ADAS Solution Documentation

Contents

1 Introduction

1.1 Background

Ecotron ADAS solution is based on smart camera, millimeter wave radar and Ecotron ADAS controller. This solution is capable of perform active safe-driving functions and driving assistance features such as ACC, AEB, LKA, FCW, RCW, PCW, CMS, LDW, RSR.

1.2 Terminology

Terminology	Definition
ADAS	Advanced Driver-Assistance Systems
ACC	Adaptive Cruise Control
AEB	Automatic Emergency Braking
LKA	Lane Keeping Assist
LDW	Lane Departure Warning
FCW	Forward Collision Warning
RCW	Rear Collision Warning
PCW	Pedestrian Collision Warning
CAN	Controller Area Network
BSD	Blind Spot Detection
CMS	Collision Mitigation System
RSR	Road Sign Recognition
HMW	Headway Monitoring Warning
TTC	Time-To-Collision

2 Overall Functions Requirement

Function	Requirement	Comment
Lane Departure Warning	1. The high-performance front-view camera is used as the main sensor to detect and track the lane line based on computer vision technology, combined with the characteristics of the driver to determine whether the vehicle is in danger of leaving the lane, and to provide the driver with sound, light, and other warnings. 2. When the vehicle deviates from its own lane, if the driver turns on the turn signal to change lanes in advance according to normal operation, the system does not issue an alarm. If the driver deviates from the lane unconsciously, the buzzer in the system will emit a rapid warning sound and the system indicator will flash.	
Forward Collision Warning	1. Taking driving safety as the basic premise, always perceive and evaluate the driving safety situation and provide auxiliary safety alert strategies. Before the vehicle is about to enter the minimum safe distance, the system reminds the driver of the possible collision through visual and auditory alerts according to the possibility of collision on the vehicle's driving path and reminds the driver to take timely measures to avoid collisions and improve driving safety.	
Road Sign Recognition	1. It has the function of speed limit sign recognition. When the camera detects the speed limit sign, it will be displayed as a large icon for 1 second. After that, the icon will be minimized and displayed on one side of the display to indicate the last specified speed limit sign, When the vehicle exceeds the specified speed, the system will issue an alarm. 2. Information can be integrated in the dashboard	
Headway Monitoring Warning	1. Displays the time distance between the vehicle and the vehicle ahead. If the time	

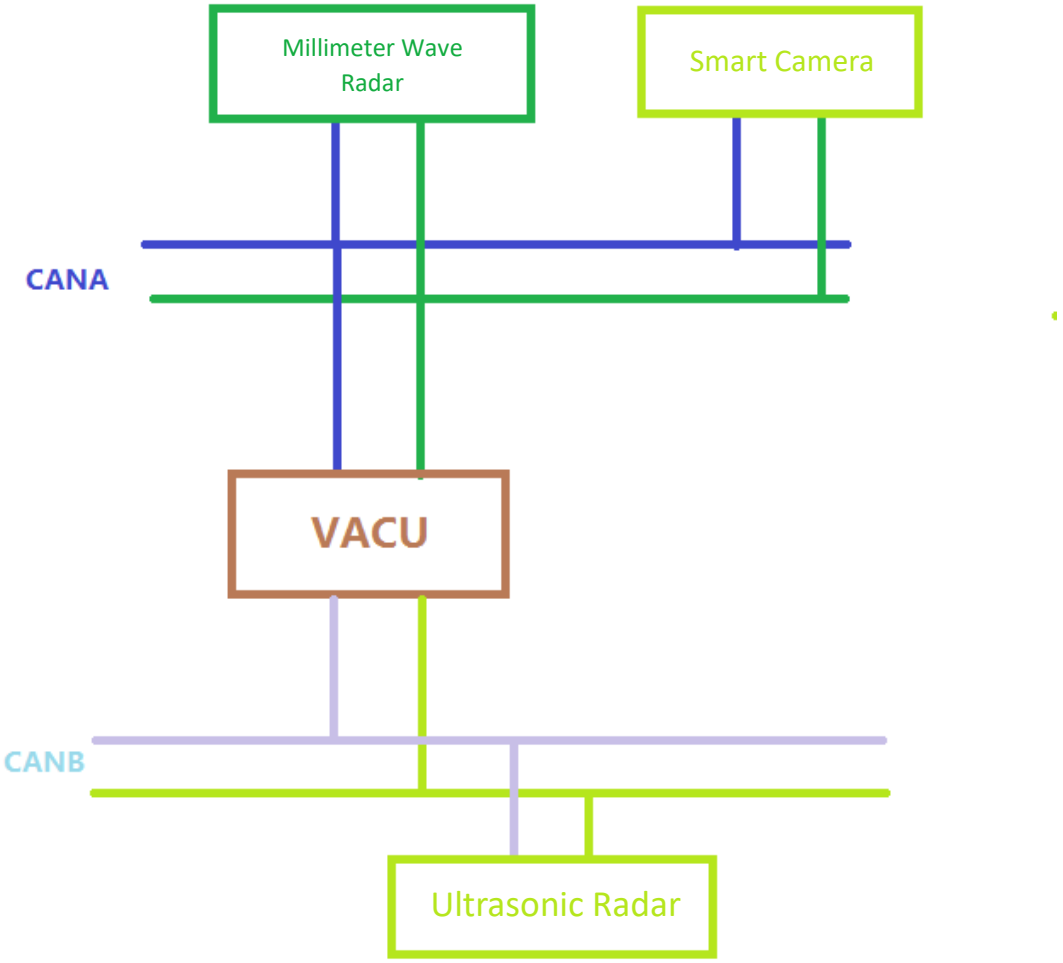
	is extremely short and dangerous, the system will issue an alarm. When the inter-vehicle time interval is equal to or lower than the preset threshold, the vehicle icon will turn to red, and the system default inter-vehicle time interval is 0.8 seconds. 2. Information can be integrated in the dashboard	
Pedestrian Collision Warning	1. When the camera recognizes a pedestrian and there is a threat of collision, the system will send a warning message to the driver through a buzzer or display. 2. Information can be integrated in the dashboard	
Collision Mitigation System	1. When the driver is negligent or improperly operating the vehicle, and there is a danger of collision between the vehicle and the obstacle in front, the collision mitigation function adopts motor feedback braking to reduce the collision hazard and consider the safety of passengers in the vehicle.	
Pedal Misapplication Control	1. When the vehicle and the vehicle in front are gradually approaching, and the relative distance is less than the threshold set by the system, the pedal misapplication control function will shield the driver's acceleration operation to ensure driving safety. The function is automatic disabled when the front vehicle is no longer in close range.	
Intelligent Energy Preserve	1. Based on the information such as the relative distance and speed of the vehicle ahead detected by the camera and radar, the vehicle optimizes the energy management of its own vehicle to reduce energy consumption and improve braking energy recovery, thereby achieving safety and energy saving.	ADAS control strategy provides corresponding signals/interfaces, and VCU control strategy functions for data processing and vehicle control
Automatic Emergency Braking	1. When the driver is negligent or improperly operating the vehicle and there is a danger of a collision between the vehicle and an obstacle in front, the AEB function requests the braking system	

	to stop the vehicle before the collision and considers the safety of passengers in the vehicle.	
Adaptive Cruise Control	1. In the ACC mode, the vehicle monitors the speed and the vehicle ahead according to its own perception system, optimizes the calculation of the expected acceleration of the vehicle, and adjusts the speed of the entire vehicle appropriately. It is comfortable to drive while keeping a certain distance from the vehicle ahead.	
Lane Keeping Assist	1. The vehicle monitors lane changes in real time through its own visual perception system, intelligently recognizes the lateral displacement of the vehicle during driving, and actively helps the driver to control the vehicle within the pavement markings to avoid possible collisions.	
Blind Spot Detection	1. Through the blind spot monitoring radar, acquires real-time perception of the situation behind the vehicle. When the vehicle changes lanes, the system will alert the driver if the road condition is not ideal for merging.	

3 ADAS Solution Architecture

Ecotron ADAS system does not directly interact with the steering system, braking system, and drive system by design. To achieve driving assist features, the ADAS system will work with the VCU, and the VCU will control the vehicle incorporating the control strategy, inputs from the sensors and the driver.

The default baud rate on CAN bus is 500kbps.



3.1 Sensors

3.1.1 Smart Camera

The smart camera includes a front-view camera and a camera controller. The camera controller directly collects and processes the image signal of the front-view camera, and outputs pavement markings, speed limit signs, and obstacle signals through the CAN bus. At the same time, the camera processes the result of the image including signals such as headway, collision time, lane departure warning, pedestrian collision warning, and fault status are sent out through the CAN bus for processing by the ADAS controller for the realization of LDW, LKA, AEB, FCW and other functions.

3.1.2 Radar Array

Ecotron ADAS solution uses 13 radars in total. One 77GHz radar is positioned in the front of the vehicle, 4 ultrasonic radar are positioned in the back, and there are 8 more ultrasonic radar positioned on both left and right side of the vehicle.

3.1.2.1 Millimeter Wave Radar

The millimeter wave radar in Ecotron ADAS solution is operating on the frequency of 77GHz. It has up to 260 meters of detection range. Leveraging the built-in CAN communication capability, this radar can broadcast the obstacle distance onto the CAN bus. This will help the ADAS system achieve features such as: AEB, FCW, ACC.

3.1.2.2 Ultrasonic Radar

The ultrasonic radars used in Ecotron ADAS system has built-in CAN capability. It can broadcast the obstacle distance on the CAN bus, helping with features such as: RCW, BSD.

3.2 Features and Functions

3.2.1 Lane Departure Warning (LDW)

The front-view camera detects the pavement markings. When the ADAS controller detects an unintentional lane departure, and the driver is not actively turning the steering wheel, the ADAS controller will notify the driver through visual and audio alerts according to vehicle status (vehicle speed greater than 55km/h, TBD).

When the vehicle speed is in Drive mode, the vehicle speed is over 55km/h, and the LDW is activated:

1. The system will be actively detecting unintentional lane departure. When the vehicle is drifting away from the current lane, and the driver is not taking any action. The left or right lane indicator will light up, audio warning be activated.

LDW output signal:

1. Lane departure warning status (adasLDW_stWaring). 0: No warning; 1: Left deviation warning; 2: Right deviation warning.

Note:

1. LDW is very similar to LKA. They both use a camera to monitor the markings on the road to determine whether the vehicle has deviated from the lane. However, the LDW system does not have the function of automatically guiding the vehicle heading, it can only remind the driver that the vehicle has deviated from the lane.

3.2.2 Front Collision Warning (FCW)

The smart camera collects images from the front of the vehicle and processes the collision status and sends it to the ADAS controller through the CAN bus. At the same time, the ADAS controller uses the data collected by the radar to make comprehensive judgments, to accurately obtain the specific information of the obstacle in front. According to the speed of the obstacle, the speed of the vehicle and the distance from the vehicle to the obstacle. The estimates of collision time will be calculated. The indicator will send out the collision status (0: no warning; 1: pre-collision warning; 2: collision warning). After the indicator receives the signal It reminds the driver by sound and lights.

When the vehicle speed is over 30km/h and the FCW function is activated:

1. As early as 2.7 seconds before a front collision is expected, ADAS will issue an early warning state, the display shows that the vehicle icon flashes, and a rapid "di-di-..." sound.
2. The ADAS controller also sends an early warning status to the IC. If it is less than 4.1s, it will be a first-level warning; less than 3.5s will be a second-level warning; less than 2.7s (smart camera collision warning) will send a three-level warning and perform emergency braking at the same time, and the IC will pass different Warning status (color change, lighting, vibration and buzzer) to remind the driver.

3.2.3 Road Sign Recognition (RSR)

This ADAS program is to identify and process speed limit cards. The images recognized by the front-view camera (recognition status of the speed limit plate, speed limit value) are sent to the ADAS controller through the CAN bus. After processing, the ADAS controller sends the specific value of the speed limit and the overspeed flag to the dashboard. At the same time, the instrument sends an alarm state to the instrument according to the different levels of overspeed, and the instrument reminds the driver by visual and audio signals.

3.2.4 Headway Monitoring Warning (HMW)

The smart front facing camera tracks the vehicle in front. Depends on the predefined safety distance, the smart camera will output current states to the dashboard through CAN bus when other vehicle is closer than the safety distance. (0: The preceding vehicle is not detected; 1: The preceding vehicle is detected without warning; 2: The preceding vehicle is detected, generating an early warning)

When the vehicle speed is over 30km/h, the time distance to the front vehicle is less than 2.5s, the physical distance monitoring will be activated. The real time distance will be displayed to the driver

When the vehicle distance is close to 1.0s (or the predefined danger threshold) from a distance, a "ding-" warning will be issued.

3.2.5 Pedestrian Collision Warning (PCW)

The front-view camera detects the pedestrian status of the vehicle in front, and the intelligent camera sends out different states through the CAN bus based on image recognition (0: no warning: 1: first warning: 2: second warning: 3: third warning-emergency braking), after the ADAS controller receives the signal, performs corresponding control, and sends it to the dashboard.

When the vehicle is running and the speed is >15km/h, it will identify the pedestrian in front and detect the distance and issue an alarm in dangerous situations to remind the driver to avoid collision with the pedestrian.

Within 30 meters of pedestrians, it is judged to be a pedestrian danger zone; at this time, no alarm is issued, only display.

When the distance is less than 16 meters and the time-to-collision (TTC) is less than 2.6s, a sound (di-di-di) alarm and image alarm are triggered.

1. Level 1: TTC <= 4.0s
2. Level 2: TTC <= 3.2s
3. Level 3: TTC <= 2.7s

Note:

1. FCW will only activated when the vehicle speed is over 30km/h
2. HMW will only activated when the vehicle speed is over 30km/h

3. LDW will only activated when the vehicle speed is over 55km/h

3.2.6 Automatic Emergency Braking (AEB)

The ADAS controller combines the collision status from the smart camera through the CAN bus and the data collected by the radar to calculate the collision time between the vehicle and the obstacle in front. The collision time is different at different vehicle speeds. When the time is less than the set time threshold for emergency braking, the ADAS controller sends the emergency braking state and braking deceleration to the VCU, and the VCU controller braking system performs braking.

AEB operates at all times.

3.2.7 Adaptive Cruise Control (ACC)

The ADAS controller uses the data collected by the radar to calculate the distance between the vehicle and the vehicle in front and adjust the speed of the vehicle relative to the vehicle speed. When the vehicle and the vehicle in front maintain a certain safe distance, the ADAS controller increases the expected acceleration/deceleration of the vehicle. The value (positive and negative) is sent to the VCU. After receiving the target acceleration of the ADAS, the VCU controls the motor and other power systems to achieve the target acceleration request of the ADAS.

ADAS's vehicle target acceleration control adopts PID and filtering to ensure the smooth driving of the vehicle. At the same time, the top speed of the vehicle is configurable.

ACC will only be activated per driver's request.

VCU will takes inputs such as the weight of the vehicle, inclination, and torque limitation, and output open loop gain to the power train.

$$Ma = \frac{T}{r} - Mgf\cos\beta - \frac{CAv^2}{21.15}$$

Where T is the torque at the wheel, r is the radii of the wheel (0.354m), M is the weight of the vehicle, a is the acceleration, f is the friction coefficient (0.0224), C is the wind resistance (0.38), A is the equivalent section plane area (3.05m^2), β is the inclination.

3.2.8 Lane Keeping Assist (LKA)

The ADAS controller adjusts the angle of the vehicle steering wheel through the pavement marking data of the smart camera received by the CAN bus. When the vehicle speed is greater than 55km/h and the vehicle is in drive (D) mode, the LKA function is turned on, and there is no turn signal activated, the LKA function is activated.

ADAS sends the LKA activation status flag (ctrlLKA_flgLkaEn) to the dashboard and steering system EPS, 0: no LKA activation; 1: LKA activation.

After the EPS receives the LKA activation signal, it vibrates the steering wheel to remind the driver. After receiving the signal, the dashboard will sound a reminder to warn the driver.

If the EPS system has a wire control function, ADAS will correct the EPS in a small range (within -5~5 degrees). ADAS will send the corrected target steering wheel angle to the VCU, and the VCU will control the EPS time target steering wheel angle to make the vehicle drive in the lane within the line.

The ADAS controller receives the LKA control level sent by the driver through the infotainment instrument (0: function off; 1: reminder only; 2: minor correction), and ADAS performs LKA control according to the control level.

The lane keeping assist system is one of the intelligent driving assist systems. It can control the brake control coordination device based on the Lane Departure Warning System (LDW). If the vehicle has the tendency of leaving the current lane, the vibration or sound of the steering wheel will be used to draw the driver's attention. If the lane keeping assist system recognizes the marking lines on both sides of the lane, the system is on standby. This is indicated by the green indicator light in the combined instrument panel.

At present, the system is mainly used on paved roads, such as highways and highways with better road conditions (clear lane lines). It is only activated when the vehicle speed reaches 55km/h or above.

The LKA system is turned on by default every time the vehicle is started, but the driver can also turn it off manually. When the system determines that the driver has not taken any actions for the situation that the vehicle is about to leave the current lane accidentally, it will issue an instruction to correct the direction of the steering system, but the correction force is quite slight, and the instrument panel will also alert the driver to hold the steering wheel. In addition, if the driver turns on the turn signal, the system will not issue any warning or corrective action when crossing the lane markings.

1. The lane keeping function depends on the lane line to work. It is recommended to use it on roads with good road conditions and clear pavement markings.
2. System performance is affected by weather and illumination. In the morning, at sunset, when the light is directly on the camera, and in rain and snow, the system performance will be significantly reduced. In severe cases, the system will issue an alarm (including sound, text, and fault lights).
3. The lane keeping function will continue to work when there is a blind spot detection alert activated. The lane keeping function will alert the driver even the turn signal is on.
4. When driving in a lane with a road edge, such as an isolation belt or curb, it is possible to identify the curb as pavement marking.
5. The system cannot be activated on roads with a curve radius less than 250 meters. If activated manually, the vehicle may drift away from the current lane.
6. If the driver puts his hands lightly on the steering wheel for a long time, a hand-off warning may appear to remind the driver to hold the direction firmly.

7. In strong assist mode, if you are driving on potholes, bumps, or wheels jumping on the road, a sudden steering intervention may cause the steering wheel to shake and cause driving discomfort.

3.2.9 Collision Mitigation System (CMS)

ADAS judges that the distance to the obstacle, vehicle, or person ahead is less than the safe distance and there is a danger of collision, and ADAS detects that the driver is not braking or decelerating, then the ADAS controller will issue a deceleration braking flag and target deceleration. To the VCU, after the VCU receives the flag and deceleration, the vehicle speed is reduced through the motor braking, and the risk of collision is further reduced. If the VCU does not perform processing, the ADAS controller activates the AEB function when it is about to collide.

3.2.10 Blind Spot Detection (BSD)

ADAS judges that the distance to the obstacle, vehicle, or person ahead is less than the safe distance and there is a danger of collision, and ADAS detects that the driver is not braking or decelerating, then the ADAS controller will issue a deceleration braking flag and target deceleration. To the VCU, after the VCU receives the flag and deceleration, the vehicle speed is reduced through the motor braking, and the risk of collision is further reduced. If the VCU does not perform processing, the ADAS controller activates the AEB function when it is about to collide.

BSD falls into three categories: front blind spot detection, rear blind spot detection, and side blind spot detection.

Front blind spot detection is activated at low speeds when the vehicle is on Drive mode.

Rear blind spot detection is activated at low speeds when the vehicle is on Reverse mode.

Side blind spot detection is activated when lane changing and parking, to protect the passengers, drivers and other people sharing the road.

Details on the control strategy listed as follow:

1. When the vehicle is moving forward (<15km/h), the ADAS controller collects 4 ultrasonic radar data in front, judges the location and distance of obstacles in front of the vehicle, and issues an alarm.
2. When the vehicle is traveling backwards, the ADAS controller collects 4 ultrasonic radar data from the rear and judges the position and distance of the obstacles behind based on the vehicle speed and the collected radar signals and sends an alarm.
3. When the vehicle is about to turn (has not turning), the ADAS controller collects the side radar signal, and controls the corresponding side blind spot detection LED signal light to keep on according to the vehicle speed and the actual obstacle distance detected by the radar. When the obstacle is far away or disappears, the blind spot detection LED signal light will be cancelled.
4. When the vehicle turns, the ADAS controller collects side radar signals. If the obstacle is detected by the radar on the steering direction side, the ADAS controller shall control the blind

spot detection LED signal light of the corresponding side to flash (or alarm). If the obstacle moves away or disappears during the turning process, the blind spot detection LED signal light will flash. After the steering is completed, if the ADAS controller still detects an obstacle on the side, the blind spot detection LED signal light will be always on.

5. The side blind spot detection, ADAS controller under Drive mode or Park mode will participate in the vehicle control. When the vehicle is parked, the ADAS controller will also collect radar signals on both sides of the vehicle. If there is an obstacle in the target detection range, the ADAS controller will also light up the corresponding side blind spot detection LED. When the obstacle is far away or disappears within the detection range, the blind spot detection LED signal light is turned off.
6. The obstacle position and distance alarm issued by the ADAS controller can be divided into six positions: front left, middle front, front right, rear left, middle rear, and rear right, 0~0.4m, 0.4~0.8m, 0.8~1.7m, 1.7m~ four levels of distance alarms (Level3, Level2, Level1, Level0).
7. The blind spot detection LED signal lights are integrated on the rearview mirrors on both sides.

Note:

1. The blind spot detection LED signal light can be directly lit by the ADAS controller or indirectly controlled by other controllers.
2. The front-and back distance alarm signal sent by the ADAS controller can trigger visual and audio alarm under the corresponding distance alarm through ICM.
3. The driver can tell the distance to the obstacle by checking how fast the icon is flashing.
4. At the same time, pay attention to distinguish the sound alarm mode under different distance alarms.

3.2.11 Pedal Misapplication Control

ADAS collects the accelerator pedal, brake pedal signal and the VCU motor torque control signal. When the ADAS function is turned on, ADAS detects that the vehicle is in danger of collision or the distance is less than the predefined safe distance, and the accelerator pedal is detected to be greater than a certain value (If the driver still accelerates without the intention of changing lanes), ADAS will issue a vehicle acceleration prohibition flag to the VCU, and the VCU will cancel the acceleration drive torque output. If the VCU does not perform processing, the ADAS controller activates the AEB function when it is about to collide.

3.2.12 Intelligent Energy Preserve

The VCU provides the torque map of the vehicle and the efficiency map of the motor. The ADAS controller can refer to its curve in the ACC function to adjust the target acceleration of the vehicle in combination with the VCU calibration data, so that the VCU can adjust motor torque output curve during the acceleration process. In the high efficiency range, the main purpose of the deceleration request output from ADAS to the VCU is to avoid excessive jumps in the demand of ADAS. VCU gives

priority to the use of motor braking energy recovery to achieve the requirements. If the motor's braking torque cannot meet the vehicle control requirements, the mechanical brake is connected to control and take over.