**
  - **724-776-4841**
- **ANSI**
  - **ANSI and ISO specifications.**
  - **http://www.ansi.org**

SAE offers specification download direct from their web site.

Warnings

- **Terminology**
  - **Beware of mis-use and confusion.**
  - **Often used incorrectly and/or differently by different people.**
- **Information provided is up-to-date (best of my knowledge).**
  - **Use this information with caution.**
  - **Things change, sometimes quickly, oft times quietly.**
  - **Manufacturers operate in their own world, usually.**
  - **There are many more players in the field than there used to be.**

Watch how individuals use the various terminology.

More players on the field; means the business climate has changed. Used to be one big guy on the block who called all/most of the shots.

My version of a legal disclaimer.