From
MS/EDA5-XC

Our Reference
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Requirements specification

Recipient

Cc

Topic **CAN BOARD PRACTICE – DIAGNOSTIC COMMUNICATION**

1 Benefit

After this practice, students will understand and have experience on Diagnostic UDS-ISO14229. This Diagnostic standard is supported by most of ECUs in Automotive nowadays.

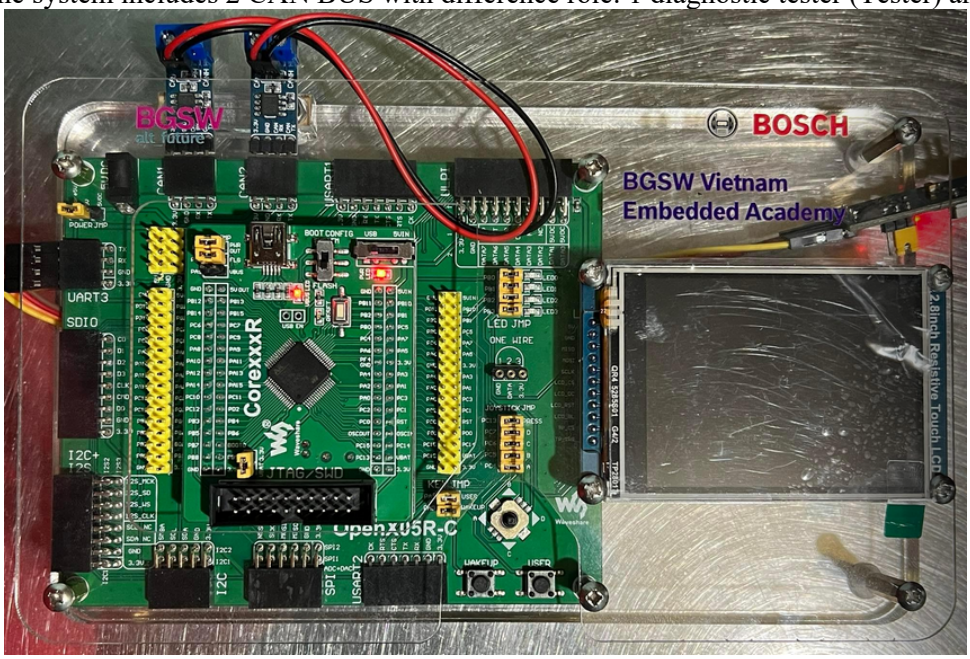
Students able to implement the most important Diagnostic services ($27 - Security access; $22-ReadDataByIdentifier and $2E- WriteDataByIdentifier)

Students also have knowledge and can implement CAN_TP layer in Transport protocol layer based on CAN protocol. The main purpose is to send and receive more than 8 bytes of data.

Also, students will get familiar with Diagnostic specification that is closely with actual project.

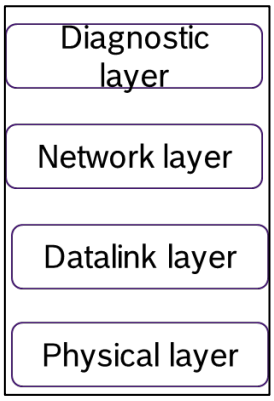
2 System Overview

The system includes 2 CAN BUS with difference role: 1 diagnostic tester (Tester) and 1 ECU.



The board can perform diagnostic communication via CAN protocol.

Below picture depicts difference layers. The detail specification of each layer in following session of this document.



3 Physical Layer

The physical layer shall fulfil with the requirements of ISO11898-2/5.

The diagnostic communication speed is the same as application communication speed.

4 Data link Layer

The data link layer shall fulfil with the requirements of ISO11898-1.

The CAN DLC contained in every diagnostic CAN frame transmitted by ECU shall always be set to eight (8) bytes. To avoid bit padding, the unused data bytes of a CAN frame shall be padded with 55h.

ECU can receive diagnostic CAN frame with a DLC less than eight (8) which is send by Tester.

5 Network layer

5.1 Addressing Method

This specification requires that the ECU only supports normal addressing, and therefore 11 bit CAN identifiers shall be used.

Only physical addressing shall be supported by ECU. Functional addressing not needs to be supported.

5.2 Diagnostic CAN ID

Request Id: 0x712

Response Id: 0x7A2

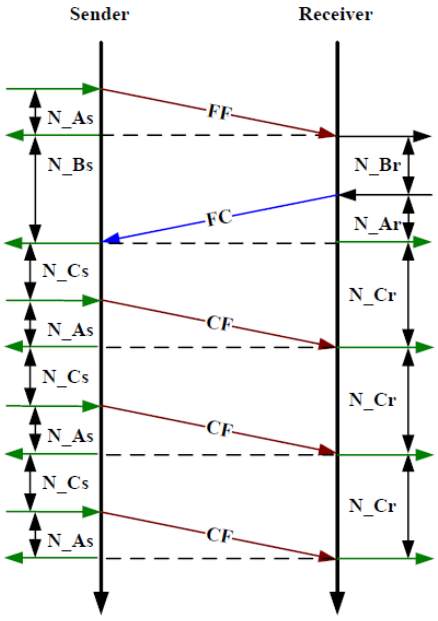
5.3 *Diagnostic Message Format*

The CAN message frame format is described in the following table. For detailed definition, please refer CAN_TP documentation or the training material.

Message Type	CAN ID	CAN Frame Data Field					
		Byte 0			Byte 1	Byte 2	Byte 3-7
		Bit 7-4	Bit 3	Bit 2-0			
SingleFrame (SF)	CAN ID	00b	SF_DL		Data		
FirstFrame (FF)	CAN ID	01b	FF_DL			Data	
ConsecutiveFrame (CF)	CAN ID	10b	SN		Data		
FolwControl (FC)	CAN ID	11b	FS		BS	STmin	-

5.4 *Parameters Definition*

The parameters and workflow of network layer are defined in the following figure and table. For detailed definition, please refer CAN_TP documentation.



When multi-message required, Sender and Receiver will communicate based on above flow chart.

The Maximum number of 'FC.Wait frame transmissions' (N_WFTmax) shall be set to zero (0). Therefore it is not allowed to use FC.Wait.

The Block Size and Separation time (ms) are defined as below:

Parameter	Symbol	Application mode
Block Size	BS	8
Separation time	ST_{min}	25

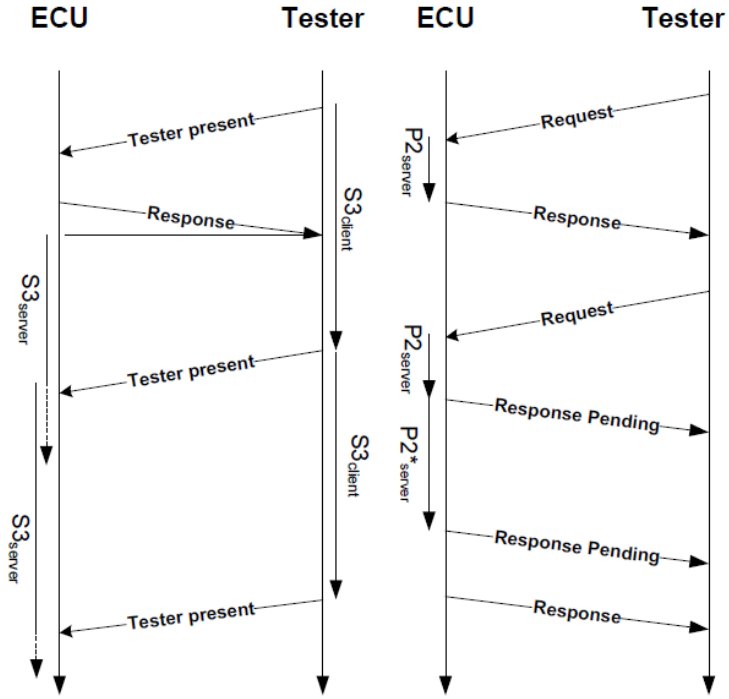
In the scope of this practice, it is not required to implement below Network layer timing parameters. This is for your reference purpose only. In real project, these timing parameters need to be implemented properly.

Parameters	Enhanced diagnostics		Legislated on-board diagnostics	
	Timeout	Performance	Timeout	Performance
N_As	70ms	—	25ms	—
N_Ar	70ms	—	25ms	—
N_Bs	150ms	—	75ms	—
N_Br	—	<70ms	—	(N_Br+N_Ar)<25ms
N_Cs	—	<70ms	—	(N_Cs+N_As) <50ms
N_Cr	150ms	—	150ms	—

6 Diagnostic layer

6.1 Common specification

6.1.1 Timing requirement



Above picture shows diagnostic layer timing between Tester and ECU. Tester will request and ECU will response based on the request contain.
The parameters of diagnostic layer are defined in the following figure and table.

Parameter	Symbol	Min	Max	Timeout	Unit
Time between client (tester) request and server (ECU) response	$P2_{server}$	0	50	n/a	ms
	$P2_{client}$	n/a	n/a	150	ms
Enhanced timeout for the client to wait after the reception of a negative response message with response code 78 h	$P2^*_{server}$	0	5000	n/a	ms
	$P2^*_{client}$	n/a	n/a	5100	ms

Parameter	Symbol	Min	Max	Timeout	Unit
Time between request and the next request from the tester – physical	$P3_{client\_phys}$	$P2_{Server\_max}$	n/a	n/a	ms
Time between consecutive request from the tester – functional	$P3_{client\_func}$	$P2_{server\_max}$	n/a	n/a	ms

Parameter	Symbol	Min	Nominal	Timeout	Unit
Session timeout; after timeout return to default-session	$S3_{server}$	n/a	n/a	5000	ms
Time for transmitting next TesterPresent to keep non-default session	$S3_{client}$	0	2000	4000	ms

To reduce the complexity of this Diagnostic practice, it is not required to implement above diagnostic parameters.

6.1.2 Diagnostic Services

The chapter defines the diagnostic services and implementation rules.

The following table shows all the UDS diagnostic services. The list has been sorted according to the Service Identifier (SID) assigned to each diagnostic service.

Diagnostic Services List	
SID (Hex)	**Service Name**
10	DiagnosticSessionControl
11	EcuReset
27	SecurityAccess
28	CommunicationControl
3E	TesterPresent
85	ControlDTCSetting
22	ReadDataByIdentifier
23	ReadMemoryByAddress
2E	WriteDataByIdentifier
3D	WriteMemoryByAddress
2A	ReadDataByPeriodicIdentifier
2C	DynamicallyDefineDataIdentifier
14	ClearDiagnosticInformation
19	ReadDTCInformation
2F	InputOutputContorlByIdentifier
31	RoutineControl
34	RequestDownload
36	TransferData
37	RequestTransferExit

suppressPositveResponseBit (SPRS) is not required for this practice.

6.1.3 Negative Response Code (NRC)

It is not required to implement NRC for this practice. Instead of response NRC, the ECU keep silent and not response anything.

In real project, the ECU need to support many differences NRC based on UDS-14229 standard. NRC helps to diagnose problem quickly.

6.1.4 Diagnostic session

Typically, all ECUs will support below 3 diagnostic sessions. However, these sessions also not in the scope of this practice.

- Default session.

- ExtendedDiagnosticSession

6.2 ReadDataByIdentifier (22h)

The request message requests data record values from the ECU identified by DataIdentifier.

The ECU sends data record values via the positive response message. The format and definition of the RecordValues is defined in separate document. RecordValues shall include analogue input and output signals, digital input and output signals, internal data and system status information if supported by the ECU.

6.2.1 Message Format:

Request

Byte	Parameter Name	Cvt	Value (hex)
#1	RequestServiceIdentifier	M	22
	DataIdentifier[ ] #1 = [		
#2	byte#1 (MSB)	M	00-FF
#3	byte#2]	M	00-FF
:	:	:	:
	DataIdentifier[ ] #m = [		
#n-1	byte#1 (MSB)	U	00-FF
#n	byte#2]	U	00-FF

Positive Response

Byte	Parameter Name	Cvt	Value (hex)
#1	PositiveResponseServiceIdentifier	M	62
	DataIdentifier [ ] #1 = [		
#2	byte#1 (MSB)	M	00-FF
#3	byte#2]	M	00-FF
	DataRecord[ ] #1 = [		

Byte	Parameter Name		Cvt	Value (hex)
#4		data#1	M	00-FF
:		:	:	:
#(k-1)+4		data#k]	U	00-FF
:	:		:	:
#n-(o-1)-2	DataIdentifier [ ] #m = [			
		byte#1 (MSB)	U	00-FF
#n-(o-1)-1		byte#2]	U	00-FF
	DataRecord[ ] #m = [			
#n-(o-1)		data#1	U	00-FF
		:	:	:
:		data#o]	U	00-FF
#n				

The maximum number of data identifiers to be read within a single request is limited to 1.

6.3 SecurityAccess (27h)

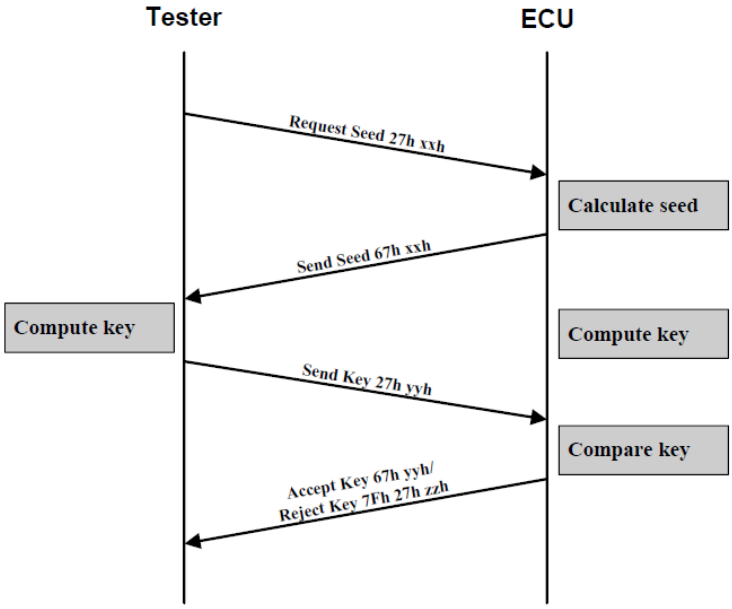
The SecurityAccess service is used to provide a means to access data and/or diagnostic services, which have restricted access for security, emissions, or safety reasons. Diagnostic services for downloading/uploading routines or data into a ECU and reading specific memory locations from a ECU are situations where security access may be required. Improper routines or data downloaded into a ECU could potentially damage the electronics or other vehicle components or risk the vehicle's compliance to emission, safety, or security standards.

The security access concept uses a seed and key algorithm. For the first step, the tester shall request the ECU to unlock by sending the service SecurityAccess - RequestSeed message.

The ECU shall respond by sending a seed using the service SecurityAccess - RequestSeed positive response message. The seed is the input parameter for tester and ECU to calculate the corresponding key value.

For the second step, the tester shall request by returning a key number back to the ECU using SecurityAccess - SendKey message. The ECU shall compare this key to onen

internally stored/calculated value. If the two numbers match, then the ECU shall enable (unlock) the tester's access to specific services/data and indicate that with the service SecurityAccess - SendKey positive response message. If the two numbers do not match, this shall be considered as a false access attempt. If access is rejected for any other reason, it shall not be considered as a false access attempt. An invalid key requires the tester to start over from the beginning with a SecurityAccess - RequestSeed message. The procedure of Send and Key algorithm is showed in following figure.



6.3.1 Message Format - Request Seed

Request

Byte	Parameter Name	Cvt	Value (hex)
#1	RequestServiceIdentifier	M	27
	Sub-Function = [		

Byte	Parameter Name	Cvt	Value (hex)
#2	RequestSeed]	M	01, 09

Positive response:

Positive Response

Byte	Parameter Name	Cvt	Value (hex)
#1	PositiveResponseServiceIdentifier	M	67
#2	Sub-Function = [RequestSeed]	M	01, 09
	SecuritySeed [ ] = [		
#3	seed#1 (high byte)	M	00-FF
#4	seed#2	M	00-FF
#5	seed#3	M	00- FF
#6	seed#4 (low byte)]	M	00-FF

6.3.2 Message Format – Send Key

Request

Byte	Parameter Name	Cvt	Value (hex)
#1	RequestServiceIdentifier	M	27

Byte	Parameter Name	Cvt	Value (hex)
#2	Sub-Function = [SendKey]	M	02, 0A
	SecurityKey [ ] = [		
#3	key#1 (high byte)	M	00-FF
#4	key#2	M	00- FF
#5	key#3	M	00-FF
#6	key#4 (low byte)]	M	00-FF

Positive Response:

Positive Response

Byte	Parameter Name	Cvt	Value (hex)
#1	PositiveResponseServiceIdentifier	M	67
#2	Sub-Function = [SendKey]	M	02, 0A

The SecuritySeed and SecurityKey are both 4 bytes (32 bits) number. The security access algorithms of each level would be defined and described in a specific file.

The SecuritySeed is a random number except for two value 00000000h and FFFFFFFFh.

Only one security level shall be active at any instant of time.

If the tester sends an invalid key, the request is rejected by ECU and insert 10s delay before it can receive and process next seed request.

6.4 WriteDataByIdentifier (2E)

The WriteDataByIdentifier service allows the tester to write information into the ECU at an internal location specified by the provided data identifier. Possible use-cases for this service are:

- Programming configuration information (e.g. VIN).
- Resetting learned values.
- Setting option content.
- Enable or disable function.

6.4.1 Message Format

Request

Byte	Parameter Name	Cvt	Value (hex)
#1	RequestServiceIdentifier	M	2E
	DataIdentifier [ ] = [		
#2	byte#1 (MSB)	M	00-FF
#3	byte#2 (LSB)]	M	00-FF
	DataRecord [ ] = [		
#4	data#1	M	00-FF
:	:	:	:
#m+3	data#m]	U	00-FF

Positive Response

Byte	Parameter Name	Cvt	Value (hex)
#1	PositiveResponseServiceIdentifier	M	6E
	DataIdentifier [ ] = [		
#2	byte#1 (MSB)	M	00-FF
#3	byte#2 (LSB)]	M	00-FF

6.4.2 Implementation Rules

Only one (1) dataIdentifier which is supported by the ECU shall be included in the request message.

7 Practice list

7.1 Practice 1 specification (SID: 0x22)

In this practice, student will implement service $22 - Read Data by Identifier to read data as requirement.

Security access required: NO

Diagnostic session required: NO (All session).

Request format table

Byte	Parameter name	Hex value
1	ReadDataByLocalIdentifier Request SID	0x22
2	RecordDataIdentifier High Byte	0x00 - 0xFF
3	RecordDataIdentifier Low Byte	0x00 - 0xFF

RecordDataIdentifier table

Parameter name	Hex value

Read CANID Value From Tester	0x0123
~~Read CANID Value From ECU~~	~~0x0321~~
~~Read EEPROM Value From Common Memmory of SID22 and SID2E~~	~~0xF001~~

Positive Response format

Byte	Parameter name	Hex value
1	ReadDataByLocalIdentifier Response SID	0x62
2	RecordDataIdentifier High Byte	0x00 - 0xFF
3	RecordDataIdentifier Low Byte	0x00 - 0xFF
4 … 4+m	RecordData Byte 0 … RecordData Byte m	Data 0 … Data m

Negative Response format

Byte	Parameter name	Hex value
1	RecordDataIdentifier Negative Response	0x7F
2	RecordDataIdentifier Response SID	0x22
3	Negative Response Code	0x00-0xFF

Negative response table

Parameter name	Hex value
Invalid length/response format	0x13
~~DID not support~~	~~0x31~~

7.2 Practice 2 specification (SID: 0x2E)

In this practice, student will implement $2E- WriteDataByIdentifier service to write a mount of data into ECU and get the outcome as requirement

Security access required: YES (Security level 1 -> Service$27 Sub Function 01/02).
The service is allowed inly in case SecA level is unlocked (LED0 is ON – pinPB0).
Diagnostic session required: NO
Request format table

Byte	Parameter name	Hex value
1	WriteDataByLocalIdentifier Request SID	0x2E
2	RecordDataIdentifier High Byte	0x00 - 0xFF
3	RecordDataIdentifier Low Byte	0x00 - 0xFF

RecordDataIdentifier table

Parameter name	Hex value
Write CANID Value From Tester. New value will be applied after Ignition cycle (IG OFF -> ON). This Ignition is User Button	0x0123
~~Write CANID Value From ECU. New value will be applied after Ignition cycle (IG OFF -> ON). This Ignition is User Button~~	~~0x0321~~

~~Write EEPROM Value From Common Memmory of SID22 and SID2E with variable buffer (more than 7 bytes) by flow control~~	~~0xF001~~

Positive Response format

Byte	Parameter name	Hex value
1	WriteDataByLocalIdentifier Response SID	0x6E

Negative Response format

Byte	Parameter name	Hex value
1	WriteDataByLocalIdentifier Negative Response	0x7F
2	WriteDataByLocalIdentifier Response SID	0x2E
3	Negative Response Code	0x00-0xFF

Negative response table

Parameter name	Hex value
Invalid minimum request length (min is 4 bytes). ~~Invalid request length of DID$F001 (min is 7 bytes).~~	0x13
DID not support.	0x31
~~Security Access denied.~~	~~0x33~~
~~Write CANID of Tester same as ECU / of ECU same as Tester.~~	~~0x22~~

7.3 Practice 3 specification (SID: 0x27)

In this practice, student will implement $27 - Security access service to unlock the ECU. The security will be unlocked with in 5 seconds and be indicated by LED-0 from pin-PB0.

This requirement uses Flow Control concept to send KEYS.

Diagnositc session required: NO (All session)

Request SEEDs format table

Byte	Parameter name	Hex value
1	SecurityAccess Request SID	0x27
2	Security SEED level	0x00 - 0xFF

Response SEED format

Byte	Parameter name	Hex value
1	SecurityAccess Response SID	0x67
2	Security SEED level	0x00 - 0xFF
3	SEED 0 (random)	0x00 - 0xFF
4	SEED 1 (random)	0x00 - 0xFF
5	SEED 2 (random)	0x00 - 0xFF
6	SEED 3 (random)	0x00 - 0xFF

Request Unlock – send KEYs format table

Byte	Parameter name	Hex value
1	SecurityAccess Request SID	0x27
2	Security KEY level	0x00 - 0xFF
3	KEY 0	0x00 - 0xFF
4	KEY 1	0x00 - 0xFF
5	KEY 2	0x00 - 0xFF
6	KEY 3	0x00 - 0xFF
7	KEY 4	0x00 - 0xFF
8	KEY 5	0x00 - 0xFF
9	KEY 6	0x00 - 0xFF
10	KEY 7	0x00 - 0xFF
11	KEY 8	0x00 - 0xFF
12	KEY 9	0x00 - 0xFF
13	KEY 10	0x00 - 0xFF
14	KEY 11	0x00 - 0xFF
15	KEY 12	0x00 - 0xFF
16	KEY 13	0x00 - 0xFF
17	KEY 14	0x00 - 0xFF
18	KEY 15	0x00 - 0xFF

Response KEY format

Byte	Parameter name	Hex value
1	SecurityAccess Response SID	0x67
2	Security KEY level	0x00 - 0xFF

Security level table

Parameter name	Hex value
Level 1: 0x01 for SEED and 0x02 for KEY	0x01/0x02
~~Level 2:~~	~~0x03/0x04~~

Negative Response format

Byte	Parameter name	Hex value
1	SecurityAccess Negative Response	0x7F
2	SecurityAccess Response SID	0x27
3	Negative Response Code	0x00-0xFF

Negative response table

Parameter name	Hex value
Invalid length/response format	0x13
~~Subfunction not support~~	~~0x31~~
Invalid Keys	0x35
~~Sequence error (request KEY before SEED)~~	~~0x24~~

The SEED and KEY Algorithm:

KEY-0 = SEED-0 XOR SEED-1
KEY-1 = SEED-1 + SEED-2
KEY-2 = SEED-2 XOR SEED-3
KEY-3 = SEED-3 + SEED-0

KEY-4 = SEED-0 | SEED-1
KEY-5 = SEED-1 + SEED-2
KEY-6 = SEED-2 | SEED-3
KEY-7 = SEED-3 + SEED-0

KEY-8 = SEED-0 & SEED-1
KEY-9 = SEED-1 + SEED-2

KEY-11 = SEED-3 + SEED-0

KEY-12 = SEED-0 - SEED-1
KEY-13 = SEED-1 + SEED-2
KEY-14 = SEED-2 - SEED-3
KEY-15 = SEED-3 + SEED-0

8 Output and evaluation

8.1 Expected output

- Requirement analysis: despite how student understand requirement. What tasks need to be done.
- OPL (Open point list) file: all of student's doubts as well as answers will be documented in this file.
- Design document: describe how your program is structure.
- Code: to evaluate clean code
- Test spec, test result, test log: follow the template here

TestSpecification_Template.xlsx

- Presentation document on process and result.

8.2 Evaluation

- Functionality: follow defined test cases.
- Requirement analysis: how well requirement was analysed.
- Design: how well design is.
- Clean code
- Test: how well of test case.
- Oscilloscope (from Osc picture -> decode to contains of CAN frame)