Interface Document

LKA common CAN protocol

protocol name MEIO.cfg: 'LKA'

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Version	0.96
Release date	19-06-11

Change Control

Version	Date	Updated by	Chapter	Essence of the change	Approved By
0.1	10-Aug-09	Uri Wolfovitz	All	First version	Uri Wolfovitz
0.2	12-Aug-09	Uri Wolfovitz	2. & 3.	View range	Uri Wolfovitz
0.3	17-Aug-09	UW		Lane type enum update 0x766 & 0x768	UW
0.4	20-Aug-09	UW	3.	Correct decode and range for ref' points	UW
0.5	25-Nov-09	UW	3.	- right lane type - curvature derivative	UW
0.7	26-Nov-09	UW	3	update curvature derivative encoding adding formals for lateral position offset in world	UW
0.8	18-Dec-09	UW	2.	Adding next lane place holders	
0.9	31-Jan-10	Noa	2 & 3	Fixing curvature and heading angle ranges. Fixing curvature model equation	
0.91	2-Feb-10	Yossi Pollak	Intro, 2	adding MSB/LSB definition; spelling (HAX-HEX)	
0.92	3-Feb-10	Tal Babaioff		Fixing wrong numbers and sign values	
0.93	7-Feb-10	Yossi Pollak	intro., 2.1	adding coordinate system	

				description; adding info. to curvature explanation	
0.94	8-Feb-10	Yossi Pollak	2.1	adding direction info. and relation to formula	
0.95	16-Sep-10 21-oct-10	Yuval Friedman-Merin Yuval Friedman-Merin	2.1.1.7 2.1.3.7 2.1.1.4 2.1.3.4 2.1.2.2 2.1.8.2	adding left\right lane mark width Changed position to signed Implemented the view range in the code	
0.96	16-Nov-10	Yuval Friedman-Merin	2.1.7.4 2.1.7 2.1.7.7 3	Position Decoding changed Implemented next lanes in the code Changed Valid signals to lane mark width Formulation	Ori Shachar
0.96	27-04-11	Almog Shany	2.1.1.2, 2.1.3.2, 2.1.7.2, 2.1.4.2, 2.1.2.2	Remark: Quality effect on road measurement	Ori Shachar
0.96	19-06	Hilla Hartman	2.1.1.4 – 2.1.1.6 2.1.2.1 2.1.3.4 – 2.1.3.6 2.1.4.1	Add comments	

			2.1.6.1 2.1.7 2.1.7.4 – 2.1.7.6		

Introduction

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.

Scope

This document applies to code residing in the EPM2 2.8.1 &2.8.5

Acronyms and Terminology

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

1 CAN messages

CAN Parameters

- 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.

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

2 CAN Interface

2.1.1 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*							

2.1.1.1Lane 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

2.1.1.2Quality

- 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

2.1.1.3Model degree

- Type: ENUM
- Meaning:
  - 1 – linear model
  - 2 – parabolic model

- 3 – 3rd-degree model

2.1.1.4 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

2.1.1.5 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)

2.1.1.6 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

2.1.1.7 Width left marking

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

2.1.2 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***							

2.1.2.1Heading 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

2.1.2.2View 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

2.1.2.3View range availability

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

2.1.3 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*							

2.1.3.1Lane 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

2.1.3.2Quality

- 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

2.1.3.3Model degree

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

2.1.3.4 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

2.1.3.5Curvature 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)

2.1.3.6Curvature 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

2.1.3.7Width right marking

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

2.1.4 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							

2.1.4.1Heading 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

2.1.4.2View 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

2.1.4.3View range availability

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

2.1.5 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.

2.1.5.1Ref 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

2.1.5.2Ref 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

2.1.5.3Ref point 1 Validity

- Type: ENUM
- Meaning: reference point 1 validity.

- 0 – invalid
- 1 - valid

2.1.5.4Ref 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

2.1.5.5Ref 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

2.1.5.6Ref point 1 Validity

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

2.1.6 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***							

2.1.6.1 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. Number of reported next lanes is dynamic and can vary from in the range of [0 – 7].

  Each next lane marker is defined by 2 message IDs.

  Potential range of next lane message IDs if all 8 next lane markers are reported is [0x76C – 0x77B]

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

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

  Remark: 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.

2.1.7 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*							

2.1.7.1Lane 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

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

2.1.7.2Quality

Remark: Not yet implemented for next lanes.

- 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

2.1.7.3Model degree

- Type: ENUM
- Meaning:
  - 1 – linear model

- 2 – parabolic model
- 3 – 3rd-degree model

2.1.7.4Position 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

2.1.7.5 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)

2.1.7.6Curvature 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

2.1.7.7*Lane mark width*

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

2.1.8 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							

2.1.8.1Heading 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

2.1.8.2View Range

Remark: Currently not available for next lanes.

- Type: unsigned 15 bits
- Meaning: physical view range of lane mark
- Decode: range = HEX/256
- Range: [0 – 127.996].
- Unit: meter

2.1.8.3View range availability

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

3 Formulation

Naming convention

Naming convention

Z – Physical longitudinal distance from camera

X – Psychical lateral offset from Camera

C0 – Lane position parameter at Z=0 (see 2.1.1.4 & 2.1.3.4, & 2.1.7.4)

C1 – Heading angle parameter at Z=0 (see 2.1.2.1 & 2.1.4.1 & 2.1.8.1)

C2 – Lane curvature parameter at Z=0 (see 2.1.1.5 & 2.1.3.5 & 2.1.7.5)

C3 – Lane curvature derivative parameter at Z=0 (see 2.1.1.6 & 2.1.3.6 & 2.1.7.6)

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.

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]

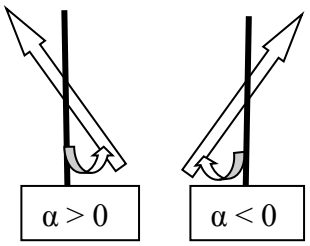
C2 - Lane Curvature(Z=0) : 2*C2 [1/m]

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:

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.



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.

Curvature Rate/Derivative :

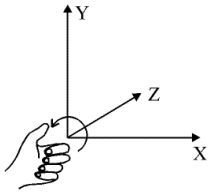
curvature_rate = d^3X(Z)/d^3Z = 6*C3
or protocol value "curvature derivative" equals 1/6 of actual curvature rate.

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.


Y
Z
X