

---

---

**Road vehicles — Diagnostics on  
Controller Area Networks (CAN) —**

**Part 4:  
Requirements for emissions-related  
systems**

*Véhicules routiers — Diagnostic sur gestionnaire de réseau de  
communication (CAN) —*

*Partie 4: Exigences applicables aux systèmes associés aux émissions*



Reference number  
ISO 15765-4:2005(E)

© ISO 2005

**PDF disclaimer**

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

© ISO 2005

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
Case postale 56 • CH-1211 Geneva 20  
Tel. + 41 22 749 01 11  
Fax + 41 22 749 09 47  
E-mail [copyright@iso.org](mailto:copyright@iso.org)  
Web [www.iso.org](http://www.iso.org)

Published in Switzerland

# Contents

Page

Foreword .....	iv
Introduction .....	v
1 Scope .....	1
2 Normative references .....	1
3 Terms, definitions, symbols and abbreviated terms .....	1
4 External test equipment initialization sequence .....	2
4.1 General .....	2
4.2 11 bit CAN identifier verification procedure .....	4
4.2.1 Request message transmit procedure .....	4
4.2.2 Response handling procedure .....	5
4.3 29 bit CAN identifier verification procedure .....	7
4.3.1 Request message transmit procedure .....	7
4.3.2 Response handling procedure .....	8
5 Session layer .....	9
6 Network layer .....	10
6.1 General .....	10
6.2 Addressing formats .....	10
6.3 Data link layer interface .....	10
6.3.1 CAN identifier requirements .....	10
6.3.2 Mapping of diagnostic addresses .....	10
6.4 Network layer parameters .....	13
6.4.1 Network layer timing parameter values .....	13
6.4.2 Definition of external test equipment network layer parameter values .....	13
6.4.3 Maximum number of legislated-OBd ECUs .....	14
7 Data link layer .....	14
8 Physical layer .....	14
8.1 General .....	14
8.2 External test equipment baudrates .....	14
8.3 External test equipment CAN bit timing .....	15
8.3.1 CAN bit timing parameter values .....	15
8.3.2 Nominal baudrate 250 kBit/s .....	16
8.3.3 Nominal baudrate 500 kBit/s .....	17
8.4 External test equipment .....	17
8.4.1 General .....	17
8.4.2 CAN interface .....	18
8.4.3 External-test-equipment cable .....	20
Bibliography .....	21

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15765-4 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

ISO 15765 consists of the following parts, under the general title *Road vehicles — Diagnostics on Controller Area Networks (CAN)*:

- *Part 1: General information*
- *Part 2: Network layer services*
- *Part 3: Implementation of unified diagnostic services (UDS on CAN)*
- *Part 4: Requirements for emissions-related systems*

## Introduction

This part of ISO 15765 has been established in order to define common requirements for vehicle diagnostic systems implemented on a Controller Area Network (CAN) communication link, as specified in ISO 11898. Although primarily intended for diagnostic systems, it also meets requirements from other CAN-based systems needing a network layer protocol.

To achieve this, it is based on the Open Systems Interconnection (OSI) Basic Reference Model specified in ISO/IEC 7498 and ISO/IEC 10731, which structures communication systems into seven layers. When mapped on this model, the services specified by ISO 15765 are divided into

- unified diagnostic services (layer 7), specified in ISO 15765-3,
- network layer services (layer 3), specified in ISO 15765-2,
- CAN services (layers 1 and 2), specified in ISO 11898,

in accordance with Table 1.

The application layer services covered by ISO 15765-3 have been defined in compliance with diagnostic services established in ISO 14229-1 and ISO 15031-5, but are not limited to use only with them. ISO 15765-3 is also compatible with most diagnostic services defined in national standards or vehicle manufacturer's specifications.

The network layer services covered by ISO 15765-2 have been defined to be independent of the physical layer implemented, and a physical layer is only specified for legislated OBD.

For other application areas, ISO 15765 can be used with any CAN physical layer.

**Table 1 — Enhanced and legislated-OBD diagnostic specifications applicable to the OSI layers**

Open Systems Interconnection (OSI) layers	Vehicle manufacturer enhanced diagnostics	Legislated on-board diagnostics (OBD)
Diagnostic application	User defined	ISO 15031-5
Application layer	ISO 15765-3	ISO 15031-5
Presentation layer	N/A	N/A
Session layer	ISO 15765-3	N/A
Transport layer	N/A	N/A
Network layer	ISO 15765-2	ISO 15765-4
Data link layer	ISO 11898-1	ISO 15765-4
Physical layer	User defined	ISO 15765-4

Copyright International Organization for Standardization

Road vehicles — Diagnostics on Controller Area Networks (CAN) —

Part 4:

Requirements for emissions-related systems

1 Scope

This part of ISO 15765 specifies requirements for the emissions-related systems of legislated-OBD-compliant controller area networks (CAN), such communications networks consisting of a road vehicle equipped with a single or multiple emissions-related ECUs and external test equipment. It is based on the specifications of ISO 15765-2, ISO 11898-1 and ISO 11898-2, while placing restrictions on those standards for legislated-OBD purposes. It does not specify in-vehicle CAN bus architecture. Legislated-OBD-compliant vehicles are to comply with external test equipment requirements.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11898 (all parts), *Road vehicles — Controller area network (CAN)*

ISO 14229-1, *Road vehicles — Unified diagnostic services (UDS) — Part 1: Specification and requirements*<sup>1)</sup>

ISO 15765-2, *Road vehicles — Diagnostics on Controller Area Networks (CAN) — Part 2: Network layer services*

ISO 15031-5, *Road vehicles — Communication between vehicle and external equipment for emissions-related diagnostics — Part 5: Emissions-related diagnostic services*<sup>1)</sup>

3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the terms and definitions given in ISO 14229-1 and the following symbols and abbreviated terms apply.

$C_1, C_2$	capacitance of a.c. termination
$C_{CAN\_H}$	capacitance between CAN_H and ground potential
$C_{CAN\_L}$	capacitance between CAN_L and ground potential
$C_{DIFF}$	capacitance between CAN_H and CAN_L

1) To be published.

$L_{\text{CABLE}}$	max. cable length between OBD connector and external test equipment
$R_1, R_2$	resistance of a.c. termination
$t_{\text{SEG1}}$	timing segment 1
$t_{\text{SEG2}}$	timing segment 2
$t_{\text{SYNCSEG}}$	synchronization segment
$t_{\text{BIT}}$	bit time
$t_{\text{BIT\_RX}}$	receive bit time
$t_{\text{BIT\_TX}}$	transmit bit time
$t_{\text{TOOL}}$	external test equipment CAN interface propagation delay (without external test equipment cable delay)
$t_{\text{CABLE}}$	external-test-equipment cable propagation delay (without external test equipment CAN interface delay)
$t_{\text{Q}}$	time quantum
$\Delta f$	oscillator tolerance
ECU	electronic control unit
OBD	on-board diagnostics
Prop_Seg	propagation segment
Phase_Seg1	phase segment 1
Phase_Seg2	phase segment 2
SA	source address
SJW	synchronization jump width
SP	nominal sample point
Sync_Seg	synchronization segment
TA	target address

## 4 External test equipment initialization sequence

### 4.1 General

The external test equipment shall support the initialization sequence specified in this part of ISO 15765. See Figure 1.

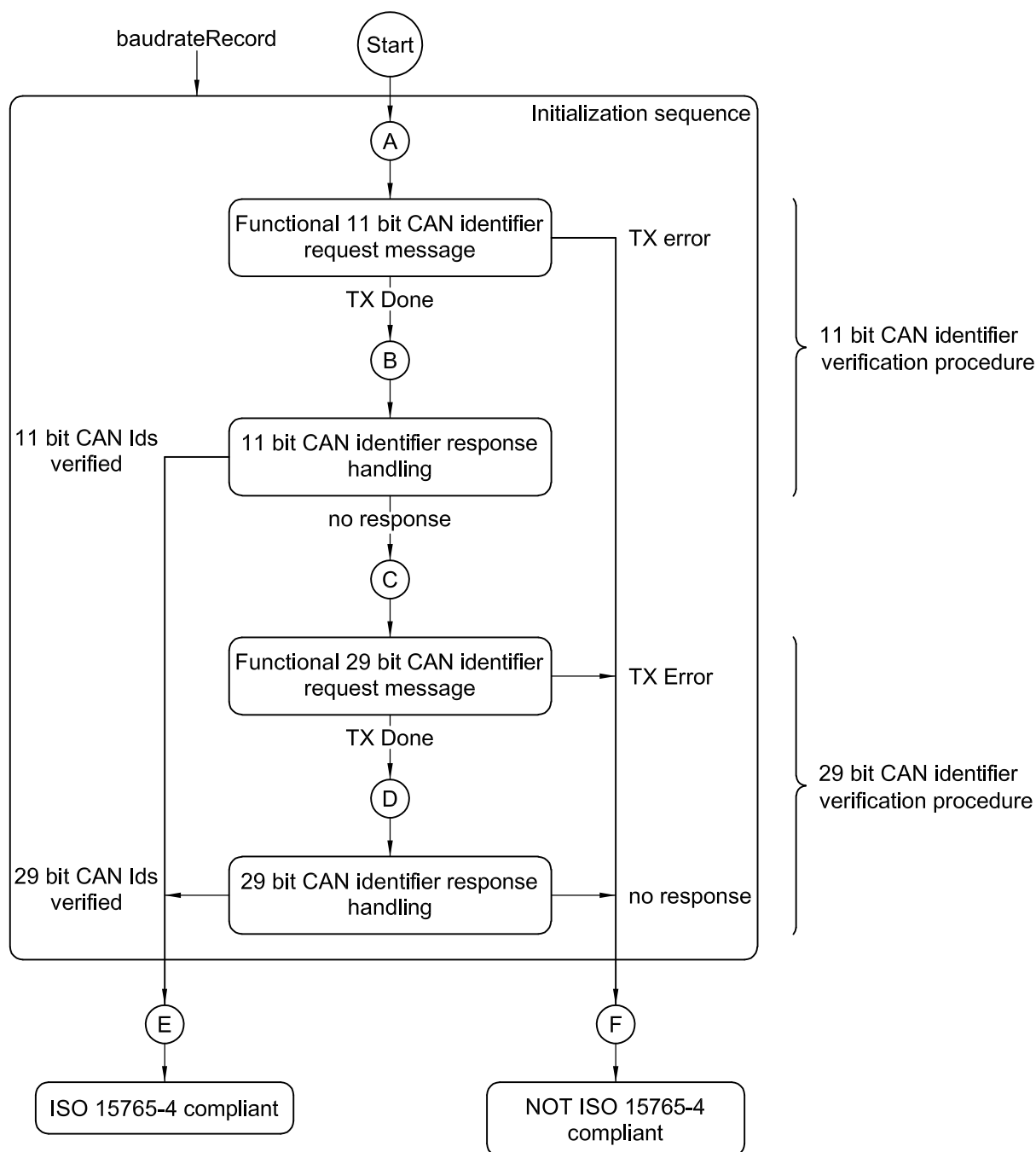
The purpose of the external test equipment initialization sequence is to automatically detect whether the vehicle supports legislated on-board diagnostics on CAN using the physical layer specified in Clause 8. Furthermore, the initialization sequence determines the legislated-OBd ECUs (CAN Id, see 6.3) expected to respond to ISO 15031-5 service 01 hex requests. Note that for each legislated-OBd service that requires the determination of “supported” information, the external test equipment has to update its list of expected responding legislated-OBd ECUs prior to any data parameter requests (see ISO 15031-5 for applicable services). The external test equipment initialization sequence supports single baudrate initialization (e.g. 500 kBit/s) and multiple baudrate initialization (e.g. 250 kBit/s and 500 kBit/s) and is separated into



a) 11 bit CAN identifier verification procedure (see 4.2), and

b) 29 bit CAN identifier verification procedure (see 4.3).

The external test equipment initialization sequence contains provisions for legacy vehicles using either CAN (same or different physical layer as defined for legislated OBD) or a different protocol (non-CAN) on the CAN pins of the ISO 15031-3 diagnostic connector.



**Figure 1 — Initialization sequence — Overview**

The parameter `baudrateRecord` shall be used to specify the type of initialization to be performed. If the `baudrateRecord` parameter contains a single baudrate, then a single baudrate initialization sequence shall be performed using the specified single baudrate (e.g. 500 kBit/s). If the `baudrateRecord` parameter contains multiple baudrates, then a multiple baudrate initialization sequence including a baudrate detection procedure shall be performed using the specified multiple baudrates (e.g. 250 kBit/s and 500 kBit/s).

By default the baudrateRecord contains all baudrates specified in 8.3. The default content of the parameter baudrateRecord can be superseded by any other list of baudrates, e.g. single 500 kBit/s baudrate as specified in 8.3.3.

For legislated-OBD baudrates, the external test equipment shall use the appropriate CAN bit timing parameter values defined in 8.3.

The following descriptions of the external test equipment initialization make use of the connectors A to F as shown in Figure 1 to reference certain entry and exit points.

## 4.2 11 bit CAN identifier verification procedure

### 4.2.1 Request message transmit procedure

The purpose of the 11 bit CAN identifier verification procedure is to determine whether 11 bit CAN identifiers are being used in legislated-OBD communication and, if multiple baudrates are specified in the baudrateRecord parameter, to determine the baudrate to be used in such communication.

The following transmit procedure shall be used to transmit the request message of the 11 bit CAN identifier verification procedure. The transmit procedure contains provisions for legacy vehicles which use either CAN (same or different physical layer as defined for legislated OBD) or a different protocol (non CAN) on the CAN pins of the ISO 15031-3 diagnostic connector.

Where the vehicle uses a CAN with a physical layer different from that specified for legislated OBD (Clause 8) or a non-CAN protocol on the CAN pins of the OBD connector, the transmit procedure given as follows shall guarantee that in all cases the external test equipment will detect that the vehicle does not support CAN as specified for legislated OBD and will stop the transmission of the request message immediately.

Where the vehicle uses CAN and the physical layer according to Clause 8, the transmit procedure given as follows shall guarantee that in all cases the external test equipment will detect that it uses the wrong baudrate for the transmission of the request message and will stop disturbing the CAN bus immediately. Under normal in-vehicle conditions (i.e. no error frames during in-vehicle communication when the external test equipment is disconnected), the external test equipment will disable its CAN interface prior to the situation where the internal error counters of the OBD ECU(s) reach critical values.

To achieve this, the external test equipment shall support the following features.

- Possibility to stop sending immediately during transmission of any CAN frame. The CAN interface should be disconnected within 12 µs from reception of a bus error signal. The maximum time for the disconnection is 100 µs. With the CAN interface disconnected, the external test equipment shall not be able to transmit dominant bits on the CAN bus.
- Possibility to immediately detect any error on the CAN bus.

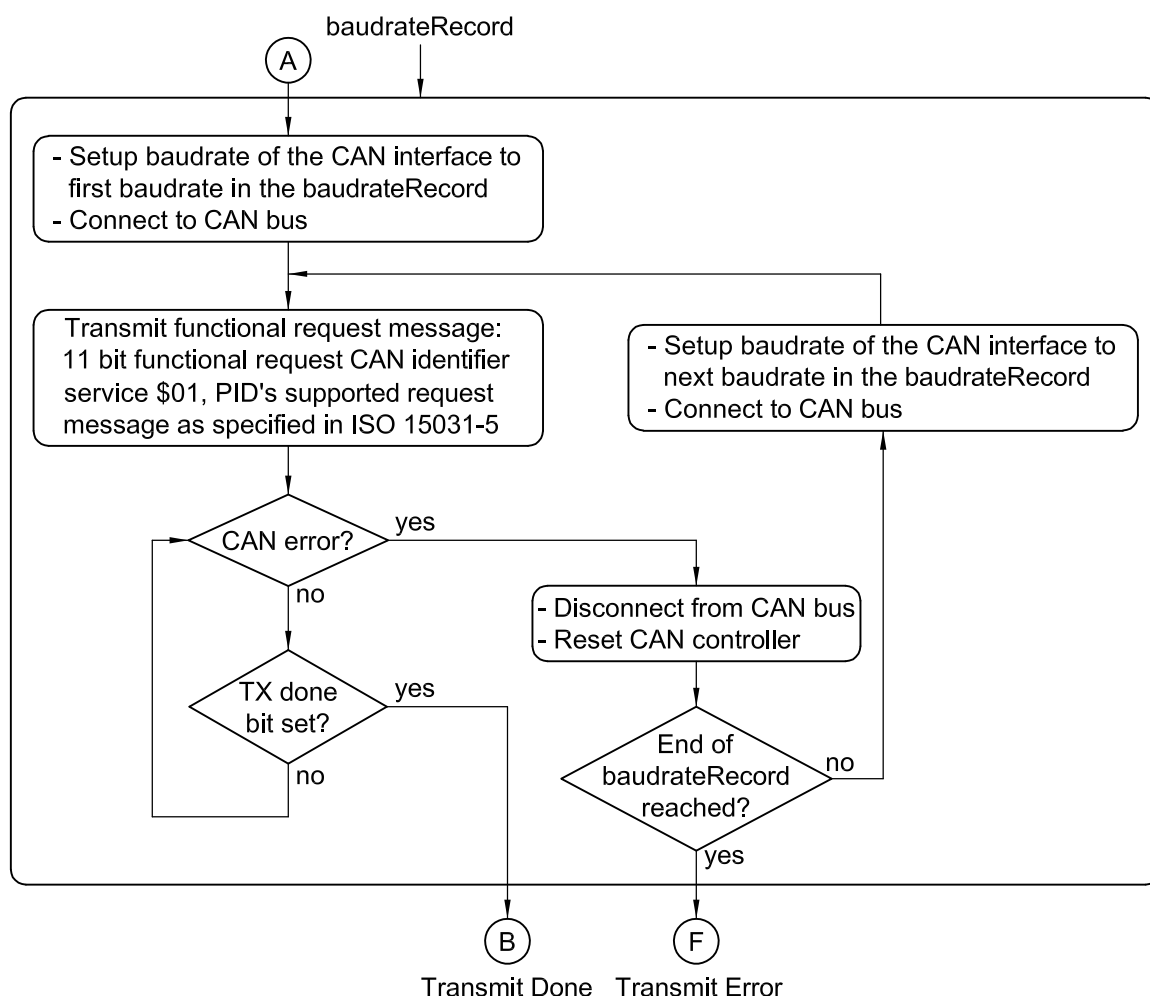
The procedure shall be performed as follows. See Figure 2.

- a) The external test equipment shall set up its CAN interface using the first baudrate contained in the baudrateRecord. It shall use the CAN bit timing parameter values defined for this baudrate (see 8.3). Following the CAN Interface set-up, it shall connect the CAN Interface to the CAN bus.
- b) The external test equipment shall transmit a functionally addressed service 01 hex request message (read-supported PIDs)<sup>2)</sup> using the legislated-OBD 11 bit functional request CAN identifier according to 6.3.2.2.

---

2) See ISO 15031-5 for the request message definition of service 01 hex to read the supported PIDs.

- c) The external test equipment shall check for any CAN error. If the request message is transmitted onto the CAN bus, it shall indicate a successful transmission (connector B).
- d) If a CAN error occurred, the external test equipment shall disconnect its CAN Interface from the CAN bus. With a disconnected CAN interface, the external test equipment shall not be able to transmit dominant bits on the CAN bus. It shall check whether more baudrates are contained in the baudrateRecord. If no further baudrate is contained in the baudrateRecord, it shall indicate that the request was not transmitted successfully (connector F).
- e) If the end of the baudrateRecord is not reached, the external test equipment shall set up its CAN interface using the next baudrate in the baudrateRecord and shall connect its CAN interface to the CAN bus. Following the setup, the external test equipment shall transmit the request message once again [continue from b)].



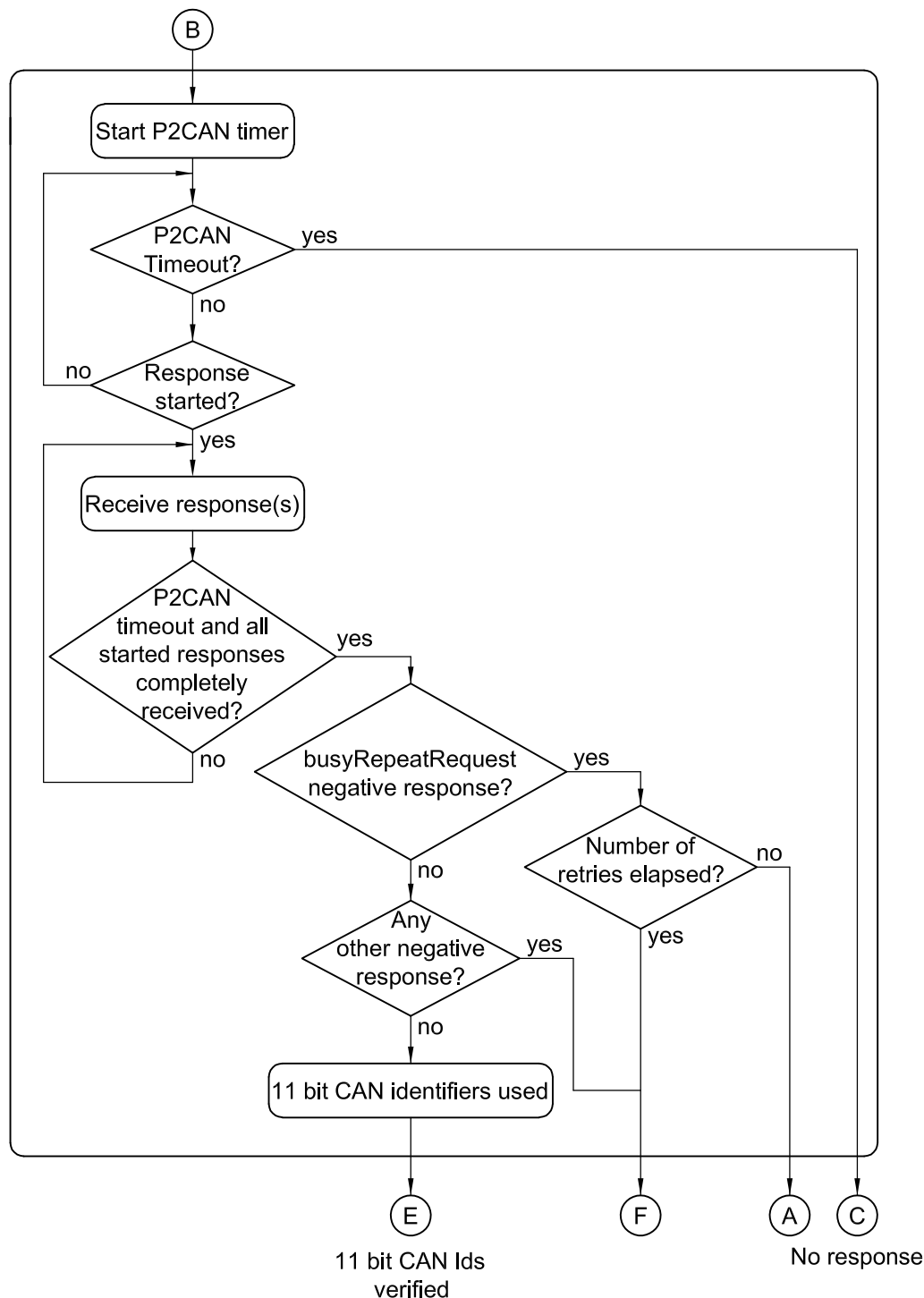
**Figure 2 — Initialization sequence — 11 bit CAN identifier request transmission**

#### 4.2.2 Response handling procedure

The response handling procedure shall be used to receive 11 bit CAN identifier response messages and indicates that no response message has been received. It shall be performed immediately after the 11 bit CAN identifier request message transmit procedure (4.2.1), as follows. See Figure 3.

- a) If the transmission of the request message was successful (connector B), the external test equipment shall start the  $P2_{CAN}$  (see ISO 15031-5) application timer.

- b) If the external test equipment determines a P2<sub>CAN</sub> timeout then no response message has been started and the external test equipment has verified that 11 bit CAN identifiers are *not* used for legislated-OBD communication (connector C). In addition, this means that the external test equipment has determined that the vehicle supports CAN using the specified physical layer and one of the baudrates contained in the baudrateRecord parameter.



**Figure 3 — Initialization sequence — 11 bit CAN identifier response handling**

- c) The start of a response message can either be the reception of a FirstFrame or SingleFrame which uses one of the specified legislated-OBD 11 bit physical response CAN identifiers (see 6.3.2.2).

- d) If at least one response message is started, the external test equipment shall continue to receive this previously started response message (only applies to multiple-frame response messages) and shall accept further response messages within  $P2_{CAN}$  which use one of the specified legislated-OBD 11 bit physical response CAN identifiers.
- e) When all started response messages are completely received (positive or negative responses) and the  $P2_{CAN}$  application timer is timed out, this means that the external test equipment has verified that the vehicle supports legislated OBD on CAN using 11 bit CAN identifiers (connector E). If all received response messages are positive response messages, then the external test equipment knows the supported PIDs and the communication parameters of the legislated-OBD ECUs expected to respond to service 01 hex data parameter requests. Where one or more of the received response messages are negative response messages with response code 21 hex (busyRepeatRequest), the external test equipment shall start the initialization sequence (Connector A) again after a minimum delay of 200 ms. If the negative response(s) appear(s) on six (6) subsequent sequences, the external test equipment will assume that the vehicle is not compliant with ISO 15765-4 (connector F). This means that the legislated OBD-related ECU(s) shall provide a positive response within a maximum of five retries.

### 4.3 29 bit CAN identifier verification procedure

#### 4.3.1 Request message transmit procedure

The purpose of the 29 bit CAN identifier verification procedure is to determine whether 29 bit CAN identifiers are being used in legislated-OBD communication.

The 29 bit CAN identifier request message transmit procedure shall be used to transmit the functionally addressed request message of the 29 bit CAN identifier verification procedure. The same requirements as specified in 4.2.1 apply to the external test equipment when transmitting this request message. The procedure shall be performed as follows. See Figure 4.

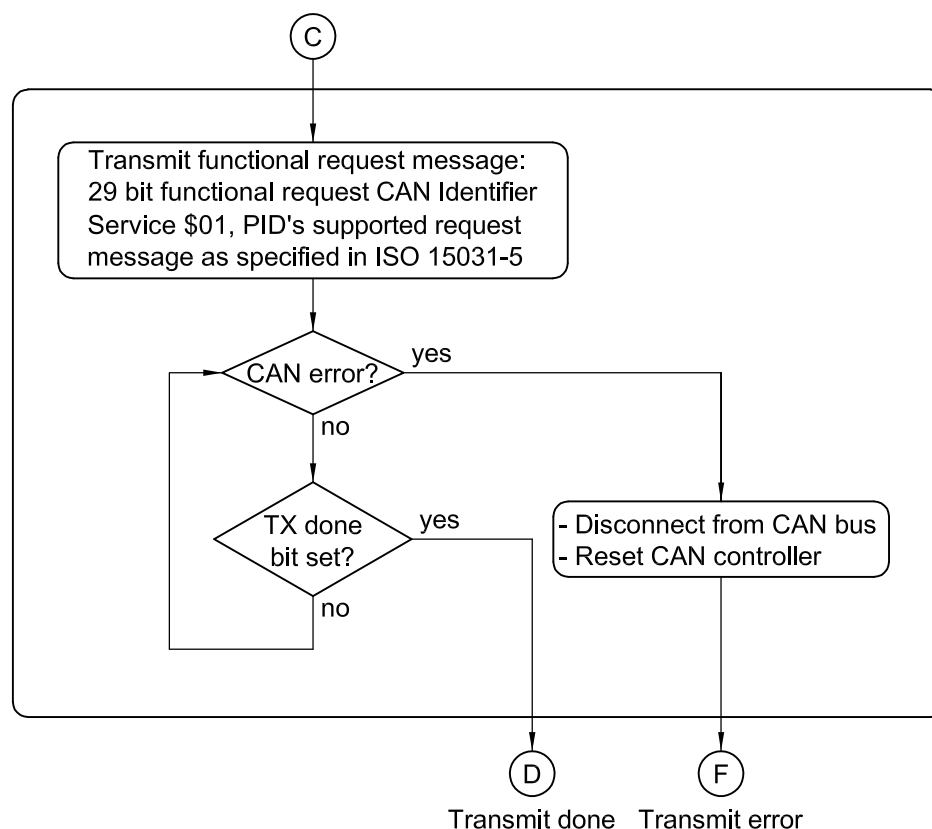


Figure 4 — Initialization sequence — 29 bit CAN identifier request transmission

- a) If the external test equipment reaches this point in the initialization sequence, this means that the CAN baudrate is already configured based on the previously performed 11 bit CAN identifier verification procedure. The external test equipment shall transmit a functionally addressed service 01 hex request message (read-supported PIDs — see ISO 15031-5) using the legislated-OBD 29 bit functional request CAN identifier according to 6.3.2.3. There is no need to set up the CAN Interface.
- b) The external test equipment shall check for any CAN error. If the request message is transmitted onto the CAN bus, it shall indicate a successful transmission (connector D). If a CAN error occurred, the external test equipment shall disconnect its CAN Interface from the CAN bus — with a disconnected CAN interface, the external test equipment shall not be able to transmit dominant bits on the CAN bus — and shall indicate a transmit error (connector F).

#### 4.3.2 Response handling procedure

The 29 bit CAN identifier response handling procedure shall be used to receive 29 bit CAN identifier response messages and indicates that no response message has been received. It shall be performed immediately after the 29 bit CAN identifier request message transmit procedure (4.3.1), as follows. See Figure 5.

- a) If the transmission of the request message was successful (connector D) then the external test equipment shall start the  $P2_{CAN}$  (see ISO 15031-5) application timer.
- b) If the external test equipment determines a  $P2_{CAN}$  timeout, this means that no response message has been started and the external test equipment has verified that 29 bit CAN identifiers are *not* used for legislated-OBD communication (connector F).
- c) The start of a response message can either be the reception of a FirstFrame or SingleFrame which uses one of the specified legislated-OBD 29 bit physical response CAN identifiers (see 6.3.2.3).
- d) If at least one response message is started, the external test equipment shall continue to receive this previously started response message (only applies to multiple-frame response messages) and shall accept within  $P2_{CAN}$  further response messages which use one of the specified legislated-OBD 29 bit physical response CAN identifiers.
- e) When all started response messages are completely received (positive or negative responses) and the  $P2_{CAN}$  application timer is timed out, this means that the external test equipment has verified that the vehicle supports legislated OBD on CAN using 29 bit CAN identifiers (connector E). If all received response messages are positive response messages, the external test equipment knows the supported PIDs and the communication parameters of the legislated-OBD ECUs expected to respond to service 01 hex data parameter requests. Where one or more of the received response messages are negative response messages with response code 2 hex (busyRepeatRequest), the external test equipment shall start the initialization sequence (connector C) again after a minimum delay of 200 ms. If the negative response(s) appear(s) on six (6) subsequent sequences, the external test equipment will assume that the vehicle is not compliant with ISO 15765-4 (connector F). This means that the legislated OBD-related ECU(s) shall provide a positive response within a maximum of five (5) retries.

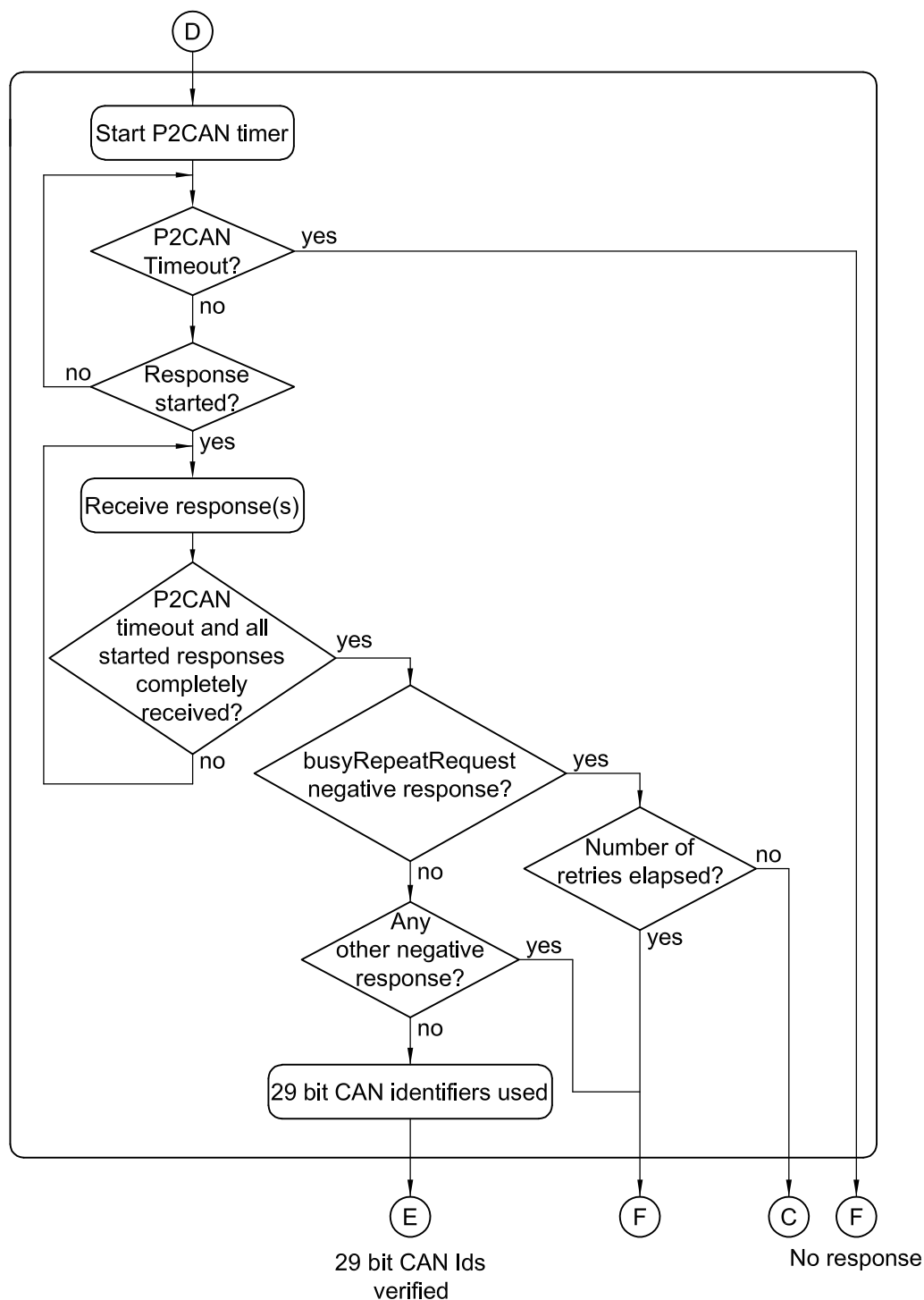


Figure 5 — Initialization sequence — 29 bit CAN identifier response handling

## 5 Session layer

All legislated OBD shall take place during the default diagnostic session.

There shall always be exactly one diagnostic session active in a legislated OBD-related ECU. A legislated-OBD-related ECU shall always start the default diagnostic session when powered up. If no other diagnostic session is started, then the default diagnostic session shall be running as long as the legislated-OBD-related ECU is powered.

A legislated-OBd-related ECU shall be capable of providing all diagnostic functionality defined for legislated OBd in the default diagnostic session and under normal operating conditions.

There is no need for any diagnostic service to be sent to the legislated-OBd-related ECU to keep the default diagnostic session active.

## 6 Network layer

### 6.1 General

The network layer of the external test equipment and the legislated-OBd-compliant vehicle ECU(s) — from the external test equipment point of view — shall be in accordance with ISO 15765-2 and the restrictions/additions given in 6.2 to 6.4.

### 6.2 Addressing formats

For legislated-OBd communication, only the normal addressing format — in the case of 11 bit CAN identifiers — and only the normal fixed addressing format — in the case of 29 bit CAN identifiers — as they are defined in ISO 15765-2, shall be used.

### 6.3 Data link layer interface

#### 6.3.1 CAN identifier requirements

##### 6.3.1.1 External test equipment

The external test equipment shall support 11 bit and 29 bit CAN identifiers for legislated-OBd communication, for which it shall only accept CAN identifiers which fit into the defined legislated-OBd CAN identifier ranges for 11 bit or 29 bit CAN identifiers (see 6.3.2).

For legislated-OBd communication following the initialization sequence, the external test equipment shall only use 11 bit or 29 bit CAN identifiers.

##### 6.3.1.2 Legislated-OBd ECU

A legislated-OBd-compliant vehicle shall use a single CAN identifier size: either 11 bit or 29 bit. From the external test equipment point of view, each legislated-OBd ECU in a given legislated OBd-compliant vehicle shall

- support either 11 bit or 29 bit CAN identifiers for legislated-OBd request and response messages,
- support one pair of physical request and response CAN identifiers in accordance with 6.3.2,
- accept the functional request CAN identifier of the supported CAN identifier set (11 bit or 29 bit — see 6.3.2) for functionally addressed legislated-OBd request messages, and
- accept the physical request CAN identifier associated with the physical response CAN identifier for physically addressed FlowControl frames sent by the external test equipment (see 6.3.2).

### 6.3.2 Mapping of diagnostic addresses

#### 6.3.2.1 Legislated-OBd CAN identifiers

The following subclauses specify the 11 bit and 29 bit CAN identifiers to be used for legislated-OBd diagnostics. Both sets of CAN identifiers represent the mapping of diagnostic addresses into CAN identifiers as follows. Table 2 defines the diagnostic addresses versus type of CAN identifier, whether physical or functional. For 11 bit CAN identifiers, the mapping of the target address (TA) and source address (SA) into a CAN identifier is implied. Table 3 specifies the 11 bit CAN identifiers to be used for legislated-OBd diagnostics. See Figure 6.



Table 2 — Definition of diagnostic addresses versus type of CAN identifier

CAN identifier	Target Address (TA)	Source Address (SA)	TA type (TAtype)	Message type (Mtype)
Functional request	Legislated OBD system = 33 hex	External test equipment = F1 hex	functional	diagnostics
Physical response	External test equipment = F1 hex	Legislated-OBD ECU = xx hex	physical	diagnostics
Physical request	Legislated OBD ECU = xx hex	External test equipment = F1 hex	physical	diagnostics
xx hex ECU physical diagnostic address				
NOTE For detailed descriptions of parameters TA, SA, TAtype and Mtype, see ISO 15765-2.				

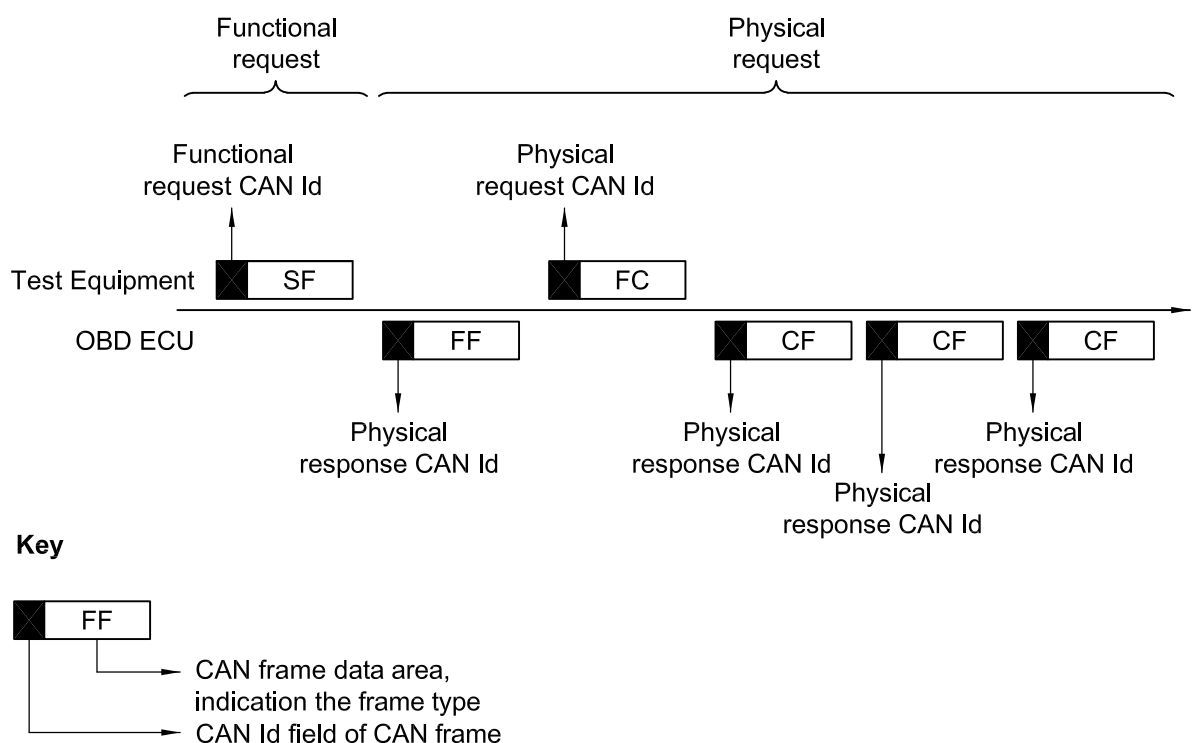


Figure 6 — CAN identifier usage

For legislated OBD:

- the functional request CAN identifier shall be used for functionally addressed request messages sent by the external test equipment, this particular CAN identifier representing the TA 33 hex (legislated-OBD functional system) and SA F1 hex (external test equipment);
- the physical response CAN Id shall be used for physically addressed response messages sent by the legislated-OBD ECU(s), this particular CAN identifier representing the TA F1 hex (external test equipment) and the physical diagnostic address (SA) of the ECU(s).
- the physical request CAN Id shall only be used for physically addressed FlowControl frames sent by the external test equipment, this particular CAN identifier representing the physical diagnostic address (TA) of the ECU and SA F1 hex (external test equipment).

The server identifier (physical diagnostic address) of a legislated-OBD ECU shall be unique to a given legislated-OBD-compliant vehicle.

The CAN identifiers specified for legislated OBD may also be used for enhanced diagnostics if this usage does not interfere with legislated OBD.

6.3.2.2 11 bit CAN identifiers

Table 3 specifies the 11 bit CAN identifiers for legislated OBD, based on the defined mapping of the diagnostic addresses.

Table 3 — 11 bit legislated-OBD CAN identifiers

CAN identifier (hex)	Description
7DF	CAN identifier for functionally addressed request messages sent by external test equipment
7E0	Physical request CAN identifier from external test equipment to ECU #1
7E8	Physical response CAN identifier from ECU #1 to external test equipment
7E1	Physical request CAN identifier from external test equipment to ECU #2
7E9	Physical response CAN identifier from ECU #2 to external test equipment
7E2	Physical request CAN identifier from external test equipment to ECU #3
7EA	Physical response CAN identifier from ECU #3 to external test equipment
7E3	Physical request CAN identifier from external test equipment to ECU #4
7EB	Physical response CAN identifier ECU #4 to the external test equipment
7E4	Physical request CAN identifier from external test equipment to ECU #5
7EC	Physical response CAN identifier from ECU #5 to external test equipment
7E5	Physical request CAN identifier from external test equipment to ECU #6
7ED	Physical response CAN identifier from ECU #6 to external test equipment
7E6	Physical request CAN identifier from external test equipment to ECU #7
7EE	Physical response CAN identifier from ECU #7 to external test equipment
7E7	Physical request CAN identifier from external test equipment to ECU #8
7EF	Physical response CAN identifier from ECU #8 to external test equipment
While not required for current implementations, it is strongly recommended (and may be required by applicable legislation) that for future implementations the following 11-bit CAN identifier assignments be used: — 7E0/7E8 for ECM (engine control module); — 7E1/7E9 for TCM (transmission control module).	

6.3.2.3 29 bit CAN identifiers

Tables 4 and 5 specify the 29 bit CAN identifiers for legislated OBD, based on the defined mapping of the diagnostic addresses. The 29 bit CAN identifiers shall comply with the normal fixed addressing format according to ISO 15765-2, summarized in Table 4.

Table 4 — Summary of 29 bit CAN identifier format — Normal fixed addressing

CAN Id bit position	2824	2316	158	70
Functional CAN Id	18 hex	DB hex	TA	SA
Physical CAN Id	18 hex	DA hex	TA	SA
NOTE The CAN identifier values given in this table use the default value for the priority information in accordance with ISO 15765-2.				

**Table 5 — 29 bit legislated-OBd CAN identifiers**

CAN identifier (hex)	Description
18 DB 33 F1	CAN identifier for functionally address request messages sent by external test equipment.
18 DA xx F1	Physical request CAN identifier from external test equipment to ECU #xx
18 DA F1 xx	Physical response CAN identifier from ECU #xx to external test equipment

The maximum number of legislated-OBd ECUs in a legislated-OBd-compliant vehicle shall not exceed eight (8). The physical ECU diagnostic address of an ECU ('xx' hex) embedded in the physical CAN identifiers shall be unique for a legislated-OBd ECU in a given vehicle.

While not required for current implementations, it is strongly recommended (and may be required by applicable legislation) that for future implementations the physical ECU addresses according to the assignments found in SAE 32178/1.

## 6.4 Network layer parameters

### 6.4.1 Network layer timing parameter values

Table 6 specifies the network layer timing parameters to be used by the external test equipment and the legislated-OBd-compliant vehicle — from the external test equipment point of view — for legislated-OBd communication.

The listed performance requirement values are the binding communication requirements for the external test equipment and the legislated-OBd ECU(s) considered as being legislated-OBd-compliant. The timeout values are defined to be higher than the values for the performance requirements in order to overcome communication conditions where the performance requirement absolutely cannot be met (owing to external conditions such as high bus load).

**Table 6 — Network layer timeout and performance requirement values**

Parameter	Timeout value	Performance requirement value
N_As/ N_Ar	25 ms	—
N_Bs	75 ms	—
N_Br	—	$(N_{Br} + N_{Ar}) < 25 \text{ ms}$
N-Cs	—	$(N_{Cs} + N_{As}) < 50 \text{ ms}$
N-Cr	150 ms	—
Owing to application layer timing requirements, the following performance requirement for the transmission of a single or first frame of an ECU response message applies: $P2_{CAN, ECU} + N_{As} \leq P2_{CANmax}$		
NOTE 1	For a detailed description of the network layer timing parameter values, see ISO 15765-2.	
NOTE 2	For a detailed description of the application layer timing parameter P2, see ISO 15031-5.	

### 6.4.2 Definition of external test equipment network layer parameter values

The external test equipment shall use the following network layer parameter values for its FlowControl frames sent in response to the reception of a FirstFrame. See Table 7.

**Table 7 — External test equipment network layer parameter values**

Parameter	Name	Value	Description
N_WFT <sub>max</sub>	WaitFrame Transmission	0	No FlowControl wait frames are allowed for legislated OBD. The FlowControl frame sent by the external test equipment following the FirstFrame of an ECU response message shall contain the FlowStatus FS set to 0 (ClearToSend), which forces the ECU to start immediately after the reception of the FlowControl frame with the transmission of the ConsecutiveFrame(s).
BS	BlockSize	0	A single FlowControl frame shall be transmitted by the external test equipment for the duration of a segmented message transfer. This unique FlowControl frame shall follow the FirstFrame of an ECU response message.
ST <sub>min</sub>	SeparationTime	0	This value allows the ECU to send ConsecutiveFrames, following the FlowControl frame sent by the external test equipment, as fast as possible.
If a reduced implementation of the ISO 15765-2 network layer is done in a legislated-OBd ECU, covering only the above listed FlowControl frame parameter values (BS, ST <sub>min</sub> ), then any FlowControl frame received during legislated-OBd communication and using different FlowControl frame parameter values as defined in this table shall be ignored by the receiving legislated-OBd ECU (treated as an unknown network layer protocol data unit).			

### 6.4.3 Maximum number of legislated-OBd ECUs

The maximum number of legislated-OBd-related ECUs in a vehicle shall not exceed eight (8). The network layer of the external test equipment shall be capable of receiving segmented data from eight (8) legislated-OBd ECUs in parallel.

## 7 Data link layer

All of ISO 11898-1 is applicable for legislated-OBd purposes, with the following restrictions/additions. The external test equipment CAN controller shall be able to transmit and receive 11 bit and 29 bit CAN identifiers (see 6.3).

The CAN DLC (data length code) contained in every diagnostic CAN frame shall always be set to eight (8). The unused data bytes of a CAN frame are undefined. Any diagnostic CAN frame with a DLC value less than eight (8) shall be ignored by the receiving entity.

## 8 Physical layer

### 8.1 General

The physical layer and physical signalling of the external test equipment shall be in accordance with ISO 11898-1 and ISO 11898-2, with the following restrictions and additions.

### 8.2 External test equipment baudrates

The external test equipment shall support the legislated-OBd baudrates. These can vary because of legislation. Where the applicable legislation does not specify baudrates, use

250 kBit/s

500 kBit/s

### 8.3 External test equipment CAN bit timing

#### 8.3.1 CAN bit timing parameter values

The specified CAN bit timing parameter values apply to the external test equipment. The legislated-OBD-compliant vehicle may use different CAN bit timing parameter values to achieve its legislated-OBD-compliant baudrate, however, it shall be able to communicate with the defined external test equipment.

The following specifies the required CAN bit timing parameter settings for the external test equipment based on the timing parameter definitions given in ISO 11898-1. All requirements are specified for operation at 250 kBit/s and 500 kBit/s. The bit timing is according to ISO 11898. The CAN controller shall support the protocol specifications CAN 2.0A (standard format) and CAN 2.0B passive (29 bit ID extended format) and shall be in accordance with ISO 11898.

For example, the enhanced protocol for higher clock tolerance shall be supported (e.g. tolerate 2 bit message intermission) and extended frame messages shall not be disturbed unless bit errors are being detected.

The CAN bit timing parameter values used in this part of ISO 15765 are based on equivalent terms in ISO 11898-1:

$t_{\text{SYNCSEG}}$	= Sync_Seg	= $1 * t_Q$
$t_{\text{SEG1}}$	= Prop_Seg + Phase_Seg1	= $t_{\text{BIT}} - t_{\text{SYNCSEG}} - t_{\text{SEG2}}$
$t_{\text{SEG2}}$	= Phase_Seg2	
$t_{\text{SJW}}$	= resynchronization jump width	
$t_{\text{BIT}}$	= $t_B$ (nominal bit time)	
$t_Q$	= time quantum	
SP	= nominal sample point position	= $(1 - t_{\text{SEG2}}/t_{\text{BIT}}) * 100 \%$

**NOTE** Compliance with the nominal bit time tolerance requirement given in this part of ISO is directly dependent on the CAN system clock tolerance of the external test equipment and the programmed nominal bit time value. In a typical CAN controller, the nominal bit time value must be an integer multiple of its system clock periods. When the programmable nominal bit time value is set exactly to the required nominal bit time value, accuracy is only affected by the system clock tolerance. Otherwise, the accuracy is dependent upon both the deviation of the programmed bit time value from the nominal bit time value and the system clock tolerance. The contributions from drift or ageing of the system clock source and from the inability to achieve the desired nominal bit time value are additive; the bit time tolerance specification must be met after consideration of both.

See Figure 7.

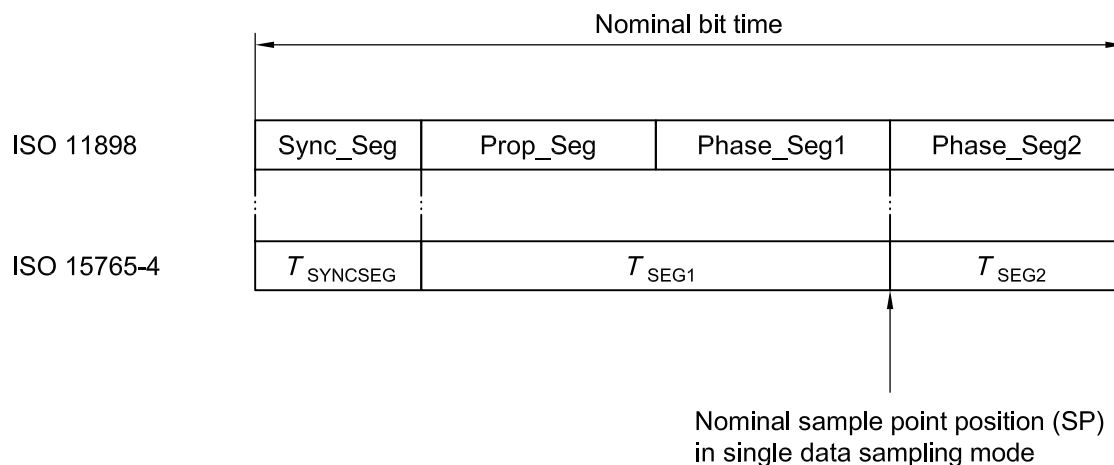


Figure 7 — Partitioning of CAN bit time

### 8.3.2 Nominal baudrate 250 kBit/s

Table 8 specifies the allowed CAN bit timing parameter values for a baudrate of 250 kBit/s. The external test equipment shall operate in single data sampling mode.

The tolerance of the external test equipment nominal baudrate 250 kBit/s shall be  $\pm 0,15 \%$ .

Table 8 — 250 kBit/s CAN bit timing parameter values — Single data sampling mode

Parameter	Minimum	Nominal	Maximum
$t_{\text{BIT\_RX}}$	3 980 ns	4 000 ns	4 020 ns
$t_{\text{BIT\_TX}}$	3 994 ns	4 000 ns	4 006 ns
$t_{\text{Q}}$	—	—	250 ns
$\Delta f$	—	—	0,15 %

The min. and max. values of the nominal bit time  $t_{\text{BIT\_RX}}$  are worst-case values for the reception of bits from the CAN bus based on a nominal baudrate tolerance of  $\pm 0,5 \%$ . The min. and max. values of the nominal bit time  $t_{\text{BIT\_TX}}$  are worst-case values for the transmission of bits onto the CAN bus based on the specified external test equipment nominal baudrate tolerance of  $\pm 0,15 \%$ .

Table 9 presents the only allowed CAN bit timing parameter values for the external test equipment based on standard time quanta ( $t_{\text{Q}}$ ) and the timing parameters listed in 8.3.1.

Table 9 — 250 kBit/s CAN bit timing parameter values for standard time quanta

$t_Q$	$t_{SJW}$	$t_{SEG1}$	$t_{SEG2}$	Nominal sample point position %
ns				
200	600	3 000	800	80
250	750	3 000	750	81,25

The nominal sample point position is specified relative to one (1) bit time.

### 8.3.3 Nominal baudrate 500 kBit/s

Table 10 specifies the allowed CAN bit timing parameter values for a baudrate of 500 kBit/s. The external test equipment shall operate in single data-sampling mode.

The tolerance of the external test equipment nominal baudrate 500 kBit/s shall be  $\pm 0,15\%$

**Table 10 — 500 kBit/s CAN bit timing parameter values — Single data sampling mode**

Parameter	Minimum	Nominal	Maximum
$t_{\text{BIT\_RX}}$	1 990 ns	2 000 ns	2 010 ns
$t_{\text{BIT\_TX}}$	1 997 ns	2 000 ns	2 003 ns
$t_{\text{Q}}$	—	—	125 ns
$\Delta f$	—	—	0,15 %

The min. and max. values of the nominal bit time  $t_{\text{BIT\_RX}}$  are worst-case values for the reception of bits from the CAN bus based on a nominal baudrate tolerance of  $\pm 0,5\%$ .

The min. and max. values of the nominal bit time  $t_{\text{BIT\_TX}}$  are worst-case values for the transmission of bits onto the CAN bus based on the specified external test equipment nominal baudrate tolerance of  $\pm 0,15\%$ .

Table 11 presents contains the only allowed CAN bit timing parameter values for the external test equipment based on standard time quanta ( $t_{\text{Q}}$ ) and the timing parameters listed in 8.3.1.

**Table 11 — 500 kBit/s CAN bit timing parameter values for standard time quanta**

$t_{\text{Q}}$	$t_{\text{SJW}}$	$t_{\text{SEG1}}$	$t_{\text{SEG2}}$	Nominal sample point position %
ns				
100	300	1 500	400	80
125	375	1 500	375	81,25

The nominal sample point position is specified relative to one (1) bit time.

## 8.4 External test equipment

### 8.4.1 General

The following specifies the electrical parameters to be fulfilled by the external test equipment. The requirements are separated into those for the external test equipment CAN interface and those for the external-test-equipment cable. See Figure 8.

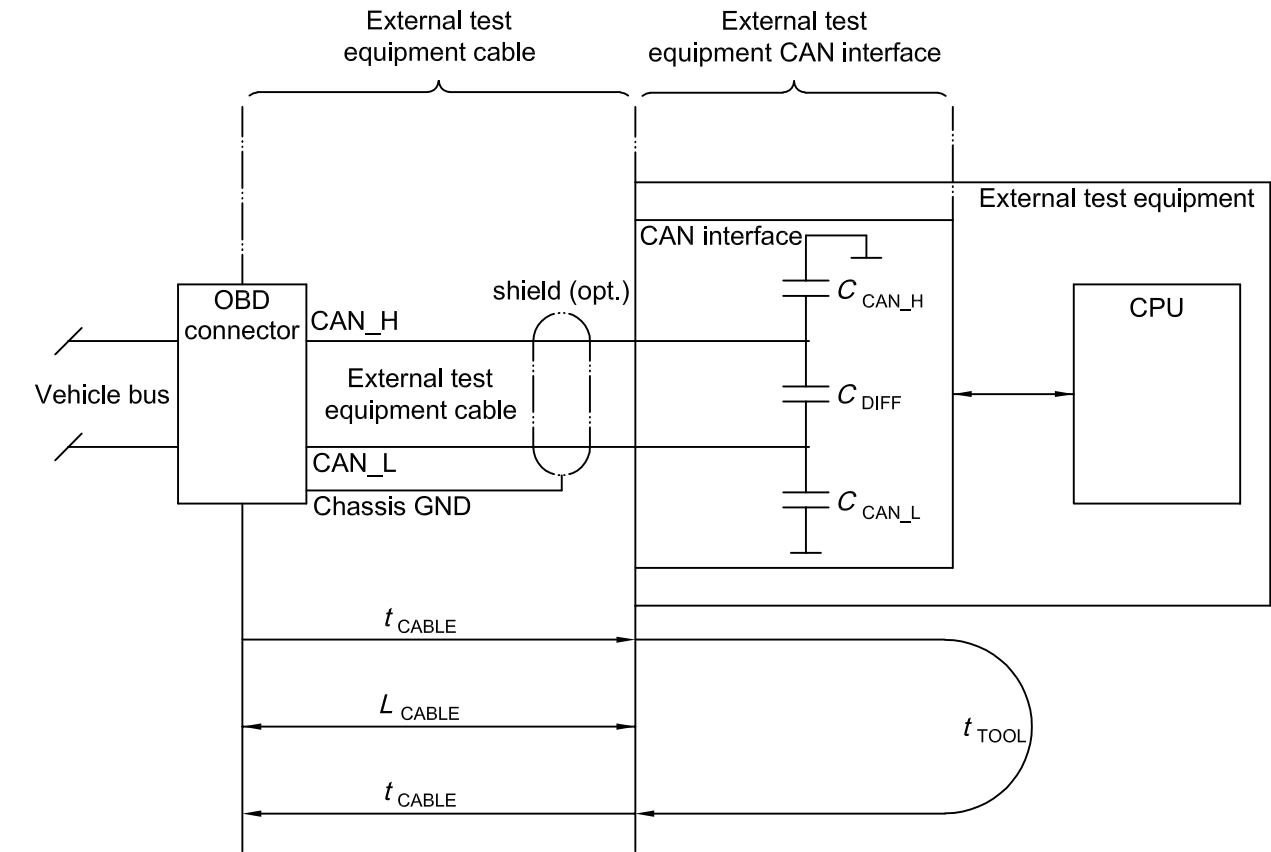


Figure 8 — External test equipment electrical parameters

8.4.2 CAN interface

8.4.2.1 Capacitive load

These subclauses specify the required electrical parameters for the external-test-equipment CAN interface, excluding the cable (see 8.4.3) and the OBD connector.

The external test equipment capacitive load does not include the capacitive load of the external-test-equipment cable. These values only apply to the CAN interface of the external test equipment hardware, with the exception of the a.c. termination (see 8.4.2.3.3), and are seen during the recessive state when the external test equipment is disconnected from the cable and the a.c. termination has not yet been inserted. See Table 12.

Table 12 — External test equipment capacitive load — Without cable capacitive load

Parameter	Minimum	Nominal	Maximum pF	Description
$C_{DIFF}$	—	—	50	CAN_H to CAN_L
$C_{CAN\_H}, C_{CAN\_L}$	—	—	100	CAN_H/CAN_L to ground potential

8.4.2.2 Propagation delay

The external test equipment propagation delay does not include the cable propagation delay. This value only applies to the CAN interface of the external-test-equipment hardware. This requirement is based on the most critical timing when operating at the legislated-OBd compliant baud rate of 500 kbit/s. The external-test-equipment propagation delay (loop delay) includes all delays that can be caused by the CAN interface of the external test equipment (e.g. CAN transceiver propagation delays, CAN controller propagation delays). See Table 13.



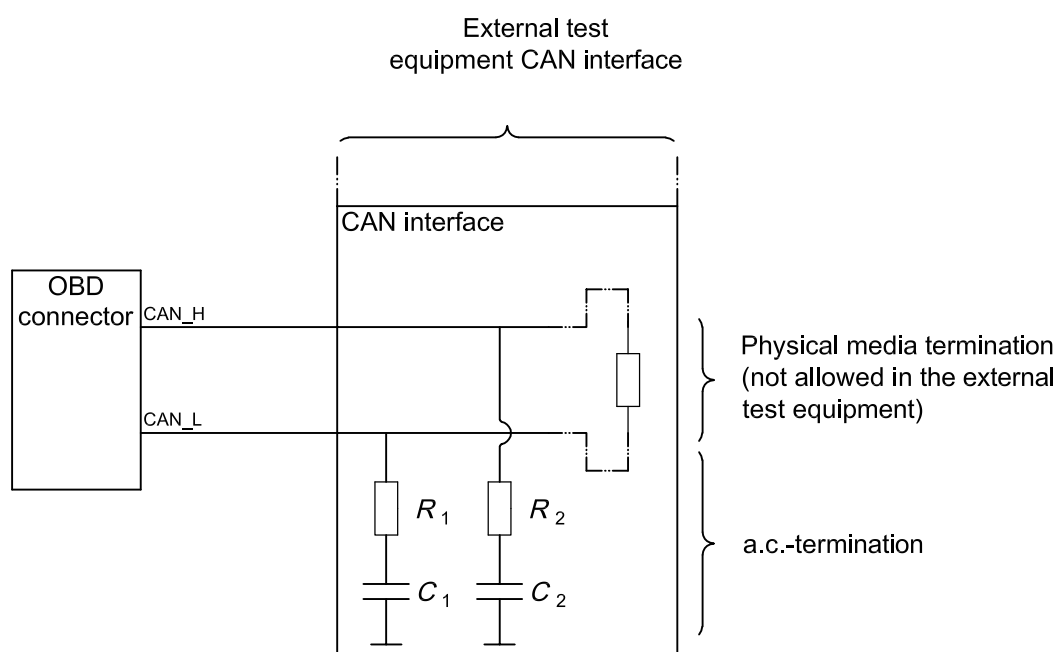
**Table 13 — External test equipment propagation delay — Loop delay without cable delay**

Parameter	Minimum	Nominal	Maximum ns	Description
$t_{\text{TOOL}}$	—	—	390	Loop delay of external test equipment

### 8.4.2.3 CAN bus termination

#### 8.4.2.3.1 General

These subclauses specify the termination requirements to be fulfilled by the external test equipment. See Figure 9.

**Figure 9 — External test equipment CAN bus termination**

#### 8.4.2.3.2 Physical media termination

There shall be no termination resistor between the CAN conductors CAN\_H and CAN\_L in the external test equipment for the adaptation to the physical media impedance. The external test equipment shall be an unterminated node on the CAN bus to which it is connected.

#### 8.4.2.3.3 a.c. termination

The external test equipment shall have an a.c. termination for the purpose of minimizing reflections on the CAN bus. See Table 14.

**NOTE** Reflections on the CAN bus occur in the external test equipment CAN interface because it is not permitted that the external test equipment use a physical media termination resistor to adapt to the physical media impedance (8.4.2.3.2).

**Table 14 — External-test-equipment a.c. termination parameters**

Parameter	Minimum	Nominal	Maximum	Description
$R_1, R_2$	90 $\Omega$	100 $\Omega$	110 $\Omega$	Resistor of the a.c. termination
$C_1, C_2$	470 pF	560 pF	640 pF	Capacitor of the a.c. termination
$R_1 = R_2$ $C_1 = C_2$				

### 8.4.3 External-test-equipment cable

#### 8.4.3.1 Cable length

The external-test-equipment cable shall provide interconnection between the vehicle OBD connector and the CAN interface of the external test equipment (see 8.4.2).

The external-test-equipment cable length is defined to be the length of the cable between the OBD connector and the external test equipment CAN interface. See Table 15.

**Table 15 — External-test-equipment cable length**

Parameter	Minimum	Nominal	Maximum m	Description
$L_{\text{CABLE}}$	—	—	5	External-test-equipment cable length

#### 8.4.3.2 Propagation delay

The cable propagation delay shall not include the external test equipment propagation delay. This value only applies to the cable. This requirement is based on the most critical timing when operating at the legislated-OBD compliant baudrate of 500 kbit/s. The cable propagation delay is defined as a one-way delay, from the OBD connector to the external test equipment CAN interface. See Table 16.

**Table 16 — External-test-equipment cable propagation delay**

Parameter	Minimum	Nominal	Maximum ns	Description
$t_{\text{CABLE}}$	—	—	27,5	External-test-equipment cable delay

#### 8.4.3.3 Cable configuration requirements

The following configuration requirements apply to the external-test-equipment cable.

- No other wires shall be twisted with CAN conductor(s) CAN\_H or CAN\_L. However, twisting of the CAN conductors with Signal Ground is allowed.

NOTE There are no further requirements for twisting.

- The CAN\_H and CAN\_L conductors shall have the same length and traverse the same path for the entire distance.
- CAN\_H and CAN\_L conductors shall not be included in a bundle containing radiating wires which induce more than 0,5 V noise modulation on either CAN conductor relative to Signal Ground.
- The cable shall be shielded where the external-test-equipment cable length exceeds 1 m. The shield shall be connected to the chassis ground pin of the cable side of the OBD connector.

## Bibliography

- [1] ISO/IEC 7498 (all parts), *Information technology — Open Systems Interconnection — Basic Reference Model*
- [2] ISO/IEC 10731, *Information technology — Open Systems Interconnection — Basic Reference Model — Conventions for the definition of OSI services*
- [3] ISO 15031-3, *Road vehicles — Communication between vehicle and external equipment for emissions-related diagnostics — Part 3: Diagnostic connector and related electrical circuits, specification and use*
- [4] SAE J2178/1, *Class B data communication network messages — Detailed header formats and physical address assignments*

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
66  
67  
68  
69  
70  
71  
72  
73  
74  
75  
76  
77  
78  
79  
80  
81  
82  
83  
84  
85  
86  
87  
88  
89  
90  
91  
92  
93  
94  
95  
96  
97  
98  
99  
100  
101  
102  
103  
104  
105  
106  
107  
108  
109  
110  
111  
112  
113  
114  
115  
116  
117  
118  
119  
120  
121  
122  
123  
124  
125  
126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138  
139  
140  
141  
142  
143  
144  
145  
146  
147  
148  
149  
150  
151  
152  
153  
154  
155  
156  
157  
158  
159  
160  
161  
162  
163  
164  
165  
166  
167  
168  
169  
170  
171  
172  
173  
174  
175  
176  
177  
178  
179  
180  
181  
182  
183  
184  
185  
186  
187  
188  
189  
190  
191  
192  
193  
194  
195  
196  
197  
198  
199  
200  
201  
202  
203  
204  
205  
206  
207  
208  
209  
210  
211  
212  
213  
214  
215  
216  
217  
218  
219  
220  
221  
222  
223  
224  
225  
226  
227  
228  
229  
230  
231  
232  
233  
234  
235  
236  
237  
238  
239  
240  
241  
242  
243  
244  
245  
246  
247  
248  
249  
250  
251  
252  
253  
254  
255  
256  
257  
258  
259  
260  
261  
262  
263  
264  
265  
266  
267  
268  
269  
270  
271  
272  
273  
274  
275  
276  
277  
278  
279  
280  
281  
282  
283  
284  
285  
286  
287  
288  
289  
290  
291  
292  
293  
294  
295  
296  
297  
298  
299  
300  
301  
302  
303  
304  
305  
306  
307  
308  
309  
310  
311  
312  
313  
314  
315  
316  
317  
318  
319  
320  
321  
322  
323  
324  
325  
326  
327  
328  
329  
330  
331  
332  
333  
334  
335  
336  
337  
338  
339  
340  
341  
342  
343  
344  
345  
346  
347  
348  
349  
350  
351  
352  
353  
354  
355  
356  
357  
358  
359  
360  
361  
362  
363  
364  
365  
366  
367  
368  
369  
370  
371  
372  
373  
374  
375  
376  
377  
378  
379  
380  
381  
382  
383  
384  
385  
386  
387  
388  
389  
390  
391  
392  
393  
394  
395  
396  
397  
398  
399  
400  
401  
402  
403  
404  
405  
406  
407  
408  
409  
410  
411  
412  
413  
414  
415  
416  
417  
418  
419  
420  
421  
422  
423  
424  
425  
426  
427  
428  
429  
430  
431  
432  
433  
434  
435  
436  
437  
438  
439  
440  
441  
442  
443  
444  
445  
446  
447  
448  
449  
450  
451  
452  
453  
454  
455  
456  
457  
458  
459  
460  
461  
462  
463  
464  
465  
466  
467  
468  
469  
470  
471  
472  
473  
474  
475  
476  
477  
478  
479  
480  
481  
482  
483  
484  
485  
486  
487  
488  
489  
490  
491  
492  
493  
494  
495  
496  
497  
498  
499  
500  
501  
502  
503  
504  
505  
506  
507  
508  
509  
510  
511  
512  
513  
514  
515  
516  
517  
518  
519  
520  
521  
522  
523  
524  
525  
526  
527  
528  
529  
530  
531  
532  
533  
534  
535  
536  
537  
538  
539  
540  
541  
542  
543  
544  
545  
546  
547  
548  
549  
550  
551  
552  
553  
554  
555  
556  
557  
558  
559  
560  
561  
562  
563  
564  
565  
566  
567  
568  
569  
570  
571  
572  
573  
574  
575  
576  
577  
578  
579  
580  
581  
582  
583  
584  
585  
586  
587  
588  
589  
590  
591  
592  
593  
594  
595  
596  
597  
598  
599  
600  
601  
602  
603  
604  
605  
606  
607  
608  
609  
610  
611  
612  
613  
614  
615  
616  
617  
618  
619  
620  
621  
622  
623  
624  
625  
626  
627  
628  
629  
630  
631  
632  
633  
634  
635  
636  
637  
638  
639  
640  
641  
642  
643  
644  
645  
646  
647  
648  
649  
650  
651  
652  
653  
654  
655  
656  
657  
658  
659  
660  
661  
662  
663  
664  
665  
666  
667  
668  
669  
670  
671  
672  
673  
674  
675  
676  
677  
678  
679  
680  
681  
682  
683  
684  
685  
686  
687  
688  
689  
690  
691  
692  
693  
694  
695  
696  
697  
698  
699  
700  
701  
702  
703  
704  
705  
706  
707  
708  
709  
710  
711  
712  
713  
714  
715  
716  
717  
718  
719  
720  
721  
722  
723  
724  
725  
726  
727  
728  
729  
730  
731  
732  
733  
734  
735  
736  
737  
738  
739  
740  
741  
742  
743  
744  
745  
746  
747  
748  
749  
750  
751  
752  
753  
754  
755  
756  
757  
758  
759  
760  
761  
762  
763  
764  
765  
766  
767  
768  
769  
770  
771  
772  
773  
774  
775  
776  
777  
778  
779  
780  
781  
782  
783  
784  
785  
786  
787  
788  
789  
790  
791  
792  
793  
794  
795  
796  
797  
798  
799  
800  
801  
802  
803  
804  
805  
806  
807  
808  
809  
810  
811  
812  
813  
814  
815  
816  
817  
818  
819  
820  
821  
822  
823  
824  
825  
826  
827  
828  
829  
830  
831  
832  
833  
834  
835  
836  
837  
838  
839  
840  
841  
842  
843  
844  
845  
846  
847  
848  
849  
850  
851  
852  
853  
854  
855  
856  
857  
858  
859  
860  
861  
862  
863  
864  
865  
866  
867  
868  
869  
870  
871  
872  
873  
874  
875  
876  
877  
878  
879  
880  
881  
882  
883  
884  
885  
886  
887  
888  
889  
890  
891  
892  
893  
894  
895  
896  
897  
898  
899  
900  
901  
902  
903  
904  
905  
906  
907  
908  
909  
910  
911  
912  
913  
914  
915  
916  
917  
918  
919  
920  
921  
922  
923  
924  
925  
926  
927  
928  
929  
930  
931  
932  
933  
934  
935  
936  
937  
938  
939  
940  
941  
942  
943  
944  
945  
946  
947  
948  
949  
950  
951  
952  
953  
954  
955  
956  
957  
958  
959  
960  
961  
962  
963  
964  
965  
966  
967  
968  
969  
970  
971  
972  
973  
974  
975  
976  
977  
978  
979  
980  
981  
982  
983  
984  
985  
986  
987  
988  
989  
990  
991  
992  
993  
994  
995  
996  
997  
998  
999  
1000  
1001  
1002  
1003  
1004  
1005  
1006  
1007  
1008  
1009  
1010  
1011  
1012  
1013  
1014  
1015  
1016  
1017  
1018  
1019  
1020  
1021  
1022  
1023  
1024  
1025  
1026  
1027  
1028  
1029  
1030  
1031  
1032  
1033  
1034  
1035  
1036  
1037  
1038  
1039  
1040  
1041  
1042  
1043  
1044  
1045  
1046  
1047  
1048  
1049  
1050  
1051  
1052  
1053  
1054  
1055  
1056  
1057  
1058  
1059  
1060  
1061  
1062  
1063  
1064  
1065  
1066  
1067  
1068  
1069  
1070  
1071  
1072  
1073  
1074  
1075  
1076  
1077  
1078  
1079  
1080  
1081  
1082  
1083  
1084  
1085  
1086  
1087  
1088  
1089  
1090  
1091  
1092  
1093  
1094  
1095  
1096  
1097  
1098  
1099  
1100  
1101  
1102  
1103  
1104  
1105  
1106  
1107  
1108  
1109  
1110  
1111  
1112  
1113  
1114  
1115  
1116  
1117  
1118  
1119  
1120  
1121  
1122  
1123  
1124  
1125  
1126  
1127  
1128  
1129  
1130  
1131  
1132  
1133  
1134  
1135  
1136  
1137  
1138  
1139  
1140  
1141  
1142  
1143  
1144  
1145  
1146  
1147  
1148  
1149  
1150  
1151  
1152  
1153  
1154  
1155  
1156  
1157  
1158  
1159  
1160  
1161  
1162  
1163  
1164  
1165  
1166  
1167  
1168  
1169  
1170  
1171  
1172  
1173  
1174  
1175  
1176  
1177  
1178  
1179  
1180  
1181  
1182  
1183  
1184  
1185  
1186  
1187  
1188  
1189  
1190  
1191  
1192  
1193  
1194  
1195  
1196  
1197  
1198  
1199  
1200  
1201  
1202  
1203  
1204  
1205  
1206  
1207  
1208  
1209  
1210  
1211  
1212  
1213  
1214  
1215  
1216  
1217  
1218  
1219  
1220  
1221  
1222  
1223  
1224  
1225  
1226  
1227  
1228  
1229  
1230  
1231  
1232  
1233  
1234  
1235  
1236  
1237  
1238  
1239  
1240  
1241  
1242  
1243  
1244  
1245  
1246  
1247  
1248  
1249  
1250  
1251  
1252  
1253  
1254  
1255  
1256  
1257  
1258  
1259  
1260  
1261  
1262  
1263  
1264  
1265  
1266  
1267  
1268  
1269  
1270  
1271  
1272  
1273  
1274  
1275  
1276  
1277  
1278  
1279  
1280  
1281  
1282  
1283  
1284  
1285  
1286  
1287  
1288  
1289  
1290  
1291  
1292  
1293  
1294  
1295  
1296  
1297  
1298  
1299  
1300  
1301  
1302  
1303  
1304  
1305  
1306  
1307  
1308  
1309  
1310  
1311  
1312  
1313  
1314  
1315  
1316  
1317  
1318  
1319  
1320  
1321  
1322  
1323  
1324  
1325  
1326  
1327  
1328  
1329  
1330  
1331  
1332  
1333  
1334  
1335  
1336  
1337  
1338  
1339  
1340  
1341  
1342  
1343  
1344  
1345  
1346  
1347  
1348  
1349  
1350  
1351  
1352  
1353  
1354  
1355  
1356  
1357  
1358  
1359  
1360  
1361  
1362  
1363  
1364  
1365  
1366  
1367  
1368  
1369  
1370  
1371  
1372  
1373  
1374  
1375  
1376  
1377  
1378  
1379  
1380  
1381  
1382  
1383  
1384  
1385  
1386  
1387  
1388  
1389  
1390  
1391  
1392  
1393  
1394  
1395  
1396  
1397  
1398  
1399  
1400  
1401  
1402  
1403  
1404  
1405  
1406  
1407  
1408  
1409  
1410  
1411  
1412  
1413  
1414  
1415  
1416  
1417  
1418  
1419  
1420  
1421  
1422  
1423  
1424  
1425  
1426  
1427  
1428  
1429  
1430  
1431  
1432  
1433  
1434  
1435  
1436  
1437  
1438  
1439  
1440  
1441  
1442  
1443  
1444  
1445  
1446  
1447  
1448  
1449  
1450  
1451  
1452  
1453  
1454  
1455  
1456  
1457  
1458  
1459  
1460  
1461  
1462  
1463  
1464  
1465  
1466  
1467  
1468  
1469  
1470  
1471  
1472  
1473  
1474  
1475  
1476  
1477  
1478  
1479  
1480  
1481  
1482  
1483  
1484  
1485  
1486  
1487  
1488  
1489  
1490  
1491  
1492  
1493  
1494  
1495  
1496  
1497  
1498  
1499  
1500  
1501  
1502  
1503  
1504  
1505  
1506  
1507  
1508  
1509  
1510  
1511  
1512  
1513  
1514  
1515  
1516  
1517  
1518  
1519  
1520  
1521  
1522  
1523  
1524  
1525  
1526  
1527  
1528  
1529  
1530  
1531  
1532  
1533  
1534  
1535  
1536  
1537  
1538  
1539  
1540  
1541  
1542  
1543  
1544  
1545  
1546  
1547  
1548  
1549  
1550  
1551  
1552  
1553  
1554  
1555  
1556  
1557  
1558  
1559  
1560  
1561  
1562  
1563  
1564  
1565  
1566  
1567  
1568  
1569  
1570  
1571  
1572  
1573  
1574  
1575  
1576  
1577  
1578  
1579  
1580  
1581  
1582  
1583  
1584  
1585  
1586  
1587  
1588  
1589  
1590  
1591  
1592  
1593  
1594  
1595  
1596  
1597  
1598  
1599  
1600  
1601  
1602  
1603  
1604  
1605  
1606  
1607  
1608  
1609  
1610  
1611  
1612  
1613  
1614  
1615  
1616  
1617  
1618  
1619  
1620  
1621  
1622  
1623  
1624  
1625  
1626  
1627  
1628  
1629  
1630  
1631  
1632  
1633  
1634  
1635  
1636  
1637  
1638  
1639  
1640  
1641  
1642  
1643  
1644  
1645  
1646  
1647  
1648  
1649  
1650  
1651  
1652  
1653  
1654  
1655  
1656  
1657  
1658  
1659  
1660  
1661  
1662  
1663  
1664  
1665  
1666  
1667  
1668  
1669  
1670  
1671  
1672  
1673  
1674  
1675  
1676  
1677  
1678  
1679  
1680  
1681  
1682  
1683  
1684  
1685  
1686  
1687  
1688  
1689  
1690  
1691  
1692  
1693  
1694  
1695  
1696  
1697  
1698  
1699  
1700  
1701  
1702  
1703  
1704  
1705  
1706  
1707  
1708  
1709  
1710  
1711  
1712  
1713  
1714  
1715  
1716  
1717  
1718  
1719  
1720  
1721  
1722  
1723  
1724  
1725  
1726  
1727  
1728  
1729  
1730  
1731  
1732  
1733  
1734  
1735  
1736  
1737  
1738  
1739  
1740  
1741  
1742  
1743  
1744  
1745  
1746  
1747  
1748  
1749  
1750  
1751  
1752  
1753  
1754  
1755  
1756  
1757  
1758  
1759  
1760  
1761  
1762  
1763  
1764  
1765  
1766  
1767  
1768  
1769  
1770  
1771  
1772  
1773  
1774  
1775  
1776  
1777  
1778  
1779  
1780  
1781  
1782  
1783  
1784  
1785  
1786  
1787  
1788  
1789  
1790  
1791  
1792  
1793  
1794  
1795  
1796  
1797  
1798  
1799  
1800  
1801  
1802  
1803  
1804  
1805  
1806  
1807  
1808  
1809  
1810  
1811  
1812  
1813  
1814  
1815  
1816  
1817  
1818  
1819  
1820  
1821  
1822  
1823  
1824  
1825  
1826  
1827  
1828  
1829  
1830  
1831  
1832  
1833  
1834  
1835  
1836  
1837  
1838  
1839  
1840  
1841  
1842  
1843  
1844  
1845  
1846  
1847  
1848  
1849  
1850  
1851  
1852  
1853  
1854  
1855  
1856  
1857  
1858  
1859  
1860  
1861  
1862  
1863  
1864  
1865  
1866  
1867  
1868  
1869  
1870  
1871  
1872  
1873  
1874  
1875  
1876  
1877  
1878  
1879  
1880  
1881  
1882  
1883  
1884  
1885  
1886  
1887  
1888  
1889  
1890  
1891  
1892  
1893  
1894  
1895  
1896  
1897  
1898  
1899  
1900  
1901  
1902  
1903  
1904  
1905  
1906  
1907  
1908  
1909  
1910  
1911  
1912  
1913  
1914  
1915  
1916  
1917  
1918  
1919  
1920  
1921  
1922  
1923  
1924  
1925  
1926  
1927  
1928  
1929  
1930  
1931  
1932  
1933  
1934  
1935  
1936  
1937  
1938  
1939  
1940  
1941  
1942  
1943  
1944  
1945  
1946  
1947  
1948  
1949  
1950  
1951  
1952  
1953  
1954  
1955  
1956  
1957  
1958  
1959  
1960  
1961  
1962  
1963  
1964  
1965  
1966  
1967  
1968  
1969  
1970  
1971  
1972  
1973  
1974  
1975  
1976  
1977  
1978  
1979  
1980  
1981  
1982  
1983  
1984  
1985  
1986  
1987  
1988  
1989  
1990  
1991  
1992  
1993  
1994  
1995  
1996  
1997  
1998  
1999  
2000  
2001  
2002  
2003  
2004  
2005  
2006  
2007  
2008  
2009  
2010  
2011  
2012  
2013  
2014  
2015  
2016  
2017  
2018  
2019  
2020  
2021  
2022  
2023  
2024  
2025  
2026  
2027  
2028  
2029  
2030  
2031  
2032  
2033  
2034  
2035  
2036  
2037  
2038  
2039  
2040  
2041  
2042  
2043  
2044  
2045  
2046  
2047  
2048  
2049  
2050  
2051  
2052  
2053  
2054  
2055  
2056  
2057  
2058  
2059  
2060  
2061  
2062  
2063  
2064  
2065  
2066  
2067  
2068  
2069  
2070  
2071  
2072  
2073  
2074  
2075  
2076  
2077  
2078  
2079  
2080  
2081  
2082  
2083  
2084  
2085  
2086  
2087  
2088  
2089  
2090  
2091  
2092  
2093  
2094  
2095  
2096  
2097  
2098  
2099  
2100  
2101  
2102  
2103  
2104  
2105  
2106  
2107  
2108  
2109  
2110  
2111  
2112  
2113  
2114  
2115  
2116  
2117  
2118  
2119  
2120  
2121  
2122  
2123  
2124  
2125  
2126  
2127  
2128  
2129  
2130  
2131  
2132  
2133  
2134  
2135  
2136  
2137  
2138  
2139  
2140  
2141  
2142  
2143  
2144  
2145  
2146  
2147  
2148  
2149  
2150  
2151  
2152  
2153  
2154  
2155  
2156  
2157  
2158  
2159  
2160  
2161  
2162  
2163  
2164  
2165  
2166  
2167  
2168  
2169  
2170  
2171  
2172  
2173  
2174  
2175  
2176  
2177  
2178  
2179  
2180  
2181  
2182  
2183  
2184  
2185  
2186  
2187  
2188  
2189  
2190  
2191  
2192  
2193  
2194  
2195  
2196  
2197  
2198  
2199  
2200  
2201  
2202  
2203  
2204  
2205  
2206  
2207  
2208  
2209  
2210  
2211  
2212  
2213  
2214  
2215  
2216  
2217  
2218  
2219  
2220  
2221  
2222  
2223  
2224  
2225  
2226  
2227  
2228  
2229  
2230  
2231  
2232  
2233  
2234  
2235  
2236