8.2.4 LKA common CAN protocol

This document describes the LKA common CAN protocol. The protocol outputs LKA required signal including for each lane: lane type and position, lane mark curvature and curvature derivative (if relevant), host heading relating lane mark. It also reports (if relevant) reference points in lane mark: lateral position of lane mark at reference point and physical distance of ref point from camera

In this document, when mentioning lateral distance from vehicle or lateral location in reference to vehicle, positive direction is right.

Term	Description
LKA	Lane Keeping and Guidance Assist
byte 1	MSB
byte 0	LSB
Unsigned	As Canalyzer defines unsigned in a dbc file

- The message is transmitted in an 11bit CAN header format.

- The baud rates are configurable (250, 500 or 1000kbps). Default baud rate is 500Kbps

- The CAN message is transmitted approximately every 66-100 ms.

8.2.4.1 Messages overview

The following messages are supported by LKA common CAN protocol:

Message	Code	Description
LKA left lane A	0x766	Left lane type validity and position Left lane Curvature and Curvature Derivative
LKA left lane B	0x767	Left lane heading, view range signal
LKA right lane A	0x768	Right lane type validity and position Right lane Curvature and Curvature Derivative
LKA right lane B	0x769	Right lane heading, view range signal
Reference points	0x76a	Reference points position and distance
Numebr of next lane markers reported	0x76b	
Next lane A	0x76C +2*N (N=[0,..,8]	Next lane n for N = [0, .., 1] Lane type, validity, position, curvature and curvature derivative
Next lane B	0x76D +2*N (N=[0,..,8]	Next lane n for N = [0, .., 1] Lane heading angle and view range

8.2.4.2   CAN Message 0x766 Details – LKA left lane A

Bit	7(MSB)	6	5	4	3	2	1	0(LSB)
Byte 0	Model degree		Quality		Lane type			
Byte 1	Position Parameter C0 byte 0							
Byte 2	Position Parameter C0 Byte 1							
Byte 3	Curvature Parameter C2 byte 0							
Byte 4	Curvature Parameter C2 byte 1							
Byte 5	Curvature derivative Parameter C3 byte 0							
Byte 6	Curvature derivative Parameter C3 byte 1							
Byte 7	Width left marking							

8.2.4.2.1   Lane type
- Type: ENUM
- Meaning:
  - 0 – dashed
  - 1 – solid
  - 2 – undecided
  - 3 – road edge
  - 4 – double lane mark (including dashed on one side)
  - 5 – Botts' dots
  - 6 – invalid

8.2.4.2.2   Quality
- Type: ENUM
- Meaning:
  - 0,1 – low quality. The lane measurements are not valid in low quality. The system will not give an LDW in that situation.
  - 2,3 – high quality

8.2.4.2.3   Model degree
- Type: ENUM
- Meaning:
  - 1 – linear model
  - 2 – parabolic model
  - 3 – 3rd-degree model

8.2.4.2.4   Position Parameter C0
- Type: signed 16 bits
- Meaning: physical distance between lane mark and camera on the lateral position. Also parameter C0 of polynomial model [see chapter 3]
- Decode: Position = HEX / 256
- Range: [-127 - 128]
- Unit: meter

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8.2.4.2.5   Curvature Parameter C2

- Type: unsigned 16 bits
- Meaning: parameter C2 of polynomial model [see chapter 3 on how to calculate curvature from this parameter]Direction: given a very low curvature derivative, positive curvature indicates a right hand side curve (as can be learned from the formula in chapter 3)
- Decode: curvature = (HEX – 0x7FFF)/1024/1000
- Range: [-0.02 – 0.02]
- Unit: n/a
- To extract the road radius (r) from curvature (C2): r = 1/(2*C2)

8.2.4.2.6   Curvature derivative Parameter C3

- Type: unsigned 16 bit
- Meaning: parameter C3 of polynomial model [see chapter 3 on how to calculate curvature derivative from this parameter]
- Decode: derivative = (HEX – 0x7FFF)/(1<<28)
- Range: [-0.00012 – 0.00012]
- Unit: n/a

8.2.4.2.7   Width left marking

- Type: unsigned 8 bit
- Meaning: Left lane marking width
- Decode: Hex * 0.01
- Range: [0 – 2.5]
- Unit

8.2.4.3   *Can Message 0x767 Details – LKA left lane B*

Bit	7(MSB)	6	5	4	3	2	1	0(LSB)
Byte 0	Heading angle byte 0							
Byte 1	Heading angle byte 1							
Byte 2	View range LSB							
Byte 3	View range availability	View range MSB						
Byte 4	Reserve							
Byte 5	Reserve							
Byte 6	Reserve							
Byte 7	Reserve							

8.2.4.3.1   Heading angle Parameter C1

- Type: unsigned 16 bits
- Meaning: physical slope of the lane mark [parameter C1 of polynomial model on chapter 3]
- Direction: positive means steering towards the right
- Decode: slope = (HEX – 0x7FFF) / 1024
- Range: [-0.357 - 0.357]
- Unit: radians

8.2.4.3.2   View Range

- Type: unsigned 15 bits
- Meaning: physical view range of lane mark
- Decode: range = HEX/256
- Range: [0 – 127.996].
- Unit: meter
- The value is valid only when the appropriate quality>1

8.2.4.3.3   View range availability

- Type: ENUM
- Meaning;
  - o   0 – not valid
  - o   1 – valid

8.2.4.4   CAN Message 0x768 Details – LKA right lane A

Bit	7(MSB)	6	5	4	3	2	1	0(LSB)
Byte 0	Model degree		Quality		Lane type			
Byte 1	Position Parameter C0 byte 0							
Byte 2	Position Parameter C0 Byte 1							
Byte 3	Curvature Parameter C2 byte 0							
Byte 4	Curvature Parameter C2 byte 1							
Byte 5	Curvature derivative Parameter C3 byte 0							
Byte 6	Curvature derivative Parameter C3byte 1							
Byte 7	Width right marking							

8.2.4.4.1 Lane type

- Type: ENUM
- Meaning:
    - 0 – dashed
    - 1 – solid
    - 2 – undecided
    - 3 – road edge
    - 4 – double lane mark (including dashed on one side)
    - 5 – Botts' dots
    - 6 – invalid

8.2.4.4.2 Quality

- Type: ENUM
- Meaning:
    - 0,1 – low quality. The lane measurements are not valid in low quality. The system will not give an LDW in that situation.
    - 2,3 – high quality

8.2.4.4.3 Model degree

- Type: ENUM
- Meaning:
    - 1 – linear model
    - 2 – Parabolic model
    - 3 – 3-degree model

8.2.4.4.4   Position Parameter C0

- Type: signed 16 bits
- Meaning: physical distance between lane mark and camera on the lateral position. Also parameter C0 of polynomial model [see chapter 3]
- Decode: Position = HEX / 256

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- Range: [-127 – 128]
- Unit: meter

8.2.4.4.5 Curvature Parameter C2

- Type: unsigned 16 bits
- Meaning: parameter C2 of polynomial model [see chapter 3 on how to calculate curvature from this parameter]
- Direction: given a very low curvature derivative, positive curvature indicates a right hand side curve (as can be learned from the formula in chapter 3)
- Decode: curvature = (HEX – 0x7FFF)/1024/1000
- Range: [-0.02 – 0.02]
- Unit: n/a
- To extract the road radius (r) from curvature (2): r = 1/(2*C2)

8.2.4.4.6 Curvature derivative Parameter C3

- Type: unsigned 16 bit
- Meaning: parameter C3 of polynomial model [see chapter 3 on how to calculate curvature derivative from this parameter]
- Decode: derivative = (HEX – 0x7FFF)/(1<<28)
- Range: [-0.00012 – 0.00012]
- Unit: n/a

8.2.4.4.7 Width right marking

- Type: unsigned 8 bit
- Meaning: Right lane marking width
- Decode: Hex * 0.01
- Range: [0 – 2.5]
- Unit: m

8.2.4.5   Can Message 0x769 Details – LKA right lane B

Bit	7(MSB)	6	5	4	3	2	1	0(LSB)
Byte 0	Heading angle Parameter C1 byte 0							
Byte 1	Heading angle Parameter C1 byte 1							
Byte 2	View range LSB							
Byte 3	View range availability	View range MSB						
Byte 4	Reserve							
Byte 5	Reserve							
Byte 6	Reserve							
Byte 7	Reserve							

8.2.4.5.1 Heading angle Parameter C1

- Type: unsigned 16 bits
- Meaning: physical slope of the lane mark [parameter C1 of polynomial model on chapter 3]
- Direction: positive means steering towards the right
- Decode: slope = (HEX – 0x7FFF) / 1024
- Range: [-0.357 - 0.357]
- Unit: radians

8.2.4.5.2 View Range

- Type: unsigned 15 bits
- Meaning: physical view range of lane mark
- Decode: range = HEX/256
- Range: [0 – 127.996].
- Unit: meter
- The value is valid only when the appropriate quality>1

8.2.4.5.3 View range availability

- Type: ENUM
- Meaning;
  - o   0 – not valid
  - o   1 - valid

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8.2.4.6 CAN Message 0x76a Details – Reference points

Bit	7(MSB)	6	5	4	3	2	1	0(LSB)
Byte 0	Ref point 1 Position byte 0							
Byte 1	Ref point 1 Poistion byte 1							
Byte 2	Ref point 1 Distance byte 0							
Byte 3	Ref point 1 validity	Ref point 1 Distance byte 1						
Byte 4	Ref point 2 Position byte 0							
Byte 5	Ref point 2 Poistion byte 1							
Byte 6	Ref point 2 Distance byte 0							
Byte 7	Ref point 1 validity	Ref point 2 Distance byte 1						

Please note: First ref' point should reflect the 1sec' ahead, middle of road infront. The rest of the reference points are currently not in use and they are located in protocol as place holders.

8.2.4.6.1 Ref point 1 Position

- Type: unsigned 16 bits
- Meaning: physical distance between camera and reference point 1 on lateral axis. The reference point defines the lateral location of the lane center at ref-Point distance (for example lane center is 0.6m to the right at 35m from the camera) . Ref Point 1 is this measurement at 1 second headway.
- Decode: Position = (HEX – 0x7FFF) / 256
- Range: [-127.996 – 127.996]
- Unit: meters

8.2.4.6.2 Ref point 1 Distance

- Type: unsigned 15 bits
- Meaning: physical distance between reference point and camera see definition at 2.1.5.1
- Decode: HEX / 256
- Range: [0 – 127.99609376]
- Unit: meters

8.2.4.6.3 Ref point 1 Validity

- Type: ENUM
- Meaning: reference point 1 validity.
    - 0 – invalid
    - 1 – valid

8.2.4.6.4 Ref point 2 Position

- Type: unsigned 16 bits
- Meaning: Empty . physical distance between camera and reference point on lateral axis. The reference point defines the lateral location of the lane center at ref-Point distance (for example lane center is 0.6m to the right at 35m from the camera)
- Decode: Position = (HEX - 0x7FFF)/ 256
- Range: [-127.996 – 127.996]
- Unit: meters

8.2.4.6.5 Ref point 2 Distance

- Type: unsigned 15 bits
- Meaning: Empty . physical distance between reference point and camera
- Decode: HEX / 256
- Range: [0 – 127.99609376]
- Unit: meters

8.2.4.6.6 Ref point 1 Validity

- Type: ENUM
- Empty . Meaning: reference point 2 validity.
  - o   0 – invalid
  - o   1 – valid

8.2.4.7   CAN Message 0x76B Details – number of next lane markers reported

Bit	7(MSB)	6	5	4	3	2	1	0(LSB)
Byte 0	Number of next lane markers reported							
Byte 1	Reserve							
Byte 2	Reserve							
Byte 3	Reserve							
Byte 4	Reserve							
Byte 5	Reserve							
Byte 6	Reserve							
Byte 7	Reserve							

8.2.4.7.1   Number of next lane markers reported

- Type: unsigned int
  Meaning: indicates how many extra lane markers are also reported, on top of left and right lane. Currently two lane marks are always reported one for left and one for right, and they are valid only if the lane type is Solid.

  Each next lane marker is defined by 2 message IDs.

  0x76C & 0x76D + 4N (N=0..3) will be for the left lane.
  0x76E & 0x76F + 4N (N=0..3) will be for the right lane.

8.2.4.8 *CAN Message 0x76C + 2*N (N = [0, .., 7] Details – next lane A*

Bit	7(MSB)	6	5	4	3	2	1	0(LSB)
Byte 0	Model degree		Quality		Lane type			
Byte 1	Position Parameter C0 Byte 0							
Byte 2	Position Parameter C0 Byte 1							
Byte 3	Curvature Parameter C2 byte 0							
Byte 4	Curvature Parameter C2 byte 1							
Byte 5	Curvature derivative Parameter C3 byte 0							
Byte 6	Curvature derivative Parameter C3 byte 1							
Byte 7	Lane mark width							

8.2.4.8.1 Lane type
- Type: ENUM
- Meaning:
  - 1 – solid
  - 2 – undecided

Remark: Currently we only support solid as lane type, and undecided when we do not recognize the lane type.

8.2.4.8.2 Quality

Remark: Not yet implemented for next lanes.

8.2.4.8.3 Model degree
- Type: ENUM
- Meaning:
  - 1 – linear model
  - 2 – parabolic model
  - 3 – 3rd-degree model

8.2.4.8.4 Position Parameter C0
- Type: signed 16 bits
- Meaning: physical distance between lane marl and camera on the lateral position. Also parameter C0 of polynomial model [see chapter 3]
- Decode: Position = HEX / 256
- Range: [-127 – 128]
- Unit: meter

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8.2.4.8.5   Curvature Parameter C2

- Type: unsigned 16 bits
- Meaning: parameter C2 of polynomial model [see chapter 3 on how to calculate curvature from this parameter]
- Direction: given a very low curvature derivative, positive curvature indicates a right hand side curve (as can be learned from the formula in chapter 3)
- Decode: curvature = (HEX – 0x7FFF)/1024/1000
- Range: [-0.02 – 0.02]
- Unit: n/a
- To extract the road radius (r) from curvature (C2): r = 1/(2*C2)

8.2.4.8.6   Curvature derivative Parameter C3

- Type: unsigned 16 bit
- Meaning: parameter C3 of polynomial model [see chapter 3 on how to calculate curvature derivative from this parameter]
- Decode: derivative = (HEX – 0x7FFF)/(1<<28)
- Range: [-0.00012 – 0.00012]
- Unit: n/a

8.2.4.8.7   Lane mark width

- Type: unsigned 8 bit
- Meaning: Lane marking width
- Decode: Hex * 0.01
- Range: [0 – 2.5]
- Unit: m

8.2.4.9   Can Message 0x76D + 2*N (N = [0, .. , 8]) Details – next lane B

Bit	7(MSB)	6	5	4	3	2	1	0(LSB)
Byte 0	Heading angle Parameter C1 byte 0							
Byte 1	Heading angle Parameter C1 byte 1							
Byte 2	View range LSB							
Byte 3	View range availability	View range MSB						
Byte 4	Reserve							
Byte 5	Reserve							
Byte 6	Reserve							
Byte 7	Reserve							

8.2.4.9.1 Heading angle Parameter C1

- Type: unsigned 16 bits
- Meaning: physical slope of the lane mark [parameter C1 of polynomial model on chapter 3]
- Direction: positive means steering towards the right
- Decode: slope = (HEX – 0x7FFF) / 1024
- Range: [-0.357 - 0.357]
- Unit: radians

8.2.4.9.2 View Range

Remark: Currently not available for next lanes.

8.2.4.9.3 View range availability

- Type: ENUM
- Meaning;
    - 0 – not valid
    - 1 – vali

8.2.4.10 Formulation

8.2.4.10.1 Naming convention

Z – Physical longitudinal distance from camera
X – Psychical lateral offset from Camera
C0 – Lane position parameter at Z=0 (see 8.2.4.2.4 & 8.2.4.4.4 & 8.2.4.8.4)
C1 – Heading angle parameter at Z=0 (see 8.2.4.3.1 & 8.2.4.5.1 & 8.2.4.8.1)
C2 – Lane curvature parameter at Z=0 (see 8.2.4.2.5 & 8.2.4.4.5 & 8.2.4.8.5)
C3 – Lane curvature derivative parameter at Z=0 (see 8.2.4.2.6 & 8.2.4.4.6 & 8.2.4.8.6)

ME is modeling each lane marker (or line) with a 3rd degree polynomial model that describes a function X(Z), where Z is the real world longitudinal distance from camera and X is the real world lateral distance from the camera ("real world" is used to distinguish it from image measurement in [pixels]). For example, given such a line model, one is capable of asking "At what lateral distance (X) lies the line with respect to a point Z=40m directly in front of the camera?"

The following formula could be used to derive the lateral distance of the lane at a given distance.

Right side is the positive direction.

8.3 Formulas

- Deriving lateral distance from longitudes distance:

$$X = C3 \cdot Z^3 + C2 \cdot Z^2 + C1 \cdot Z + C0$$

- Lane marker curvature at distance Z:

$$curvature(Z) = 2 \cdot C2 + 6 \cdot C3 \cdot Z$$

C0 - Lane Position(Z=0) = C0 [meters]

C1 - Heading Angle(Z=0) = arctan(C1) ~= C1 [radian]

C2 - Lane Curvature(Z=0) : 2*C2 [1/m]

C3 - Lane Curvature Derivative(Z): 6*C3 [1/m^2]

ME is providing one set of coefficients per line.
From that polynomial you can derive the actual heading angle, curvature and curvature rate (or curvature derivative) of the lane marker itself:

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8.3.1.1.1 Heading angle:

- heading_angle(Z) = arctan(dX/dZ) ~= dX/dZ (small angle estimation ; accurate to 99% for all practical angle spectrum)

- heading_angle(Z) ~= dX(Z)/dZ = 3*C3*Z^2 + 2*C2*Z + C1.
  However, usually one is interested in heading angle at camera meaning at Z=0

- heading_angle(Z=0) = C1
  (in other words the protocol's heading angle parameter C1 is a very good estimator of vehicle heading angle with respect to lane marker at camera line)

- If you are looking forward, and the angle is 0.5 Rad, you will see that the left lane mark is getting closer to you. If the angle will be negative, you will see that the left lane mark is going away from you.

8.3.1.1.2 Curvature:

- curvature(Z) = (dX(Z)/dZ) / dZ = d^2X(Z)/d^2Z = 6*C3*Z + 2*C2.

- Again, one might be interested only in the lane curvature at camera line (Z = 0). In that case, the curvature take the following form:

- curvature(Z=0) = 2*C2
  or protocol value "curvature" equals 1/2 of actual curvature are camera line.

- Nevertheless, a sophisticated LKA implementation would probably like to know also the curvature reading at some distance other than Z=0m in front of the car, say at wheels line (Z~=1m) or 5m in front of the vehicle (Z=5m). That is especially important if the road takes a "S" shape, e.g. curving to the right at camera line, but curving to the left somewhere in front of vehicle.

8.3.1.1.3 Curvature Rate/Derivative :

curvature_rate = d^3X(Z)/d^3Z = 6*C3
or protocol value "curvature derivative" equals 1/6 of actual curvature rate.

8.3.1.1.4 Coordinate System

The ME coordinate system is as follows:
(0,0) is at FOE; Y grows UPWARDS, as appose to conventional (vision) systems where Y grows DOWNWARDS.

Measurements are with respect to camera, are in real world (that is meters and not pixels) and coordinate system follow the normal directions (X, Y, Z for lateral, vertical and longitudinal, respectively)

Angles are positive to the right, and negative to the left.