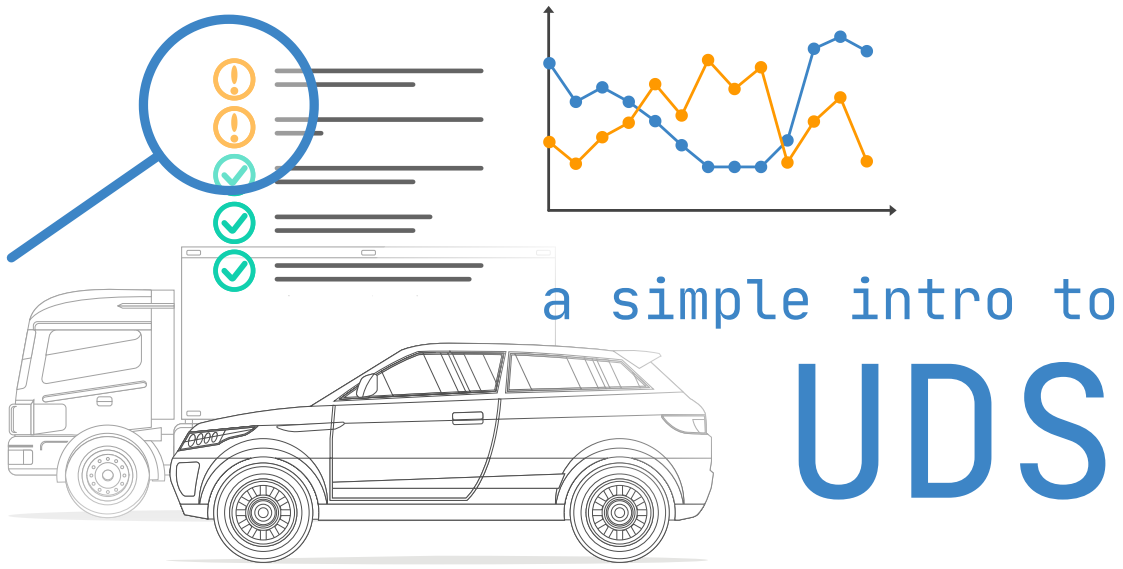
UDS Explained - A Simple Intro (Unified Diagnostic Services)



Need a simple intro to UDS (Unified Diagnostic Services)?

In this practical tutorial, we introduce the UDS basics with focus on UDS on CAN bus (UDSonCAN) and Diagnostics over CAN (DoCAN). We also introduce the ISO-TP protocol and explain the difference between UDS, OBD2, WWH-OBD and OBDonUDS.

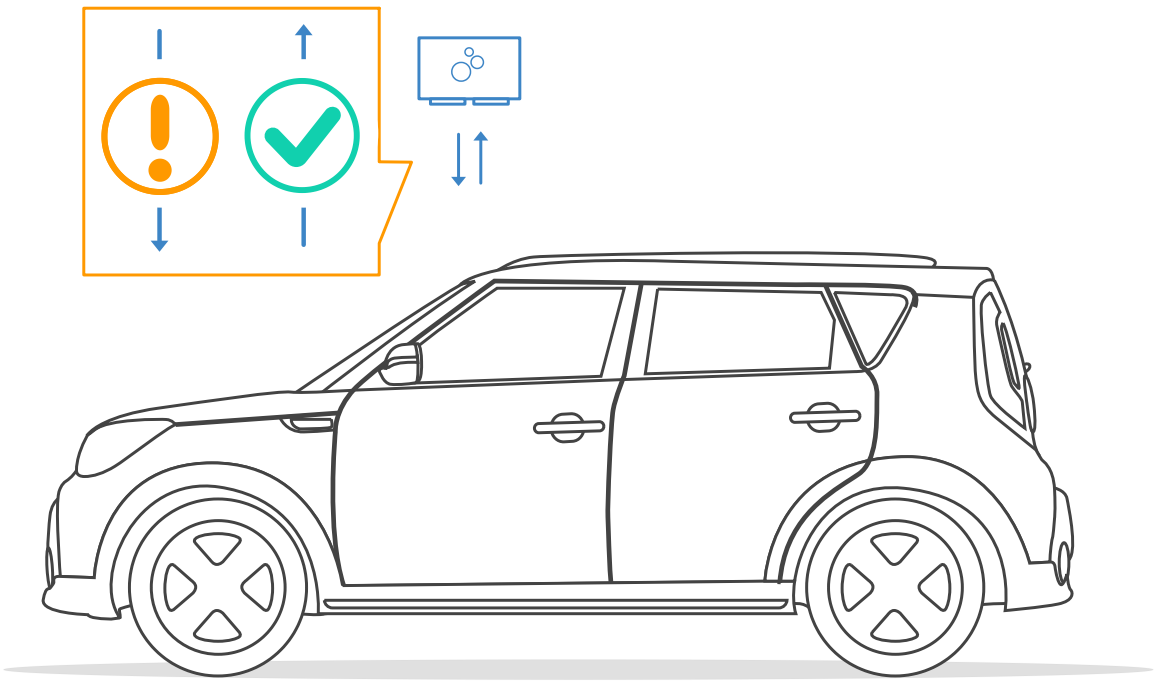
Finally, we'll explain how to request, record & decode UDS messages - with practical examples for logging EV State of Charge and the Vehicle Identification Number (VIN).

What is the UDS protocol?

Unified Diagnostic Services (UDS) is a communication protocol used in automotive Electronic Control Units (ECUs) to enable diagnostics, firmware updates, routine testing and more.

The UDS protocol (ISO 14229) is standardized across both manufacturers *and* standards (such as CAN, KWP 2000, Ethernet, LIN). Further, UDS is today used in ECUs across all tier 1 Original Equipment Manufacturers (OEMs).

In practice, UDS communication is performed in a client-server relationship - with the client being a tester-tool and the server being a vehicle ECU. For example, you can connect a CAN bus interface to the OBD2 connector of a car and send UDS requests into the vehicle. Assuming the targeted ECU supports UDS services, it will respond accordingly.



In turn, this enables various use cases:

- Read/clear diagnostic trouble codes (DTC) for troubleshooting vehicle issues
- Extract parameter data values such as temperatures, state of charge, VIN etc
- Initiate diagnostic sessions to e.g. test safety-critical features
- Modify ECU behavior via resets, firmware flashing and settings modification

UDS is sometimes referred to as '*vehicle manufacturer enhanced diagnostics*' or '*enhanced diagnostics*' - more on this below.

Example: Nissan Leaf SoC%

UDS and CAN ISO-TP are complex topics. As motivation, we've done a case study to show how it can be useful. Specifically, we use a CANedge2 to request data on State of Charge (SoC%) and battery temperatures from a Nissan Leaf EV.

In the example, we also add a CANmod.gps and CANmod.temp to add GNSS, IMU and temperature data.

The multiframe ISO-TP responses and CANmod signals are DBC decoded via our Python API and written to a database for visualization in Grafana dashboards. Check it out below!

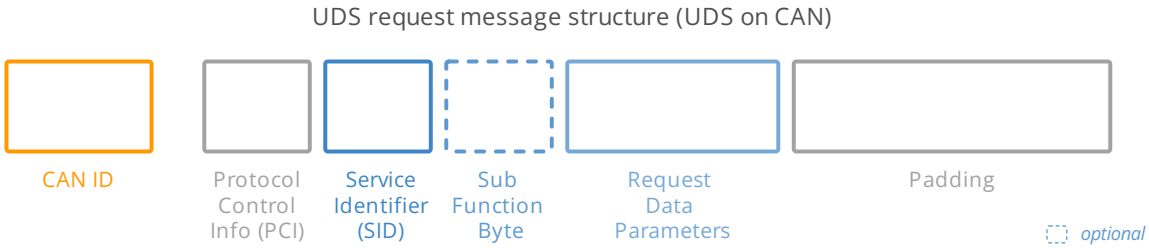
nissa leaf can bus uds case study soc

playground

case study

UDS message structure

UDS is a request based protocol. In the illustration we've outlined an example of an **UDS request frame** (using CAN bus as basis):



A diagnostic UDS request on CAN contains various fields that we detail below:

Protocol Control Information (PCI)

The **PCI** field is not per se related to the UDS request itself, but is required for diagnostic UDS requests made on CAN bus. In short, the PCI field can be 1-3 bytes long and contains information related to the transmission of messages that do not fit within a single CAN frame. We will detail this more in the section on the CAN bus transport protocol (ISO-TP).

UDS Service ID (SID)

The use cases outlined above relate to different UDS services. When you wish to utilize a specific UDS service, the UDS request message should contain the **UDS Service Identifier (SID)** in the data payload. Note that the identifiers are split between request SIDs (e.g. 0x22) and response SIDs (e.g. 0x62). As in OBD2, the response SIDs generally add 0x40 to the request SIDs.

See also the overview of all standardized UDS services and SIDs. We will mainly focus on UDS service 0x22 in this article, which is used to read data (e.g. speed, SoC, temperature, VIN) from an ECU.

UDS service identifiers (SIDs)

	UDS SID (request)	UDS SID (response)	Service	Details
Diagnostic and Communications Management	0x10	0x50	Diagnostic Session Control	Control which UDS services are available
	0x11	0x51	ECU Reset	Reset the ECU ("hard reset", "key off", "soft reset")
	0x27	0x67	Security Access	Enable use of security-critical services via authentication
	0x28	0x68	Communication Control	Turn sending/receiving of messages on/off in the ECU
	0x29	0x69	Authentication	Enable more advanced authentication vs. 0x27 (PKI based exchange)
	0x3E	0x7E	Tester Present	Send a "heartbeat" periodically to remain in the current session
	0x83	0xC3	Access Timing Parameters	View/modify timing parameters used in client/server communication
	0x84	0xC4	Secured Data Transmission	Send encrypted data via ISO 15764 (Extended Data Link Security)
	0x85	0xC5	Control DTC Settings	Enable/disable detection of errors (e.g. used during diagnostics)
	0x86	0xC6	Response On Event	Request that an ECU processes a service request if an event happens
	0x87	0xC7	Link Control	Set the baud rate for diagnostic access
Data Transmission	0x22	0x62	Read Data By Identifier	Read data from targeted ECU - e.g. VIN, sensor data values etc.
	0x23	0x63	Read Memory By Address	Read data from physical memory (e.g. to understand software behavior)
	0x24	0x64	Read Scaling Data By Identifier	Read information about how to scale data identifiers
	0x2A	0x6A	Read Data By Identifier Periodic	Request ECU to broadcast sensor data at slow/medium/fast/stop rate
	0x2C	0x6C	Dynamically Define Data Identifier	Define data parameter for use in 0x22 or 0x2A dynamically
	0x2E	0x6E	Write Data By Identifier	Program specific variables determined by data parameters
	0x3D	0x7D	Write Memory By Address	Write information to the ECU's memory
DTCs	0x14	0x54	Clear Diagnostic Information	Delete stored DTCs
	0x19	0x59	Read DTC Information	Read stored DTCs, as well as related information
	0x2F	0x6F	Input Output Control By Identifier	Gain control over ECU analog/digital inputs/outputs
Upload/ Download	0x31	0x71	Routine Control	Initiate/stop routines (e.g. self-testing, erasing of flash memory)
	0x34	0x74	Request Download	Start request to add software/data to ECU (incl. location/size)
	0x35	0x75	Request Upload	Start request to read software/data from ECU (incl. location/size)
	0x36	0x76	Transfer Data	Perform actual transfer of data following use of 0x74/0x75
	0x37	0x77	Request Transfer Exit	Stop the transfer of data
	0x38	0x78	Request File Transfer	Perform a file download/upload to/from the ECU
		0x7F	Negative Response	Sent with a Negative Response Code when a request cannot be handled

UDS SIDs vs other diagnostic services

The standardized UDS services shown above are in practice a subset of a larger set of diagnostic services - see below overview. Note here that the SIDs 0x00 to 0x0F are reserved for legislated OBD services (more on this later).

Diagnostic service identifiers - overview (0x00 - 0xFF)

Service Identifier (SID)	Service type	Further details
0x00 - 0x0F	OBD service requests	ISO 15031-5
0x00 - 0x3E	**ISO 14229 (requests)**	**ISO 14229**
0x3F	Not applicable	Reserved
0x40 - 0x4F	OBD service responses	ISO 15031-5
0x50 - 0x7E	**ISO 14229 (responses)**	**ISO 14229**
0x7F	Negative response SID	ISO 14229
0x80	Not applicable	ISO 14229 (reserved)
0x81 - 0x82	Not applicable	ISO 14229 (reserved)
0x83 - 0x88	**ISO 14229 (requests)**	**ISO 14229**
0x89 - 0x9F	Service requests	Reserved
0xA0 - 0xB9	Service requests	Defined by vehicle OEM
0xBA - 0xBE	Service requests	Defined by systems OEM
0xBF	Not applicable	Reserved
0xC0	Not applicable	ISO 14229 (reserved)
0xC1 - 0xC2	Not applicable	ISO 14229 (reserved)
0xC3 - 0xC8	**ISO 14229 (responses)**	**ISO 14229**
0xC9 - 0xDF	Service responses	Reserved
0xE0 - 0xF9	Service responses	Defined by vehicle OEM
0xFA - 0xFE	Service responses	Defined by systems OEM
0xFF	Not applicable	Reserved

UDS request SIDs UDS positive response SIDs UDS negative response SID

UDS security via session-control (authentication)

As evident, UDS enables extensive control over the vehicle ECUs. For security reasons, critical UDS services are therefore restricted through an authentication process. Basically, an ECU will send a 'seed' to a tester, who in turn must produce a 'key' to gain access to security-critical services. To retain this access, the tester needs to send a 'tester present' message periodically.

In practice, this authentication process enables vehicle manufactures to restrict UDS access for aftermarket users and ensure that only designated tools will be able to utilize the security-critical UDS services.

Note that the switching between authentication levels is done through diagnostic session control, which is one of the UDS services available. Vehicle manufactures can decide which sessions are supported, though they must always support the 'default session' (i.e. which does not involve any authentication). With that said, they decide what services are supported within the default session as well. If a tester tool switches to a non-default session, it must send a 'tester present' message periodically to avoid being returned to the default session.

UDS Sub Function Byte

The **sub function byte** is used in *some* UDS request frames as outlined below. Note, however, that in some UDS services, like 0x22, the sub function byte is not used.

Generally, when a request is sent to an ECU, the ECU may respond positively or negatively. In case the response is positive, the tester may want to suppress the response (as it may be irrelevant). This is done by setting the 1st bit to 1 in the sub function byte. Negative responses cannot be suppressed.

The remaining 7 bits can be used to define up to 128 sub function values. For example, when reading DTC information via SID 0x19 (Read Diagnostic Information), the sub function can be used to control the report type - see also below table.

UDS services - sub function types

UDS SID (request)	UDS SID (response)	Service	Sub function types
0x10	0x50	Diagnostic Session Control	Diagnostic session type
0x11	0x51	ECU Reset	Reset type
0x27	0x67	Security Access	Security access type
0x28	0x68	Communication Control	Control type
0x3E	0x7E	Tester Present	"Zero sub function"
0x83	0xC3	Access Timing Parameters	Timing parameter access type
0x85	0xC5	Control DTC Settings	DTC setting type
0x86	0xC6	Response On Event	Event type
0x87	0xC7	Link Control	Link control type
0x2C	0x6C	Dynamically Define Data Identifier	Definition type
0x19	0x59	Read DTC Information	Report type
0x31	0x71	Routine Control	Routine control type

Example: Service 0x19 sub functions

If we look specifically at service 0x19, we can see an example of the various sub functions below:

UDS service 0x19 - sub function byte values & types

UDS SID (request)	UDS SID (response)	Report type (sub function value)	Report
0x19	0x59	0x01	Number of DTC by status mask
		0x02	DTC by status mask
		0x03	DTC snapshot identification
		0x04	DTC snapshot record by DTC number
		0x05	DTC stored data by record number
		0x06	DTC extended data record by DTC number
		0x07	Number of DTC by severity mask record
		0x08	DTC by severity mask record
		0x09	Severity information of DTC
		0x0A	Supported DTC
		0x0B	First failed DTC
		0x0C	First confirmed DTC
		0x0D	Most recent failed DTC
		0x0E	Most recent confirmed DTC
		0x0¤	Mirror memory DTC by status mask
		0x10	Mirror memory DTC by DTC number
		0x11	Number of mirror memory DTC by status mask
		0x12	Number of emissions OBD DTC by status mask
		0x13	Emissions OBD DTC by status mask
		0x14	DTC fault detection counter
		0x15	DTC with permanent status
		0x16	DTC extended data record by record number
		0x17	User defined memory DTC by status mask
		0x18	User defined memory DTC snapshot by number
		0x19	User defined memory DTC record by number
		0x42	WWH-OBD DTC by status mask record
		0x55	WWH-OBD DTCs with permanent status

UDS 'Request Data Parameters' - incl. Data Identifier (DID)

In most UDS request services, various types of **request data parameters** are used to provide further configuration of a request beyond the SID and optional sub function byte. Here we outline two examples.

Service 0x19 (Read DTC information) -request configuration

For example, service **0x19** lets you read DTC information. The UDS request for SID 0x19 includes a sub function byte - for example, 0x02 lets you read DTCs via a status mask. In this specific case, the sub function byte is followed by a 1-byte parameter called DTC Status Mask to provide further information regarding the request. Similarly, other types of sub functions within 0x19 have specific ways of configuring the request.

Service 0x22 (Read data by Identifier) - Data Identifiers

Another example is service **0x22** (Read Data by Identifier). This service uses a Data Identifier (DID), which is a 2-byte value between 0 and 65535 (0xFFFF). The DID serves as a parameter identifier for both requests/responses (similar to how the parameter identifier, or PID, is used in OBD2).

For example, a request for reading data via a single DID in UDS over CAN would include the PCI field, the UDS service 0x22 and the 2-byte DID. Alternatively, one can request data for additional DIDs by adding them after the initial DID in the request.

We will look further into this in the section on how to record and decode UDS communication.

Data Identifiers can be proprietary and only known by OEMs, though some DIDs are standardized. This is for example the case for the WWH-OBD DIDs (more on this later) and the Vehicle Identification Number (VIN) is 0xF190. See the separate table for a list of standardized DIDs across UDS.

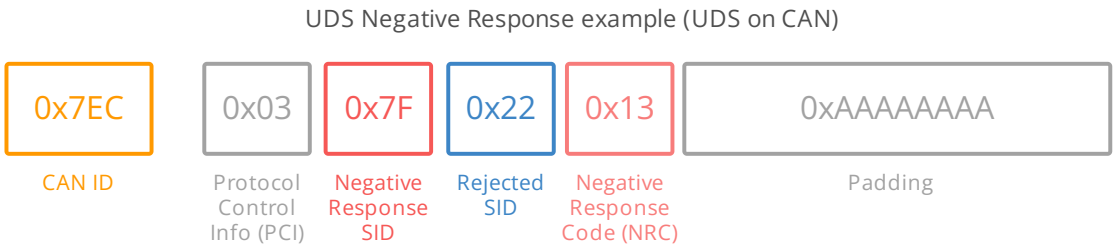
UDS - standardized data identifiers (DID)

UDS DID (data identifier)	Description
0xF180	Boot software identification
0xF181	Application software identification
0xF182	Application data identification
0xF183	Boot software fingerprint
0xF184	Application software fingerprint
0xF185	Application data fingerprint
0xF186	Active diagnostic session
0xF187	Manufacturer spare part number
0xF188	Manufacturer ECU software number
0xF189	Manufacturer ECU software version
0xF18A	Identifier of system supplier
0xF18B	ECU manufacturing date
0xF18C	ECU serial number
0xF18D	Supported functional units
0xF18E	Manufacturer kit assembly part number
0xF190	Vehicle Identification Number (VIN)
0xF192	System supplier ECU hardware number
0xF193	System supplier ECU hardware version number
0xF194	System supplier ECU software number
0xF195	System supplier ECU software version number
0xF196	Exhaust regulation/type approval number
0xF197	System name / engine type
0xF198	Repair shop code / tester serial number
0xF199	Programming date
0xF19D	ECU installation date
0xF19E	ODX file

Positive vs. negative UDS responses

When an ECU responds positively to an UDS request, the response frame is structured with similar elements as the request frame. For example, a 'positive' response to a service 0x22 request will contain the response SID 0x62 (0x22 + 0x40) and the 2-byte DID, followed by the actual data payload for the requested DID. Generally, the structure of a positive UDS response message depends on the service.

However, in some cases an ECU may provide a negative response to an UDS request - for example if the service is not supported. A negative response is structured as in below CAN frame example:



Details + Negative Response Code table

Below we briefly detail the negative response frame with focus on the NRC:

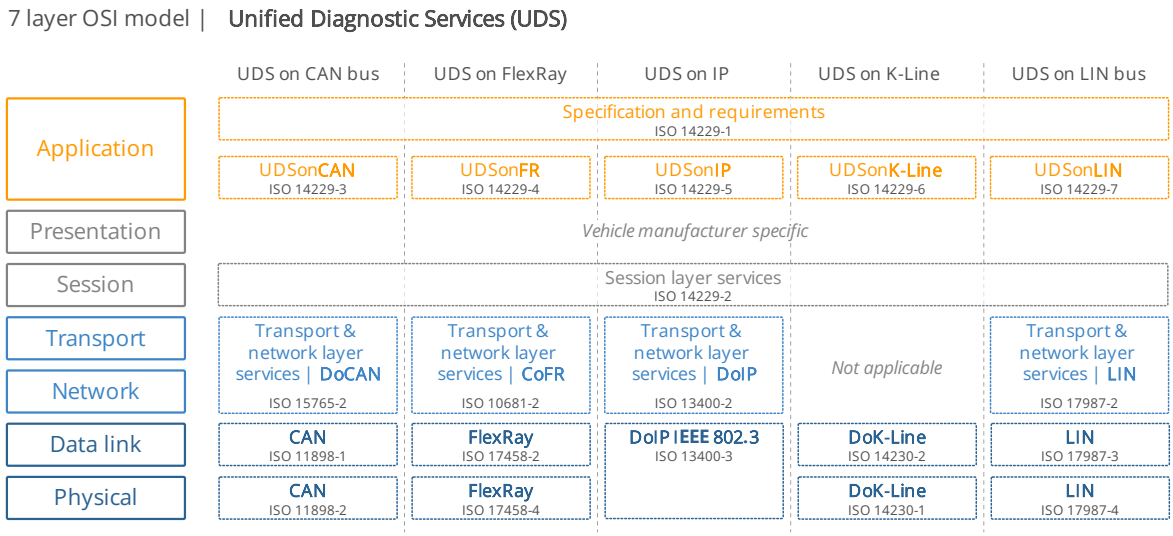
- The 1st byte is the PCI field
- The 2nd byte is the Negative Response Code SID, 0x7F
- The 3rd byte is the SID of the rejected request
- The 4th byte is the Negative Response Code (NRC)

In the negative UDS response, the NRC provides information regarding the cause of the rejection as per the table below.

UDS vs CAN bus: Standards & OSI model

To better understand UDS, we will look at how it relates to CAN bus and the OSI model.

As explained in our CAN bus tutorial, the Controller Area Network serves as a basis for communication. Specifically, CAN is described by a data-link layer and physical layer in the OSI model (as per ISO 11898). In contrast to CAN, UDS (ISO 14229) is a '**higher layer protocol**' and utilizes both the session layer (5th) and application layer (7th) in the OSI model as shown below:



Overview of UDS standards & concepts

UDS refers to a large number of standards/concepts, meaning it can be a bit overwhelming. To give you an overview, we provide a high level explanation of the most relevant ones below (with focus on CAN as the basis).

Quick overview of the UDS OSI model layers

In the following we provide a quick breakdown of each layer of the OSI model:

- **Application**: This is described by ISO 14229-1 (across the various serial data link layers). Further, separate ISO standards describe the UDS application layer for the various lower layer

protocols - e.g. ISO 14229-3 for CAN bus (aka UDSonCAN)
- **Presentation**: This is vehicle manufacturer specific
- **Session**: This is described in ISO 14229-2
- **Transport + Network**: For CAN, ISO 15765-2 is used (aka ISO-TP)
- **Data Link**: In the case of CAN, this is described by ISO 11898-1
- **Physical**: In the case of CAN, this is described by ISO 11898-2

As illustrated, multiple standards other than CAN may be used as the basis for UDS communication - including FlexRay, Ethernet, LIN bus and K-line. In this tutorial we focus on CAN, which is also the most common lower layer protocol.

ISO 14229-1 (Application Layer)

The ISO 14229-1 standard describes the application layer requirements for UDS (independent of what lower layer protocol is used). In particular, it outlines the following:

- Client-server communication flows (requests, responses, ...)
- UDS services (as per the overview described previously)
- Positive responses and negative response codes (NRCs)
- Various definitions (e.g. DTCs, parameter data identifiers aka DIDs, ...)

ISO 14229-3 (Application Layer for CAN)

The purpose of 14229-3 is to enable the implementation of Unified Diagnostic Services (UDS) on Controller Area Networks (CAN) - also known as UDSonCAN. This standard describes the application layer requirements for UDSonCAN.

This standard does not describe any implementation requirements for the in-vehicle CAN bus architecture. Instead, it focuses on some additional requirements/restrictions for UDS that are specific to UDSonCAN.

Specifically, 14229-3 outlines which UDS services have CAN specific requirements. The affected UDS services are ResponseOnEvent and ReadDataByPeriodicIdentifier, for which the CAN specific requirements are detailed in 14229-3. All other UDS services are implemented as per ISO 14229-1 and ISO 14229-2.

ISO 14229-3 also describes a set of mappings between ISO 14229-2 and ISO 15765-2 (ISO-TP) and describes requirements related to 11-bit and 29-bit CAN IDs when these are used for UDS and legislated OBD as per ISO 15765-4.

ISO 14229-2 (Session Layer)

This describes the session layer in the UDS OSI model. Specifically, it outlines service request/confirmation/indication primitives. These provide an interface for the implementation of UDS (ISO 14229-1) with any of the communication protocols (e.g. CAN).

ISO 15765-2 (Transport + Network Layer for CAN)

For UDS on CAN, ISO 15765-2 describes how to communicate diagnostic requests and responses. In particular, the standard describes how to structure CAN frames to enable communication of multi-frame payloads. As this is a vital part of understanding UDS on CAN, we go into more depth in the next section.

ISO 11898 (Physical + Data Link Layer for CAN)

When UDS is based on CAN bus, the physical and data link layers are described in ISO 11898-1 and ISO 11898-2. When UDS is based on CAN, it can be compared to a higher layer protocol like J1939, OBD2, CANopen, NMEA 2000 etc. However, in contrast to these protocols, UDS could alternatively be based on other communication protocols like FlexRay, Ethernet, LIN etc.

UDSonCAN vs DoCAN

When talking about UDS based on CAN bus, you'll often see two terms used: UDSonCAN (UDS on CAN bus) and DoCAN (Diagnostics on CAN bus). Some UDS tutorials use these terms interchangeably, which may cause confusion.

In ISO 14229-1 the terms are used as in our OSI model illustration. In other words, UDSonCAN is used to refer to ISO 14229-3, while DoCAN is used to refer to ISO 15765-2 aka ISO-TP.

However, part of the confusion may arise because ISO 14229-3 also provides an OSI model where DoCAN is both used in relation to ISO 15765-2 *and* as an overlay across OSI model layers 2 to 7. In ISO 14229-2, DoCAN is referred to as the communication protocol on which UDS (ISO 14229-1) is implemented. This is in sync with the illustration from ISO 14229-3. In this context, DoCAN can be viewed as a more over-arching term for the implementation of UDS on CAN, whereas UDSonCAN seems consistently to refer to ISO 14229-3 only.

ISO 15765-3 vs ISO 14229-3

UDS on CAN bus (UDSonCAN) is sometimes referred to through ISO 15765-3. However, this standard is now obsolete and has been replaced by ISO 14229-3.

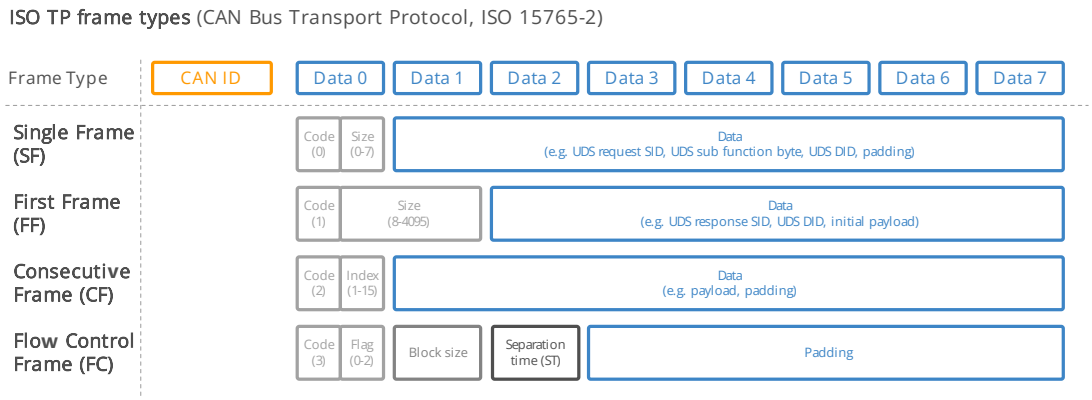
CAN ISO-TP - Transport Protocol (ISO 15765-2)

When implementing diagnostics on CAN, one challenge is the size of the CAN frame payload: For Classical CAN frames, this is limited to 8 bytes and for CAN FD the payload is limited to 64 bytes. Vehicle diagnostics often involves communication of far larger payloads.

ISO 15765-2 was established to solve the challenge of large payloads for CAN based vehicle diagnostics.

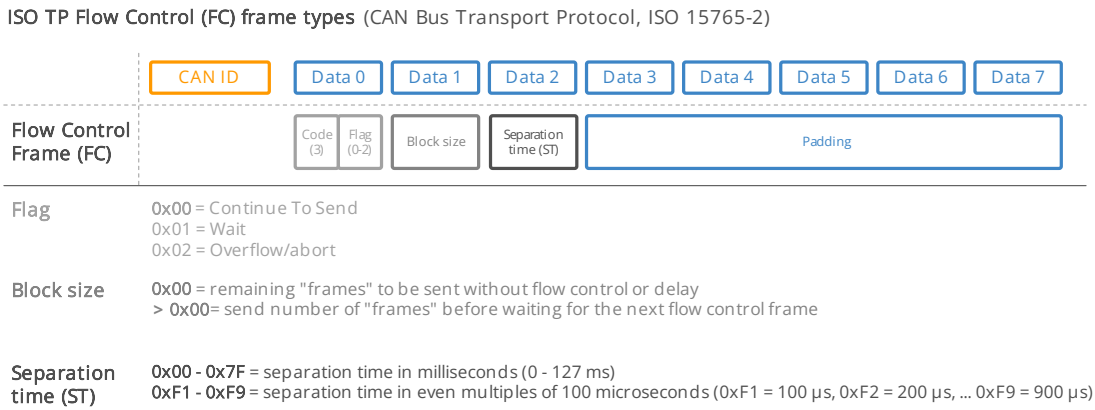
The standard specifies a transport protocol and network layer services for use in CAN based vehicle networks. The most common use cases include UDS (ISO 14229-1), OBD (SAE J1979, ISO 15031-5) and world-wide harmonized OBD aka WWH-OBD (ISO 27145).

The ISO-TP standard outlines how to communicate CAN data payloads up to 4095 bytes through **segmentation**, **flow control** and **reassembly**. ISO-TP defines specific CAN frames for enabling this communication as shown below:



Regading the Flow Control frame

The flow control frame is used to 'configure' the subsequent communication. It can be constructed as below:



Other ISO-TP frame comments

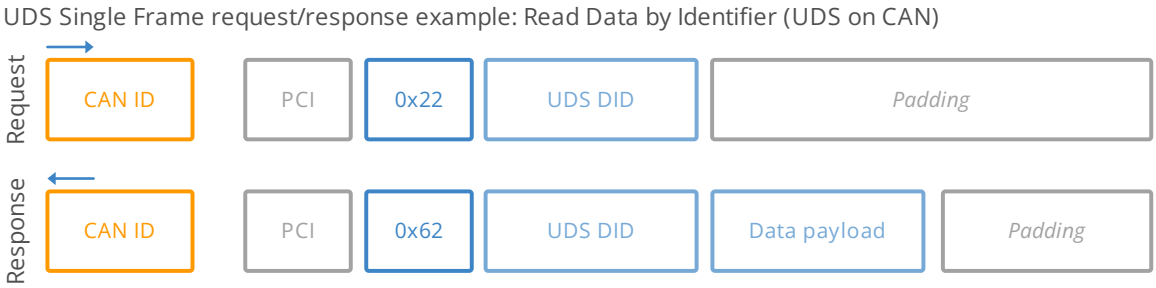
- The ISO-TP frame type can be identified from the first nibble of the first byte (0x0, 0x1, 0x2, 0x3)
- The total frame size can be up to 4095 bytes (0xFFF) as evident from the FF frame
- The CF index runs from 1 to 15 (0xF) and is then reset if more data is to be sent
- Padding (e.g. 0x00, 0xAA, ...) is used to ensure the frame payloads equal 8 bytes in length

Below we outline how the ISO-TP protocol works for single-frame and multi-frame communication:

ISO-TP: Single-frame communication

In vehicle diagnostics, communication is initiated by a tester tool sending a request. This request frame is a **Single Frame (SF)**.

In the simplest case, a tester tool sends a Single Frame to request data from an ECU. If the response can be contained in a 7-byte payload, the ECU provides a **Single Frame response**.



ISO-TP: Multi-frame communication

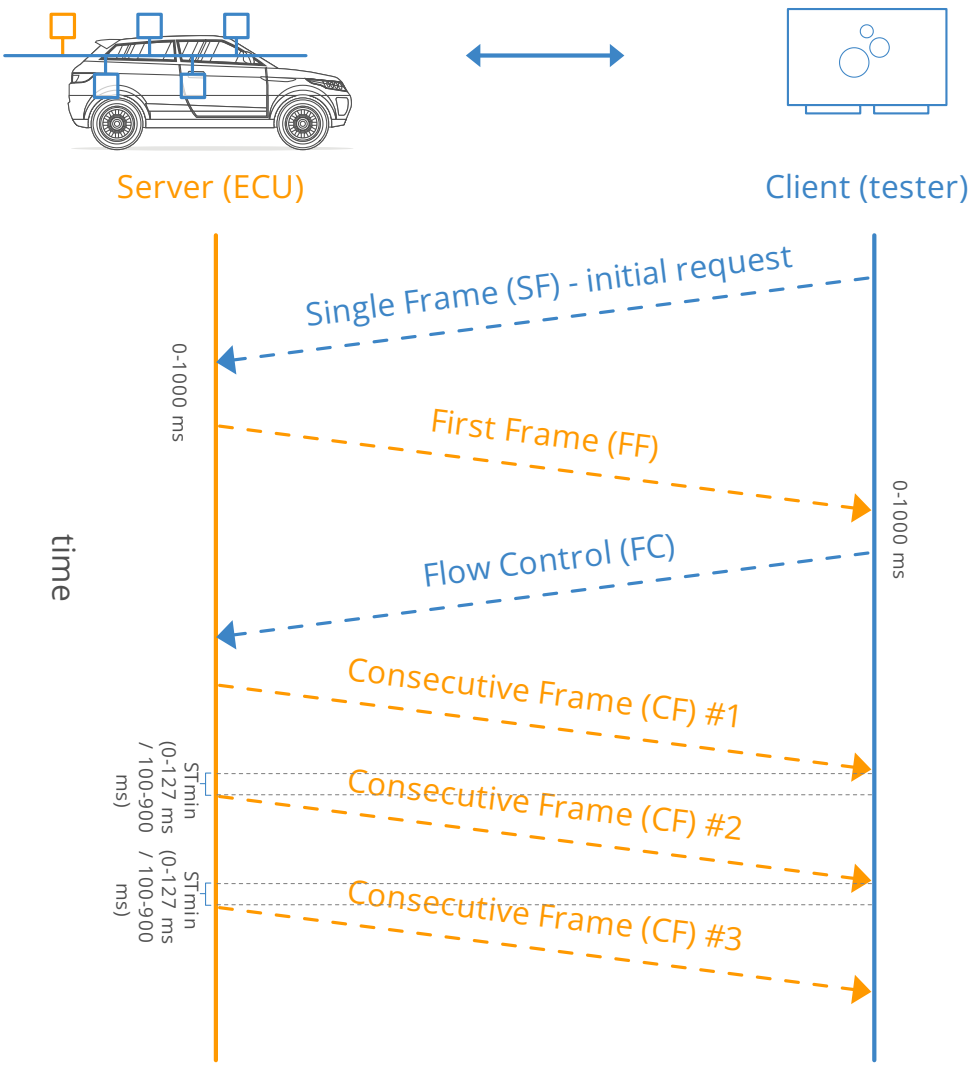
When the payload *exceeds 7 bytes*, it needs to be split across multiple CAN frames.

As before, a tester starts by sending a **Single Frame (SF)** request to an ECU (sender). However, in this case the response exceeds 7 bytes.

Because of this, the ECU sends a **First Frame (FF)** that contains information on the total packet length (8 to 4095 bytes) as well as the initial chunk of data.

When the tester receives the FF, it will send a **Flow Control (FC)** frame, which tells the ECU how the rest of the data transfer should be transmitted.

Following this, the ECU will send **Consecutive Frames (CF)** that contain the remaining data payload.



ISO-TP plays an important role in most CAN based diagnostics protocols. Before we show practical examples of such communication flows, it is useful to get an overview of the most common vehicle diagnostic protocols.

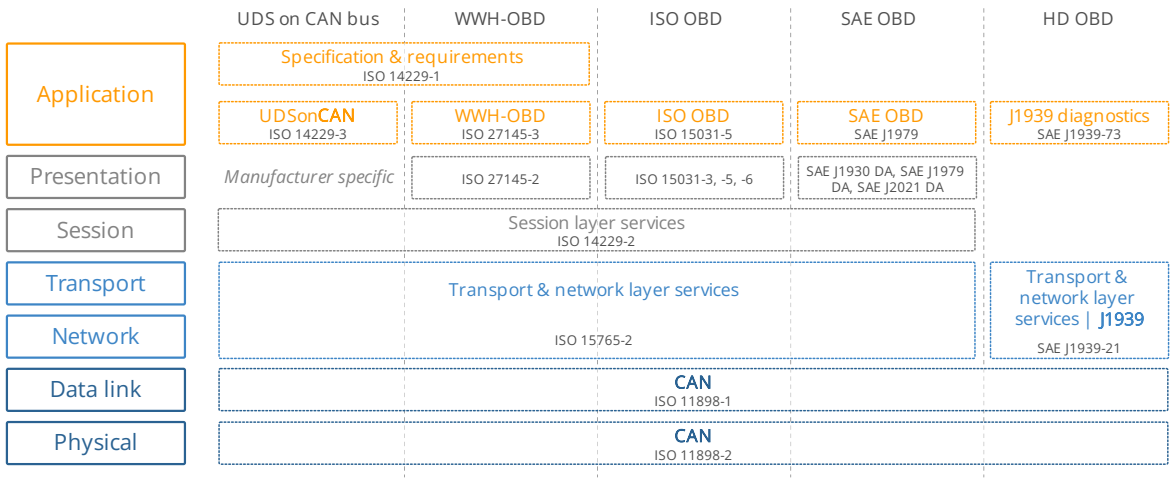
UDS vs. OBD2 vs. WWH-OBD vs. OBDonUDS

A common question is how UDS relates to On-Board Diagnostics (OBD2), World-Wide Harmonized OBD (WWH-OBD) and OBDonUDS.

To understand this, it is important to first note the following:

OBD (On-Board Diagnostics) is today implemented in different ways across countries and vehicles.

This is illustrated via the below OSI model comprising CAN based vehicle diagnostic protocols in use today:



Let's look at each diagnostic protocol:

- **ISO OBD** (or EOBD) refers to the OBD protocol specification legislated for use in EU cars, while **SAE OBD** refers to the OBD protocol specification legislated for use in US. The two are technically equivalent and hence often referred to simply as OBD or OBD2
- **HD OBD** (SAE J1939) typically refers to heavy duty OBD and is commonly implemented through the J1939 protocol in both US and EU produced vehicles with J1939-73 specifying diagnostic messages
- **UDS** (ISO 14229) has been implemented by vehicle manufacturers to serve the need for richer diagnostics data/functionality - beyond the limits of the emissions-focused OBD protocols. It is implemented in most ECUs today, across markets and vehicle types - though in itself, UDS does not offer the necessary standardization required to serve as an alternative to OBD
- **WWH-OBD** (and/or possibly **OBDonUDS**) provide an updated version of OBD2 for emissions-related diagnostics - based on UDS

To understand UDS, it is useful to better understand WWH-OBD and OBDonUDS:

What is WWH-OBD (ISO 27145)?

WWH-OBD is a global standard for vehicle diagnostics, developed by the UN under the Global Technical Regulations (GTR) mandate. It aims to provide a single, future-proof alternative to the existing OBD protocols (ISO OBD, SAE OBD, HD OBD). Further, WWH-OBD is based on UDS in order to suit the enhanced diagnostics functionality already deployed by most automotive OEMs today.

Advantages of WWH-OBD

Moving from OBD2 to WWH-OBD will involve a number of benefits, primarily derived from using the UDS protocol as the basis.

First of all, the data richness can be increased. OBD2 parameter identifiers (PID) are limited to 1 byte, restricting the number of unique data types to 255, while the UDS data identifier (DID) is 2 bytes, enabling 65535 parameters.

For diagnostic trouble codes (DTCs), OBD2 would allow for 2-byte DTCs. Here, WWH-OBD allows for 'extended DTCs' of 3 bytes. This allows for grouping DTCs by 2-byte types and using the 3rd byte as a failure mode indicator to specify the DTC sub type.

Further, WWH-OBD enables a classification of DTCs based on how severe an issue is in regards to the exhaust emissions quality.

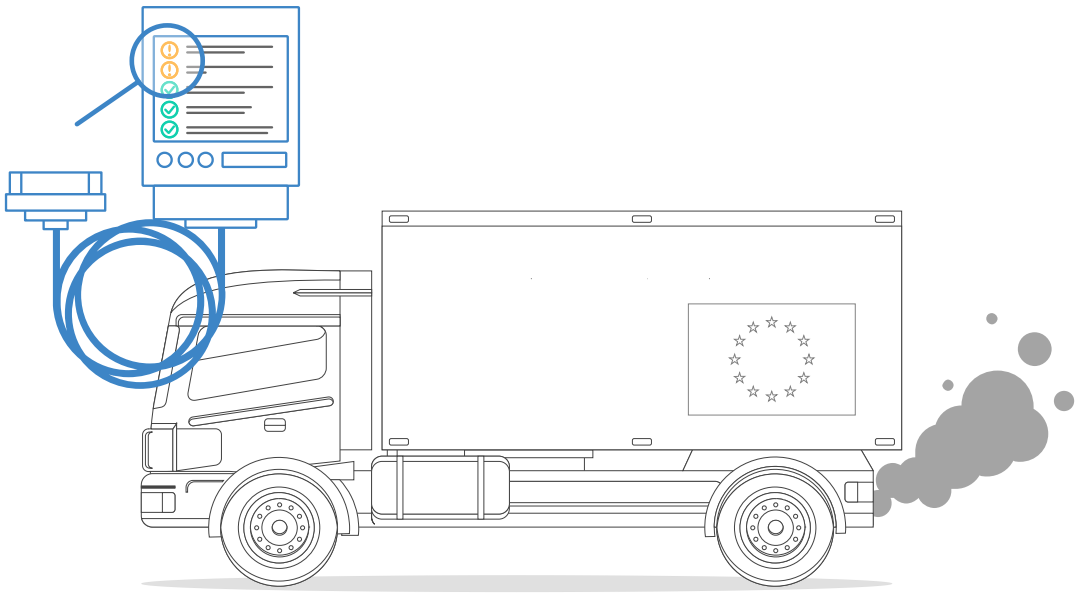
WWH-OBD also seeks to take potential future requirements into account by allowing for the Internet Protocol (IP) to be used as an alternative to CAN, meaning that UDSonIP will also be possible in future implementations of WWH-OBD. One potential benefit from this will be the ability to one day perform remote diagnostics through the same protocol.

What is the status on WWH-OBD roll-out?

The intent of WWH-OBD is to serve as a global standard, across all markets and across all vehicle types (cars, trucks, buses, ...). Further, the aim is to potentially expand the standardized functionality beyond just emissions-control.

In practice, WWH-OBD has been required in EU since 2014 for newly developed heavy duty vehicles (as per the Euro-VI standards). Note in this case that HD OBD (as per J1939) remains allowed in these vehicles.

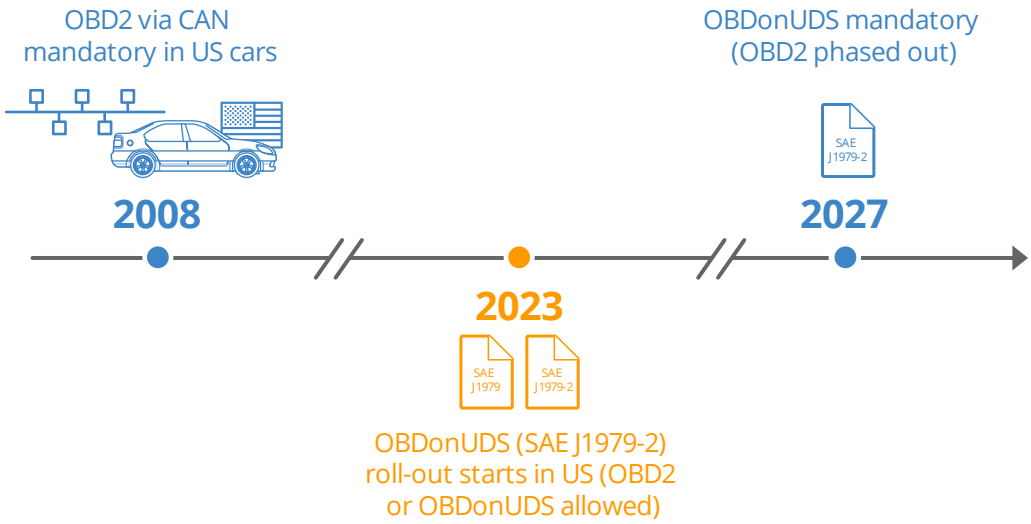
Beyond this, however, the roll-out of WWH-OBD has been limited. One challenge is that WWH-OBD is currently not accepted by EPA/CARB in USA. See e.g. this discussion for potential motivations. However, recently OBDonUDS (SAE J1979-2) is being adopted in US.



What is OBDonUDS (SAE J1979-2)?

Similar to how OBD2 has been split into 'SAE OBD' (SAE J1979) for US and 'ISO OBD' (ISO 15031) for EU, the 'next generation' of OBD2 may again be regionally split.

Specifically, WWH-OBD (ISO 21745) has been adopted in EU for heavy duty vehicles already - but not yet in the US. Instead, it has recently been decided to adopt OBD on UDS in US vehicles in the form of the SAE J1979-2 standard, which serves as an update to the SAE J1979. The new SAE J1979-2 standard is also referred to as OBDonUDS. The aim is to initiate a transition phase starting in 2023, where ECUs are allowed to support either OBD2 or OBDonUDS. From 2027, OBDonUDS will be a mandatory requirement for all vehicles produced in the US.



Looking ahead: WWH-OBD vs OBDonUDS

To recap, WWH-OBD and OBDonUDS both serve as possible solutions for creating a 'next generation" protocol for emissions-related on-board diagnostics. It remains to be seen if the two will exist in parallel (like ISO/SAE OBD), or if one of the protocols will become the de facto standard across both US, EU and beyond.

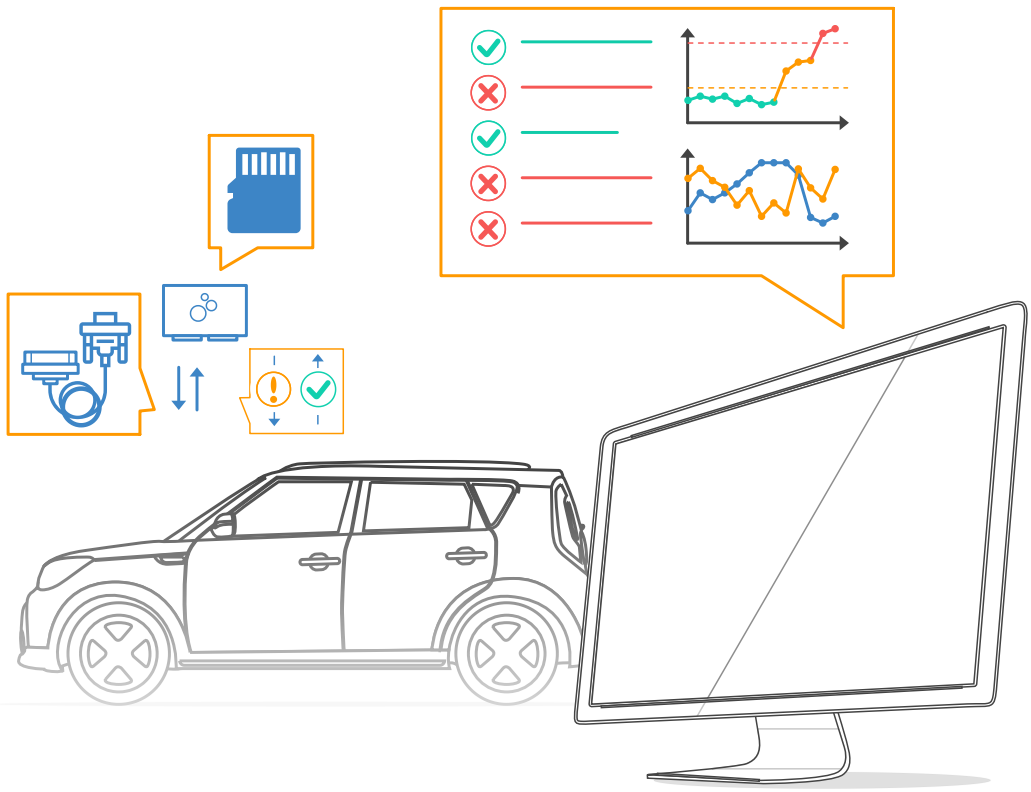
In either case, the basis for emissions-related diagnostics will be UDS, which will serve to simplify ECU programming as the emissions-related diagnostics can increasingly be implemented within the same UDS based structure as the manufacturer specific enhanced diagnostics.

FAQ: How to request/record UDS data

We have now gone through the basics of UDS and the CAN based transport protocol.

With this in place, we can provide some concrete guidance on how you can work with UDS data in practice. In particular, we will focus on how UDS can be used to log various data parameters - like state of charge (SoC) in electric vehicles.

Before the examples, we'll cover frequently asked questions on UDS data logging:

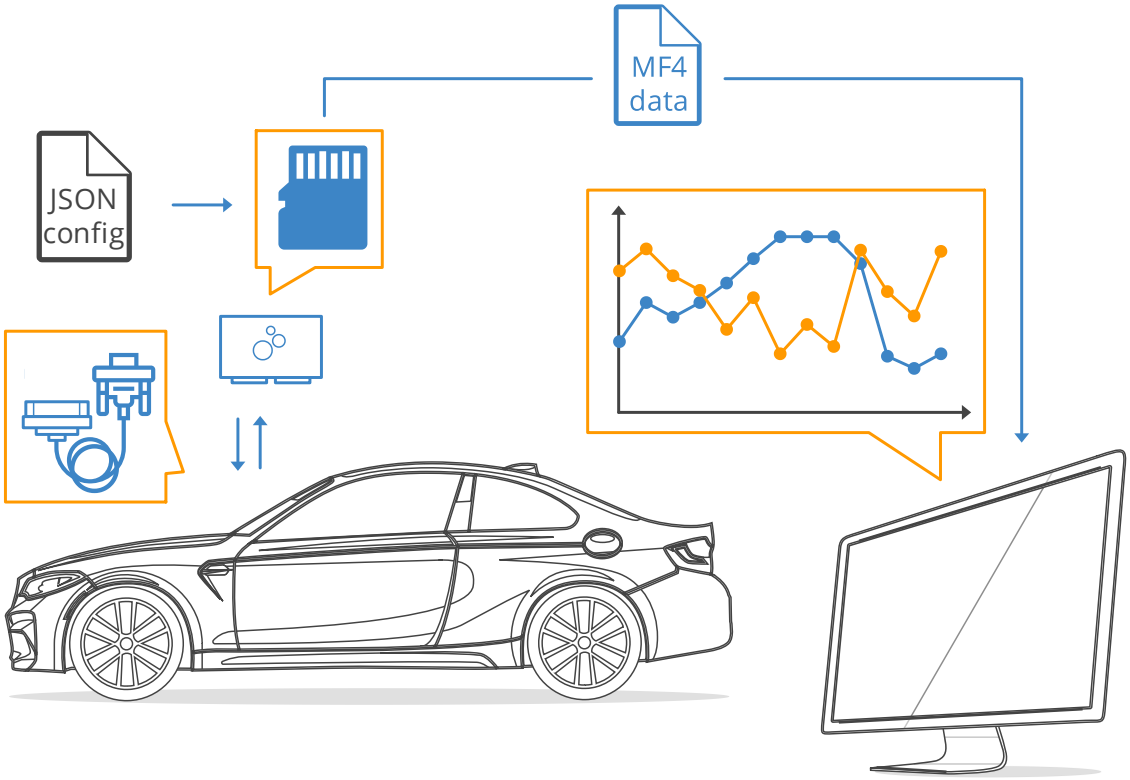


Can the CANedge record UDS data

Yes, as we'll show further below, the CANedge can be configured to request UDS data. Effectively, the device can be configured to transmit up to 64 custom CAN frames as periodic or single shot frames. You can control the CAN ID, CAN data payload, period time and delay.

For **single-frame** UDS communication, you simply configure the CANedge with the request frame, which will trigger a single response frame from the ECU.

For **multi-frame** communication, you can again configure the CANedge with a request frame and then add the Flow Control frame as a separate frame to be transmitted X milliseconds after the request frame. By adjusting the timing, you can set this up so that the Flow Control is sent after the ECU has sent the First Frame response.



Note that the CANedge will record the UDS responses as raw CAN frames. You can then process and decode this data via your preferred software (e.g. Vector tools) or our CAN bus Python API to reassemble and decode the frames.

Note: In future firmware updates, we may enhance the transmit functionality to enable the CANedge to transmit custom CAN frames based on a trigger condition, such as receiving a specific frame. This would allow for sending the Flow Control frame with a set delay after receiving the First Frame, providing a simpler and more robust implementation. With that said, the current functionality will serve to support most UDS communicated related to services 0x22 (Read Data by Identifier) and 0x19 (Read DTC Information).

What data can I log via UDS

A very common use case for recording UDS data via 'standalone' data loggers will be to acquire diagnostic trouble code values, e.g. for use in diagnosing issues.

In addition to the trouble codes, UDS lets you request the 'current value" of various sensors related to each ECU. This allows e.g. vehicle fleet managers, researchers etc. to collect data of interest such as speed, RPM, state of charge, temperatures etc. from the car (assuming they know how to request/decode the data, as explained below).

Beyond the above, UDS can of course also be used for more low-level control of ECUs, e.g. resets and flashing of firmware, though such use cases are more commonly performed using a CAN bus interface - rather than a 'standalone' device.

Is UDS data proprietary - or are there public parameters

Importantly, UDS is a manufacturer specific diagnostic protocol.

In other words, while UDS provides a standardized structure for diagnostic communication, the actual 'content" of the communication remains proprietary and is in most cases only known to the manufacturer of a specific vehicle/ECU.

For example, UDS standardizes how to request parameter data from an ECU via the 'Read Data By Identifier" service (0x22). But it does not specify a list of standardized identifiers and interpretation rules. In this way, UDS differs from OBD2, where a public list of OBD2 PIDs enable almost anyone to interpret OBD2 data from their car.

With that said, vehicles that support WWH-OBD or OBDonUDS may support some of the usual OBD2 PIDs like speed, RPM etc via the usual PID values - but with a prefix of 0xF4 as shown in Example 1 below.

Generally, only the manufacturer (OEM) will know how to request proprietary parameters via UDS - and how to interpret the result. Of course, one exception to this rule is cases where companies or individuals successfully reverse engineer this information. Engaging in such reverse engineering is a very difficult task, but you can sometimes find public information and DBC files where others have done this exercise. Our intro to DBC files contain a list of public DBC/decoding databases.

Who benefits from logging UDS data?

Because of the proprietary nature of UDS communication, it is typically most relevant to automotive engineers working at OEMs. Tools like the CANedge CAN bus data logger allow these users to record raw CAN traffic from a vehicle - while at the same time requesting diagnostic trouble codes and specific parameter values via UDS.

Further, some after market users like vehicle fleet managers and even private persons can benefit from UDS assuming they are able to identify the reverse engineered information required to request and decode the UDS parameters of interest.

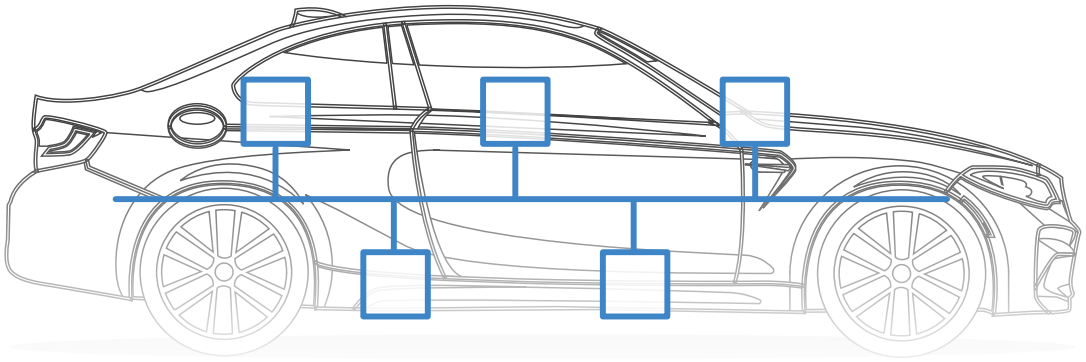
Logging UDS data will also become increasingly relevant assuming WWH-OBD gets rolled out as expected. Already today, WWH-OBD is used in EU heavy duty vehicles produced after 2014, meaning UDS communication will be relevant for use cases related to on-board diagnostics in these vehicles.

Central Gateway (CGW): Why log sensor data via UDS vs CAN?

If you're looking to request UDS-based diagnostic trouble codes (DTC), you'll of course have to use UDS communication for this purpose. However, if your aim is to record current sensor values it is less clear.

Typically, data parameters of interest for e.g. vehicle telematics (speed, state of charge etc) will already be communicated between ECUs on the CAN bus in the form of raw CAN frames - without the need for a diagnostic tool requesting this information. That is because ECUs rely on communicating this information as part of their operation (as explained in our intro to CAN bus).

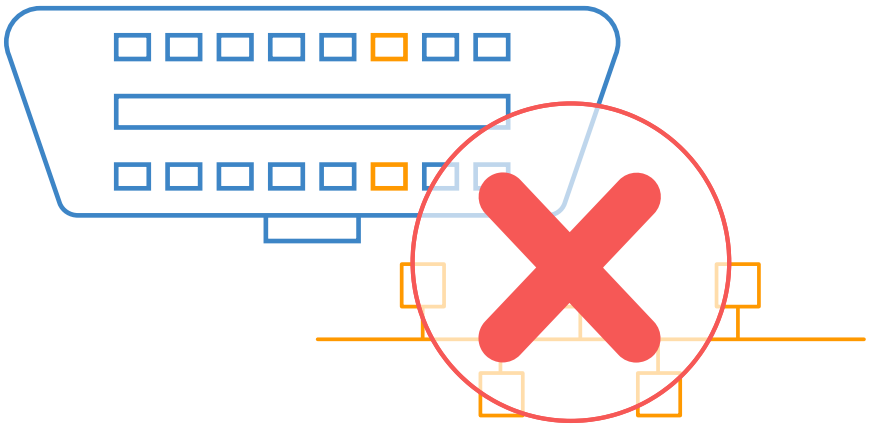
If you have direct access to the CAN bus, it would thus appear easier to simply log this raw CAN traffic and process it. If you are the vehicle manufacturer, you will know how to interpret this raw CAN data either way - and it'll be simpler to perform your device configuration and post processing in most cases. If you're in the aftermarket, it'll also be simpler to reverse engineer the raw CAN frames as you can focus on single frames - and avoid the request/response layer of complexity.



However, one key reason why UDS is frequently used for extracting sensor values despite the above is due to 'gateways'. Specifically, an increasing share of modern cars have started to block the access to the raw CAN bus data via the OBD2 connector. This is particularly often the case for German vehicles, as well as electric vehicles.

To record the existing CAN traffic in such a car, you would need to e.g. use a CANCrocodile adapter and 'snap' it onto the CAN low/high wiring harness. This in turn will require exposing the wiring harness by removing a panel, which is often prohibitive for many use cases. In contrast, the OBD2 connector gateways typically still allow for UDS communication - incl. sensor value communication.

A secondary - and more subtle - reason is that most reverse engineering work is done by 'OBD2 dongle manufacturers'. These develop tools that let you extract data across many different cars through the OBD2 connector. Increasingly, the only way for these dongles to get useful information through the OBD2 connector is through UDS communication, which drives a proportionally higher availability of information/databases related to UDS parameters vs. raw CAN parameters.



Does my vehicle support UDS?

Since most ECUs today support UDS communication, the answer is in "yes, most likely".

If you're the vehicle manufacturer, you will in most cases have the information required to construct UDS requests for whatever data you need - and you'll also know how to decode it.

For the specific case of recording WWH-OBD data in EU trucks, standardized DID information can be recorded by both OEMs and after-market users - similar to how you can record public OBD2 PIDs from cars/trucks.

Beyond the above, if you are in the after market and wish to record proprietary UDS information from a car/truck, it will be difficult. In this case, you would either have to contact the OEM (e.g. as a system integrator/partner) or identify the request/decoding information through reverse engineering. The latter is in practice impossible for most people.

In select cases you may be able to utilize public information shared on e.g. github to help in constructing UDS requests - and decoding the responses. Just keep in mind that public resources are based on reverse engineering efforts - and may risk being incorrect or outdated. You should therefore take all information with a significant grain of salt.

Why is UDS increasingly important?

If your use case involves recording data from cars produced between 2008 and 2018, you will most often be interested in data that can be collected via OBD2 data logging. This is because most ICE cars after 2008 support a large share of the public OBD2 parameter identifiers like speed, RPM, throttle position, fuel level etc.

However, the availability of OBD2 data is expected to decrease over time for multiple reasons.

First of all, as we explained in the previous section, WWH-OBD (based on UDS) or OBDonUDS are expected to gradually replace OBD2 as the de facto standard for vehicle diagnostics.

Second, with the rise of electric vehicles, legislated OBD2 is not necessarily supported at all. And even if an EV supports some OBD2 PIDs, you'll note from our OBD2 PID list that some of the most relevant EV parameters like State of Charge (SoC) and State of Health (SoH) are not available via OBD2. In contrast, UDS remains supported in most EVs and will provide access to a far broader range of data - although without the after-market convenience of a public list of UDS parameters (at least yet). It is expected that EV sales will overtake ICE car sales between 2030 and 2040 - and thus UDS communication will become increasingly relevant.

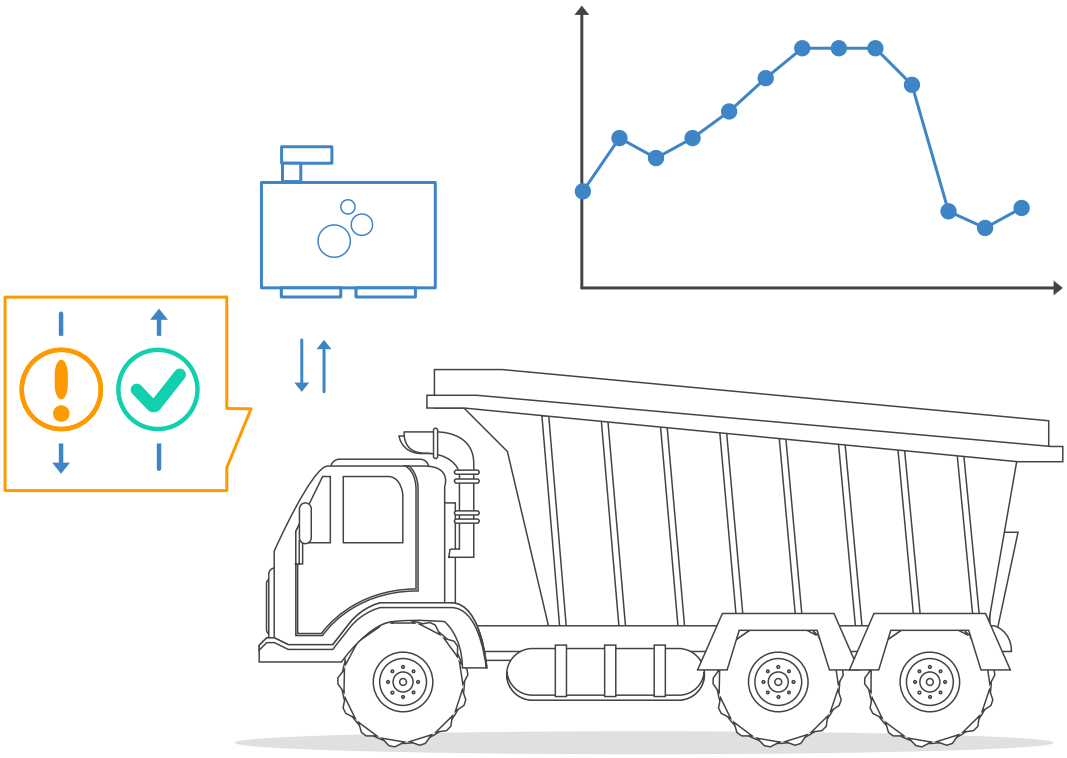
Example 1: Record single frame UDS data (Speed via WWH-OBD)

To show how UDS works in practice, we will start with a basic example. As outlined before, WWH-OBD is based on UDS - and is mandated in all EU trucks after 2014.

As part of this, many EU heavy duty trucks will let you request parameters like speed, RPM, fuel level etc in a way similar to how you'd request this information via OBD2 PID requests in a car - see our OBD2 intro and OBD2 data logger intro for details. However, under WWH-OBD (ISO 21745-2), the OBD2 PIDs are replaced by the **WWH-OBD DIDs**.

For service 01, WWH-OBD PIDs are equivalent to the OBD2 PIDs, except that **0xF4** is added in front.

For example, the OBD2 PID Vehicle Speed is **0x0D** - which becomes **0xF40D** in the WWH-OBD context.



In this case, we will use a CANedge2 CAN bus data logger as our "tester" tool. This tool lets you record raw CAN bus data, as well as transmit custom CAN frames. To request WWH-OBD Vehicle Speed, we will use the UDS service 0x22 (Read Data by Identifier) and the Data Identifier 0xF40D. The request/response looks as below:

UDS on CAN - single frame communication example

Time	CAN ID (HEX)	DataBytes (HEX)	Sender	Frame type
4.0435	18DB33F1	03 22 F4 0D AA AA AA AA	CANedge (client)	Single Frame (SF)
4.0468	18DAF100	04 62 F4 0D 32 AA AA AA	ECU (server)	First Frame (FF)

Legend
PCI field
UDS SID (request)
UDS DID
UDS SID (response)
padding/unused
payload (1 byte)

Communication flow details

Note how the request is sent with CAN ID 0x18DB33F1. This is the same 29-bit CAN ID that would be used to perform a functionally addressed OBD2 PID request in heavy duty vehicles and can be compared with the 11-bit 0x7DF CAN ID used for OBD2 requests in cars.

The response has CAN ID 0x18DAF100, an example of a physical response ID matching the IDs you'd see in regular OBD2 responses from heavy duty vehicles.

Let's break down the communication flow message payloads:

First, the CANedge2 sends a **Single Frame (SF)** request:

- The initial 4 bits of the PCI field equal the frame type (0x0 for SF)
- The next 4 bits of the PCI field equal the the length of the request (3 bytes)
- The 2nd byte contains the Service Identifier (SID), in this case 0x22
- The 3rd and 4th bytes contain the DID for Vehicle Speed in WWH-OBD (0xF40D)
- The remaining bytes are padded

In response to this request, the truck responds with a Single Frame (SF) response:

- The 1st byte again reflects the PCI field (now with a length of 4 bytes)
- The 2nd byte is the response SID for Read Data by Identifier (0x62, i.e. 0x22 + 0x40)
- The 3rd and 4th bytes again contain the DID 0xF40D
- The 5th byte contains the value of Vehicle Speed, 0x32

Here we can use the same decoding rules as for ISO/SAE OBD2, meaning that the physical value of Vehicle Speed is simply the decimal form of 0x32 - i.e. **50 km/h**. See also our OBD2 PID conversion tool.

If you are familiar with logging OBD2 PIDs, it should be evident that WWH-OBD requests are very similar, except for using the UDSonCAN payload structure for requests/responses.

Example 2: Record & decode multi frame UDS data (SoC)

In this section, we illustrate how multi frame UDS communication works in the context of CAN ISO-TP.

Specifically, we will use the CANedge2 and the UDS service SID 0x22 (Read Data By Identifier) to request the current value of State of Charge (SoC%) from a Hyundai Kona electric vehicle.

First, the CANedge is configured to send two CAN frames:

1. A Single Frame (SF) request (period: 5000 ms, delay: 0 ms)
2. A Flow Control (FC) frame (period: 5000 ms, delay: 100 ms)

A subset of the resulting communication flow looks as below:

The CANedge2 can be used to request UDS data from e.g. a Hyundai Kona EV for visualization in dashboards - learn more in our telematics dashboards intro.

Commnication flow details

In the following we explore this communication between the CANedge and ECU in detail.

First of all, the initial **Single Frame (SF)** request is constructed via the same logic as in our previous example - containing the PCI field, the SID 0x22 and the DID. In this case, we use the DID 0x0101.

In response to the initial SF request, the targeted ECU sends a **First Frame (FF)** response:

- The initial 4 bits equal the frame type (0x1 for FF)

- The next 12 bits equal the data payload size, in this case 62 bytes (0x03E)
- The 3rd byte is the response SID for Read Data by Identifier (0x62, i.e. 0x22 + 0x40)
- The 4th and 5th bytes contain the Data Identifier (DID) 0x0101
- The remaining bytes contain the initial part of the data payload for the DID 0x0101

Following the FF, the tester tool now sends the **Flow Control (FC)** frame:

- The initial 4 bits equal the frame type (0x3 for FC)
- The next 4 bits specifies that the ECU should "Continue to Send" (0x0)
- The 2nd byte sets remaining frames to be sent without flow control or delay
- The 3rd byte sets the minimum consecutive frame separation time (ST) to 0

Once the ECU receives the FC, it sends the remaining **Consecutive Frames (CF)**:

- The initial 4 bits equal the frame type (0x2 for CF)
- The next 4 bits equal the index counter, incremented from 1 up to 8 in this case
- The remaining 7 bytes of each CF contain the rest of the payload for the DID

Regarding proprietary UDS data

Part of the information used here is proprietary. In particular, it is generally not known what Data Identifier (DID) to use in order to request e.g. State of Charge from a given electric vehicle, unless you're the vehicle manufacturer (OEM). Further, as explained in the next section, it is not known how to decode the response payload.

However, various online resources exist e.g. on github, where enthusiasts create open source databases for specific parameters and certain cars (based on reverse engineering). The information we use for this specific communication is taken from one such database.

Regarding the CAN IDs used

In this case we use the CAN ID 0x7E4 to request data from a specific ECU, which in turn responds with CAN ID 0x7EC. This is known as a physically addressed request.

In contrast, functionally addressed request would use the CAN ID 0x7DF (or 0x18DB33F1 in heavy duty vehicles).

Generally, request/response CAN IDs are paired (as per the table below) and you can identify the physical request ID corresponding to a specific physical response ID by subtracting the value 8 from the response ID. In other words, if an ECU responds via CAN ID 0x7EC, the physical request ID targeting that ECU would be 0x7E4 (as in our EV example).

Since you may not know what address to target initially, you can in some cases start by sending out a functional request using the CAN ID 0x7DF, in which case the relevant ECU should provide a positive First Frame response if the initial request payload is structured correctly. In some vehicles, you may be able to also send the subsequent Flow Control frame using the same CAN ID, 0x7DF, in order to trigger the ECU to send the remaining Consecutive Frames. However, some implementations may require that you instead utilize the physical addressing request ID for the Flow Control frame.

Implementing a request structure with dynamically updating CAN IDs may be difficult. If you're the manufacturer, you will of course know the relevant CAN IDs to use for sending physically addressed service requests. If not, you may perform an analysis using e.g. a CAN bus interface to identify what response CAN IDs appear when sending functionally addressed service requests - and using this information to construct your configuration.

On a separate note, ISO 15765-4 states that enhanced diagnostics requests/responses may utilize the legislated OBD2 CAN ID range as long as it does not interfere - which is what we are seeing in this specific Hyundai Kona example where the IDs 0x7EC/0x7E4 are used for proprietary data.

See also the table from ISO 15765-4 for an overview of the legislated OBD CAN identifiers for use in functional and physical OBD PID requests:

Legislated OBD CAN identifiers (11-bit)

CAN ID	Description
0x7DF	Functionally addressed request sent by tester
0x7E0 to 0x7E7	Physical request from tester to ECU #1 to #8
0x7E8 to 0x7EF	Physical response from ECU #1 to #8 to tester

Legislated OBD CAN identifiers (29-bit)

CAN ID	Description
0x18DB33F1	Functionally addressed request sent by tester
0x18DAxxF1	Physical request from tester to ECU #xx
0x18DAF1xx	Physical response from ECU #xx to tester

Regarding timing parameters

In the above example, we generally focus on the sequence of CAN frames. The sequence is important: For example, if your tester tool sends the Flow Control frame before receiving the First Frame, the Flow Control frame will either be ignored (thus not triggering the Consecutive Frames) or cause an error.

However, in addition to this, certain timing thresholds will also need to be satisfied. For example, if your tester tool receives the First Frame from an ECU of a multi frame response, the ECU will 'time out' if the Flow Control frame is not sent within a set timeperiod.

As a rule of thumb, you should configure your tester (e.g. the CANedge) so that the Flow Control frame is always sent after the First Frame response is received from the ECU (typically this happens within 10-50 ms from sending the initial request) - but in a way so that it is sent within a set time after receiving the First Frame (e.g. within 0-50 ms). For details on this, feel free to contact us.

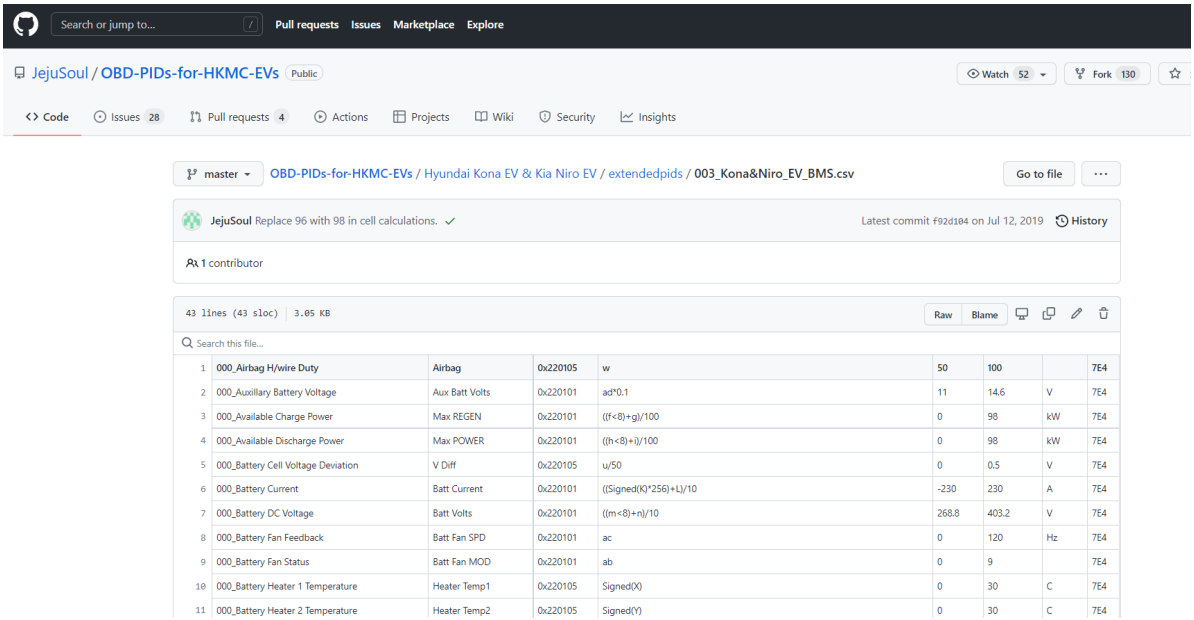
How to reassemble and decode multi-frame UDS data?

We've now shown how you can request/record a multi-frame UDS response to collect proprietary ECU sensor data. In order to extract 'physical values' like State of Charge, you need to know how to interpret the response CAN frames.

As explained, the 'decoding' information is typically proprietary and only known to the OEM.

However, in the specific case of the Hyundai Kona EV, we know the following about the SoC signal from online resources:

- The signal is in the 8th byte of the data payload
- The signal is Unsigned
- The signal has a scale 0.5, offset 0 and unit "%"



1	000_Airbag H/wire Duty	Airbag	0x220105	w	50	100		7E4
2	000_Auxillary Battery Voltage	Aux Batt Volts	0x220101	ad*0.1	11	14.6	V	7E4
3	000_Available Charge Power	Max REGEN	0x220101	((f<8)+g)/100	0	98	kW	7E4
4	000_Available Discharge Power	Max POWER	0x220101	((h<8)+i)/100	0	98	kW	7E4
5	000_Battery Cell Voltage Deviation	V Diff	0x220105	u/50	0	0.5	V	7E4
6	000_Battery Current	Batt Current	0x220101	((Signed(K)*256)+L)/10	-230	230	A	7E4
7	000_Battery DC Voltage	Batt Volts	0x220101	((m<8)+n)/10	268.8	403.2	V	7E4
8	000_Battery Fan Feedback	Batt Fan SPD	0x220101	ac	0	120	Hz	7E4
9	000_Battery Fan Status	Batt Fan MOD	0x220101	ab	0	9		7E4
10	000_Battery Heater 1 Temperature	Heater Temp1	0x220105	Signed(X)	0	30	C	7E4
11	000_Battery Heater 2 Temperature	Heater Temp2	0x220105	Signed(Y)	0	30	C	7E4

Many online github repos exist with reverse engineered decoding rules for e.g. electric vehicles via UDS - see our DBC intro for an overview

So how do we use this knowledge to decode the signal?

First, we need to **reassemble the segmented CAN frames**. The result of this is shown in the previous communication example.

Via reassembly, we get a "CAN frame" with ID 0x7EC and a payload exceeding 8 bytes. The payload in this case contains the SID in the 1st byte and DID in the 2nd and 3rd bytes.

You could process the reassembled CAN frame manually in e.g. Excel. However, we generally recommend to use CAN databases (DBC files) to store decoding rules.

In this particular case, you can treat the reassembled CAN frame as a case of **extended multiplexing**. We provide an example UDS DBC file for the Hyundai Kona incl. State of Charge and temperature signals, which can be useful as inspiration.

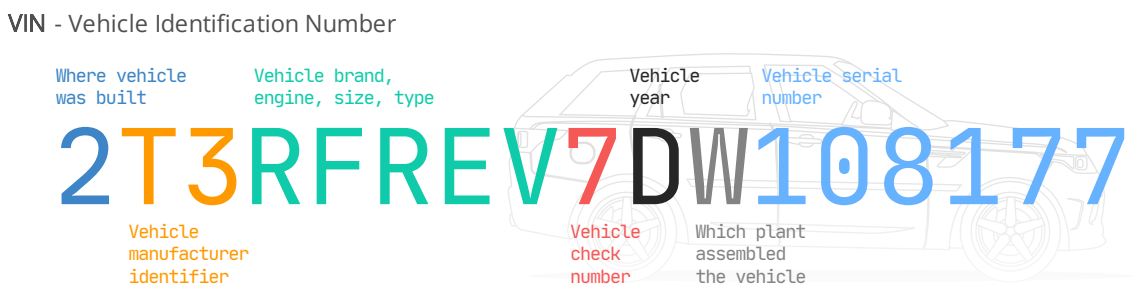
Our CAN bus Python API enables reassembly & DBC decoding of multi-frame UDS responses - see our API examples repository for more details incl. the Hyundai Kona sample data.

```
BO_ 2028 Battery: 62 Vector__XXX
 SG_ M_SID_0x220101_StateOfChargeBMS m257 : 56|8@1+ (0.5,0) [0|0] "%" Vector__XXX
 SG_ response m98M : 15|16@0+ (1,0) [0|0] "unit" Vector__XXX
 SG_ service M : 7|8@0+ (1,0) [0|0] "" Vector__XXX

BO_ 1979 Temperature: 54 Vector__XXX
 SG_ M_SID_0x220100_IndoorTemp m256 : 64|8@1+ (0.5,-40) [0|0] "degC" Vector__XXX
 SG_ response m98 : 15|16@0+ (1,0) [0|0] "unit" Vector__XXX
 SG_ service M : 7|8@0+ (1,0) [0|0] "" Vector__XXX
 SG_ M_SID_0x220100_OutdoorTemp : 79|8@0+ (0.5,-40) [0|0] "" Vector__XXX
 SG_ M_SID_0x220100_Speed : 255|8@0+ (0.5,0) [0|0] "" Vector__XXX


BA_DEF_ BO_  "VFrameFormat" ENUM  "StandardCAN","ExtendedCAN","StandardCAN_FD","ExtendedCAN_FD","J1939PG";
BA_DEF_  "ProtocolType" STRING ;
BA_DEF_DEF_  "VFrameFormat" "";
BA_DEF_DEF_  "ProtocolType" "";
BA_ "ProtocolType" "";
BA_ "VFrameFormat" BO_ 2028 0;

SG_MUL_VAL_ 2028 M_SID_0x220101_StateOfChargeBMS response 257-257;
SG_MUL_VAL_ 2028 response service 98-98;
```

The above shows an extract of a 'UDS DBC file' using extended multiplexing to filter responses based on the response SID and DID.

Example 3: Record the Vehicle Identification Number (VIN)

The **Vehicle Identification Number** (aka VIN, chassis number, frame number) is a unique identifier code used for road vehicles. The number has been standardized and legally required since the 1980s - for details see the VIN page on Wikipedia.



A VIN consists of 17 ASCII characters and can be extracted on-request from a vehicle. This is useful in e.g. data logging or telematics use cases where a unique identifier is required for association with e.g. CAN bus log files.

CAN data bytes can be converted from HEX to ASCII via tables, online HEX to ASCII converters, Python packages etc.

For example, the byte 0x47 corresponds to the letter "G".

Since a VIN is 17 bytes (17 ASCII characters) long, it does not fit into a single CAN frame, but has to be extracted via a multi frame diagnostic request/response as in Example 2. Further, the VIN is extracted differently depending on the protocol used.

Below we provide three examples on how to record the VIN.

HEX-to-ASCII conversion table

HEX	Binary	ASCII	HEX	Binary	ASCII	HEX	Binary	ASCII
0x00	00000000	NUL	0x2B	00101011	+	0x56	01010110	V
0x01	00000001	SOH	0x2C	00101100	,	0x57	01010111	W
0x02	00000010	STX	0x2D	00101101	-	0x58	01011000	X
0x03	00000011	ETX	0x2E	00101110	.	0x59	01011001	Y
0x04	00000100	EOT	0x2F	00101111	/	0x5A	01011010	Z
0x05	00000101	ENQ	0x30	00110000	0	0x5B	01011011	[
0x06	00000110	ACK	0x31	00110001	1	0x5C	01011100	\
0x07	00000111	BEL	0x32	00110010	2	0x5D	01011101	]
0x08	00001000	BS	0x33	00110011	3	0x5E	01011110	^
0x09	00001001	HT	0x34	00110100	4	0x5F	01011111	_
0x0A	00001010	LF	0x35	00110101	5	0x60	01100000	`
0x0B	00001011	VT	0x36	00110110	6	0x61	01100001	a
0x0C	00001100	FF	0x37	00110111	7	0x62	01100010	b
0x0D	00001101	CR	0x38	00111000	8	0x63	01100011	c
0x0E	00001110	SO	0x39	00111001	9	0x64	01100100	d
0x0F	00001111	SI	0x3A	00111010	:	0x65	01100101	e
0x10	00010000	DLE	0x3B	00111011	;	0x66	01100110	f
0x11	00010001	DC1	0x3C	00111100	<	0x67	01100111	g
0x12	00010010	DC2	0x3D	00111101	=	0x68	01101000	h
0x13	00010011	DC3	0x3E	00111110	>	0x69	01101001	i
0x14	00010100	DC4	0x3F	00111111	?	0x6A	01101010	j
0x15	00010101	NAK	0x40	01000000	@	0x6B	01101011	k
0x16	00010110	SYN	0x41	01000001	A	0x6C	01101100	l
0x17	00010111	ETB	0x42	01000010	B	0x6D	01101101	m
0x18	00011000	CAN	0x43	01000011	C	0x6E	01101110	n
0x19	00011001	EM	0x44	01000100	D	0x6F	01101111	o
0x1A	00011010	SUB	0x45	01000101	E	0x70	01110000	p
0x1B	00011011	ESC	0x46	01000110	F	0x71	01110001	q
0x1C	00011100	FS	0x47	01000111	G	0x72	01110010	r
0x1D	00011101	GS	0x48	01001000	H	0x73	01110011	s
0x1E	00011110	RS	0x49	01001001	I	0x74	01110100	t
0x1F	00011111	US	0x4A	01001010	J	0x75	01110101	u
0x20	00100000	Space	0x4B	01001011	K	0x76	01110110	v
0x21	00100001	!	0x4C	01001100	L	0x77	01110111	w
0x22	00100010	"	0x4D	01001101	M	0x78	01111000	x
0x23	00100011	#	0x4E	01001110	N	0x79	01111001	y
0x24	00100100	$	0x4F	01001111	O	0x7A	01111010	z
0x25	00100101	%	0x50	01010000	P	0x7B	01111011	{
0x26	00100110	&	0x51	01010001	Q	0x7C	01111100	|
0x27	00100111	'	0x52	01010010	R	0x7D	01111101	}
0x28	00101000	(	0x53	01010011	S	0x7E	01111110	~
0x29	00101001	)	0x54	01010100	T	0x7F	01111111	DEL
0x2A	00101010	*	0x55	01010101	U			

3.1: How to record the VIN via OBD2 (SAE J1979)

To extract the Vehicle Identification Number from e.g. a passenger car using OBD2 requests, you use Service 0x09 and the PID 0x02:

VIN - Vehicle Identification Number request/response (OBD2)

Time	CAN ID (HEX)	DataBytes (HEX)	Sender	Frame type
1.0135	7E0	02 09 02 AA AA AA AA AA	CANedge (client)	Single Frame (SF)
1.0228	7E8	10 14 49 02 01 32 54 33	ECU (server)	First Frame (FF)
1.0235	7E0	30 00 00 00 00 00 00 00	CANedge (client)	Flow Control (FC)
1.0426	7E8	21 52 46 52 45 56 37 44	ECU (server)	Consecutive Frame (CF)
1.0486	7E8	22 57 31 30 38 31 37 37	ECU (server)	Consecutive Frame (CF)

Reassembled OBD2 frame

1.0135	7E8	49 02 01 32 54 33 52 46 52 45 56 37 44 57 31 30 38 31 37 37

VIN = 2T3RFREV7DW108177

Legend

- PCI field
- OBD service (request)
- OBD PID
- OBD service (response)
- NODI
- padding/unused
- FC block size, ST
- payload (17 bytes)

Commnication flow details

The logic of the frame structure is identical to Example 2, with the tester tool sending a Single Frame request with the PCI field (0x02), request service identifier (0x09) and data identifier (0x02).

The vehicle responds with a First Frame containing the PCI, length (0x014 = 20 bytes), response SID (0x49, i.e. 0x09 + 0x40) and data identifier (0x02). Following the data identifier is the byte 0x01 which is the Number Of Data Items (NODI), in this case 1 (see SAE J1979 or ISO 15031-5 for details).

The remaining 17 bytes equal the VIN and can be translated from HEX to ASC via the methods previously discussed.

3.2: How to record the VIN via UDS (ISO 14229-2)

To read the Vehicle Identification Number via UDS, you can use the UDS SID 0x22 and the DID 0xF190:

VIN - Vehicle Identification Number request/response (UDS on CAN)

Time	CAN ID (HEX)	DataBytes (HEX)	Sender	Frame type
1.0135	7E0	03 22 F1 90 AA AA AA AA	CANedge (client)	Single Frame (SF)
1.0228	7E8	10 14 62 F1 90 32 54 33	ECU (server)	First Frame (FF)
1.0235	7E0	30 00 00 00 00 00 00 00	CANedge (client)	Flow Control (FC)
1.0426	7E8	21 52 46 52 45 56 37 44	ECU (server)	Consecutive Frame (CF)
1.0486	7E8	22 57 31 30 38 31 37 37	ECU (server)	Consecutive Frame (CF)

Reassembled UDS frame

1.0135	7E8	62 F1 90 32 54 33 52 46 52 45 56 37 44 57 31 30 38 31 37 37

VIN = 2T3RFREV7DW108177

Legend
PCI field
UDS SID (request)
UDS DID
UDS SID (response)
padding/unused
FC block size, ST
payload (17 bytes)

Commnication flow details

As evident, the request/response communication flow looks similar to the OBD2 case above. The main changes relate to the use of the UDS service 0x22 instead of the OBD2 service 0x09 - and the use of the 2-byte UDS DID 0xF190 instead of the 1 byte OBD2 PID 0x02. Further, the UDS response frame does not include the Number of Data Items (NODI) field after the DID, in contrast to what we saw in the OBD2 case.

3.3: How to record the VIN via WWH-OBD (ISO 21745-3)

If you need to request the Vehicle Identification Number from an EU truck after 2014, you can use the WWH-OBD protocol. The structure is identical to the UDS example, except that WWH-OBD specifies the use of the DID 0xF802 for the VIN.

VIN - Vehicle Identification Number request/response (WWH-OBD on CAN)

Time	CAN ID (HEX)	DataBytes (HEX)	Sender	Frame type
1.0135	18DB33F1	03 22 F8 02 AA AA AA AA	CANedge (client)	Single Frame (SF)
1.0228	18DAF100	10 14 62 F8 02 32 54 33	ECU (server)	First Frame (FF)
1.0235	18DB33F1	30 00 00 00 00 00 00 00	CANedge (client)	Flow Control (FC)
1.0426	18DAF100	21 52 46 52 45 56 37 44	ECU (server)	Consecutive Frame (CF)
1.0486	18DAF100	22 57 31 30 38 31 37 37	ECU (server)	Consecutive Frame (CF)

Reassembled WWH-OBD frame

1.0135	18DAF100	49 F8 02 32 54 33 52 46 52 45 56 37 44 57 31 30 38 31 37 37

VIN = 2T3RFREV7DW108177

Legend
PCI field
UDS SID (request)
UDS DID
UDS SID (response)
padding/unused
FC block size, ST
payload (17 bytes)

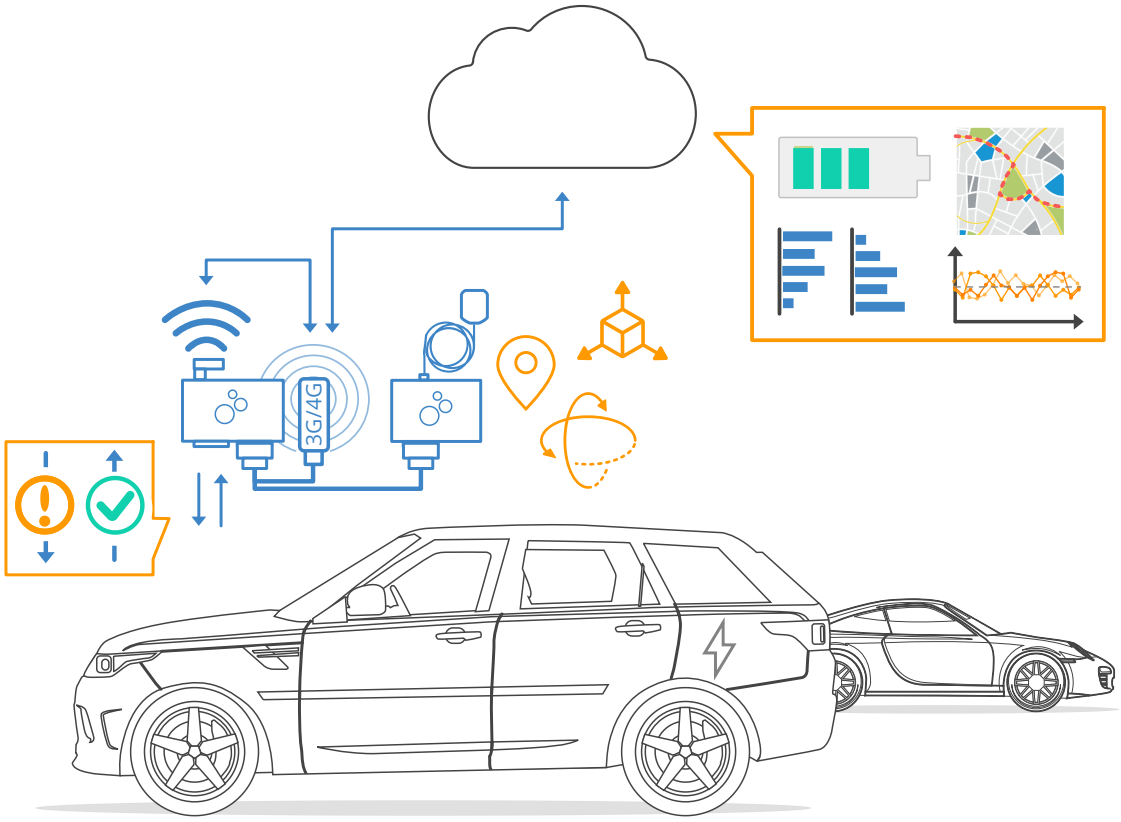
UDS data logging - applications

In this section, we outline example use cases for recording UDS data.

UDS telematics for prototype electric vehicles

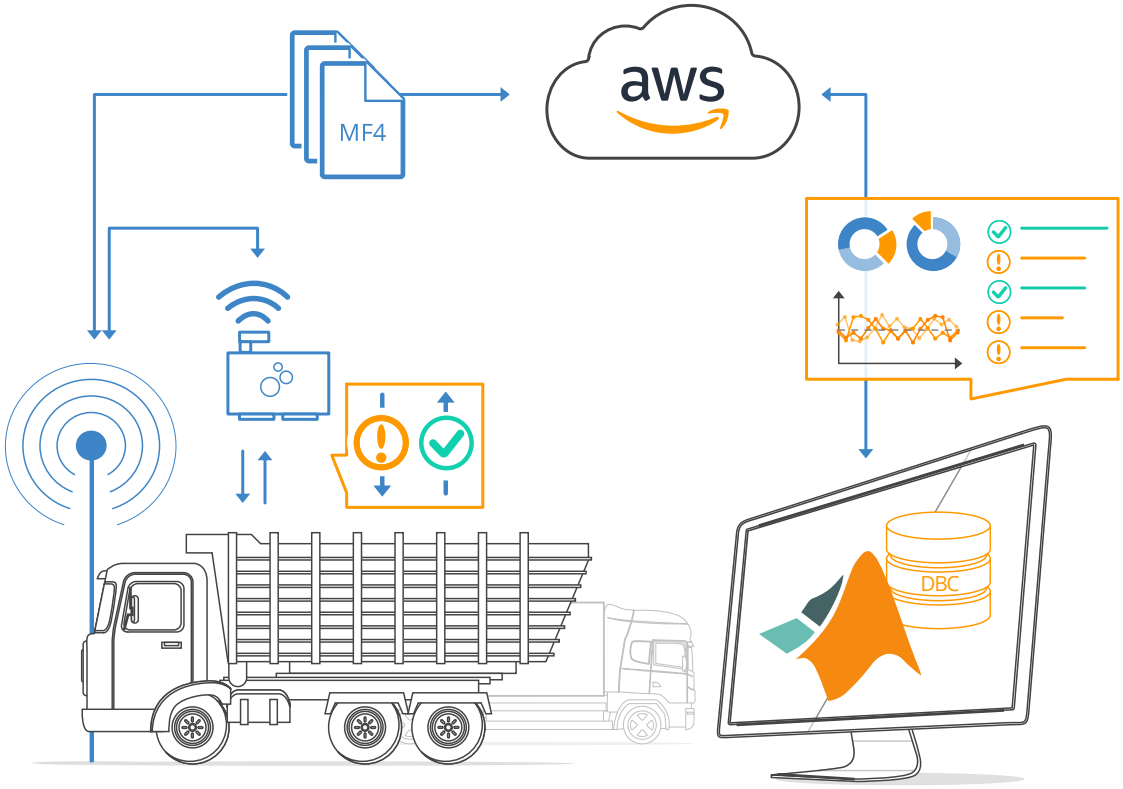
As an OEM, you may need to get data on various sensor parameters from prototype EVs while they are operating in the field. Here, the CANedge2 can be deployed to request data on e.g. state of charge, state of health, temperatures and more by transmitting UDS request frames and flow control frames periodically. The data can e.g. be combined with GNSS/IMU data from a

CANmod.gps and sent via a 3G/4G access point to your own cloud server for analysis via Vector tools, Python or MATLAB.



Training a predictive maintenance model

If you're looking to implement predictive maintenance across fleets of heavy duty vehicles, the first step is typically to "train your model". This requires large amounts of training data to be collected, including both sensor data (speed, RPM, throttle position, tire pressures etc) and "classification results" (fault / no fault). One way to obtain the latter is by periodically requesting diagnostic trouble codes from the vehicle, providing you with log files that combine both types of data over time. You can use the CANedge1 to collect this data offline onto SD cards, or the CANedge2 to automatically offload the data - e.g. when the vehicles return to stationary WiFi routers in garages.


MF4
aws
DBC