

Adaptive Cruise Control System Overview

1 Introduction

Adaptive Cruise Control (ACC) is an automotive feature that allows a vehicle's cruise control system to adapt the vehicle's speed to the traffic environment. A radar system attached to the front of the vehicle is used to detect whether slower moving vehicles are in the ACC vehicle's path. If a slower moving vehicle is detected, the ACC system will slow the vehicle down and control the clearance, or time gap, between the ACC vehicle and the forward vehicle. If the system detects that the forward vehicle is no longer in the ACC vehicle's path, the ACC system will accelerate the vehicle back to its set cruise control speed. This operation allows the ACC vehicle to autonomously slow down and speed up with traffic without intervention from the driver. The method by which the ACC vehicle's speed is controlled is via engine throttle control and limited brake operation.

2 Definitions and Physical Overview

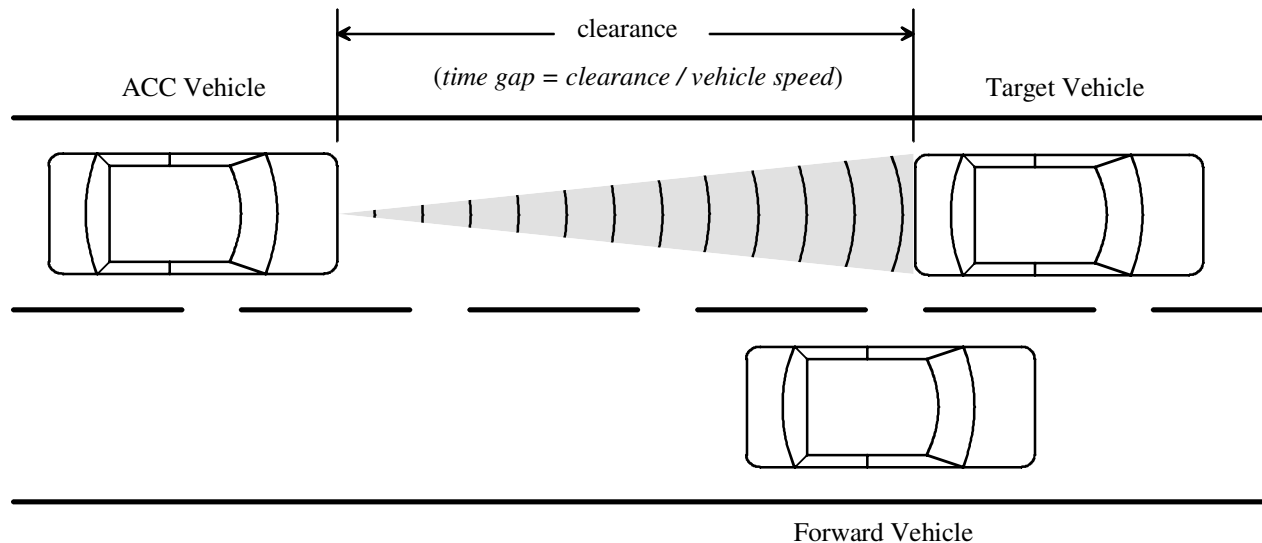


Figure 1 – ACC Vehicle Relationships

2.1 Definitions

Adaptive Cruise Control (ACC) – An enhancement to a conventional cruise control system which allows the ACC vehicle to follow a forward vehicle at an appropriate distance.

ACC vehicle – the subject vehicle equipped with the ACC system.

active brake control – a function which causes application of the brakes without driver application of the brake pedal.

clearance – distance from the forward vehicle's trailing surface to the ACC vehicle's leading surface.

forward vehicle – any one of the vehicles in front of and moving in the same direction and traveling on the same roadway as the ACC vehicle.

set speed – the desired cruise control travel speed set by the driver and is the maximum desired speed of the vehicle while under ACC control.

system states

ACC off state – direct access to the 'ACC active' state is disabled.

ACC standby state – system is ready for activation by the driver.

ACC active state – the ACC system is in active control of the vehicle's speed.

ACC speed control state – a substate of 'ACC active' state in which no forward vehicles are present such that the ACC system is controlling vehicle speed to the 'set speed' as is typical with conventional cruise control systems.

ACC time gap control state – a substate of 'ACC active' state in which time gap, or headway, between the ACC vehicle and the target vehicle is being controlled.

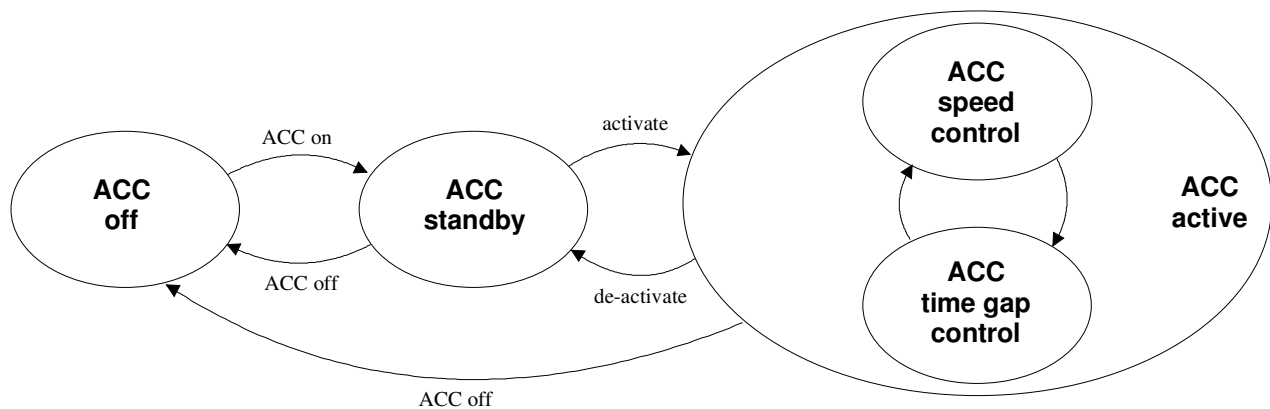


Figure 2 – ACC States and Transitions

target vehicle – one of the forward vehicles in the path of the ACC vehicle that is closest to the ACC vehicle.

time gap – the time interval between the ACC vehicle and the target vehicle. The 'time gap' is related to the 'clearance' and vehicle speed by:

$$\text{time gap} = \text{clearance} / \text{ACC vehicle speed}$$

2.2 Physical Layout

As shown in Figure 3, the ACC system consists of a series of interconnecting components and systems. The method of communication between the different modules is via a serial communication network known as the Controller Area Network (CAN).

ACC Module – The primary function of the ACC module is to process the radar information and determine if a forward vehicle is present. When the ACC system is in 'time gap control', it sends information to the Engine Control and Brake Control modules to control the clearance between the ACC Vehicle and the Target Vehicle.

Engine Control Module – The primary function of the Engine Control Module is to receive information from the ACC module and Instrument Cluster and control the vehicle's speed based on this information. The Engine Control Module controls vehicle speed by controlling the engine's throttle.

Brake Control Module – The primary function of the Brake Control Module is to determine vehicle speed via each wheel and to decelerate the vehicle by applying the brakes when requested by the ACC Module. The braking system is hydraulic with electronic enhancement, such as an ABS brake system, and is not full authority brake by wire.

Instrument Cluster – The primary function of the Instrument Cluster is to process the Cruise Switches and send their information to the ACC and Engine Control Modules. The Instrument Cluster also displays text messages and telltales for the driver so that the driver has information regarding the state of the ACC system.

CAN – The Controller Area Network (CAN) is an automotive standard network that utilizes a 2 wire bus to transmit and receive data. Each node on the network has the capability to transmit 0 to 8 bytes of data in a message frame. A message frame consists of a message header, followed by 0 to 8 data bytes, and then a checksum. The message header is a unique identifier that determines the message priority. Any node on the network can transmit data if the bus is free. If multiple nodes attempt to transmit at the same time, an arbitration scheme is used to determine which node will control the bus. The message with the highest priority, as defined in its header, will win the arbitration and its message will be transmitted. The losing message will retry to send its message as soon as it detects a bus free state.

Cruise Switches – The Cruise Switches are mounted on the steering wheel and have several buttons which allow the driver to command operation of the ACC system. The switches include:

'On': place system in the 'ACC standby' state

'Off': cancel ACC operation and place system in the 'ACC off' state

- 'Set +': activate ACC and establish set speed or accelerate
- 'Coast': decelerate
- 'Resume': resume to set speed
- 'Time Gap +': increase gap
- 'Time gap -': decrease gap

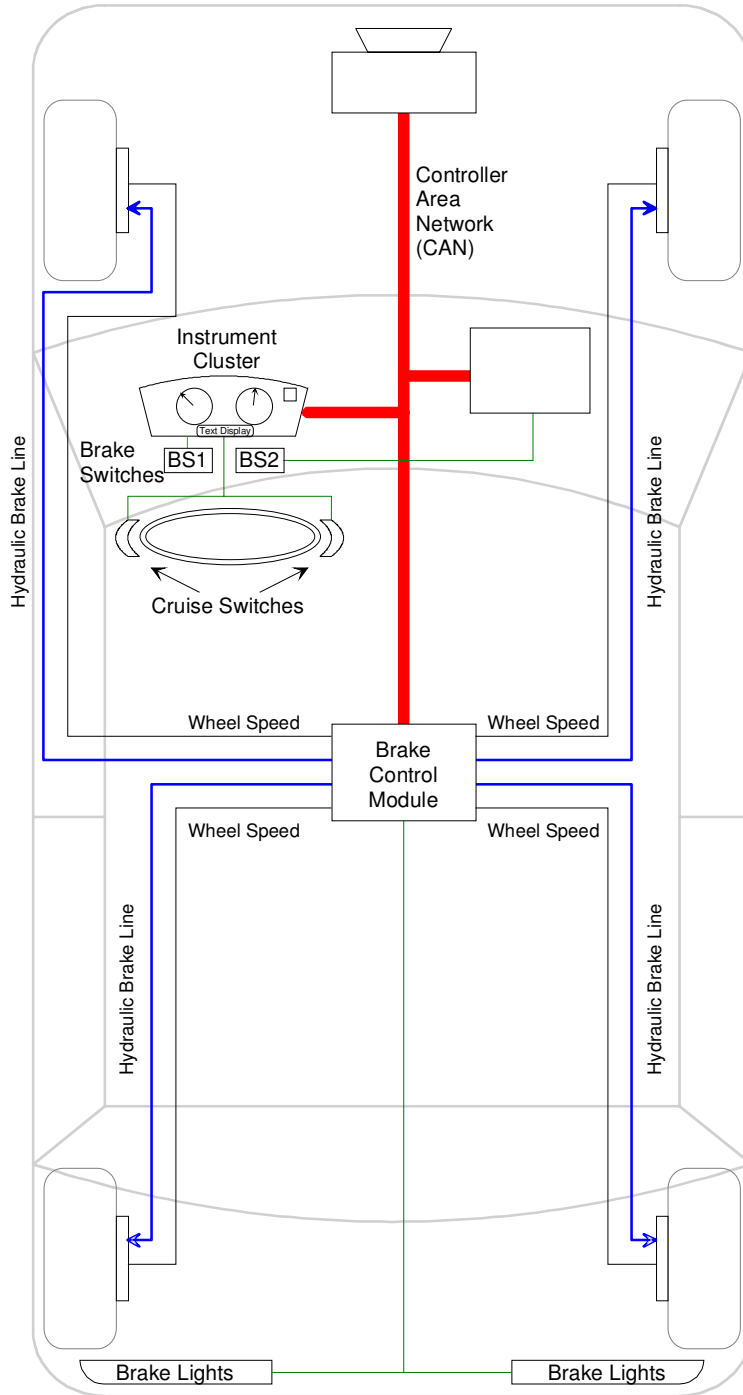


Figure 3 – Physical Layout

Brake Switches – There are two brake switches, Brake Switch 1 (BS1) and Brake Switch 2 (BS2). When either brake switch is activated, Cruise Control operation is deactivated and the system enters 'ACC standby' state.

Brake Lights – When the Brake Control Module applies the brakes in response to an ACC request, it will illuminate the brake lights to warn vehicles behind the ACC vehicle that it is decelerating.

3 Operational Overview

The driver interface for the ACC system is very similar to a conventional cruise control system. The driver operates the system via a set of switches on the steering wheel. The switches are the same as for a conventional cruise control system except for the addition of two switches to control the time gap between the ACC vehicle and the target vehicle. In addition there are a series of text messages that can be displayed on the instrument cluster to inform the driver of the state of the ACC system and to provide any necessary warnings. The driver engages the ACC system by first pressing the ON switch which places the system into the 'ACC standby' state. The driver then presses the Set switch to enter the 'ACC active' state at which point the ACC system attempts to control the vehicle to the driver's set speed dependent upon the traffic environment.

3.1 Control System Interfaces

Figure 4 shows the information and signal flows between the different systems for ACC operation.

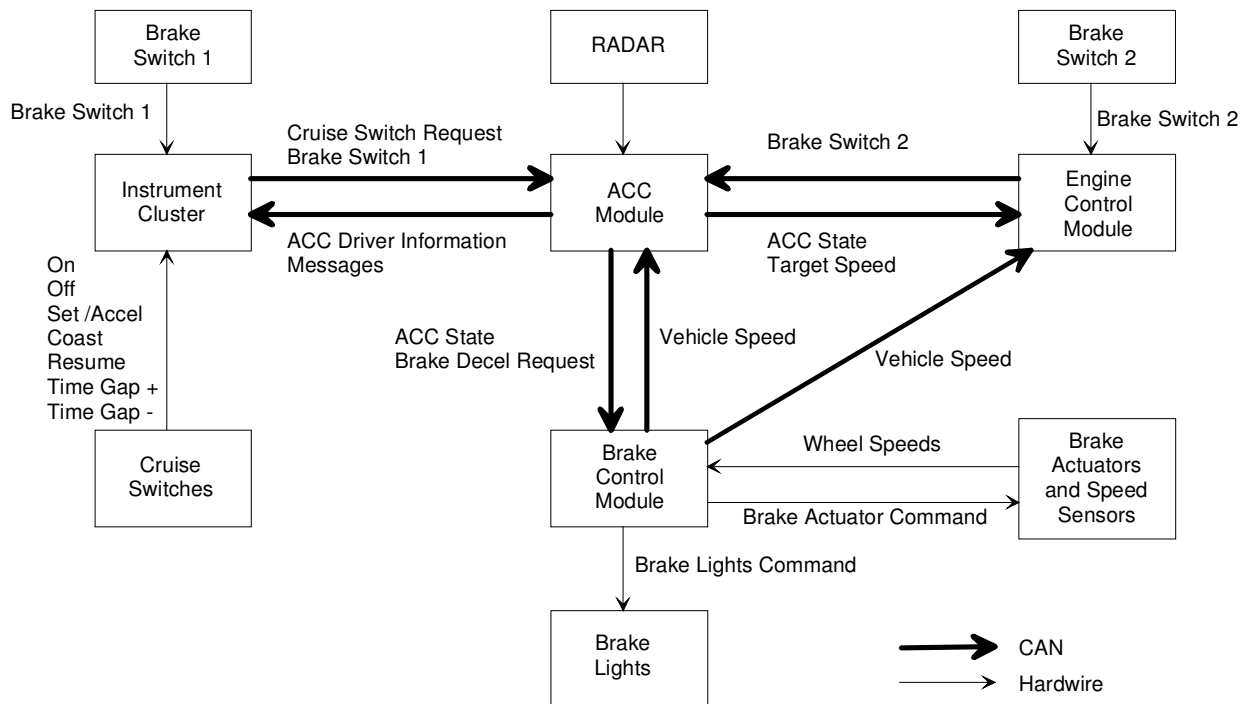


Figure 4 – ACC signals and Information Flow

3.2 Initialization

When the ignition key is in the off position, no power is applied to any of the systems. When the key is cycled to the on position, the ACC system initializes to the 'ACC off' state.

3.3 Engaging Cruise Control

Entering 'ACC standby' - Before active cruise control can be engaged the driver must first enter 'ACC standby'. This is performed by the driver pressing the ACC 'On' button. If no system faults are present, the ACC system will transition to the 'ACC standby' state.

Entering 'ACC active' – The driver enters the 'ACC active' state by pressing the 'Set' or 'Resume' button. If a prior set speed is present in memory, the system uses this prior value as the target speed when Resume is pressed, else, the current speed of when the Set button was pressed will become the target speed. The following conditions must be true for the system to enter 'ACC active' in response to the cruise switches:

- Brake Switch 1 = brake not applied
- Brake Switch 2 = brake not applied
- Vehicle Speed \geq 25 mph

When entering active ACC control, the vehicle speed is controlled either to maintain a set speed or to maintain a time gap to a forward vehicle, whichever speed is lower.

3.4 Operation During Speed Control Mode (ACC Speed Control)

Operation during this mode is equivalent to that of conventional speed control. If no forward vehicle is present within the Time Gap or clearance of the system, the vehicle's speed is maintained at the target speed. The engine control system controls the engine output via throttle control to maintain the vehicle speed at the target speed.

3.5 Operation During Follow Mode (ACC Time Gap Control)

The ACC system enters follow mode or 'ACC time gap control' if the radar detects a forward vehicle at or within the clearance distance. During this mode of operation, the ACC system sends a target speed to the Engine Control Module and deceleration commands to the Brake Control module to maintain the set time gap between the vehicles.

deceleration control – The ACC system decelerates the vehicle by lowering the target speed sent to the Engine Control Module and sending a brake deceleration command to the Brake Control Module. The maximum allowed braking effort of the system is 0.2 [g]. During brake deceleration events, the Brake Control Module activates the brake lights.

acceleration control – The ACC system accelerates the vehicle by increasing the target speed sent to the Engine Control Module. The Engine Control Module tries to maintain the target speed and can accelerate the vehicle at a rate of up to 0.2 [g] of acceleration.

adjusting the time gap – The driver can adjust the time gap via the 'Time Gap +' and 'Time Gap –' switches. Pressing the 'Time Gap +' switch causes the time gap value to increase and therefore the clearance between the two vehicles to increase. Pressing the 'Time Gap –' switch causes the time gap value to decrease and therefore the clearance between the two vehicles to decrease.

reaction to a slow moving or stopped vehicle – Situations may occur such that the ACC system is not able to maintain the time gap within the deceleration authority of the system, 0.2 [g]. The clearance between the ACC vehicle and the forward vehicle may be rapidly decreasing or the minimum vehicle speed of 25 [mph] may be reached. Under these situations the ACC system enters 'ACC standby' and alerts the driver by displaying a "Driver Intervention Required" text message on the instrument cluster and by turning on an audible chime. If the brakes were being applied by the ACC system, they will be slowly released. At this point the driver must take control of the vehicle.

3.6 Transitioning Between Speed Control and Follow Modes

The ACC system automatically transitions between Speed Control and Time Gap (Follow) Modes. The mode of operation is determined by the lower of the set speed for Speed Control Mode and the target speed to maintain the gap between the ACC vehicle and a forward vehicle. Basically, if no vehicle is present within the clearance distance, the system will operate in Speed Control mode, else, it will operate in Time Gap mode.

3.7 Canceling Cruise Control Operation

Cruise Control operation may be canceled by the operator or automatically via the ACC system. Either of the following conditions will deactivate ACC:

- Brake pedal is pressed
- 'Off' button is pressed
- Vehicle Speed < 25 mph
- An ACC system fault is detected

4 A Note to the Reader

This document was developed for use in a workshop on software system safety. There are known deficiencies in both this document and the system described by this document. It is not intended to represent an existing or future production intent system implementation.