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General Motors Computerized Vehicle Control Systems: A Short History

The modern automobile has progressed greatly in the last 100 years. Just as our everyday consumer life has become sophisticated, our transportation has followed suit. Just how complex the modern automobile has become, though, is most likely not known by the average person. We see all the high tech gadgets nowadays, high speed internet, high speed computers and fancy entertainment systems, these concepts are all in the modern car. This paper will explain a few details of our modern automotive computer systems.

To understand the need for automotive networks, a short explanation of a cars electrical system is necessary. The earliest vehicles started out with some primitive control systems. The ignition coil for firing the fuel charge in the internal combustion engine was "clocked" by the ignition points and timed to the engines firing order. It was a basic mechanical system and was not always the most efficient as it relied on a mechanical devices to provide timing which followed a set curve and had moving parts to wear out. Numerous moving contact type controls for different parts of vehicles tended to fail or wear out quickly due to the harsh conditions present in cars such as heat, cold and continuous vibrations. Modern solid state control systems started to appear in the early seventies as transistor technology and cheaper solid state products entered the market. The transistor provided an excellent way to incorporate things such as the ignition's mechanical points into electronic ignition modules which didn't require maintenance, were much more reliable and could be produced cheaply. Other things that helped bring about a change in automobile management systems was the need to more precisely control a vehicle's engine systems so as to keep up with increasing emissions and fuel economy standards.

In the early sixties, with automobile production soaring and Eisenhower's new federal highway system making automobile travel much easier, people started to realize that the Earth's atmosphere was getting increasingly polluted from the noxious fumes that were belching out of the automotive jungle. Large cities such as Los Angeles and New York City were developing large smog problems and there was some need to improve the amount of pollution entering our atmosphere. The Clean Air Act in 1967 started a trend in controlling our vehicles very precisely to clean up our urban areas.

The first Clean Air Act only did very minimal things such as requiring the crankcase gases to be a closed system and nitrous oxides emissions to be reduced with an

EGR system. The really big change came in 1980 with the initiation of the revised 1977 version of the Clean Air Act which set some higher emissions standards, outlawed leaded gasoline, introduced the catalytic converters as mandatory equipment and required vehicles to monitor their emissions controls with a light on the dashboard called the "check engine light".

This was the real start, the check engine light. All vehicles sold in the US were required to have a monitoring system which would turn on this lamp if there were an electrical failure of any emissions related component and vehicles would need to be able to display a "failure code" which would tell the repairer which system was the culprit. Of course with the stricter emissions standards, the manufacturers would need to switch over to modern fuel injection anyway (as it was way more efficient) and computerized controls were necessary to control this injection. General Motors was the forerunner in computerized technologies with the other two domestic car manufacturers only meeting the bare minimum to abide with the new regulations. So the modern story really begins in 1980 with a check engine light and a primitive computer in every U.S. vehicle.

These computers were pretty primitive all right, big tin boxes with edge-board connectors which had a tendency to oxidize and cause drivability problems. I remember well removing the computer connectors on early 1980's Cadillac models and rubbing the edge-board connectors with a pencil eraser. This would clean the oxidation on the circuit board traces and restore a poorly conducting circuit. The early automotive computers also had mechanical devices in them such as vacuum sensors which would require a small vacuum hose to enter the computer's external case which affected case integrity. Eventually someone got the right idea to put the vacuum sensor external in the engine compartment with sealed wires with weatherproof terminals entering the computer cases. We used to have what's called the "tap-test" which was just what it sounded like; you tapped lightly on the computer of a vehicle with a strange engine problem. If tapping on the computer caused the car to react, the computer was failing. This was quite common in the eighties and early nineties until a more robust case and circuit board was designed in 1996 with the advent of more stringent emissions laws. The new circuit boards had a coating on them to resist corrosion of the solder joints due to vibration and the new cases were made of cast aluminum and sealed much better.

Figure 4. SFI 66U Powertrain Control Module (PCM)

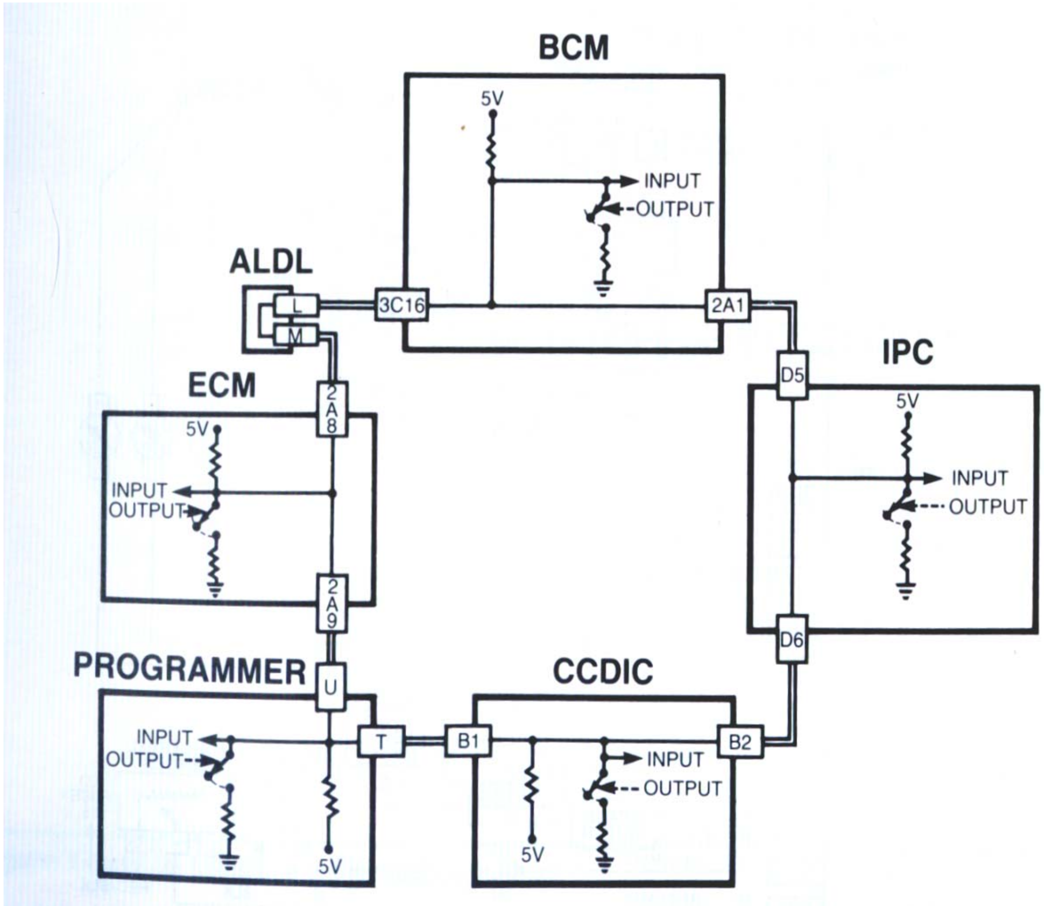
← This is a modern computer case. You can see the case is much thicker than the old case below it. The small access cover on the top is for the electronic spark control (knock sensor) module which is removable. The removable PROM is now an EEPROM and is hard soldered to the circuit board.

Figure 5. SFI4 PCM

← This is the old style thin sheet metal case. The removable panel in the back was for the PROM which could be changed.

The first beginnings of automotive networks began in the Cadillac and Oldsmobile models of the early eighties with the advent of a second computer other than the central engine control module. This new computer had a microprocessor and was called the BCM (Body Control Module). The engine control module (ECM) would control all engine functions while the BCM controlled items such as automatic lighting, HVAC (heating and air conditioning) controls and alarm and lock functions. The BCM came about as consumer demands and competition led to newer creature comforts in the modern automobile. GM needed to get a method to tie these two computers together.

The ECM and BCM would communicate such things as engine temperature and vehicle run time info with each other through a protocol called **UART** (universal asynchronous receiver transmitter). Communications on a single wire reduced redundant wiring greatly with sensors just wired to one module. This UART was a binary language with the on or off values controlled by a zero volt or 5 volt signal that varied in pulse width. One of my training manuals from 1986 on Cadillac Allante BCM electronics describes the operation of UART. With the system resting at 5 volts, the BCM, which controlled bus timing and traffic, pulses out an address code. All the modules see this code as in Ethernet protocol but only the module with that particular code can respond to the message. All modules can listen in and decode any messages, though, so they can read certain info such as engine coolant temp data which is on the bus often. A module isn't allowed to respond unless it is addressed directly by the BCM. The BCM can't send any other messages until it has first finished the conversation it was just having. The receiving device will pull the system high so it is declared idle, then it will respond by sending its own address code, then it sends its data. It will then hold the system high so it is once again declared idle. The BCM will then be allowed to continue talking.



↑ 1986 Cadillac Allante Network, circuit 800, UART line - The ALDL is the diagnostic connector.

A few years later the digital instrument panel cluster (IPC) received another microprocessor which communicated with the other two modules on the UART dedicated serial data line. This was a single circuit that was referenced to ground and was shared to a certain pin on each module. To prevent collisions of data and to establish a communications protocol, one of the modules would be designated the "Master of the Bus", which meant it had the duty of checking with all of the modules and assigning transmission timing so as to facilitate a functional network on the serial data "bus" as it was now called. At one point the Cadillac models received a new module under the dash called the Central Power Supply which acted as a universal power supply to isolate the various microprocessor modules from the rest of the automotive power system which could have damaging spikes and variations in voltage. One-by-one more modules appeared such as the Fan Control Module (to precisely control the engine cooling fan), the Remote Keyless Entry Module which received the microwaves from a vehicle remote to unlock doors and send an alarm “off” signal to the BCM. The fancy Oldsmobile Cutlass Trofeo had a CRT touch screen display in the dash which added to the UART bus. An Electronic Brake Control Module appeared in the mid-eighties to higher end cars which controlled all the functions of the anti-lock brake system. This EBCM needed engine run and vehicle sensor information from the other modules and found this out by being wired to the UART bus. Add a suspension control module to the mix, an airbag system module (SDM), etc and the network got busier and busier as time went on.

The main engine control computers went through a series of changes throughout the years. The early ones were called the ECM short for engine control module. This just controlled the engine system. As this main computer started to control the new electronically controlled automatic transmissions its designation changed to a PCM or powertrain control module. Some main computers controlled the transmission, the engine and the ABS; these were called the VCM’s or vehicle control module. As automatic transmissions became more complex, some systems started to separate the PCM back into the ECM and a separate TCM or transmission control module. This was possible as networking systems had become more complex to allow integration of the one into two. As in internet and business networking the acronym list began to grow!

The earliest systems had a baud rate of around 1,024 bits per second and considering the little amount of data that was being processed, that was OK. As time went on and more and more modules were added and the data transfer grew, baud rates increased to 8,192 bps until the UART system itself became a little too slow in it’s architecture to be effective. A new system was developed in 1995 using what was called “**Class 2 data**” and had a dedicated Class 2 bus separate from the UART bus. Some vehicles used class 2 data explicitly and others had two buses, one for class 2 data and others for the slower UART system. Generally the engine and brake control functions that required high speed real time data used the class 2 bus and slower things such as the airbag and entertainment system were on the UART bus. Class 2 data used a pulsed signal that was different than UART data as it went from an “on” voltage level of around 7 volts to a reference of 0 volts. The UART data had a fixed pulse width and was at a level of 5 volts with no communication and was pulled low to talk. The class 2 data was at a resting level of 0 volts and was pulled high to around 7 volts to talk. The class 2 data didn't have a fixed pulse width, bits could be different durations which meant that more data could be transmitted increasing the baud rate to10,400 bits per second. Class 2 modules could also be programmed at 41,600 bps. Class 2 also didn't need a master of the bus, each message included bits that identified the module sending and the module that was to receive the message.

UART - CLASS 2 COMPARISON

UART	CLASS 2
• 5 volts • Voltage pulled low to talk • All bits equal width • Messages sent as a continuous stream	• 7 volts • Voltage pulled high to talk • 2 bit widths used • Messages sent in packets. Packets can have priorities so more than one controller can send messages simultaneously

Vehicles could also have a third bus which was called the Entertainment and Comfort bus (**E&C),** this bus used a protocol similar to UART but was at 12 volts at rest and was pulled to low to communicate. There was no master of the bus, the transmit signals were driver initiated (by a button push or knob turn or steering wheel controls) and the binary code would got to the appropriate module. E&C messages were only sent and received at 1024 bps and messages had a priority system. The vehicle's time clock signal was broadcast on this line to display at both the radio and HVAC module as needed. Generally E&C busses were limited to communications between the radio and HVAC modules, but sometimes the HVAC module would be on two buses at once and acted as a gateway. It would translate the E&C bus messages to the class 2 data line for all modules to see.

The UART line generally was wired in series with each module having a data in and a data out to the next module which meant that if one module had an open, all the modules after it would lose their data. The class 2 bus was generally wired with a star topology, but in both systems it was still possible for one module to bring the serial data line down and affect all the other modules. Most of the newer cars nowadays have the center of this star topology wired into a connector (splice-pack), which had a removable "comb" which could be used to separate the serial lines for each module at a common point for easier diagnosis. The comb terminal connector would be removed from this connector and circuits could be jumped together to remove certain suspect modules from the rest.

Since all automotive systems share a common ground through the vehicle's metal body, the serial data line (bus) that modules communicated with was usually a single wire circuit that had a common number at all modules. The UART data line was usually circuit number 800 and the class 2 data line was usually circuit 1807. This was common among all GM body and chassis platforms. There were a few exceptions such as the late 1990's Oldsmobile Cutlass and Pontiac Grand Prix which had a body control module called the Body Function Controller (BFC) which controlled theft deterrent, lighting and other body functions. This controller used what was called the Serial Peripheral Interface (SPI), which used three wires to talk to the PCM. Two wires carried the data back and forth and the third line carried the clock signal that synchronized data on those two circuits. The SPI uses values of 12 volts and 0 volts for its binary data. The BFC is the master of the bus on this system.

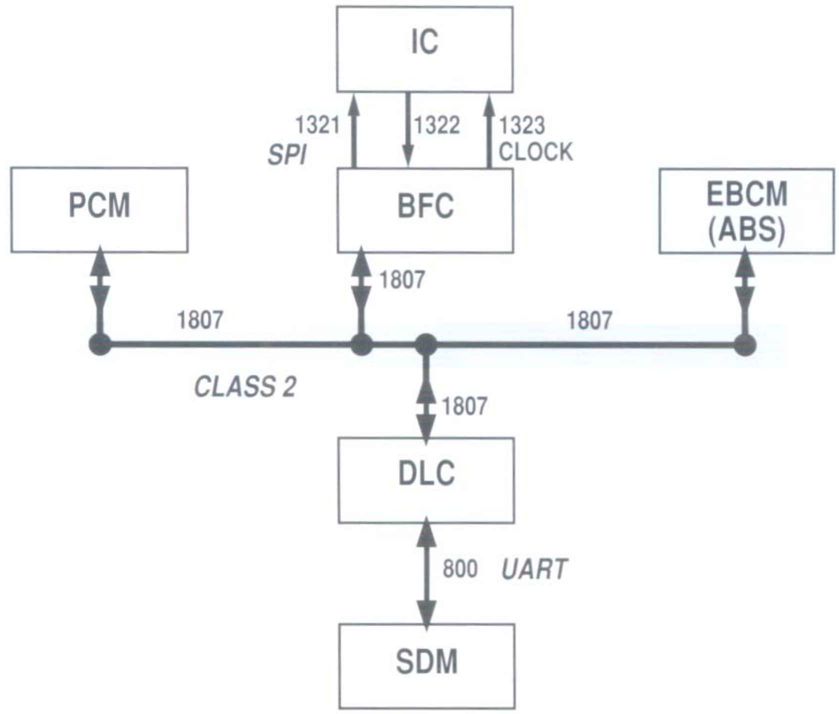
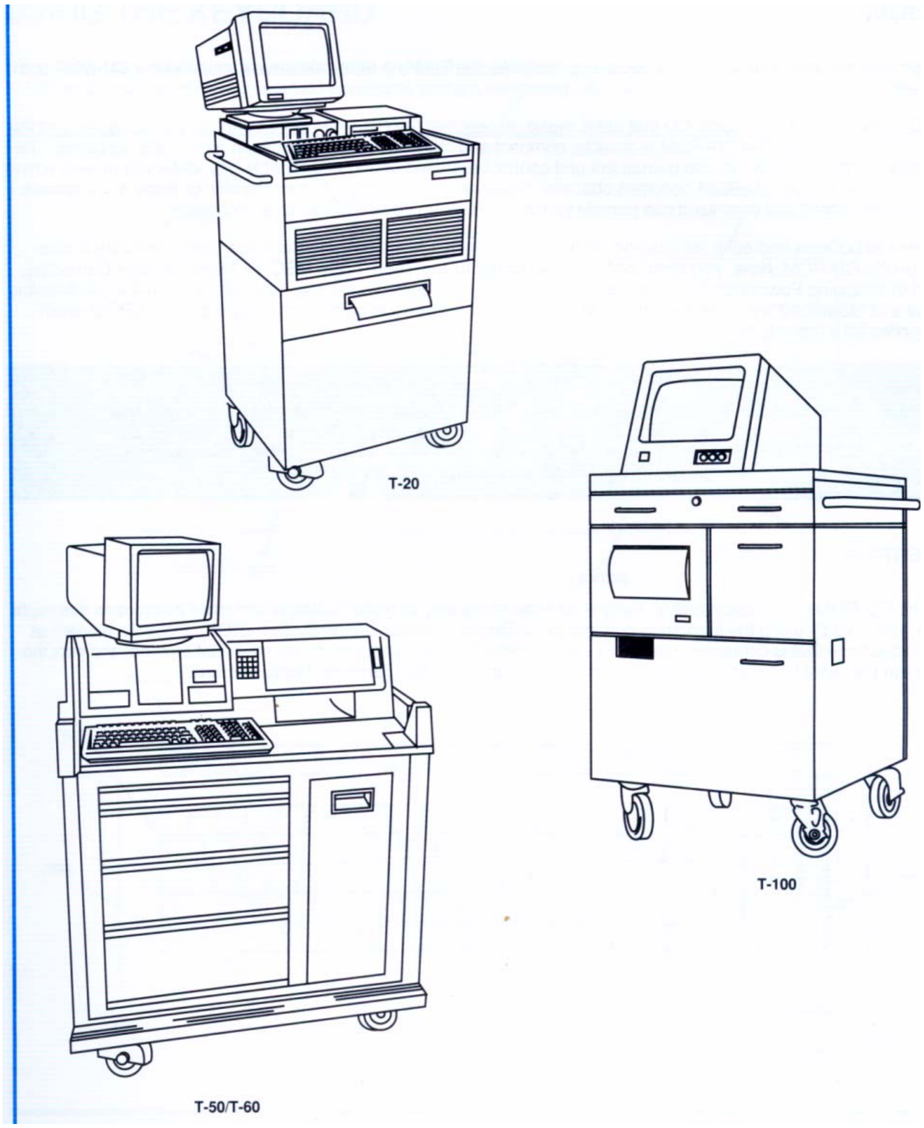


Figure 7. 1997 Cutlass Serial Data Lines

A later model vehicle shown above ↑. You can see the Class 2 data on circuit 1807, the UART on circuit 800 and the Serial Peripheral Interface using a three wire arrangement. IC is instrument cluster, BFC is Body Function Controller (BCM), DLC is the Data Link Connector and SDM is the Sensing and diagnostic module (airbag).

Diagnosing these systems when there was a problem with one of the modules was always a problem especially in the early days. Automotive mechanics who didn't have a great knowledge of electronic systems would often guess incorrectly causing great unnecessary expense to the customer when "all three of his modules" were bad, when really it was just one of them or a wiring issue. Often one bad module would cause the data line to go dead (dashboard and HVAC display would go black) giving the appearance that all the modules weren't working. Sometimes disconnecting one module at a time would cause the system to come back online identifying the bad module. Dealers would often stock one or more of each module to make diagnosis easier. I fondly recall us (I worked for Cadillac/Oldsmobile for the last fifteen years) using what we would call the "try and fry" approach. We would "borrow" a new module from the parts department to find the bad module. When one module fixed the problem; that was the bad one. We could then return the other modules back to parts. The "fry" part resulted when a bad module or improper handling inadvertently spiked one of the good modules and we were stuck trying to explain to parts why we had received a "bad" module from them! This type of diagnosis was encouraged by GM as a lot of diagnostic charts told the automotive technician to "try a known good module". I'm not quite sure where they expected us to find these "known good" modules except to borrow them from the parts department. Independent shops must have loved to read this, as guessing at the problem could become real expensive for them!

Diagnosis started to become a little easier (but not much) through the use of various diagnostic tools. From 1980 on, the computer would turn the check engine light on if there was an issue with the system. This would trigger a diagnostic code for the guilty system or sensor to be set in the computer's memory. The computer code or codes would be obtained by either shorting two terminals together on various styled diagnostic connectors or grounding a specific terminal. This would cause the check engine light to go into code display mode and flash a trouble code in a predetermined sequence. The system always started with a code 12 (one flash, a pause then two flashes). This would tell you that diagnostic mode was entered and then the actual code would be displayed, each code repeating itself three times. Codes were cleared by disconnecting the ECM fuse for more than 18 seconds. A standardized 12 pin connector was adopted in 1982. In the 1985, a small handheld scan tool called the Tech 1 was adopted that would allow the tech to plug the tool into the diagnostic connector called the ALDL (assembly line diagnostic link, later called the DLC or data link connector) and use the cigarette lighter for power. This tool would display the codes on-screen and observe live engine data for diagnosis. The Tech 1 couldn't clear codes, though, for another few years. Codes still had to be cleared by disconnecting battery power to the ECM or to the module setting them. GM also came out with a roll-around computer station that could be rolled up to a vehicle and plugged in to obtain info. This machine called the CAMS system had a neat touch screen and also had some service information on it such as service bulletins and torque and engine specs for each vehicle. The machine could be hooked to the phone line with a RJ-11 jack to use its lightening quick 14.4K modem to hook to GM. As time went on this system was abandoned for a quicker PC based system with DOS, then Windows 3.1., Windows 95, Windows 98, etc. These terminals were pretty good back then as they started the trend of putting technical service bulletins, a major source of known fixes to known problems, on a searchable database versus the previous system of having to rummage through hundreds of pieces of printed bulletins which was time consuming and didn't always find the correct documents. As you can imagine the terminals progressed through the changes in technology going from a 486 processor with 500 MHz of hard disc space to the latest advances in technology. The dealers weren't too happy about this as they were required to purchase these "essential" tools every year at considerable cost. Paper service manuals were also being integrated to a computer environment with a different system every six months, one using 30 different floppy discs to 10 CD's (each having to be loaded as they were used) to info loaded onto the newer larger hard drives. The current system is internet based with the current info being able to be updated every day on a website. The only problem with this is that if the internet connection goes down, your shop loses access to service information. The handheld scan tools are still used more than the PC stations as they can be taken on a road test and are quicker to set-up. The current PC station is hard-wired with an Ethernet connection to the internet and is no longer portable. They're used mostly to read service information and download the software updates to the handheld tools which are then brought back to the vehicle and programmed through the handheld tool. Paper service manuals are no longer sent to the dealers, but some are still available for purchase.



Some GM diagnostic stations used through the years. ↑ The middle one was the earliest called the CAMS machine (forgot what the acronym meant!) with a neat touch screen and was used in the mid-eighties. The upper one was used in the mid nineties and the lower one up until a few years ago.

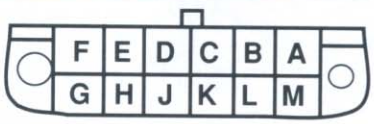
A huge change in automotive systems came about in 1996 with the advent of an EPA protocol called OBD 2 or Onboard Diagnostics second generation. The previous EPA standard which required a check engine light and engine monitoring system was called OBD 1, but each different manufacturer used a different connector, different communications protocols and different codes for faults. It was very expensive for independent garages to find out dealer proprietary information and having to buy different adapters and test tools caused a lot of cars to go unfixed due to the lack of info and high dealer repair costs. I do recall a number of vehicles where the light bulb in the check engine light was simply removed to appease the customer! The new OBD2 protocol required all vehicles sent to the USA, regardless of manufacturer to have a standardized 16 pin connector, standardized protocols and to have trouble codes be the same for all manufacturers. Of course each car company could also have their own specific codes, but an independent garage would now be able to know what all vehicle codes meant. The standards for monitoring systems also got stricter with parts turning on the check engine light when they were *starting* to fail rather than after complete failure. Vehicle emissions were also made stricter. During OBD 1, a vehicles computer would be generic to a few models and have a removable chipset (PROM) with the vehicle specific info in it. The OBD 2 standards required a vehicle to have a soldered in EEPROM that was programmed at the factory with vehicle specific programming to prevent the amount of tampering by garages and consumers changing their "chip" to a performance one that didn't meet emissions standards. Because of this programmable feature, new vehicles could simply be reprogrammed or "reflashed" to fix certain problems caused by software glitches that in the past would have required hardware changes. This happens quite often nowadays with computers being updated frequently to fine tune vehicle systems.

TERMINAL IDENTIFICATION

The various on-board microprocessors interface with the Tech 2 through the DLC. Examples of such microprocessors are the :

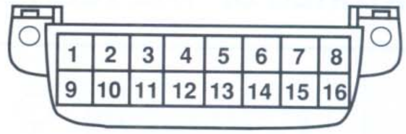
- ABS - Anti-Lock Brake System Control Module
- BCM - Body Control Module
- DERM - Diagnostic Energy Reserve Module for S.I.R.
- ECM - Electronic Control Module
- PCM - Powertrain Control Module
- TCM - Transmission Control Module
- VCM - Vehicle Control Module

The DLC connector allows access to monitor data and control some of the microprocessor's operations (figures 1-5 and 1-6). The Tech 2 reads the serial data signal from the DLC connector and translates that signal into the information provided on the Tech 2 display screen.



A	DLC Ground
B	Diagnostic Request (ECM)
C	AIR Solenoid
D	Malfunction Indicator Lamp
E	Serial Data Link (160 baud)
F	Torque Converter Clutch Solenoid
G	Fuel Pump
H	Anti-Lock Brake System
J	Entertainment and Comfort
K	SIR Diagnostic Request
L	Serial Data Loop (8192 baud)
M	Serial Data Link (8192 baud)

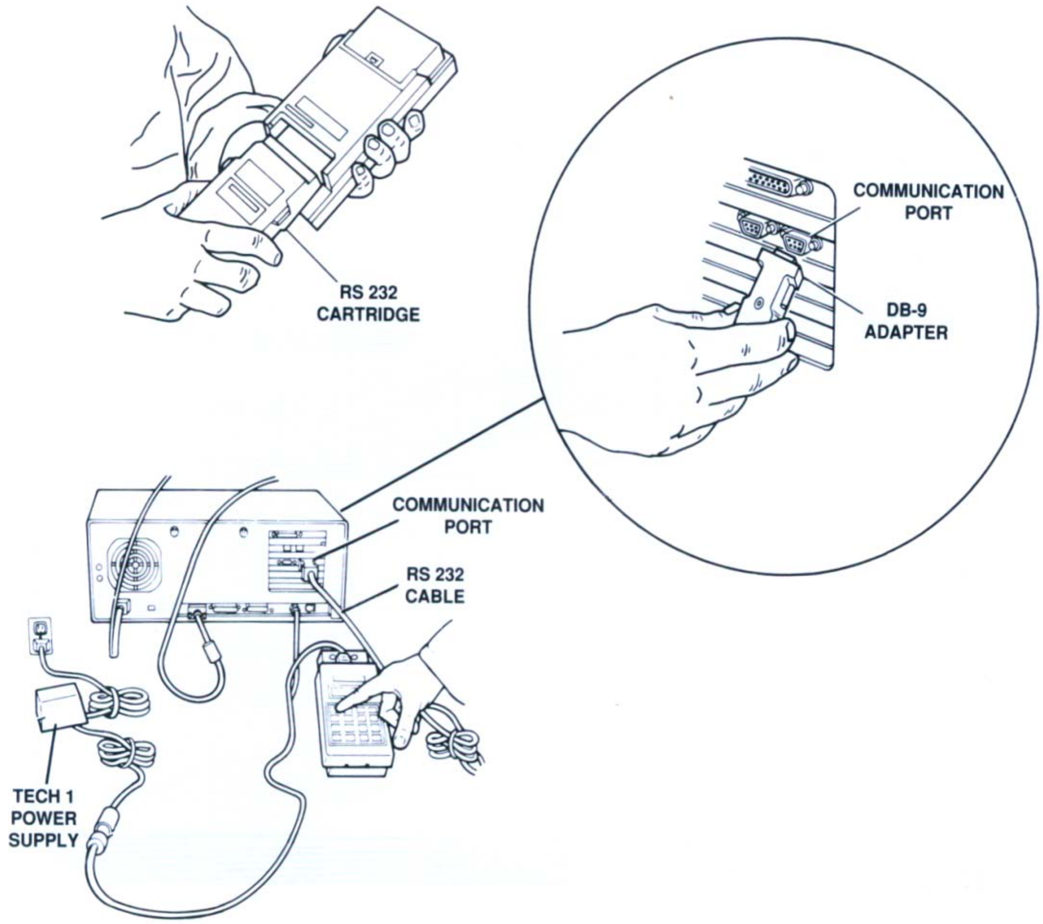
Figure 1-5, **DLC (12 PIN) Identification (Typical)**



1	Secondary UART 8192 Baud Serial Data (CKT 800), Secondary Class B (CKT 710) or 160 Baud Serial Data (1995 only) (CKT 461)
2	J1850 Bus + L Line on 2-Wire Systems, or Single Wire (Class 2) (CKT 1807)
3	Ride Control Diagnostic Enable (CKT 1826)
4	Chassis/Body Ground Pin (CKT 150)
5	Signal Ground Pin (CKT 451)
6	PCM/VCM Diagnostic Enable (CKT 448)
7	K Line for International Standards Organization (ISO) Application
8	Keyless Entry Enable (CKT 1455) or MRD Theft Diagnostic Enable (CKT 477)
9	Primary UART (CKT 1061)
10	J1850 Bus-Line for J1850-2 Wire Applications
11	Electronic Variable Orifice (EVO) Steering (CKT 1294) or Magnetic Steering Variable Assist (MSVA)
12	ABS Diagnostic (CKT 799) or CCM Diagnostic Enable (CKT 555)
13	SIR Diagnostic Enable (CKT 326)
14	E&C Bus (CKT 835)
15	L Line for International Standards Organization (ISO) Application
16	Battery Power from Vehicle Unswitched (4 AMP MAX.)

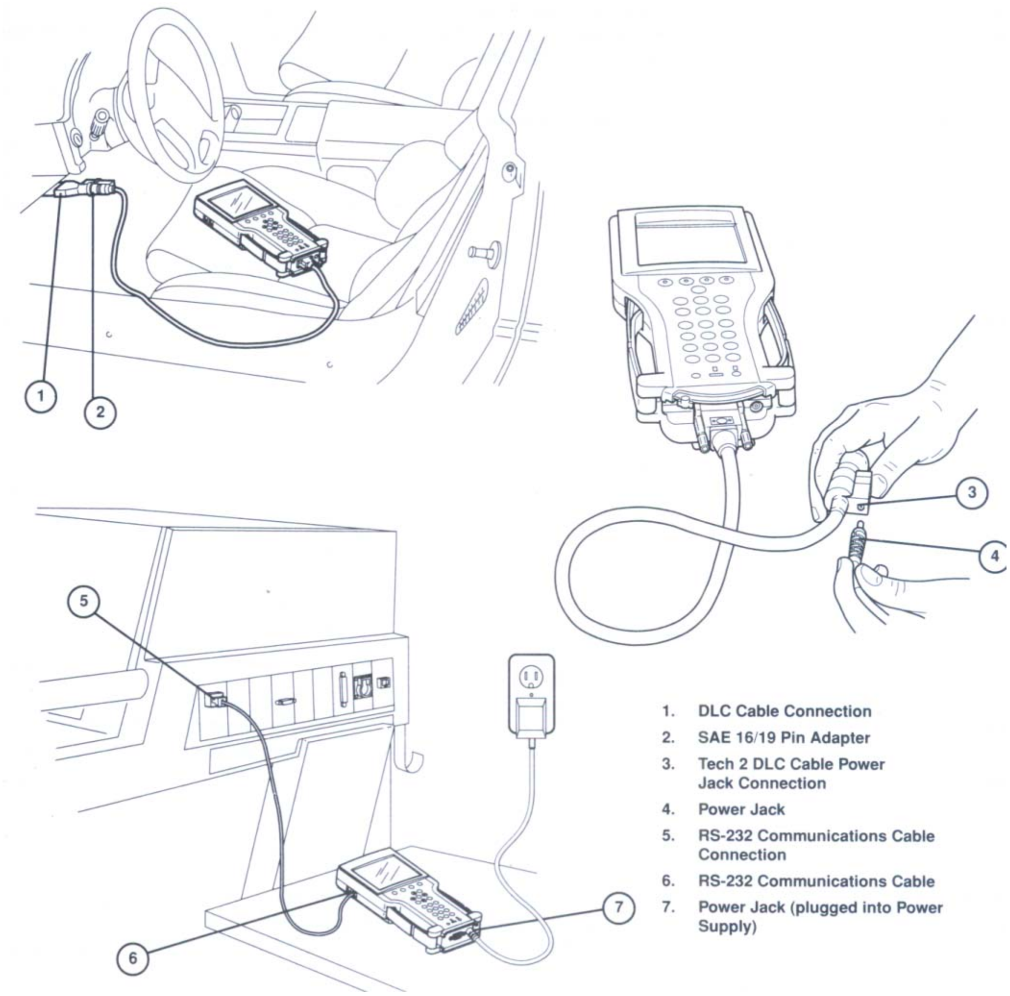
Figure 1-6, **DLC (16 PIN) Identification (Typical)**

Old 12 pin connector and new standardized OBD2 16 pin connector ↑



Training material illustrations showing Tech 1 scan tool hookup to PC for car module ↑ reprogramming.

With these new standards GM issued a new scan tool in 1996 called the Tech 2. This new tool had a more powerful processor and storage capability to interface with both the vehicle and a PC to download and transfer new software updates to vehicle computers. While the TECH 1 could do this, file sizes were becoming larger than its memory capacity. The Tech 2 had considerably more memory. The software programming for both tools is done with a RJ-45 hook-up to a PC's serial port using the RS-232 protocol. This scan tool also has much more data that could be observed in real time and has bidirectional control to operate different computer outputs for diagnosis. This tool is a vast improvement over the Tech 1 which was becoming old and underpowered. The Tech 1 also only supported UART and very limited class 2 data with a needed adapter to read class 2 data.

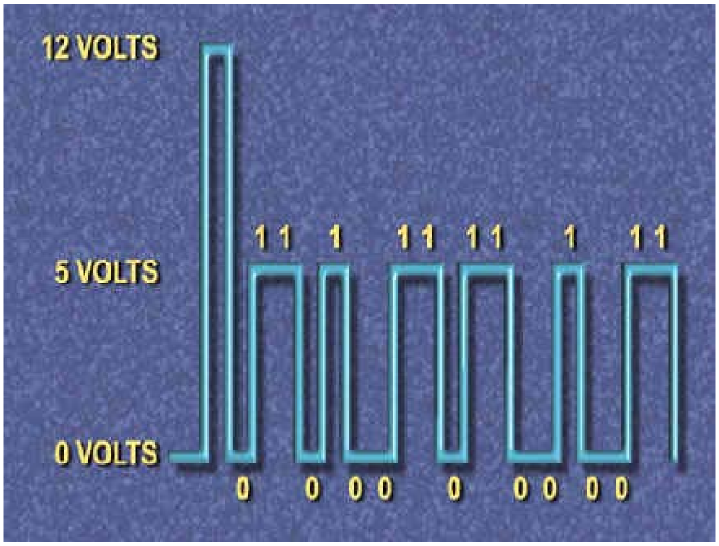


The new Tech 2 hookup which is similar to the Tech 1 but a little easier. ↑

The new OBD 2 standard also mandated communication codes that would set when modules on an automotive network lost communication with another on the network. The amount of modules on a single vehicle network is increasing rapidly with the 1998 Cadillac Seville having 18 modules networked together, talking continuously. The 2007 Tahoe has 25 modules in its network, 2007 Corvette with 21! This monitoring of the network is achieved by having each module send out a pulse every two seconds called a “state of health” pulse; ….ECM here, I’m OK … BCM here, I’m OK … etc. When a state of health pulse isn’t received by another module or when a module attempts to communicate with another and doesn’t receive a response, a communication code will set in the transmitting module. A bad module will end up having codes set in all the other modules about the bad module. A network communication code has the prefix "U", for example, U1000 will set if the modules know there is a loss of communications but don't know where it came from. Codes also have identifiers attached to them, for instance, the PCM is always module 016 so if it is the bad module, the other ones will set U1016, the EBCM causing a code U1064, etc.

Well, as any technology becomes too slow or inefficient, UART and class 2 data shared the same fate. UART basically went away and class 2 data became the slow one. Introduced in 1997 the Cadillac Catera and a few other GM vehicles had a new high speed data bus called **CAN,** short for Controller Area Network. CAN was the system being developed in the European market as our class 2 and UART were being used. CAN protocol uses two different buses, high and low, to deliver data at two different speeds. CAN data uses values of 5 and 0 volts for its binary data and uses an initial pulse of 12 volts to "turn" a module on that had been offline. This was used with the engine, transmission, and brake controllers and class 2 was used for the other modules. CAN uses bits to identify the priority of the message and the type of message (engine coolant temp info etc.). Only the modules that have that message type stored in their acceptance list will process that packet. If multiple messages are sent, the one with the highest priority will be accepted and the others will have to wait. If a module doesn't get to transmit its message, it will listen until the network isn't busy and then retransmit its message. The increased speeds of the CAN signals give better control of drivability as data is processed in real-time with no lag. The use of CAN, in addition to being a lot quicker, also makes our protocol compatible to that of the many European automakers.

A newer form of this CAN system is called the GM **LAN** system (Local Area Network). This uses the CAN protocol but has three speeds of the CAN bus. The high speed CAN is used for all real-time decisions such as fuel injection, transmission and brake operation. This uses a two wire bus and operates at a speed of 500 kbps. Low speed and mid speed buses use a one wire bus. The mid speed CAN is used for entertainment such as DVD player graphics where a lot of info has to be transmitted quickly; it is not currently being implemented. The mid speed bus would run around 95.2 kbps. The low speed is used for functions that the driver selects such as HVAC functions. Response time for low speed is 100 – 200ms. Low speed bus runs at around 33.33 kbps with programming at 83.33 kbps. Gateway modules would interface the different speed buses together.



GM LAN high speed bus waveform. ↑

The future is migrating toward even faster systems. While the LAN mid speed bus was originally going to control graphics in vehicles, technology advances in both networking and graphics technology have started to even surpass that! As LAN was even being developed, a fiber optic system was being developed for some graphics applications in car DVD players and dashboard screens. The GM **MOST** system (Media Oriented System Transfer) is used on the Saab 9-3 and has a baud rate of 25 Mbps. This uses 3mm cables with a 1mm center fiber optic core. This system is limited to use within the cars interior cabin due to the punishing conditions outside. It uses a class one laser to initiate the light pulses. It uses a ring *and* star topology with the radio being the master of the bus and the gateway to other networks within the vehicle. The modules are all awakened by the key on signal with the star pattern and then the modules use a token ring style protocol to do their business.

As you can see the automotive control systems are far beyond what most people realize. I could probably write another 10 pages on the fifty or so modules that I haven't talked about such as the RIM, DIM, ELC, etc. They have advanced just as PC and network technology have done in the non automotive setting. Because of this increased complexity and the fact that wages for automotive technicians (can't call them mechanics anymore) haven't increased in proportion to the technology, there is a real shortage of people willing to fix these complex systems. Working for GM for the last 15 years I have watched all these systems evolve from the simple systems that were around in the eighties to the ridiculously complex systems nowadays. I think sometimes of the vulnerability of some of these vehicles to outside influences. An intense solar flare could potentially cause millions of vehicles to simply stop working as they are so dependent on computer technology. I'm not quite sure what the future holds for the auto industry, perhaps soon we will see robots working on our cars, I know the technician base is rapidly dwindling and the new technicians not necessarily seeing a big incentive to join it's ranks. I, myself, am getting my college degree to find some more respectable work that gets a little more recognition along with a better paycheck. Only time will tell.

Sources:

I'm sorry for the length; I actually edited a few pages out. Most of this is just common knowledge of what I might have more of an inside line on, having watched the evolvement of these systems go on throughout the years. I just sat down and started writing and when I stopped five or six hours later, I had around 25 pages written. I did consult a few of my training materials and the picture sources are listed below.

Oldsmobile Service Alert (reference guide), "The 3100 Engine (1994)-Diagnostic Information" January 1994

Oldsmobile Service Alert (reference guide), "Data Lines – Look Who's Riding the Bus!" December 1994

Tech 2 Familiarization Course #16018.15-1 course guide 1995

Oldsmobile Service Alert (reference guide), "The Cutlass's BFC, the Intrigue's BCM and the Class 2 Serial Data Line" August 1997

http://www.gmtcny.com/lan.htm … color picture of waveform