SURVEY OF VEHICLE CONTROLS AND DISPLAYS

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16. Abstract FMVSS 101 addresses vehicle controls and displays and was last updated in 2005. We surveyed 40 newer passenger vehicles to identify how vehicle manufacturers are implementing controls and displays related to new technologies not currently addressed by FMVSS 101. A general comparison of infotainment systems and instrument clusters across manufacturers is included. In addition, the report includes a detailed comparison of the controls and displays related to transmissions, drive modes, blind spot warning, traction control, cruise control, forward collision warning, automatic emergency braking, lane-related assistance, and parking brakes. Samples of controls and displays related to hybrid or electric functions are included, as well as a list of technologies that are available but not covered in the report. Manufacturers are implementing many new displays and controls not currently addressed by FMVSS 101. Manufacturers do not use consistent terminology for similar functions, making it challenging to identify differences and similarities across products.			
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Introduction

FMVSS 101, which covers displays and controls, was last updated in 2005. Since then, manufacturers have implemented many new technologies in vehicles. The purpose of this task was to survey vehicles from the current U.S. fleet to document how new controls and displays are being implemented.

Methods

Vehicle Selection

The initial project plan included a survey of the controls and displays of 50 passenger vehicles and 25 medium/heavy trucks. A preliminary review of interior photos from manufacturer websites showed minimal variation among the controls/displays of medium/heavy trucks for each manufacturer. In addition, there were minimal differences between the controls/displays of medium/heavy trucks and lighter passenger vehicles. As a result, we limited the medium/heavy truck survey to one full-size truck from Isuzu as well as pickups from Ford, GM, Honda, and Ram.

Our initial strategy for selecting passenger vehicles was to focus on the fifty highest selling vehicles. However, our first review indicated that the variability within a manufacturing group was much smaller than variability between manufacturers. This led us to revise our selection strategy to target measurement of two vehicles per manufacturing group. The review of 2022 sales data showed that there are 17 manufacturing groups currently selling 279 different types of passenger vehicles in the United States. Our definitions of the manufacturing groups and the abbreviations used in subsequent tables are shown in Table 1 (totaling 18 after including Isuzu, which only sells trucks in the US). Ideally, we would measure one sedan and one SUV (plus the above-mentioned pickup trucks), and one would be gas-powered and one hybrid or electric. However, in some instances, we were not able to achieve these combinations because of limited inventory at local dealerships. For two manufacturers (Mazda and Volvo) there were minimal differences among the vehicles that were available locally so we only measured one. We also reduced the target number of total vehicles to 40, because of the large amount of information being collected for each vehicle, the generally limited variation within manufacturers, and what could be achieved within budget constraints.

Table 1. Summary of manufacturer groups, abbreviations, models measured by body type and power

Manufacturer Group	Abbreviation	Sedans	SUVs	Pickups
Audi/VW/Porsche	AVP	Jetta	Q3	
BMW/Mini	BM	*i7*	X5	
Ford/Lincoln	FL		**Escape,** *Mach-E*	*Lightning,* **F150**
Chrysler/Dodge/Jeep/ AlfaRomeo/Fiat	CDJAF		Grand Cherokee, **Wrangler**	Ram
GM/GMC/Chevrolet/ Buick/Cadillac	GCBC	Malibu	Enclave, Escalade	Silverado
Honda/Acura	HA	TLX	CRV	Ridgeline
Hyundai/Genesis	HG		Tucson, **Santa Fe**	
Isuzu	I			NRR*
Jaguar/Range Rover	JR		Defender	
Kia	K		Rio, **Niro**	
Mazda	Ma		CX-5	
Mercedes	Me	*EQS*	GLC300	
Mitsubishi	Mi	Mirage G4	**Outlander**	
Nissan/Infiniti	NI	Q50, *Leaf*	Rogue	
Subaru	S	Outback	Ascent	
Tesla	T	*S Plaid, Y*		
Toyota/Lexus	TL	Camry	RAV4, NC350	
Volvo	V		XC40	
Total Count		12	22	6
Total Electric		5	1	1
Total Hybrid		0	4	1

Electric, **Hybrid**, Gas, *Heavy truck

We supplemented the detailed vehicle analysis by reviewing websites for each manufacturer and extracting overview photos of 233 vehicles, which are included in Appendix A. In this appendix, vehicles that were included in the survey are underlined. Review of these photos relative to the ones we collected at dealerships helped us identify additional vehicles with unique characteristics that we used to select the last group of vehicles for measurement.

Vehicle Documentation

We went through several iterations to identify the best way to document the large amount of information being collected through this project within the constraints of the budget. For our first effort, we created a spreadsheet where we reviewed vehicle manuals for 10 pilot vehicles, where each button or control had a separate row and columns described the characteristics. This effort resulted in too much inconsistency among coders, and resulted in well over 100 rows per vehicle. Our second effort used the items documented in ISO 2675-2021. While this led to more consistency, it still resulted in more data than were feasible to collect within the budget.

Our strategy evolved to start with a set of overview pictures for the vehicle. Researchers created a row for each overview picture, typically 15 to 20 per vehicle. They then added rows below

each overview picture to provide details on some controls. Rows were also added to show examples of warning displays excerpted from the vehicle manuals. This led to about 50 rows per vehicle.

The spreadsheet for each vehicle includes the following information:

- **Vehicle Make, Model, Year, Trim Level and VIN:** vehicle description

- **Number**: scheme allows sorting by related items.

- **Generic Term**: general terms for the controls and displays created by the team

- **Manufacturer Term**: terms used by manufacturers for controls and displays listed in the vehicles' manuals.

- **Location**: where the listed controls and displays are located in the vehicle. Options include left door, side view mirror, steering wheel, steering column, left or right stalk, infotainment, center console, center, instrument cluster, lower left or right dashboard, head up display, upper, as shown in Figure 1.
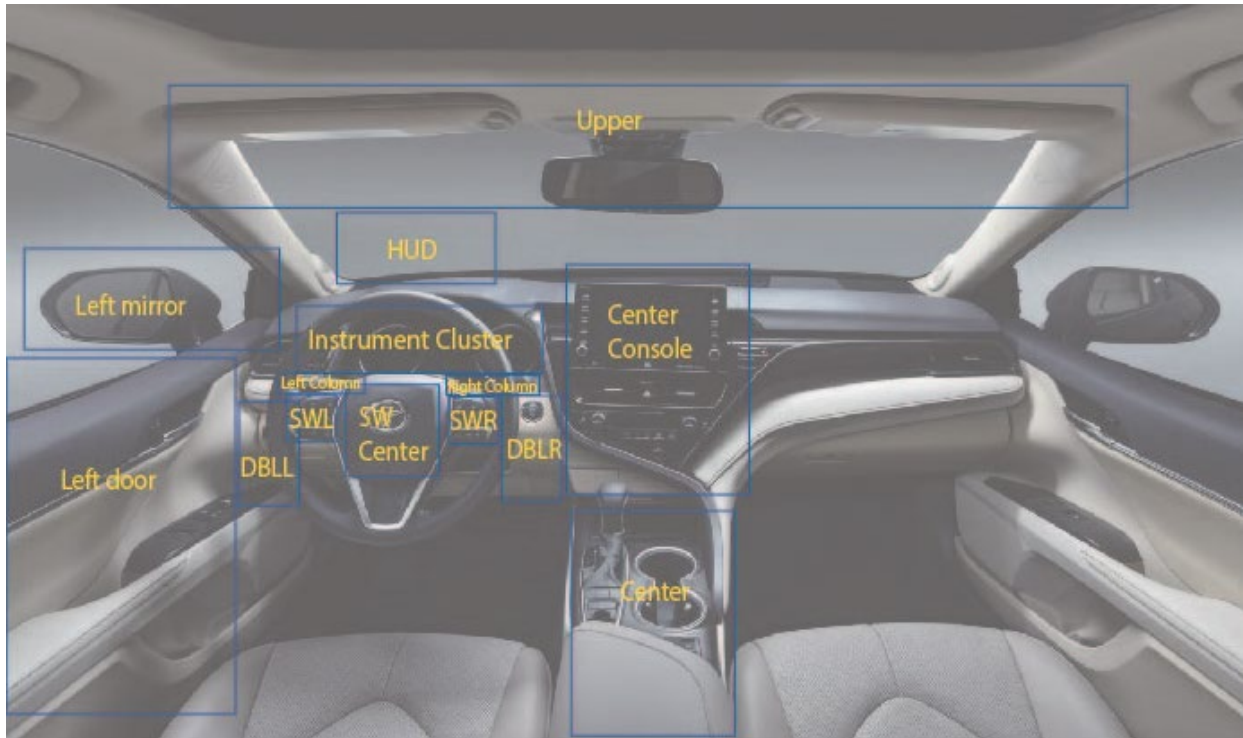

Figure 1. Location definitions.

- **Text**: This reports any text that is written on the controls and or displays.

- **Symbol/Icon/Image**: This displays any symbols/icon/images that is written on the controls and or displays, using icons from ISO or FMVSS No.

- **Control**: whether the item is a control that operates something

- **Indicator**: whether the item displays a magnitude or setting

- **Telltale**: whether the item changes/appears when an item is on or off or malfunctioning

- **Group**: category of item. Includes overview, warnings, safety, communication, transmission, lighting & signaling, transmission, parking, choices, operation, information, and comfort.

- **When**: whether item is permanent, pop-up, warning, when operating, when activated, or selectable.

- **Description**: describes what the controls do and how the displays change

- **Screen**: whether the item is associated with a screen.

- **Page #**: page number to find more information in vehicle manual

- **Photo**: One column to show photos/screenshots from manual of each item

While we had originally thought to have one large spreadsheet that would allow sorting and comparison of how different manufacturer groups implement controls and displays, inclusion of the photos and manual excerpts made the files too large. The spreadsheets for each vehicle, as well as the full photo documentation, are available through the University of Michigan's Deep Blue Data Archive at https://doi.org/10.7302/06g0-e092.

Infotainment systems

We documented infotainment systems by taking a photo of each screen available. This led to over 100 pictures per infotainment screen for most vehicles. This led us to limit our documentation of infotainment screens to one per manufacturer group unless they were obviously different versions.

To maximize the value of this photo documentation, the photos are also available at the above link through the University of Michigan's DeepBlue Data Archival service. We developed a labeling scheme for the photos such that scrolling through the photos in alphabetical order provides a similar experience to scrolling through the infotainment system. An example is shown in Figure 2.

HondaCRVIT_01HomeMenu.JPG
HondaCRVIT_01HomeMenu_01AllApps.JPG
HondaCRVIT_01HomeMenu_01AllApps_01Audio.JPG
HondaCRVIT_01HomeMenu_01AllApps_02AppInstall.JPG
HondaCRVIT_01HomeMenu_01AllApps_03BluetoothAudio.JPG
HondaCRVIT_01HomeMenu_01AllApps_04Clock.JPG
HondaCRVIT_01HomeMenu_01AllApps_05Compass.JPG
HondaCRVIT_01HomeMenu_01AllApps_06Display.JPG
HondaCRVIT_01HomeMenu_01AllApps_07FM.JPG
HondaCRVIT_01HomeMenu_01AllApps_08GeneralSettings.JPG
HondaCRVIT_01HomeMenu_01AllApps_08GeneralSettings_01System_01.JPG
HondaCRVIT_01HomeMenu_01AllApps_08GeneralSettings_01System_01Page1.JPG
HondaCRVIT_01HomeMenu_01AllApps_08GeneralSettings_01System_02Page2.JPG
HondaCRVIT_01HomeMenu_01AllApps_08GeneralSettings_02SmartphoneConnections.JPG
HondaCRVIT_01HomeMenu_01AllApps_08GeneralSettings_02SmartphoneConnections_01.JPG
HondaCRVIT_01HomeMenu_01AllApps_08GeneralSettings_03Connections.JPG
HondaCRVIT_01HomeMenu_01AllApps_08GeneralSettings_03Connections_01.JPG
HondaCRVIT_01HomeMenu_01AllApps_08GeneralSettings_04Display.JPG

Figure 2. Illustration of photo naming scheme to document infotainment systems.

After documenting the infotainment systems in detail, we did a high-level comparison to identify how strategies to implement controls and displays vary with manufacturers.

Results

Datasets, Photo Documentation, Manuals

Spreadsheets and photos are available through the UM DeepBlue Data Archive via https://doi.org/10.7302/06g0-e092.

Parking Brake

Table 2 summarizes how parking brake controls are implemented in vehicles. The most common locations are the center to the right of the driver or the lower left dashboard, and the most common style is a pull button, with examples shown in Figure 3. Some of these include a telltale light but not all. Some vehicles still use a brake pedal or center lever for the parking brake. For the Teslas, the parking brake can be activated through the infotainment system; in the Tesla Y it can also be operated by pushing the button at the end of the right stalk (photo in table), while for the Tesla S Plaid it can be activated by holding the P button on the center pad for 5 seconds. Most manufacturers refer to the control as Parking Brake or Electronic Parking Brake

Table 2. Summary of Parking brake locations and styles

Group	Manufacturer	Model	Location	Type
AVP	Audi	Q3	Center	Pull button
AVP	Volkswagen	Jetta	Center	Pull button
BM	BMW	X5, I7	Center	Pull Button
CDJAF	Jeep	Grand Cherokee	Center	Pull Button
CDJAF	Dodge	Ram	Not visible	Not visible
CDJAF	Jeep	Wrangler	Center	Lever
FL	Ford	Escape, Mach E	Center	Pull Button
FL	Ford	F-150, F-150 Lightning	LLDB	Pull Button
GCBC	Buick	Enclave	LLDB	Button
GCBC	Cadillac	Escalade	LLDB	Button
GCBC	Chevrolet	Malibu	Center	Pull Button
GCBC	Chevrolet	Silverado	LLDB	Pull Button
HA	Acura	TLX	LLDB	Pull Button
HA	Honda	CRV	Center	Pull Button
HA	Honda	Ridgeline	Below dashboard	Foot Pedal
HG	Hyundai	Santa Fe	LLDB	Pull Button
HG	Hyundai	Tucson	Center	Pull Button
JL	Land Rover	Defender	LLDB	Pull Button
I	Isuzu	NRR	Center	Pull handle or knob handle
K	Kia	Rio	Center	Lever
K	Kia	Niro	Center	Pull Button

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Group	Manufacturer	Model	Location	Type
Ma	Mazda	CX5	Center	Pull Button
Me	Mercedes	GLC300, EQS	LLDB	Pull Button
Mi	Mitsubishi	Outlander	Center	Pull Button
Mi	Mitsubishi	Mirage	Center	Lever
NI	Infiniti	Q50	Below dashboard	Foot Pedal
NI	Nissan	Rogue	Center	Pull Button
NI	Nissan	Leaf	Below dashboard Center	Foot Pedal Pull Button
S	Subaru	Ascent, Outback	Center	Pull Button
T	Tesla	S Plaid	Center	Hold P button five seconds
T	Tesla	Y	Right stalk, infotainment	Push button
TL	Toyota	RAV4, Camry	Center	Pull Button
TL	Lexus	NX350	Center	Pull Button
V	Volvo	XC40	Center	Pull Button

Figure 3. Examples of pull button controls for the parking brake.

Transmission

Table 3 summarizes the styles of gear shifters from each manufacturer observed in the survey and supplemented with observations from the vehicle photos in Appendix A. Figure 4 shows examples of stick gear shifts, Figure 5 shows rotary gear shifts, Figure 6 shows stalk gear shifts, Figure 7 shows button gear shifts, and Figure 8 shows other styles of gear shifts. Pickup trucks and vans are most likely to have classic stalk shifters located on the right steering column, although some high-end model sedans do as well. Most gear shifts are located in the center area between the front row seats to the right of the driver, although some are located higher up on the steering column. About half of manufacturers include paddle shifters on the steering wheel (example shown in Figure 9), but this may vary with vehicle model.

Table 3. Transmission Summary by Manufacturer Group

Manufacturer Group	Type	Location	SW Shift Paddles on some models?
AVP	Stick	Center	Yes
BM	Stick or Rotary	Center	Yes
FL	Stick, Rotary, Stalk	Center, Steering Column, Lower Right Dashboard	No
CDJAF	Stick	Center	(Buttons)
GCBC	Stick, Rotary, Stalk	Center, Center console, Steering Column	Yes
HA	Stick, Button, Stalk	Center, Steering Column	Yes
HG	Stick, Button	Center, Center console	Yes
I	Stick	Center	No
JL	Stick, Button, Rotary	Center, Center Console	No
K	Stick	Center	Yes
Ma	Stick	Center	Yes
Me	Stick, Stalk	Center, steering column	Yes
Mi	Stick, Stalk	Center, steering column	Yes
NI	Stick, Joystick	Center	Yes
S	Stick, Stalk	Center, Steering column	Yes
TL	Stick, rotary	Center	Yes
Te	Slider, Stalk	Infotainment, Steering column, center console	No
V	Stick, Stalk	Center, Steering Column	No

Figure 4. Examples of stick gear shifts.

Figure 5. Examples of rotary gear shifts.

Figure 6. Examples of stalk gear shifts.

Figure 7. Examples of button gear shifts; from left to right (Acura TLX, Buick Enclave,Honda Ridgeline, Hyundai Santa Fe).

Figure 8. Example of other gear shift (slider Tesla, joystick Nissan Leaf, center console strip Tesla).

Figure 9. Example of shift paddle on steering wheel

Drive Modes

Most vehicles, with the exception of more basic models, offer options to vary the feel of the vehicle handling characteristics. Most often this is called Drive Mode, but other descriptions include Drive Select, My Mode, Dynamic Mode, or Intelligent Traction Management. Table 4 summarizes the choices, locations, and type of drive mode control for each vehicle. The most common location is in the center, but other locations include the center console, lower left dashboard, steering wheel, or infotainment center. Figure 10 shows examples of button controls, Figure 11 shows examples of switch controls, Figure 12 shows examples of rotary controls, and Figure 13 shows examples of other types of drive mode controls. For the BMW I7, the My Mode function adjusts both vehicle handling characteristics and interior settings. The Ford Mustang Mach E and Teslas have the most unique descriptions of their drive modes.

Table 4. Drive Mode Controls and Options by Vehicle

Group	Manufacturer	Model	Choices	Location	Type
AVP	Audi	Q3	Drive Select: Offroad, Comfort, Auto, Dynamic, Individual	Center	Button
AVP	Volkswagen	Jetta	Custom, Eco	Center	Button
BM	BMW	X5	Sport, Comfort, EcoPro, Adaptive	Center	Button
BM	BMW	I7	My Mode: personal, sport, efficient, expressive, relax, theater (both vehicle handling and interior settings)	Center	Button
CDJAF	Jeep	Grand Cherokee	Sand/mud, snow, auto, sport	Center	Switch
CDJAF	Dodge	Ram	2WD, 4WD High, 4WD Low	LLDB	Button
CDJAF	Jeep	Wrangler	2H, 4H, 4H Part, N, 4L	Center	Second gear shift
FL	Ford	Escape	Normal, deep snow/sand, slippery, eco, sport	Center	Button
FL	Ford	F-150	2H, 4H, 4L, 4A	Center console	Buttons + knob
FL	Ford	Mach E	Drive Mode: Unbridled, Engage, Whisper	Infotainment	Digital
FL	Ford	Lightning	Normal, Sport, Tow/Haul, or Off-Road	Infotainment	Digital
GCBC	Buick	Enclave	Tour, Sport, Tow/Haul, AWD	Center Console	Button
GCBC	Cadillac	Escalade	N, 2WDH, A4WD,4WDH, 4WDL; Tour, Sport, Snow/Ice, Off-Road, Tow/Haul, and Terrain	LLDB	Buttons
GCBC	Chevrolet	Malibu	None	NA	NA
GCBC	Chevrolet	Silverado	2WDH, A4WD,4WDH, 4WDL	LLDB	Buttons
HA	Acura	TLX	Dynamic Mode: Normal, Sport, Snow, Smart	Center middle	Rotary
HA	Honda	CRV	Dynamic Mode: Normal, Sport, Snow, Smart	Center middle	Switch
HA	Honda	Ridgeline	Intelligent Traction Management: Snow, Sand, Mud, Normal	Center	Button
HG	Hyundai	Santa Fe	Eco, Sport, Snow, Smart	Center	Rotary
HG	Hyundai	Tucson	Sport, Snow, Smart	Center	Switch
I	Isuzu	NRR	None	NA	NA
JL	Land Rover	Defender	High, Lo	Center Console	Button

Group	Manufacturer	Model	Choices	Location	Type
K	Kia	Rio	Sport	Center	Button
K	Kia	Niro	Normal, Sport, Snow, Smart	SWL	Button
Ma	Mazda	CX5	Sport, Normal, Off-Road	Center	Switch
Me	Mercedes	EQS	Individual, Sport, Comfort, Eco	Center Console	Digital button
Me	Mercedes	GLC300	Individual, Sport, Comfort, Eco	Center	Switch
Mi	Mitsubishi	Outlander	Eco, Normal, Tarmac, Gravel, Snow, Mud	Center	Rotary
Mi	Mitsubishi	Mirage	None	NA	NA
NI	Infiniti	Q50	Standard, sport, snow, eco	Center	Switch
NI	Nissan	Rogue	Off-road, snow, auto, eco OR sport, standard, eco	Center	Rotary or switch
NI	Nissan	Leaf	Eco	Center	Button
S	Subaru	Ascent, Outback	X-Mode: Deep Snow/Mud, Snow/Dirt	Infotainment	Digital buttons
T	Tesla	S Plaid	Acceleration: Chill, Sport, Plaid, Drag Strip; Steering: Comfort, Standard, Sport; Suspension: Comfort, Auto, Sport, Advanced	Infotainment	Digital buttons
T	Tesla	Y	Acceleration: Chill, Standard, Sport; track mode	Infotainment	Digital buttons
TL	Toyota	RAV4	Eco, Normal, Sport, Snow, Mud & Sand, Rock & Dirt AWD	Center Center	Buttons
TL	Toyota	Camry	Eco, Normal, Sport	Center	Buttons
TL	Lexus	NX250	Eco, Normal, Sport	Center Console	Rotary
V	Volvo	XC40	Comfort, Polestar Engineered, Off-Road OR Hybrid, Pure, Power, Constant AWD, Off-road.	Infotainment	Digital

Figure 10. Examples of button drive mode selectors

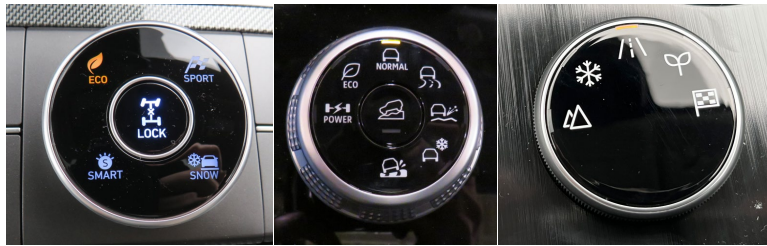Figure 11. Examples of switch drive mode selectors

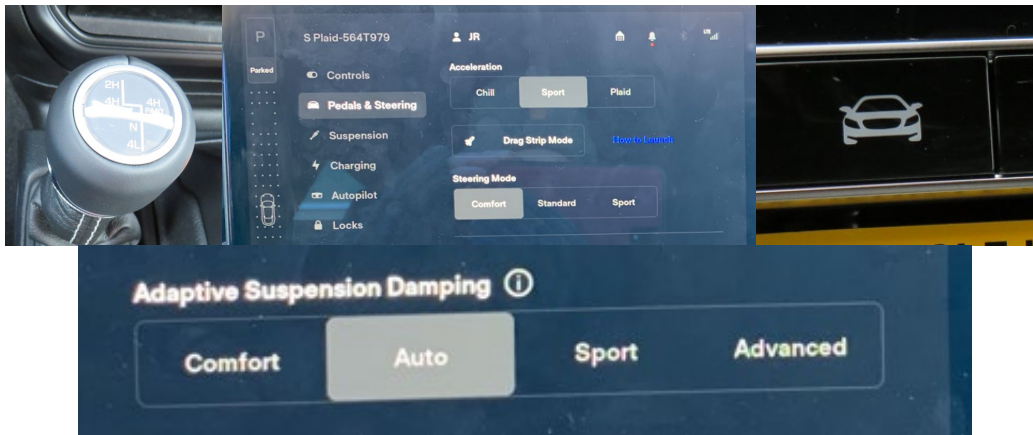Figure 12. Examples of rotary drive mode selectors

Figure 13. Examples of other drive mode selectors

Traction Control/ Electronic Stability Control (ESC)

Manufacturers use many terms to refer to Electronic Stability Control (ESC), as shown in the summary in Table 5. Almost no manufacturers exclusively use the term ESC, and it is challenging to understand from the vehicle manual descriptions how the different technologies may vary. Vehicles include an option to shut this feature off in case a vehicle is stuck in snow or mud, and a typical implementation of this control, including a telltale light, is shown in Figure 14. The location of physical control buttons can be on the lower left dashboard, center console, or center, but some vehicle manufacturers use the infotainment system or instrument cluster menus paired with steering wheel controls to shut ESC off.

Table 5. Summary of electronic stability control terminology and locations for shut off control.

Group	Manufacturer	Model	Name	Location
AVP	Audi	Q3	Electronic Stabilization Control	Center Console
AVP	Volkswagen	Jetta	Braking support system	Center
BM	BMW	X5	Dynamic Stability Control	Center
BM	BMW	I7	Dynamic Stability Control	Center (my mode)
CDJAF	Jeep	Grand Cherokee	Electronic Stability Control	Center Console
CDJAF	Dodge	Ram	Electronic Stability Control	Center Console
CDJAF	Jeep	Wrangler	Electronic Stability Control	Center Console
FL	Ford	Escape	AdvanceTrac/Traction Control/Stability Control	Cluster
FL	Ford	F-150	Traction Control/Electronic Stability Control	Center Console
FL	Ford	Mach E	Traction Control/Electronic Stability Control	LLDB
FL	Ford	Lightning	Traction Control/Electronic Stability Control/Roll Stability Control	Center Console
GCBC	Buick	Enclave	Traction Control/Electronic Stability Control/Roll Stability Control	SWR+ Cluster
GCBC	Cadillac	Escalade	Traction Control/Stabilitrak/ Electronic Stability Control	Infotainment
GCBC	Chevrolet	Malibu	Traction Control	Center
GCBC	Chevrolet	Silverado	Traction Control/Stabilitrak	Center console
HA	Acura	TLX	Vehicle Stability Assist	Lower Left Dashboard
HA	Honda	CRV	Vehicle Stability Assist	Lower Left Dashboard
HA	Honda	Ridgeline	Vehicle Stability Assist	Lower Left Dashboard
HG	Hyundai	Santa Fe	Traction Control/Electronic Stability Control	Lower Left Dashboard
HG	Hyundai	Tucson	Traction Control/Electronic Stability Control	Lower Left Dashboard

Group	Manufacturer	Model	Name	Location
I	Isuzu	NRR	Anti-Slip Regulator	Upper Right Dashboard
JL	Land Rover	Defender	Dynamic Stability Control	Center Console
K	Kia	Niro, Rio	Electronic Stability Control	Lower Left Dashboard
Ma	Mazda	CX5	Traction Control System/ Dynamic Stability Control	Lower Left Dashboard
Me	Mercedes	EQS	Electronic Stability Program	Infotainment
Me	Mercedes	GLC300	Electronic Stability Program	Center
Mi	Mitsubishi	Outlander	Active Stability Control	SWL+Cluster
Mi	Mitsubishi	Mirage	Active Stability Control	Lower Left Dashboard
NI	Infiniti	Q50	Vehicle Dynamical Control	Lower Left Dashboard
NI	Nissan	Rogue, Leaf	Vehicle Dynamical Control	Cluster+SWL
S	Subaru	Ascent, Outback	Vehicle Dynamics Control	Infotainment
T	Tesla	S Plaid	Traction Control (Slip start)	Infotainment
T	Tesla	Y	Traction Control (Slip start, off-road assist)	Infotainment
TL	Toyota	RAV4	Vehicle Stability Control, Enhanced Vehicle Stability Control, Traction Control	Center Console
TL	Toyota	Camry	Vehicle Stability Control, Enhanced Vehicle Stability Control, Traction Control	Lower Left Dashboard
TL	Lexus	NX350	Traction Control, Vehicle Stability Control	Center
V	Volvo	XC40	Electronic Stability Control (+5 subfunctions)	Digital?

Figure 14. Example of typical ESC shutoff control.

Cruise Control

Table 6 summarizes cruise control terminologies, controls, and displays available in vehicles. Several manufacturers provide different types of cruise control on the same vehicle. Variations may include conventional Cruise Control and Adaptive/Smart/Active Cruise Control. Others use the name of the technology in the description. Examples include sonar cruise control, radar cruise control, and GPS-based cruise control. Some vehicles have an option to set the speed relative to speed limit signs either visually detected or based on GPS specifications. Other types of cruise control include a Speed Limiter, where the driver sets a speed relative to the speed limit by a certain threshold above or below, traffic jam assist, excessive speed warning. Some manufacturers describe how to use the distance-setting features with the adaptive cruise control, while others have it as a choice for the FCW/AEB settings. Other manufacturers pair cruise control functions with lane centering or steering assist functions.
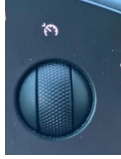
The most common location for these controls is the left or right steering wheel, although Audi uses controls on the left stalk. The variety of implementations is shown in Table 6. The set and actual speed are displayed in the instrument cluster and the head up display (HUD) if it is available and selected. Since not all vehicle manuals include examples of the cruise control display, only some examples are provided.

Table 6. Summary of cruise control terminologies, controls, and displays.

Group	Manufacturer	Model	Name	Control Location	Control Symbol	Display Location
AVP	Audi	Q3	Adaptive Cruise Assist	Left Stalk 2		Cluster
AVP	Volkswagen	Jetta	Cruise Control, Adaptive Cruise control	SWL		Cluster
BM	BMW	X5	Active Cruise Control	SWL		Cluster
BM	BMW	I7	Speed Control Systems (4 types)	SWL		
CDJAF	Jeep	Grand Cherokee	Adaptive Cruise Control	SWR		Cluster
CDJAF	Dodge	Ram	Adaptive Cruise Control	SWR		Cluster/HUD
CDJAF	Jeep	Wrangler	Adaptive Cruise Control	SWR		Cluster

Group	Manufacturer	Model	Name	Control Location	Control Symbol	Display Location
FL	Ford	Escape	Cruise Control, Adaptive Cruise Control, Intelligent Adaptive Cruise Control	SWL		
FL	Ford	F-150	Cruise Control, Adaptive Cruise Control, Intelligent Adaptive Cruise Control	SWL		
FL	Ford	Mach E	Adaptive Cruise Control, Intelligent Adaptive Cruise Control, Speed Sign Recognition	SWL		
FL	Ford	Lightning	Cruise Control, Adaptive Cruise Control, Intelligent Adaptive Cruise Control	SWL		
GCBC	Buick	Enclave	Cruise Control/ Adaptive Cruise Control	SWL		
GCBC	Cadillac	Escalade	Cruise Control/ Adaptive Cruise Control/ Super Cruise	SWL		
GCBC	Chevrolet	Malibu	Adaptive Cruise Control/Super Cruise Control	SWL		Cluster
GCBC	Chevrolet	Silverado	Cruise Control/ Adaptive Cruise Control/Super Cruise	SWL		Cluster, no example
HA	Acura	TLX	Adaptive Cruise Control	SWR		Cluster
HA	Honda	CRV	Adaptive Cruise control	SWR		Cluster

Group	Manufacturer	Model	Name	Control Location	Control Symbol	Display Location
HA	Honda	Ridgeline	Adaptive Cruise control	SWR		
HG	Hyundai	Santa Fe Tucson	Smart Cruise Control	SWR		
JL	Land Rover	Defender	Adaptive Cruise Control/Speed Limiter	SWR		Cluster, HUD
I	Isuzu	NRR	None	NA	NA	NA
K	Kia	Rio	Cruise Control	SWR		Cluster
K	Kia	Niro	Smart Cruise Control	SWL		Cluster, HUD
Ma	Mazda	CX5	Smart Cruise Control + Radar Cruise Control	SWR		Cluster
Me	Mercedes	EQS	Cruise Control, Active Distance Assist DISTRONIC	SWL		
Me	Mercedes	GLC300	Cruise Control, Active Distance Assist DISTRONIC	SWL		
Mi	Mitsubishi	Outlander	Cruise Control, Adaptive Cruise Control	SWR		
Mi	Mitsubishi	Mirage	Cruise Control	SWR		
NI	Infiniti	Q50	Cruise Control, Intelligent Cruise Control	SWR		

Group	Manufacturer	Model	Name	Control Location	Control Symbol	Display Location
NI	Nissan	Rogue	Intelligent Cruise Control	SWR		Cluster, HUD
NI	Nissan	Leaf	Cruise Control, Intelligent Cruise Control	SWR		
S	Subaru	Ascent, Outback	Cruise control, Advanced Adaptive Cruise Control	SWR		
T	Tesla	S Plaid	Traffic Aware Cruise Control	SWR		
T	Tesla	Y	Traffic Aware Cruise Control	Right Stalk, SWR, Infotainment		
TL	Toyota	RAV4	Dynamic Radar Cruise Control	SWR		
TL	Toyota	Camry	Cruise Control/ Dynamic Radar Cruise Control	SWR		
TL	Lexus	NX350	Cruise Control/ Dynamic Radar Cruise Control	SWR		Cluster, HUD
V	Volvo	XC40	Cruise Control, Adaptive Cruise Control, Distance Alert, Pilot Assist	SWL		Cluster, HUD

Blind Spot Warning (BSW), Lane Keeping Assist (LKA), Lane Departure Warning (LDW)

Table 7 summarizes information about blind spot warning (BSW) technologies by vehicle manufacturing group. The Technology Names column refers to the terminology used by the manufacturer for technology that alerts the driver to the presence of a vehicle in the blind spot. Some manufacturers have advanced versions of these technologies that help prevent the driver from changing lanes if there is a vehicle in the blind spot. BSW Telltale Type describes how each manufacturer provides a visible signal to the driver. Examples of the light, triangle, ISO symbol, and hazard symbol used among manufacturers are shown in Figure 15. Location specifies where the symbol is located on the sideview mirror, frame, or inside the vehicle as illustrated in Figure 16. The last column describes how the telltales function, and other actions that occur with the telltale, that may include audible signals, haptic signals, lowering media volume, and steering.

Table 7. Summary of BSW Technologies by Vehicle Manufacturing Group

Manufacturer Group	Technology Names	Telltale Type	Location	Other
AVP	Side Assist	Light	MF	None
BM	Active Blind Spot Detection/ Side Collision Warning	Triangle	MM	Flashes, SW vibrates
CDJAF	Blind Spot Monitoring/Alert	Triangle	MM	Audible, lowers radio
FL	Blind-spot monitoring system/Blind-spot information system/ Blind Spot Assist	ISO	UM	Lights, then flashes
GCBC	Side Blind Zone Alert, Lane Change Warning	✱🚗 (SAE J2400)	MM?	Flash only
HA	Blind Spot Information System	ISO	IV, MM, UM	Audible
HG	Blind-Spot Collision Warning Blind-Spot Collision Avoidance Assist	Hazard	UM	Beep, braking
I	None	NA	NA	NA
JL	Blind Spot Monitor, Blind Spot Assist	ISO	UM	Audible, resistive force, warning icon
K	Blind Spot Collision Warning, Blind-Spot Collision Avoidance Assist	Hazard	MM	Audible, braking
Ma	Blind Spot Monitoring	ISO	UM	Audible
Me	Blind Spot Assist, Active Blind Spot Assist with exit warning	Triangle	LM	Audible, turns from green to red and flashes
Mi	Blind Spot Warning, Active Blind Spot Assist	Triangle	UM	Audible, steering

Manufacturer Group	Technology Names	Telltale Type	Location	Other
NI	Blind Spot Warning, Intelligent Blind Spot Intervention	Hazard	UM/IV	Audible, steering
S	Blind Spot Detection/Side Assist	Light	UF	Audible
T	Automatic Blind Spot Camera	Diagram	Infotainment	White, yellow, orange, red based on proximity; Audible
TL	Blind Spot Monitor	ISO	MM	Audible, Flashes
V	Blind Spot Information System	Arc light	UM	None

Figure 15. Examples of blind spot warning telltales: light, hazard symbol, ISO symbol, triangle.

Figure 16. Examples of locations where blind spot warning telltales appear. Upper mirror (UM), middle mirror (MM), lower mirror (LM), upper frame (UF), middle frame (MF), lower frame (LF), inside vehicle (IV).

Tesla takes a different approach and does not include blind spot warnings on or near the left mirror. Instead, a view of vehicle (Figure 17) includes markings that change color (white, red, orange, yellow) depending on how close objects are. This feature encompasses the lane assist features as well.
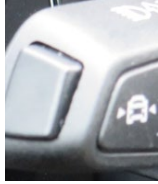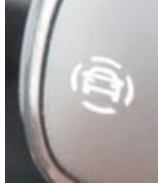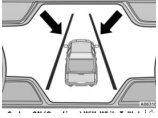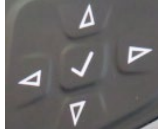
Figure 17. Tesla Y blind spot camera view; colors change with proximity.

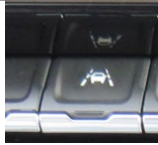Table 8 summarizes controls and displays related to lane-related safety technologies. It is difficult to ascertain how technologies align with traditional terms used by NHTSA of lane departure warning (LDW), lane keeping assist (LKA), and lane centering because of the variety of terms used by manufacturers. Controls to turn on lane safety technologies are usually on the steering wheel, but may also be selectable and reconfigurable through the instrument cluster or infotainment system or a button located on the lower left dashboard. The Ford Escape was the only one that had one of these controls on the left stalk. In some vehicles, the manual was not clear on how they were activated and they may be operational by default.
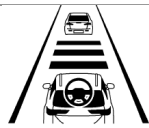
The displays seem to fall into two main types. For the more detailed version, the instrument cluster shows a display with two lanes, with or without a vehicle representation; these types also generally show the amount of following distance selected through other technologies. The lanes are usually white or green when detected and white or gray when not detected. When the vehicle crosses the detected lane line, the lines turn yellow or orange. For excessive departure, the lines turn red and may flash. For the second style, a smaller symbol is on the instrument cluster and changes color in a similar way. Some vehicles also have audible and/or haptic warnings. Interventions may include resistance or active steering back into the lane. In addition to the previous warnings, there may be popup messages indicating that steering is required.
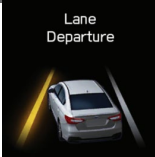
Table 8. Summary of lane-related safety technology names, controls, and displays.

Group	Make	Model	Name	Control Location	Control	Display	Warning
AVP	Audi	Q3	Lane guidance	L Stalk 1			Changes color
AVP	Volkswagen	Jetta	Lane Assist	Left Stalk			Changes color
BM	BMW	X5	Lane Departure Warning	SWL			Flash, wheel vibration
BM	BMW	I7	Assisted Driving	??			Yellow flash, vibrate, red flash
CDJAF	Jeep	Grand Cherokee	LaneSense	Center console			Lane lines flash & change color
CDJAF	Dodge	Ram	LaneSense	Infotainment?		Same as previous	Same as previous
CDJAF	Jeep	Wrangler	None	NA	NA	NA	NA
FL	Ford	Escape	Lane Centering, Lane Keeping System	L Stalk			Green on, yellow alert, red assist, haptic and steering

Group	Make	Model	Name	Control Location	Control	Display	Warning
FL	Ford	F-150	Active Drive Assist (Lane Centering Assist), Lane Keeping System	Infotainment			Green on, yellow assist, red alert
FL	Ford	Mach E	Lane Centering, Lane Keeping System	SWL			Green on, yellow detecting, red+ beep alert
FL	Ford	Lightning	Lane Centering, Lane Keeping System	SWL			Green on, yellow detecting, red+ beep alert
GCBC	Buick	Enclave	Lane Keep Assist/Lane Change Alert	Center Console			Green working, amber assist
GCBC	Cadillac	Escalade	Lane Keep Assist	SWL			Green working, amber assist
GCBC	Chevrolet	Malibu	Lane Keep Assist/Lane Change Alert	SWR			Green working, amber assist
GCBC	Chevrolet	Silverado	Lane Change Alert, Super Cruise, Automatic Lane Changes	Center Console			Green=ready to assist. Amber: when assisting. Flashing: Lane departure warning
HA	Acura	TLX	Lane Keeping Assist System, Road Departure Mitigation	SWR			White detected

Group	Make	Model	Name	Control Location	Control	Display	Warning
HA	Honda	CRV	Lane Keeping Assist System, Lane Departure	SWR			Audible, haptic, Green working, ?? alert
HA	Honda	Ridgeline	Road Departure Mitigation, Lane Keeping Assist System	SWR			Not described
HG	Hyundai	Tucson Santa Fe	Lane Keeping Assist + Lane Departure Warning	SWR			Displays lanes, flashes and beeps
JL	Land Rover	Defender	Lane Keeping Assist	SWR			Green on, red intervening, HUD warning
I	Isuzu	NRR	None	NA	NA	NA	NA
K	Kia	Niro, Rio	Lane Keeping Assist, Lane following assist	SWL			Audible, haptic, Green on, orange warning
Ma	Mazda	CX5	Lane Keep Assist System+ Lane Departure Warning	Infotainment			White on, amber departure; audible, haptic, steering options
Me	Mercedes	EQS	Active Steering Assist, Active Lane Change Assist	Infotainment			Visual icon then audible prompt. Green or red arrow for lane change

Group	Make	Model	Name	Control Location	Control	Display	Warning
Me	Mercedes	GLC300	Active Steering Assist, Active Lane Change Assist	Infotainment			Green ready, red limits detected, red hands: hands on wheel prompt
Mi	Mitsubishi	Outlander	Lane Departure Warning, Lane Departure Prevention, Lane Keep Assist	SWL, Cluster			Green on, orange warning
Mi	Mitsubishi	Mirage	Lane Departure Warning	LLDB			Audible, flash yellow
NI	Infiniti	Q50	Active Lane Control	SWR			green on, orange departure, haptic
NI	Nissan	Rogue	Steering Assist, Lane Departure Warning, Intelligent Lane Intervention	Cluster +SWL or LRDB or LLDB			LDW Blink, haptic; ILI: orange, blink, brake
NI	Nissan	Leaf	Lane Departure Warning, Intelligent Lane Intervention, Steering Assist	Cluster + SWL, LLDB, or SWR			Flash, haptic

Group	Make	Model	Name	Control Location	Control	Display	Warning
S	Subaru	Ascent, Outback	Lane Centering/ Lane Departure Warning/ Lane Sway Warning	SWR, Infotainment			White detected, flash yellow + beeps
T	Tesla	S Plaid	Lane Assist, Lane Departure Avoidance	Infotainment			White, yellow, orange, red based on proximity; haptic and steering options
T	Tesla	Y	Lane Assist, Lane Departure Avoidance	Infotainment			White, yellow, orange, red based on proximity; haptic and steering options
TL	Toyota	RAV4, Camry	Lane Tracing Assist	SWR			Green on, orange flashing alert
TL	Lexus	NX350	Lane Tracing Assist/ Lane Change Assist/ Lane Departure Alert	SWR			
V	Volvo	XC40	Lane Keeping Aid	Infotainment	Digital (default on)		White available, orange warning

Some manufacturers but not all pair BSW technologies with the rear cross traffic alert functions, using the same flashing signs in the mirror to indicate either. Some vehicles have the option to view the blind spot via the infotainment system. Other lane related technologies not addressed in detail include emergency assist (vehicle will navigate off the road if the driver is nonresponsive), lane change assist, and passing assist.

Forward Collison Warning (FCW) and Automatic Emergency Braking (AEB)
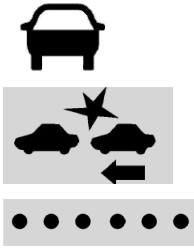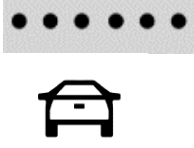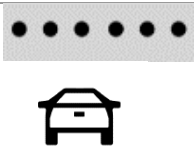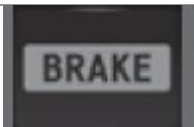
Table 9 summarizes FCW warning names, displays, and warnings, while Table 10 does the same for AEB. For many vehicles, the information is the same, and some manufacturers do not even list them as separate technologies. Again, it is sometimes challenging to discern what technologies correspond to the terms manufacturers use. Some manufacturers include non-frontal types of crashes in their collision prevention technologies.
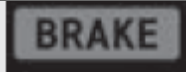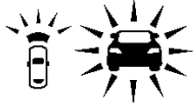
FCW and AEB are generally on by default, but the settings (including shutting it off) can be adjusted using the cluster menu/steering controls or the infotainment system. There is often a button on the steering wheel to set the following distance; sometimes this adjustment is made with FCW/AEB but other times it is with advanced cruise control settings.

The levels of warnings are similar to those seen for the lane-related technologies. If the cluster includes a display of the lanes, it will generally add a warning to the display, such as turning flashing, changing color, adding text such as BRAKE or Collision warning, or having an additional icon appear. The simpler displays are generally an icon that changes color or flashes to warn of a collision or braking. Some vehicles include audible and haptic warnings. BMW seems to be the most advanced system, providing a red icon corresponding to different types of impending obstacles (pedestrian, vehicle ahead, vehicle from right, vehicle from left, general hazard.) The two electric Ford vehicles are the only ones that use an accessible color scheme of blue, yellow, red to signify the amount of distance. Warnings appear on the cluster or the HUD if available.

Table 9. Summary of forward collision warning technology names, display characteristics, and warnings

Group	Make	Model	Name	Location	Symbol	Warning
AVP	Audi	Q3	Pre sense front prewarning	Cluster		
AVP	Volkswagen	Jetta	Front Assist	Cluster		Appears
BM	BMW	X5	Forward Collision Warning	Cluster		Turns red
BM	BMW	I7	Forward collision mitigation	Cluster		Red Icon appears, flashes, audible, braking
CDJAF	Jeep	Grand Cherokee	Forward Collision Warning	Cluster		Appears, audible, haptic
CDJAF	Dodge	Ram	Forward Collision Warning	Cluster		Appears

Group	Make	Model	Name	Location	Symbol	Warning
CDJAF	Jeep	Wrangler	Forward Collision Warning	Cluster	¡BRAKE!	Appears, audible, braking
FL	Ford	Escape	Pre-collision assist, Distance Alert	Cluster		Flash, audible, braking
FL	Ford	F-150	Pre-collision assist	Cluster		Flash, audible, braking
FL	Ford	Mach E	Pre-collision assist	Cluster, Infotainment?		Flash, distance by color, audible, braking
FL	Ford	Lightning	Pre-collision assist	Cluster, Infotainment?		Flash, distance by color, audible, braking
GCBC	Buick	Enclave	Forward Collision Alert	HUD, cluster		Yellow too close, alert flashes red, audible
GCBC	Cadillac	Escalade	Forward Collision Alert	HUD, cluster		Yellow too close, alert flashes red, audible, haptic
GCBC	Chevrolet	Malibu	Forward Collision Alert	HUD		Flashes red
GCBC	Chevrolet	Silverado	Forward Collision Alert	HUD, cluster		Yellow too close, alert flashes red, audible, haptic
HA	Acura	TLX	Collision Mitigation Braking System	HUD/Cluster	BRAKE	Audible, HUD light, message IC

Group	Make	Model	Name	Location	Symbol	Warning
HA	Honda	CRV	Collision Mitigation Braking System	Cluster	BRAKE	Audible, message IC
HA	Honda	Ridgeline	Collision Mitigation Braking System	Cluster	BRAKE	Audible, message IC, haptic, braking
HG	Hyundai	Tucson Santa Fe	Forward Collision Warning Assist	Cluster		Audible
JL	Land Rover	Defender	Forward Alert	Cluster, HUD	Unknown	Audible
I	Isuzu	NRR	None			
K	Kia	Niro, Rio	Forward collision warning assist	Cluster		Audible
Ma	Mazda	CX5	Smart City Brake Support	Cluster	BRAKE!	Audible
Me	Mercedes	GLC300, EQS	Active Brake Assist	Cluster		Symbol appears, audible, braking
Mi	Mitsubishi	Outlander	Forward Collision Mitigation, Predictive Forward Collision Warning	Cluster		Audible
Mi	Mitsubishi	Mirage	Forward Collision Mitigation Warning Function	Cluster		Audible
NI	Infiniti	Q50	Distance Control assist	Infotainment		Orange, audible
NI	Nissan	Rogue, Leaf	Intelligent Forward Collision Warning	Cluster		Flash yellow, audible
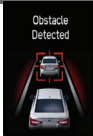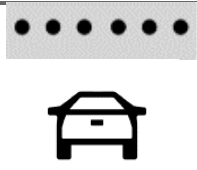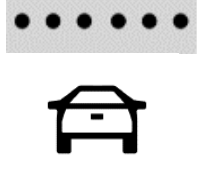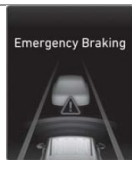
Group	Make	Model	Name	Location	Symbol	Warning
S	Subaru	Ascent, Outback	Pre collision braking: Following Distance Warning	Cluster		Audible
T	Tesla	Y, S Plaid	Forward Collision Warning	Infotainment		Forward vehicle turns red, audible, haptic
TL	Toyota	RAV4, Camry	Pre-Collision System Warning	Cluster		Audible, IC message
TL	Lexus	NX350	Pre-collision System	Cluster, HUD		Audible
V	Volvo	XC40	Collision warning	Cluster		Audible

Table 10. Summary of automatic emergency braking technology names, display characteristics, and warnings

Group	Manufacturer	Model	Name	Display Location	Symbol	Warning
AVP	Audi	Q3	Pre sense front automatic braking	Cluster		Please take over! Message appears
AVP	Volkswagen	Jetta	Front Assist Advance Warning	Cluster		Appears, audible, braking
BM	BMW	X5	FCW with light Braking	Cluster		Flashes and beeps when braking

Group	Manufacturer	Model	Name	Display Location	Symbol	Warning
BM	BMW	I7	Forward collision mitigation	Cluster		Red Icon appears, flashes, audible, braking
CDJAF	Jeep	Grand Cherokee	Forward Collision Warning with Mitigation	Cluster		Flashes, audible, haptic
CDJAF	Dodge	Ram	Forward Collision Warning with Mitigation	Cluster		Appears
CDJAF	Jeep	Wrangler	Forward Collision Warning with Mitigation	Cluster		Appears, audible, braking
FL	Ford	Escape	Pre-collision assist automatic emergency braking	Cluster		Flash, audible, braking
FL	Ford	F-150	Pre-collision assist	Cluster		Flash, audible, braking
FL	Ford	Mach E	Pre-collision assist	Cluster, Infotainment?		Flash, distance by color, audible, braking
FL	Ford	Lightning	Pre-collision assist	Cluster, Infotainment?		Flash, distance by color, audible
GCBC	Buick	Enclave	Forward Collision Alert	HUD, cluster		Yellow too close, alert flashes red, audible

Group	Manufacturer	Model	Name	Display Location	Symbol	Warning
GCBC	Cadillac	Escalade	Automatic Emergency Braking	HUD, cluster		Yellow too close, alert flashes red, audible, haptic, braking
GCBC	Chevrolet	Malibu	Forward Automatic Braking	HUD		Flashes red and beeps
GCBC	Chevrolet	Silverado	Automatic Emergency Braking	HUD, cluster		Yellow too close, alert flashes red, audible, haptic
HA	Acura	TLX	Collision Mitigation Braking System	HUD/Cluster	BRAKE	Audible, HUD light, message IC
HA	Honda	CRV	Collision Mitigation Braking System	Cluster	BRAKE	Audible, message IC
HA	Honda	Ridgeline	Collision Mitigation Braking System	Cluster	BRAKE	Audible, message IC, haptic, braking
HG	Hyundai	Tucson Santa Fe	Forward Collision Warning Assist	Cluster	Emergency Braking	Audible
JL	Land Rover	Defender	Autonomous Emergency braking	Cluster/HUD	Unknown	Message IC
I	Isuzu	NRR	None			
K	Kia	Niro, Rio	Emergency Braking	Cluster	Emergency Braking	Message IC, Audible
Ma	Mazda	CX5	Smart City Brake Support	Cluster	BRAKE!	Audible

Group	Manufacturer	Model	Name	Display Location	Symbol	Warning
Me	Mercedes	GLC300, EQS	Active Brake Assist	Cluster		Symbol appears, audible, braking
Mi	Mitsubishi	Outlander	Forward Collision Mitigation, Predictive Forward Collision Warning	Cluster		Audible
Mi	Mitsubishi	Mirage	Forward Collision Mitigation Braking Function	Cluster, turn off LLDB		Audible, blinking
NI	Infiniti	Q50	Forward Emergency Braking	Cluster		Flash orange, audible
NI	Nissan	Rogue, Leaf	Automatic Emergency Braking with Pedestrian Detection	Cluster		Yellow, red, audible
S	Subaru	Ascent, Outback	Pre collision braking: First + Second Braking and Distance Warning	Cluster		Audible, two levels
T	Tesla	Y, S Plaid	Automatic Emergency Braking	Infotainment		Appears with AEB, audible
TL	Toyota	RAV4, Camry	Pre-Collision System Brake Assist	Cluster		Audible, IC message, braking
TL	Lexus	NX350	Pre-collision brake Assist	Cluster, HUD		Audible, braking
V	Volvo	XC40	Assisted braking	Cluster		Audible

Infotainment Systems

Framework

The analysis for the infotainment systems follows the framework shown in Table 11. These items are common across vehicles and most infotainment systems include them through different designs. The infotainment systems equipped in the vehicles of the same manufactures are usually quite similar, so we investigated one infotainment system for each manufacturing group.

Table 11. Framework for Infotainment Interface Analysis

Category	Items to be compared
Overview	• Number of layers • Home access • Item layout for each layer
Home	• Number of pages • Number of items
Radio/Music/Media	• Station selection method • List of preset channels • Searching function
Climate	• Temperature • Fan speed • Air direction
Navigation	• Apple CarPlay, Android Auto, or OEM equipped device • Destination input (address, POI, …) • Shortcut to preset destinations • Map zoom in/out
ADAS Adjustment	• Settings for ADAS or safety features
Sound Settings	• Sound settings

Overview

Table 12 provides an overview for each infotainment system, including the home access, number of menu layers in the system, and the general layout in each layer. Among the vehicles in this survey, all the menus have five or fewer layers. The 'List' structure exists in the deeper layers because those items usually have more text as labels or instructions. The Mazda CX5 has a system that only applies 'List' in their design. Examples of the layouts are shown in Figure 18. Tesla has the fewest number of layers but the most functions through the touchscreen.

Table 12. Infotainment Overview

Manf.	Model	Home access	# of layers (Home=0)	0	1st	2nd	3rd	4th
Audi	Q3	Virtual	4	Grid	Grid/ List	Grid/ List	Multi	na
Volkswagen	Jetta	Permanent, printed	5	Grid	Multi	Multi	List	List
BMW	i7	Virtual	5	Grid	Grid/ list	List	List	List
Jeep	Grand Cherokee	Virtual	5	Grid	Grid	Grid/ List	Grid/ List	List
Jeep	Wrangler	Virtual	3	Grid	Grid	List	na	na
Ford	SYNC4	Virtual	3	Grid	Grid/ list	List	na	na
Buick	Enclave	Virtual	3	Grid	Grid/ list	List	na	na
Chevrolet	Silverado	Permanent, physical	5	Grid	Grid	List	List	List
Acura	TLX	Permanent, physical	5	Grid	List	List	List	List
Honda	CRV	Permanent, physical	5	Grid	Grid/ list	List	List	List
Honda	Ridgeline	Permanent, printed	5	Grid	Grid/ list	List	List	List
Hyundai	Santa Fe/ Tucson	Permanent, virtual	5	Grid	Grid	List	List	List
Isuzu	NRR	Permanent, printed	2	Grid	Grid	na	na	na
Land Rover	Defender	Virtual	5	Grid	Grid/ list	List	List	List
Kia	Rio/Niro	Virtual	5	Grid	Grid	List	List	List
Mazda	CX5	Permanent, physical	5	List	List	List	List	List
Mercedes	EQS	Virtual	5	Grid	Grid/ list	List	List	List

Manf.	Model	Home access	# of layers (Home=0)	0	1st	2nd	3rd	4th
Mitsubishi	Outlander	Virtual	3	Grid	Grid	List	na	na
Nissan	Rogue/ Leaf	Permanent, physical	4	Grid	Grid/ tab	Grid/ list	List	na
Subaru	Outback	Virtual	3	Grid	Grid/ list	Grid/ list	na	na
Tesla	S Plaid	Virtual	2	Grid	Grid/ list	na	na	na
Toyota	RAV4	Permanent, physical	4	Grid	List	List	Grid/ list	na
Volvo	XC40	Virtual	3	Grid	Grid/ list	List	List	na

*na: not applicable from the infotainment system

	Grid	**List**
Home		
1st layer		
2nd layer		
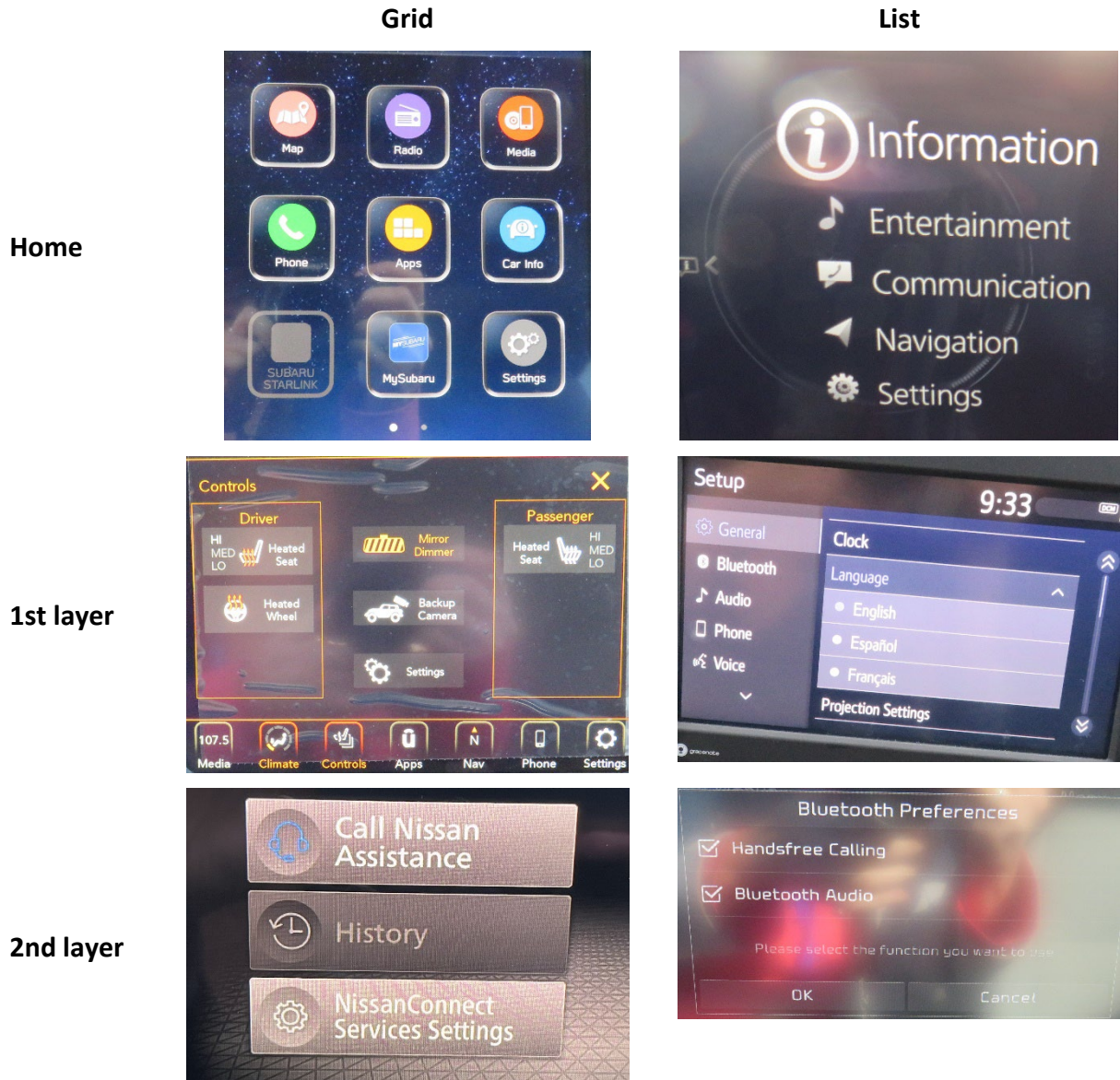
Figure 18. Examples of grid and list in different layers

HOME screen

The items in the 'Home' screen are summarized in Table 13, including the number of pages in the home layer, number of items in each page, and the item types. The number of items ranges from six to eighteen in a page, but mostly ten or fewer. Those labeled as 'o' are in different layers other than Home, 'na' are in different systems or areas of the vehicle, and 'ne' are not equipped in this vehicle. Examples in Figure 19 and Figure 20, respectively, show the systems that have most and least number of home screen items.

Table 13. Items in the Home Screen

Manf.	Model	# of Pages	# of Items	Radio	Media	Telephone	Navigation	(Phone) App	Vehicle	Climate	Setting	Messages
Audi	Q3	3	8/page	2	1,2	1,2	1,2	2	2	o	2	3
Volkswagen	Jetta	2	8/page	1	1	1	1	1	1	2	2	na
BMW	I7	2	18/page	1	1	1	1	1	1	2	1	2
Jeep	Grand Cherokee	1	7/page	o	1	1	1	1	1	1	o	na
Jeep	Wrangler	1	7/page	o	1	1	1	1	o	1	1	na
Ford	SYNC	1	7/page	o	1	1	1	1	1	na	1	o
Buick	Enclave	3	8/page	o	1	1	1	1	o	2	1	o
Chevrolet	Silverado	2	8/page	o	1	1	1	1	o	2	2	na
Acura	TLX	2	8/page, c	1	1	1	1	1	o	na	2	2
Honda	CRV	3	8/page, c	1,2	o	1	ne	1	2	na	2	ne
Honda	Ridgeline	2	6/page, c	o	1	1	ne	2	o	na	1	ne
Hyundai	Santa Fe/ Tucson	2	12/page	o	1	1	1	1	o	1	1	o
Isuzu	NRR	1	6/page	1	ne	ne	ne	1	na	na	na	ne
Land Rover	Defender	3	3/page, c	c	1	1	1	c	na	c	1	ne
Kia	Rio/Niro	2	8/page	1	1	1	ne	1	na	na	1	ne
Mazda	CX5	1	5/page	o	1	1	1	ne	o	na	1	ne
Mercedes	EQS	2	8/page	1	1	1	o	1	o	1	1	o
Mitsubishi	Outlander	1	7/page	1	1	1	1	o	o	na	1	na

Manf.	Model	# of Pages	# of Items	Radio	Media	Telephone	Navigation	(Phone) App	Vehicle	Climate	Setting	Messages
Nissan	Rogue/ Leaf	1	5/page, c	o	1	1	ne	o	na	na	1	ne
Subaru	Outback	2	9/page	1	1	1	1	1	1	o	1	o
Tesla	S Plaid	1	10/page, c	o	1	1	1	1	1	1	1	1
Toyota	RAV4	1	6/page	o	1	1	o	1	na	na	1	ne
Volvo	XC40	1	10/page	1	1	1	1	1	na	1	o	ne

*ne: not equipped; na: not applicable from the infotainment system; o: in the other layer/area; 1: on the first page; 2: on the second page; 3: on the third page; c: menu can be customized
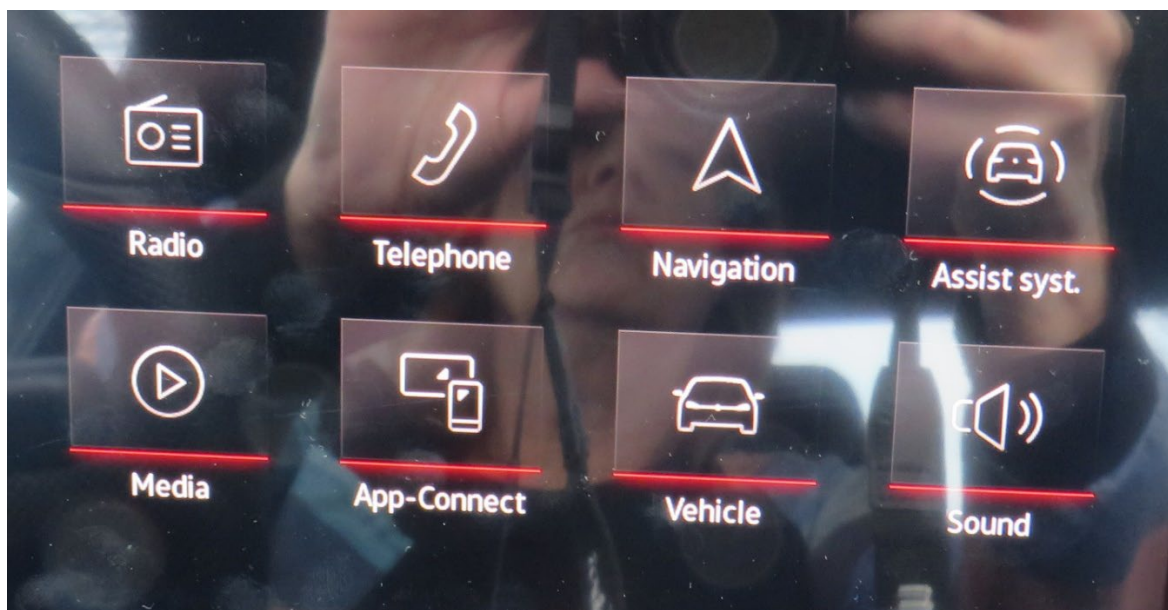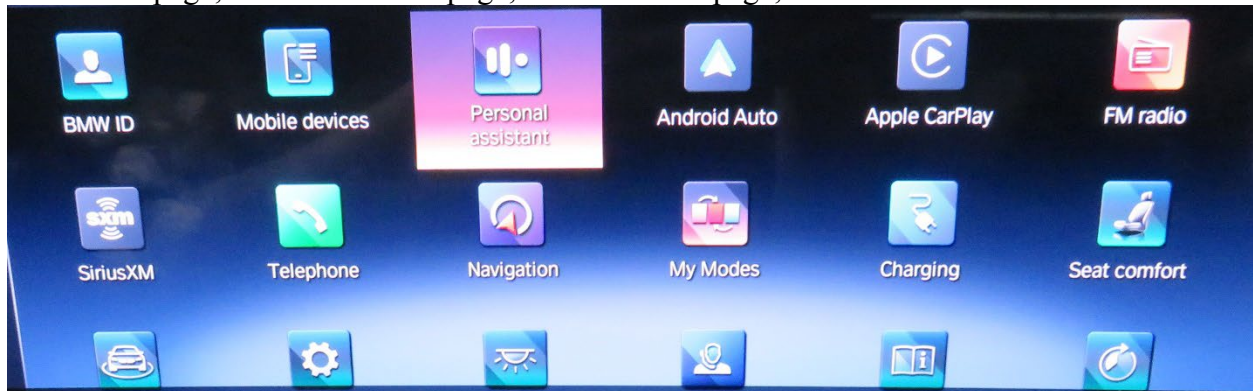
Figure 19. Examples of Systems with All/Most Common Items in the Home Screen

Figure 20. Examples of Systems with Least Items in the Home Screen

Radio/Music/Multimedia

Most infotainment systems support Apple CarPlay and Android Auto. In addition, they also have factory equipped media players as summarized below. Table 14 compares the method and layout of station and preset selections. The radio stations or music can be selected by using virtual icons and physical controls (examples shown in Figure 21). More advanced design is to flick or tab on the list, as shown in Figure 22 and Figure 23. Tesla's touchscreen is the only system with the grid design for the entire media (Figure 24). For some luxury vehicles, the music or radio stations can be searched by entering characters with keyboard, numpad, or handwriting (Figure 25).

Table 14. Interfaces of Radio, Music, or Multimedia

Group	Manufacturer	Model	Station selection	Preset channel/ Song selection	Searching function
AVP	Audi	Q3	Vertical list	List	QWERTY keyboard
AVP	Volkswagen	Jetta	Physical knob	Grid	Numeric keypad
BM	BMW	I7	Vertical list	Vertical list	?
CDJAF	Jeep	Grand Cherokee	Tab, </> icon	Horizontal list	na
CDJAF	Jeep	Wrangler	Physical knob, vertical list	Horizontal list	na
FL	Ford	SYNC4	Physical knob, </> icon	Horizontal list	na
GCBC	Buick	Enclave	Vertical list	Horizontal list	na
GCBC	Chevrolet	Silverado	Vertical list	Horizontal list	na
HA	Acura	TLX	Vertical list	Horizontal list	Handwriting
HA	Honda	CRV	</> icon	Horizontal list	na
HA	Honda	Ridgeline	</> icon	Horizontal list	na
HG	Hyundai	Santa Fe/ Tucson	Vertical list	Horizontal list	na
I	Isuzu	NRR	</> icon	Horizontal list	na
JL	Land Over	Defender	>/< icon	Grid	QWERTY keyboard
K	Kia	Rio/Niro	</> icon	Vertical list	
Ma	Mazda	CX5	Vertical list	Vertical list	na
Me	Mercedes	EQS	Horizontal list	Vertical list	QWERTY keyboard
Mi	Mitsubishi	Outlander	Physical knob	Horizontal list	na
NI	Nissan	Rogue/Leaf	Vertical list	Horizontal list	na
S	Subaru	Outback	Vertical list	Grid	na
T	Tesla	S Plaid	Grid	Grid	QWERTY keyboard
TL	Toyota	RAV4	Vertical list	Grid	na
V	Volvo	XC40	Vertical list	Vertical list	na
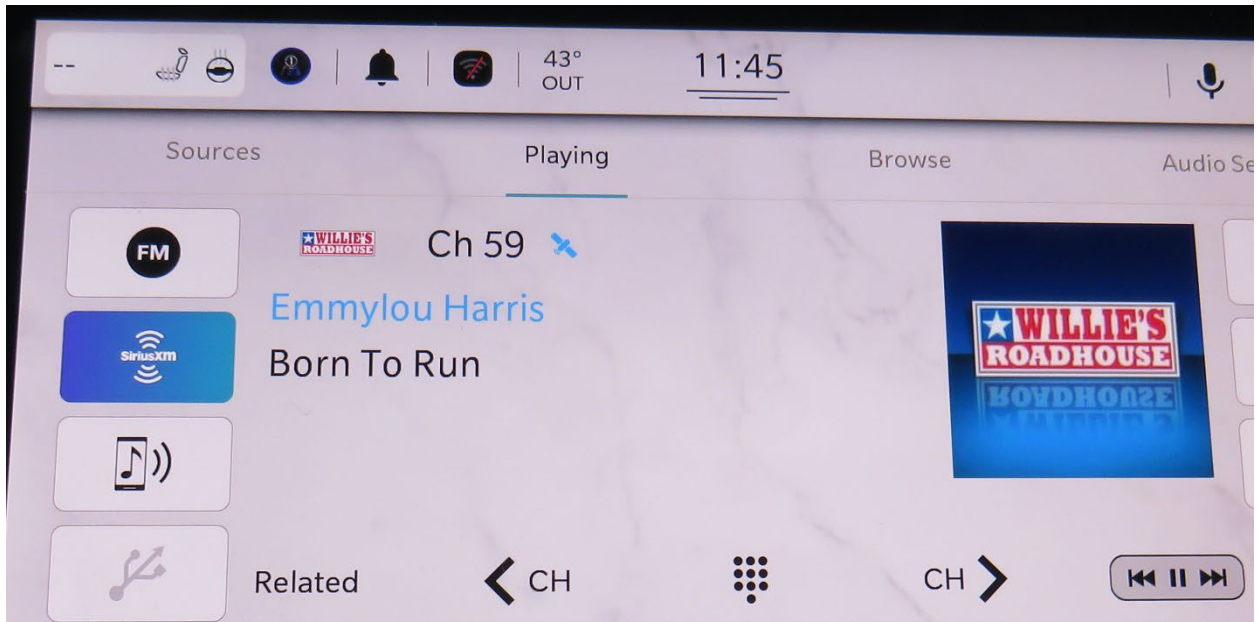
Figure 21. Example of Selecting Stations by Virtual Icons and Physical Controls

Figure 22. Example of Vertical List Menus
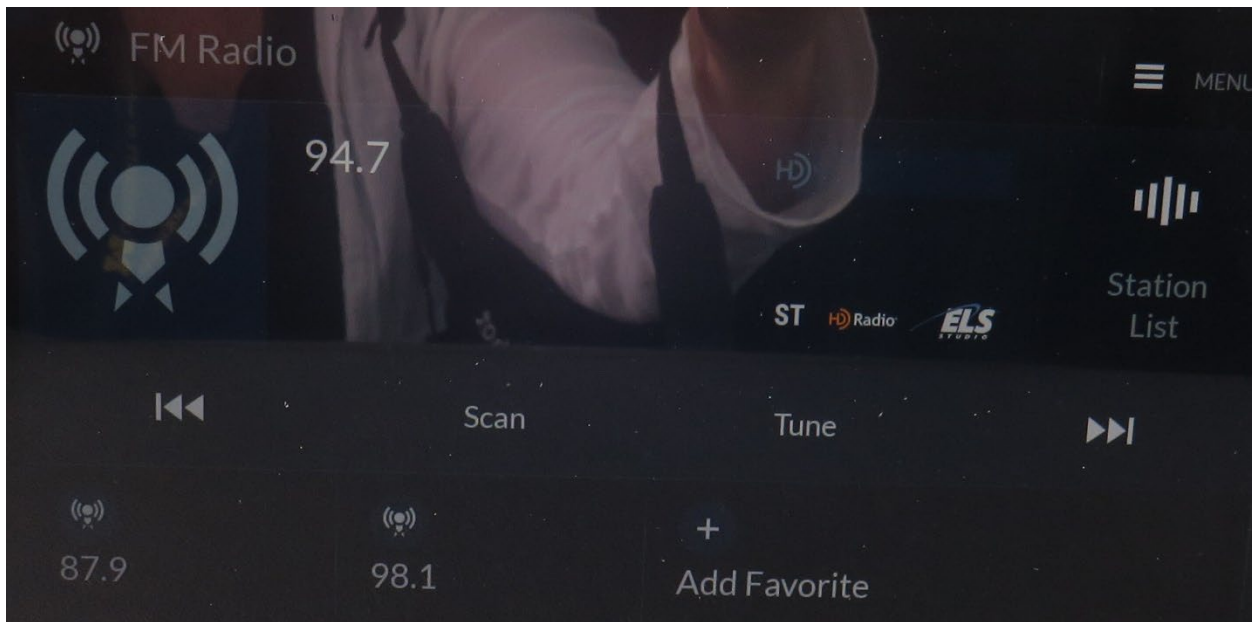
Figure 23. Examples of Horizontal List Menu

Figure 24. Examples of Grid Menu
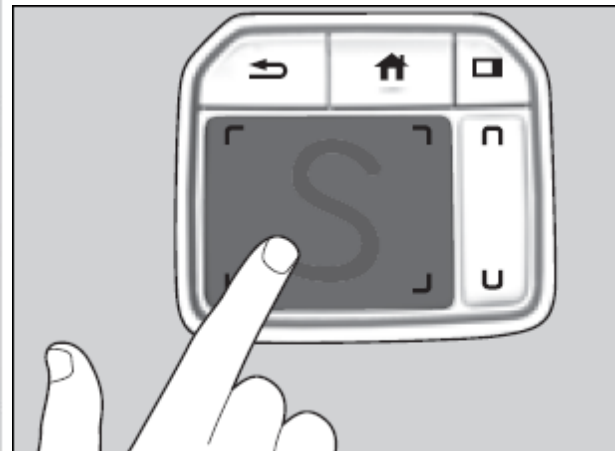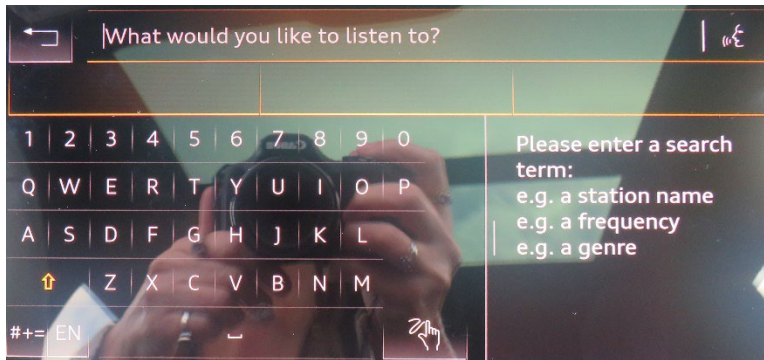
Figure 25. Examples of Different Searching Input Methods: Keyboard, Numpad, and Handwriting

Climate

Table 15 summarizes the controls and displays to adjust the in-cab climate. A common design with displays and controls on the screen is shown in Figure 26. Some of them only include displays operated by controls in another area (e.g., Ford, Acura, Hyundai in Figure 27). Several manufacturers do not include climate control in the infotainment systems, instead using physical controls generally located below the infotainment screen (example shown in Figure 28). These tend to be the Asian car manufacturers (Honda, Hyundai, Kia, Nissan, Toyota).

Table 15. Interfaces for Climate Systems

Group	Manufacturer	Model	Temperature	Fan speed	Air direction
AVP	Audi	Q3	na	na	na
AVP	Volkswagen	Jetta	Physical knob	Slider	Button
BM	BMW	I7	+/- icon	+/- icon	</> icon
CDJAF	Jeep	Grand Cherokee	Physical knob	</> icon	Button
CDJAF	Jeep	Wrangler	</> icon	Button	Icon
FL	Ford	SYNC4	Display only	na	na
GCBC	Buick	Enclave	</> icon	</> icon	Button
GCBC	Chevrolet	Silverado	</> icon	</> icon	Button
HA	Acura	TLX	na	na	na
HA	Honda	CRV	na	na	na
HA	Honda	Ridgeline	na	na	na
HG	Hyundai	Santa Fe/ Tucson	Display only	Display only	Display only
I	Isuzu	NRR	na	na	na
JL	Land Rover	Defender	Physical knob	Button	Icon
K	Kia	Rio/Niro	na	na	na
Ma	Mazda	CX5	na	na	na
Me	Mercedes	EQS	</> icon	Fan icon	Icon
Mi	Mitsubishi	Outlander	Physical knob	na	na
NI	Nissan	Rogue/Leaf	na	na	na
S	Subaru	Outback	Physical button	Button	Button
T	Tesla	S Plaid	</> icon	</> icon	Button
TL	Toyota	RAV4	na	na	na
V	Volvo	XC40	</> icon	</> icon	Icon

*na: not applicable from the infotainment system

Figure 26. Examples of Climate Systems with Displays and Controls
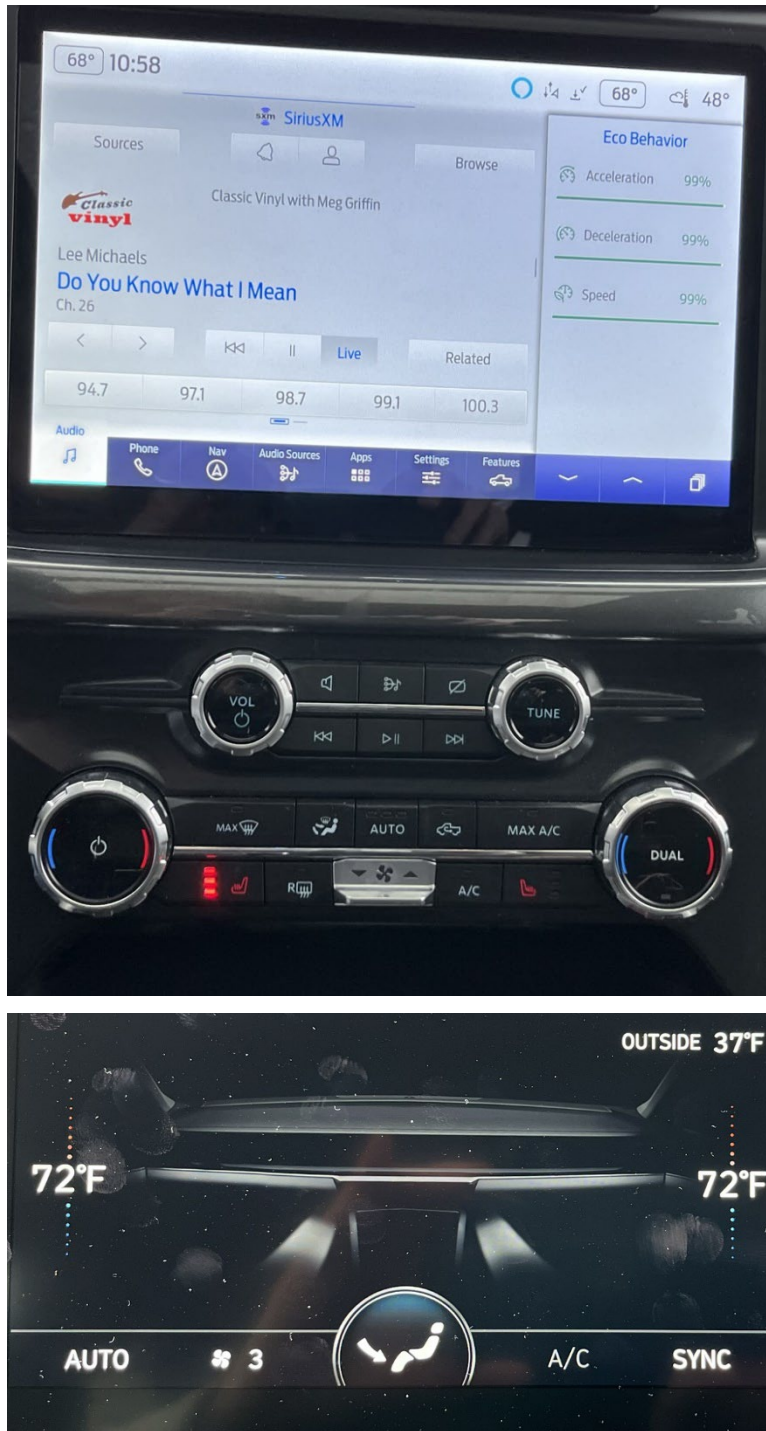
Figure 27. Examples of Climate Systems with Displays Only

Figure 28. Example of Climate Systems in the Other Areas

Settings Control for ADAS or Safety Features

Many manufacturers use the infotainment systems to control settings on the Advanced Driver Assistance Systems (ADAS) and safety features. Table 16 summarizes what settings can be adjusted for ACC, FCW/AEB, BSW, and LDW/LKA, and some examples are also shown below. The adjustments include system switching on/off (Figure 28), change for warning timing (Figure 29), and change for modality (Figure 30). For some Asian vehicle manufacturers (i.e., Hyundai, Kia, Nissan, Subaru, and Toyota), their infotainment systems do not support adjusting the ADAS. For Hyundai and Kia, their ADAS settings are shown in the instrument cluster (Figure 32).

Table 16. Adjusting ADAS Features

Manufacturer	Model	ACC	FCW/AEB	BSW	LDW/LKA
Audi	Q3	Lane guidance on/off	Warning on/off	System on/off	Steering wheel vibration on/off
Volkswagen	Jetta	Distance setting	Warning on/off, timing	System on/off	Steering wheel vibration on/off
BMW	I7	na	Warning timing	Warning sensitivity, on/off	Sensitivity, on/off
Jeep	Grand Cherokee	na	Warning sensitivity, on/off	Modality, on/off	Modality, timing, feedback strength
Jeep	Wrangler	ne	ne	Physical control	ne
Ford	SYNC4	Mode	Warning sensitivity, on/off	System on/off	Modality, intensity
Buick	Enclave	na	System on/off	System on/off	System on/off
Chevrolet	Silverado	na	System on/off	System on/off	na
Acura	TLX	Alert on/off	Warning timing	Modality	System on/off
Honda	CRV	System on/off	Warning timing	Modality	System on/off
Honda	Ridgeline	System on/off	Warning timing	Modality, system on/off	System on/off
Hyundai	Santa Fe/ Tucson	na	na	na	na
Isuzu	NRR	ne	ne	ne	ne
Land Rover	Defender	na	Warning timing, system on/off	na	System on/off
Kia	Rio/Niro	na	na	na	na
Mazda	CX5	na	Warning timing, system on/off	Modality	Modality, system on/off
Mercedes	EQS	System on/off, driving style	Warning timing, system on/off	System on/off	Timing, system on/off
Mitsubishi	Outlander	na	na	na	na
Nissan	Rogue/Leaf	na	na	na	na
Subaru	Outback	na	na	na	na
Tesla	S Plaid	Alert on/off	System on/off	System on/off	System on/off
Toyota	RAV4/Camry	na	na	na	na
Volvo	XC40	na	na	na	System on/off

*ne: not equipped; na: not applicable from the infotainment system
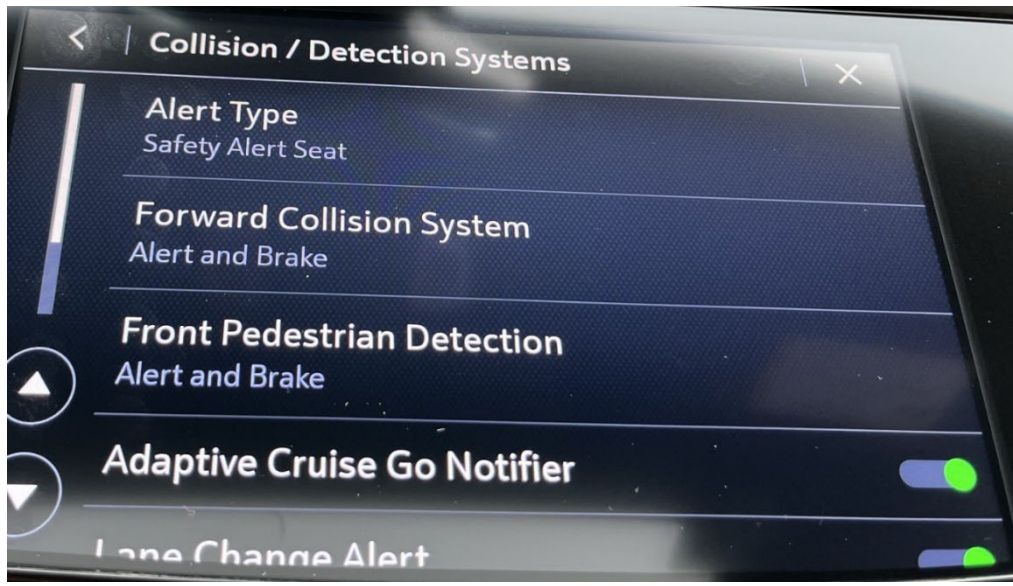
Figure 29. Examples of Switching Systems On/Off
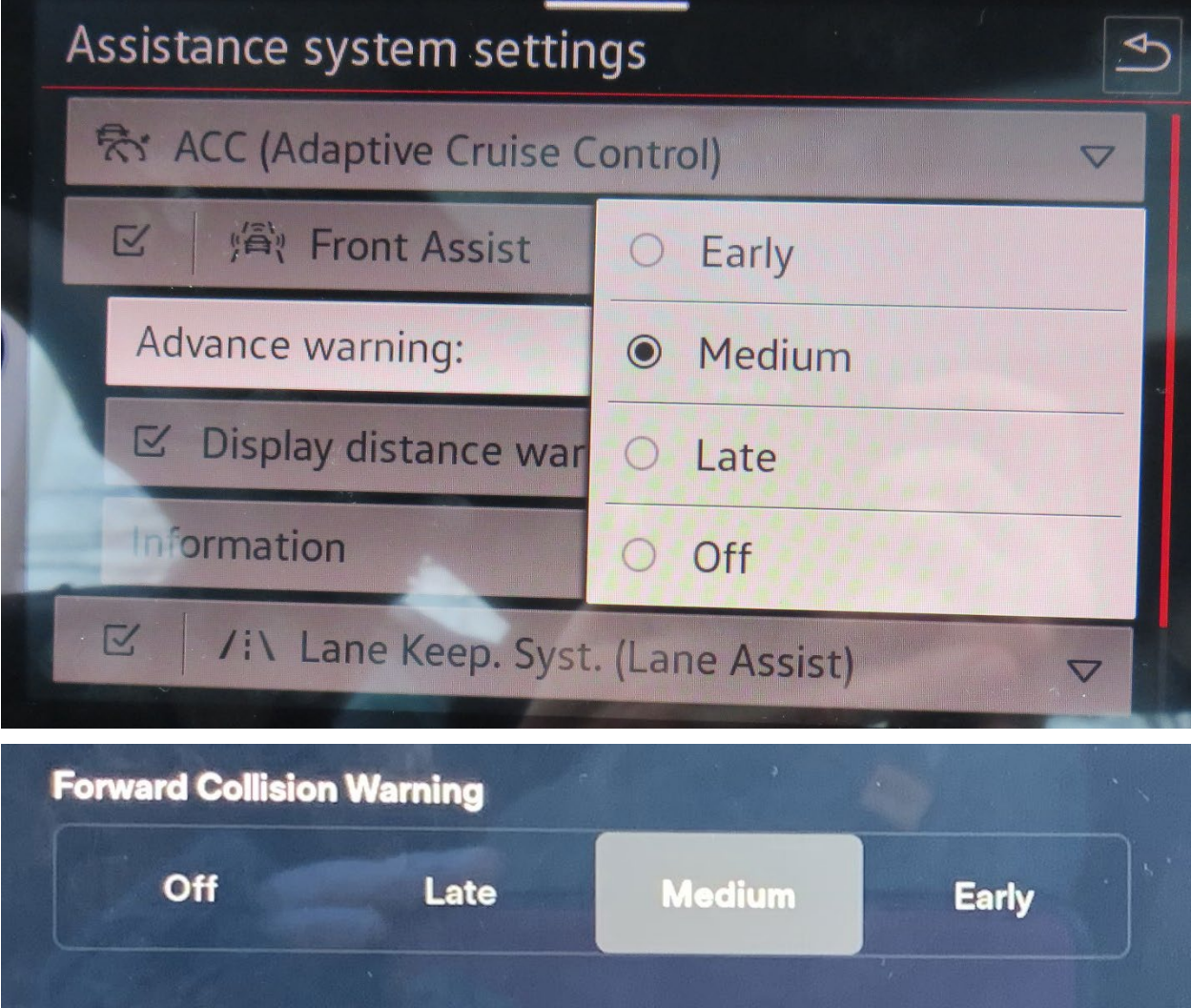
Figure 30. Examples of Changing the Warning Timing
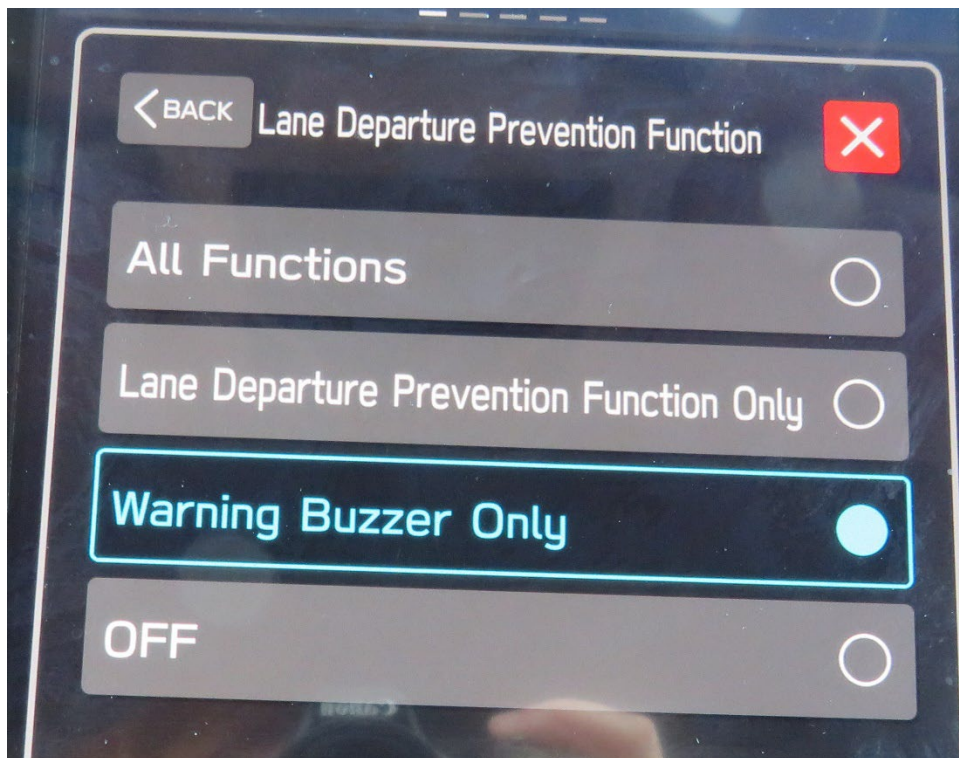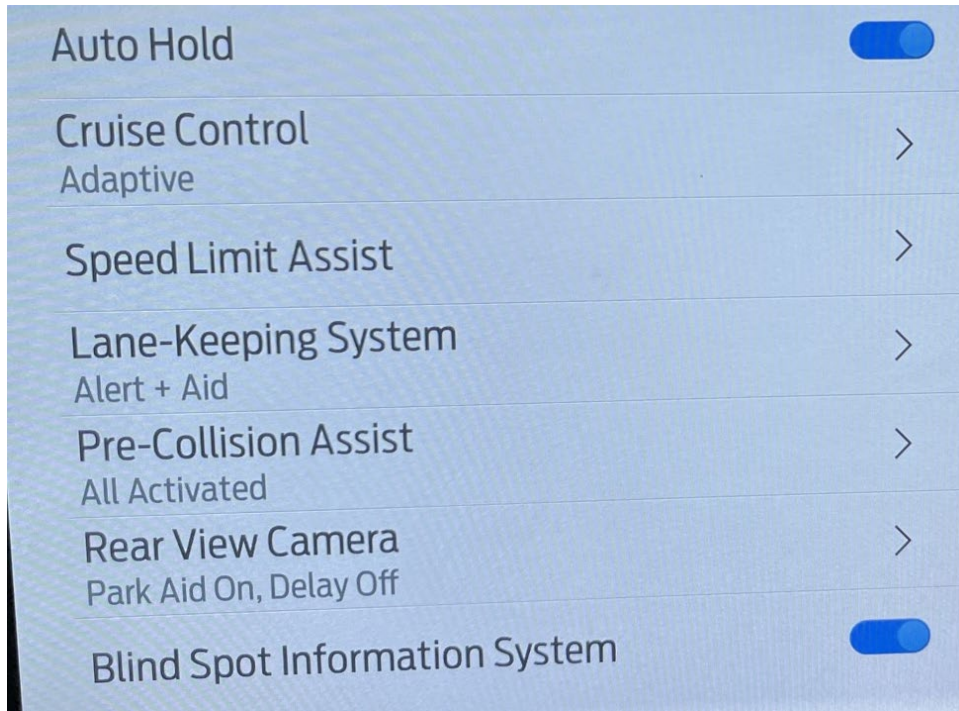
Figure 31. Examples of Changing the Warning Modality

Figure 32. Examples of Warning System Settings in the Instrument Cluster (Hyundai, Kia Specifically)

Sound Settings

The interfaces for sound equalizers and positioning functions are summarized in Table 17, for which there are two major types of control: icon/button and sliders. Examples are shown in Figure 33 and Figure 34.

Table 17. Interfaces for Sound Settings

Group	Manufacturer	Model	Sound Equalizer	Sound position
AVP	Audi	Q3	Slider, +/- icon, button	Button
AVP	Volkswagen	Jetta	Button	Drag icon, button
BM	BMW	I7	+/- icon	Radio button
CDJAF	Jeep	Grand Cherokee	+/- icon	</> icon
CDJAF	Jeep	Wrangler	+/- icon	</> icon
FL	Ford	SYNC4	</> icon	</> icon
GCBC	Buick	Enclave	</> icon	</> icon
GCBC	Chevrolet	Silverado	</> icon	</> icon
HA	Acura	TLX	+/- icon	Radio button
HA	Honda	CRV	+/- icon	Button
HA	Honda	Ridgeline	+/- icon	Button
HG	Hyundai	Santa Fe/Tucson	+/- icon	Button
I	Isuzu	NRR	ne	ne
JL	Land Rover	Defender	Slider, +/- icon	Drag icon, button
K	Kia	Rio/Niro	+/- icon	</> icon
Ma	Mazda	CX5	Slider	Slider
Me	Mercedes	EQS	</> icon	Drag icon
Mi	Mitsubishi	Outlander	+/- icon	ne

Group	Manufacturer	Model	Sound Equalizer	Sound position
NI	Nissan	Rogue/Leaf	+/- icon	ne
S	Subaru	Outback	Slider	</> icon
T	Tesla	S Plaid	Slider	Drag icon
TL	Toyota	RAV4	na	na
V	Volvo	XC40	Slider	Icon

*ne: not equipped; na: not applicable from the infotainment system
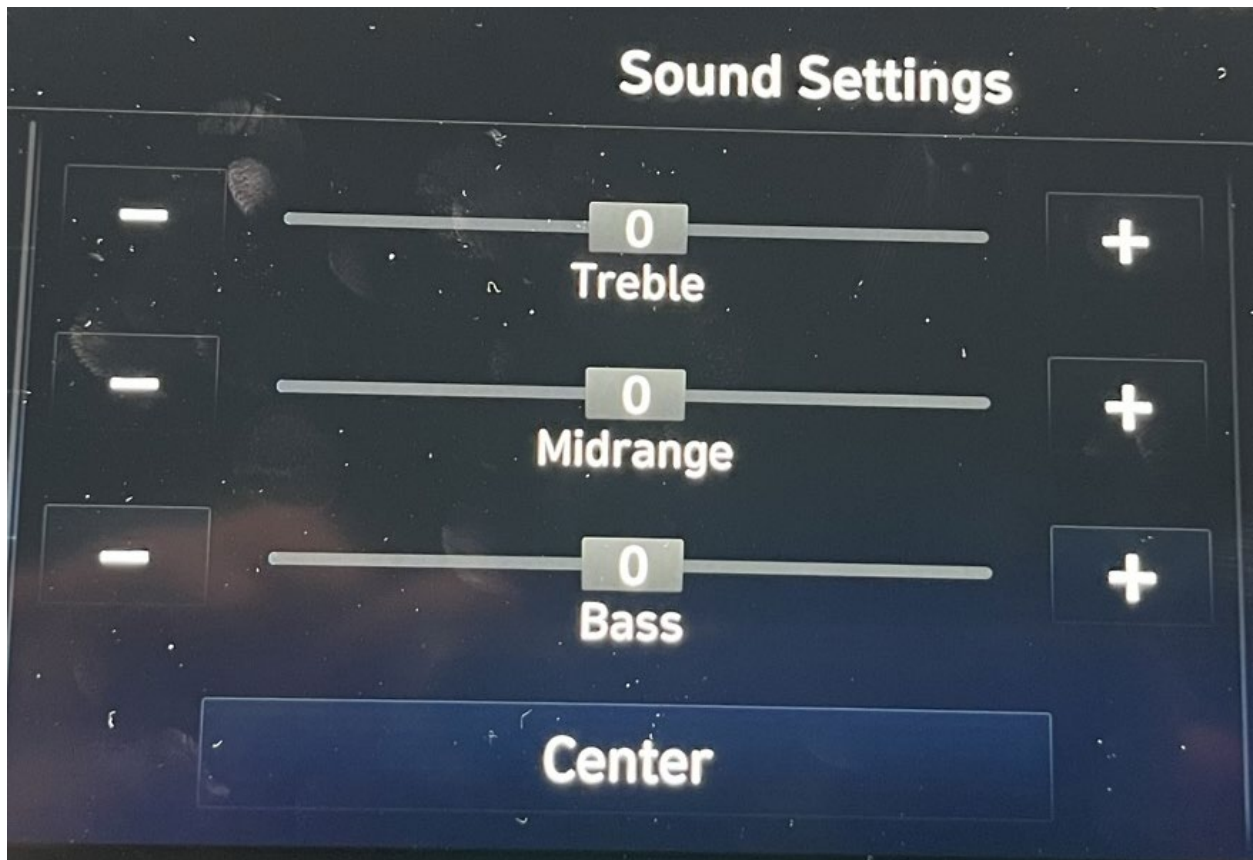
Figure 33. Examples of Adjusting Sound Equalizers
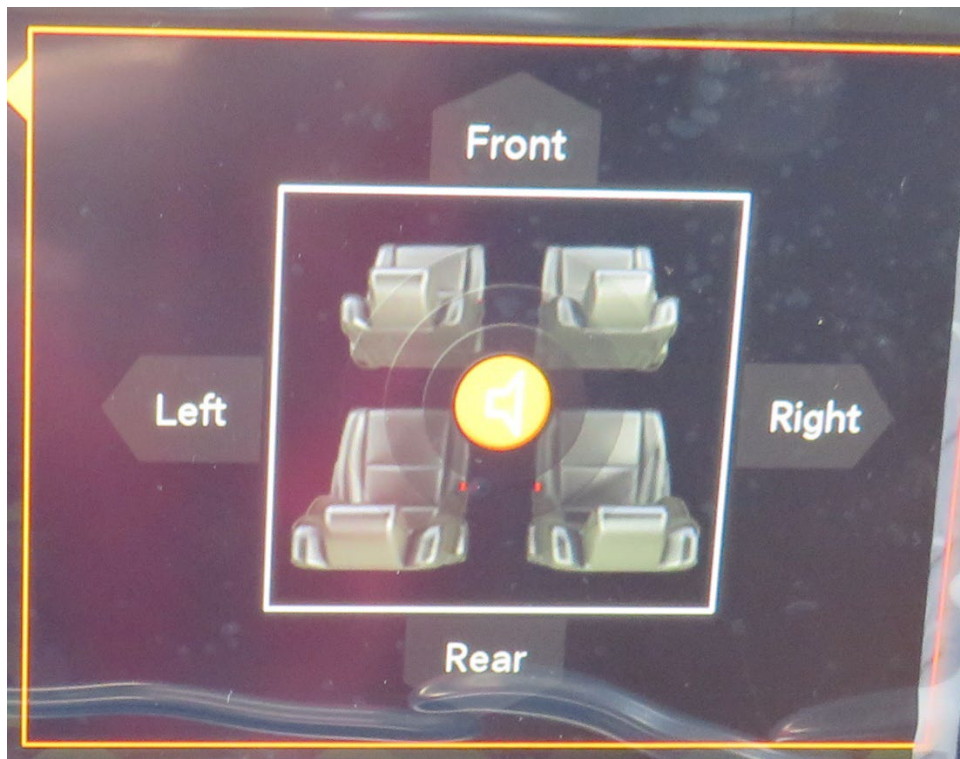
Figure 34. Examples of Sound Positioning

Navigation

Almost all the vehicles support CarPlay or Android Auto from their infotainment systems, even Isuzu, which has the least functionality. Because the controls and displays from the CarPlay or Android Auto connected to different infotainment systems are very similar and not produced by the automotive manufacturers, we will only focus on the factory equipped navigations. Setting up the destinations by selecting from the preset list or entering addresses and points of interest (POI) is the most common method. Figure 35 shows a typical example for typing in the characters with a virtual QWERTY keyboard. Voice input is available for some of these vehicles. Selecting destinations from a preset list or grid-aligned icons (Figure 36) are the two layouts we found from these vehicles. Figure 37 shows maps that can be zoomed in and out with two input methods: tapping on a '+' or '-' icon, and pinching by fingers. Some navigations support both, such as Jeep Grand Cherokee and Toyota RAV4.

Table 18. Comparisons for Navigations

Group	Manufacturer	Model	Vendor	Destination input	Shortcut to preset destination	Map zoom in/out
AVP	Audi	Q3	Factory Equipped, CarPlay, Android Auto	Address, POI, voice	List	+/- icon
AVP	Volkswagen	Jetta	CarPlay	CarPlay	CarPlay	CarPlay
BM	BMW	I7	Factory equipped, CarPlay, Android Auto	Address, POI	List	Slider
CDJAF	Jeep	Grand Cherokee	Factory equipped	Address, POI, voice	Grid icon	Pinch, +/- icon
CDJAF	Jeep	Wrangler	Factory equipped	Address	Grid icon	+/- icon
FL	Ford	SYNC4	Factory equipped, CarPlay	POI, voice	List	Pinch
GCBC	Buick	Enclave	Factory equipped, CarPlay, Android Auto	Address, voice	List	Pinch
GCBC	Chevrolet	Silverado	Google Maps, CarPlay, Android Auto	Google Maps	List	Pinch
HA	Acura	TLX	Factory equipped	Address, POI, voice	List	+/- icon
HA	Honda	CRV	CarPlay, Android Auto	CarPlay, Android Auto	CarPlay, Android Auto	CarPlay, Android Auto
HA	Honda	Ridgeline	CarPlay, Android Auto	CarPlay, Android Auto	CarPlay, Android Auto	CarPlay, Android Auto

Group	Manufacturer	Model	Vendor	Destination input	Shortcut to preset destination	Map zoom in/out
HG	Hyundai	Santa Fe/ Tucson	Factory equipped	Address, POI	List	+/- icon
I	Isuzu	NRR	CarPlay, Android Auto	CarPlay, Android Auto	CarPlay, Android Auto	CarPlay, Android Auto
JL	Land Rover	Defender	Factory equipped, CarPlay, Android Auto	Address, POI	List	+/- icon
K	Kia	Rio, Niro	CarPlay, Android Auto	CarPlay, Android Auto	CarPlay, Android Auto	CarPlay, Android Auto
Ma	Mazda	CX5	Factory equipped	Address, POI	List	+/- icon
Me	Mercedes	EQS	Factory equipped	Address, POI	List	Pinch
Mi	Mitsubishi	Outlander	Factor equipped, CarPlay	Address, POI	List	Pinch
NI	Nissan	Rogue, Leaf	Factory equipped, CarPlay, Android Auto	Address, POI	List	+/- icon
S	Subaru	Outback	Factory equipped	Address, POI, voice	List	+/- icon
T	Tesla	S Plaid	Factory equipped	Address, POI, voice	List	Pinch
TL	Toyota	RAV4, Camry	Factory equipped, CarPlay, Android Auto	Address, POI	List	Pinch, +/- icon
V	Volvo	XC40	Google Map, CarPlay	Address, POI	List	Pinch
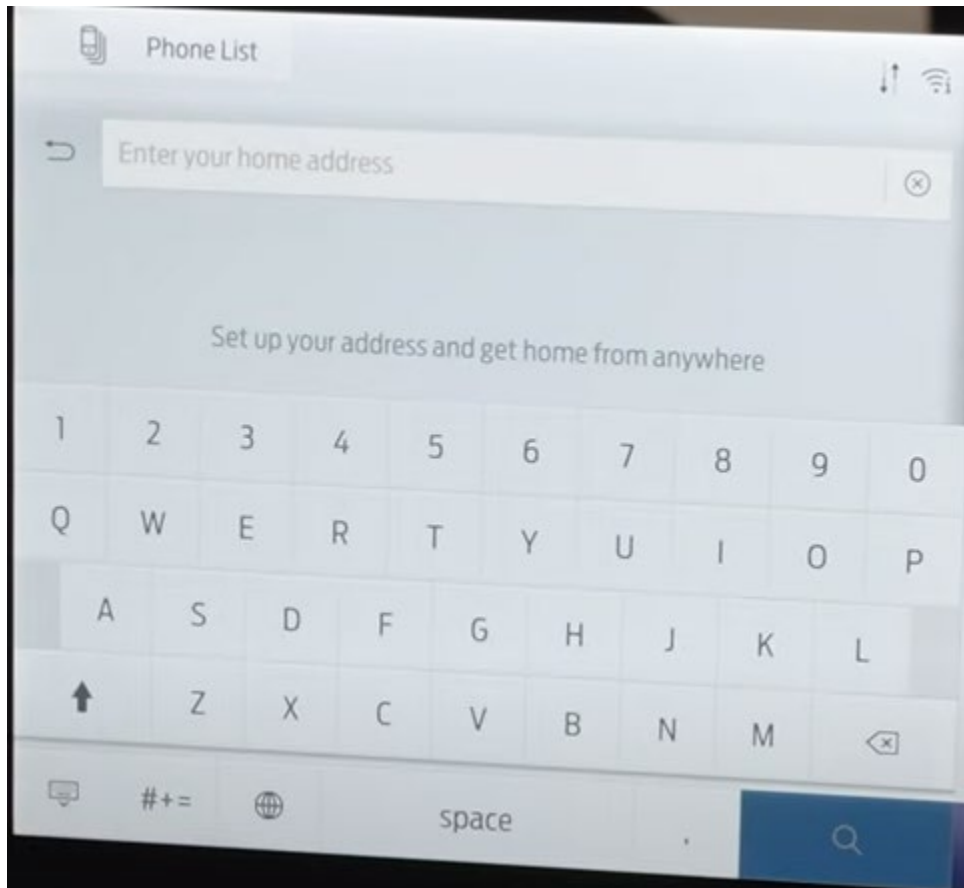
Figure 35. Example of Address and POI Input Method
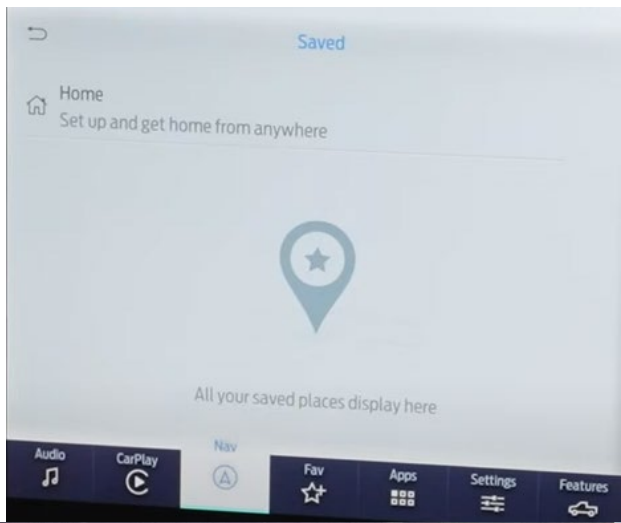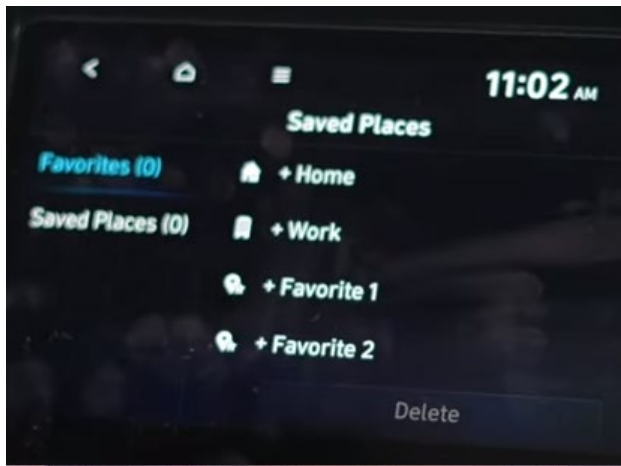
Figure 36. Examples of Selecting from Preset Destinations
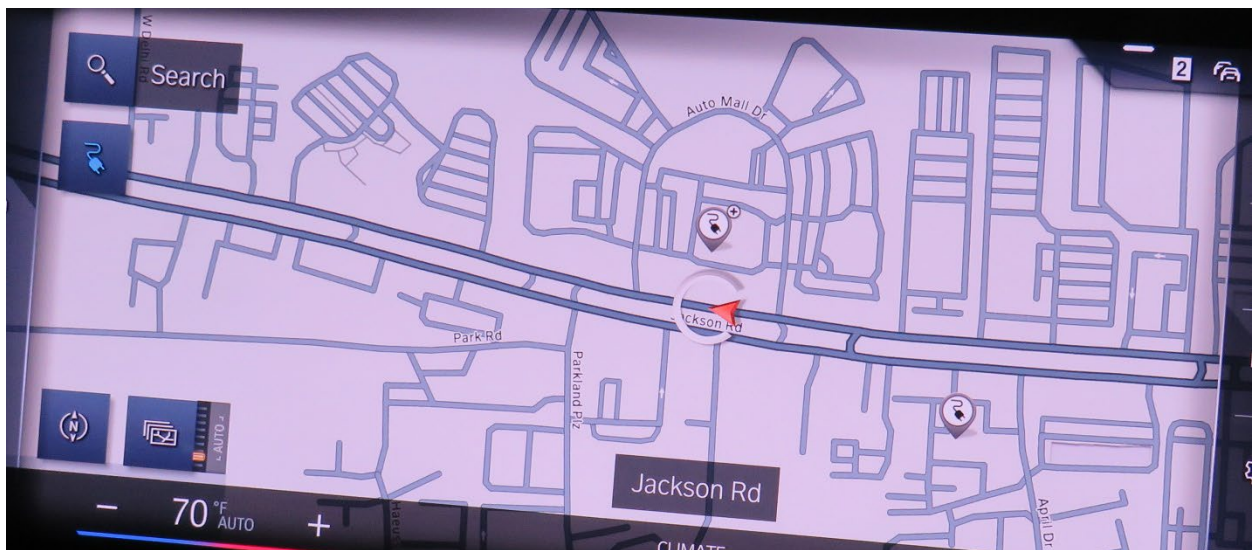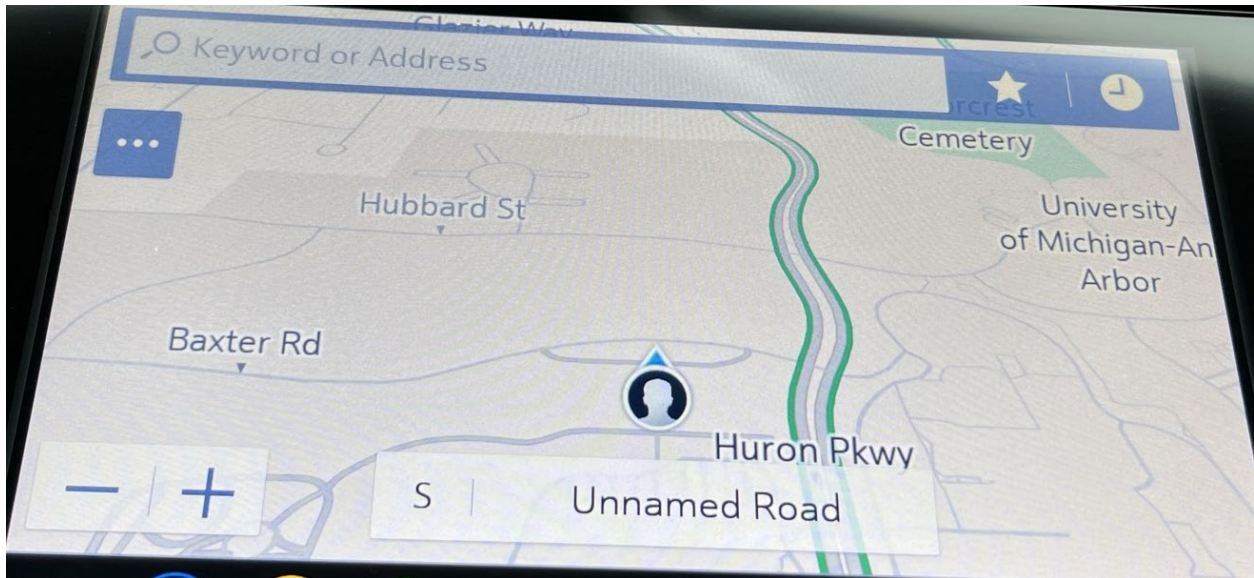
Figure 37. Examples of Methods for Zooming In/Out (+/- Icon vs Pinch)

Instrument Clusters

Photos of the instrument clusters documented in this study are shown in Figure 38 through Figure 50. They are grouped by similarities in physical vs. screen elements and their locations, from the least to most advanced in terms of technology. Figure 38 shows the clusters for the Mitsubishi Mirage and Isuzu NRR. They have physical gages and only a basic small screen in the center. Figure 39 shows five vehicles (Toyota RAV4, Infiniti Q50, Subaru Outback and Ascent, and Ka Rio) with physical tachometer and temperature gages on the left, physical speedometers and fuel gage on the right, and a narrow central digital screen. Figure 40 shows instrument clusters for four vehicles (Nissan Rogue, Jeep Wrangler, Dodge Ram 1500, Toyota Camry) with similar arrangement but a larger center screen.

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Figure 38. Physical gages and small screens.

Figure 39. Physical tachometer and temperature gage on left, physical speedometer and fuel gage on right, narrow central digital screen.

Figure 40. Physical tachometer and temperature gage on left, physical speedometer and fuel gage on right, wider or shaped central digital screen.

The two instrument clusters (Acura TLX and Ford F150) shown in Figure 41 have physical tachometers and speedometers on the left and right, but include digital representations of fuel gage and temperature gage on the center screens. The instrument cluster for the hybrid Ford Escape shown in Figure 42 has a physical power gage on the left, physical power gage on the right, and temperature and fuel gages located on the bottom left and right.

Figure 41. Instrument clusters with physical tachometer on left, physical speedometer on right, digital screen including temperature and fuel gage in center.

Figure 42. Instrument cluster for hybrid vehicle with physical power gage on left, physical speedometer on right, and digital screen in center.

The instrument cluster for the Nissan Leaf is shown in Figure 43, with a physical speedometer on the right and a screen filling the center and left. The Land Rover Defender instrument cluster shown in Figure 44 has a physical speedometer and tachometer, but a central screen with a mapping feature. Figure 45 shows instrument clusters with a physical tachometer on left, physical temperature and fuel gages on right, and central digital screen including speedometer; these are from the Buick Enclave, Chevy Malibu, Honda Ridgeline, and Mazda CX5.

Figure 43. Instrument cluster with screen on the left and physical speedometer on right, plus upper warning screen.

Figure 44. Instrument cluster with physical speedometer on left, physical tachometer on right, and wider contoured center screen including map feature.

Figure 45. Instrument clusters with physical tachometer on left, physical temperature and fuel gages on right, and central digital screen including speedometer.

The remaining instrument clusters are primarily digital. The instrument cluster for the VW Jetta in Figure 46 has digital simulations of a typical tachometer and speedometer but separate areas to the side for the temperature and fuel gages. The instrument cluster for the Chevy Silverado shown in Figure 47 also includes digital simulations of a typical tachometer and speedometer, plus separate panels for warning lights below. The five clusters shown in Figure 48 (Hyundai Tucson and Santa Fe, Honda CRV, Mercedes GLC300, and Mitsubishi Outlander) are completely digital and have simulated tachometer and speedometer on either side of a central screen.

Figure 46. Primarily digital instrument clusters with simulated physical gages and separate areas for temperature and fuel gages.

Figure 47. Primarily digital instrument clusters with simulated physical gages and separate areas for warning lights.

Figure 48. Digital instrument clusters with simulated traditional gages.

Figure 49 shows three digital instrument clusters (BMW X5, Ford F150 Lightning, Lexus NX350) with simulated gages that differ from the traditional setup seen in Figure 39 and Figure 40. Figure 50 shows the cluster for the Cadillac Escalade, which is the only one to have a main central and secondary left screen; the infotainment system is adjacent to the right (but not shown).

Figure 49. Digital instrument clusters with simulated nontraditional gages.

Figure 50. Two part instrument cluster on Cadillac Escalade.

Examples of three digital instrument clusters with a strong central map element in between simulations of traditional tachometers and speedometers are show in Figure 51 for the Volvo SC40, Audi Q3, and Mercedes EQS. Figure 52 shows digital clusters for five vehicles that do not simulate the form of traditional gages (BMW I7, Ford Mach E, Kia Niro, and Tesla S Plaid.) The Tesla Y is not included in this section because it has no instrument cluster located behind the steering wheel.

Figure 51. Digital instrument clusters with simulated gages and large mapping area options.

Figure 52. Digital instrument clusters without simulated gages.

Table 19 summarizes key elements of instrument clusters. Locations are describe as left (L), right (R), or center (C). Regular text signifies physical gages, while bold text means digital. Italics mean a nontraditional gage representation is used. Blank cells mean that element was not visible on the baseline instrument cluster, although in some cases it could be collected. Most of the vehicles without tachometers are hybrid or electric.

Table 19. Summary of key instrument cluster elements.

Group	Manufacturer	Model	Tachometer	Speedometer	Fuel/ Battery	Temp	Screen
AVP	Audi	Q3	**L**	**R**	**R**	**L**	**Full+sides**
AVP	Volkswagen	Jetta	**L**	**R**	**R**	**L**	**Full+sides**
BM	BMW	X5		**L**	**L**	**R**	**Full**
BM	BMW	I7		*L*	*L*		**Full**
CDJAF	Jeep	Grand Cherokee		R	**R**	L	C, wide
CDJAF	Jeep	Wrangler, Ram	L	R	R	L	C, Wide
FL	Ford	Escape		R	R	L	C, Wide
FL	Ford	F-150	L	R	**R**	L	C, wide
FL	Ford	Mach E		*R*	*L*		**Full**
FL	Ford	Lightning		**R**	**C**	**C**	**Full**
GCBC	Buick	Enclave	L	**C**	R	R	C, wide
GCBC	Cadillac	Escalade	**L**	**C**	**R**		**Full + left**
GCBC	Chevrolet	Malibu	L	**C**	R	R	C, wide
GCBC	Chevrolet	Silverado	**R, C**	**L**	**R**	**L**	**Full+below**
HA	Acura	TLX	L	R	**R**	**L**	C, wide
HA	Honda	CRV	**L**	**R**	**C**		**Full**
HA	Honda	Ridgeline	L	**C**	R	R	C, wide
HG	Hyundai	Santa Fe		**L**	**L**		**Full**
HG	Hyundai	Tuscon	**R**	**L**	**L**	**R**	**Full**
I	Isuzu	NRR	L	R	L	R	C, small
JL	Land Rover	Defender	R	**L**	**L**	**R**	C, map
K	Kia	Rio	L	R	R	L	C, narrow
K	Kia	Niro	*L*	*R*	**L**	**R**	**Full**
Ma	Mazda	CX5	L	**C**	R	R	C, wide
Me	Mercedes	EQS		**R**	**R**		**Full**
Me	Mercedes	GLC300	**R**	**L**	**L**	**R**	**Full**
Mi	Mitsubishi	Outlander		**R**	**C**		**Full**

Group	Manufacturer	Model	Tachometer	Speedometer	Fuel/ Battery	Temp	Screen
Mi	Mitsubishi	Mirage	L	C	**C**	None	C, Small
NI	Infiniti	Q50	L	R	R	L	C, Narrow
NI	Nissan	Rogue	L	R	R	L	C, Wide
NI	Nissan	Leaf		R	**L**		Left
S	Subaru	Ascent, Outback	L	R	R	L	C, Narrow
T	Tesla	S Plaid			*L*		**Full**
T	Tesla	Y					None
TL	Toyota	RAV4	L	R	R	L	C, Narrow
TL	Toyota	Camry	L	R	R	L	C, Wide
TL	Lexus	NX350		**C**	**R**	**R**	**Full**
V	Volvo	XC40	**R**	**L**	**C**		**Full**

Controls Related to Hybrid/Electric Functions

In this survey, we documented controls and displays on 7 electric and 6 Hybrid vehicles. In general, there were limited extra physical controls related to alternative fuel systems, perhaps because these vehicles use the infotainment systems as much as possible.

Among the hybrid vehicles, the Kia Niro and Hyundai Santa Fe did not have any physical controls related to power selection. Figure 53 shows the controls located on the lower left dashboard for the Jeep Wrangler, Ford Escape, and Mitsubishi Outlander allowing selection of the power source. Figure 54 shows the remaining range display for the Ford Escape, with the amount of mileage left for battery and gas displayed separately.

Figure 53. Power selection for Hybrid Jeep Wrangler, Ford Escape, Mitsubishi Outlander.

Figure 54. Examples of range displays for hybrid vehicles.

For the electric vehicles, the instrument cluster usually several unique types of information. The first is the amount of range in the battery. Examples are shown in Figure 55. The range left is shown, and the remaining battery level is expressed as a percent. Figure 56 shows examples of power meters, while Figure 57 shows different temperature gages for batteries and motors. Figure 58 shows information about charging, while Figure 59 shows an illustration of the charging indicators for the Nissan Leaf that are visible from inside and outside the vehicle.
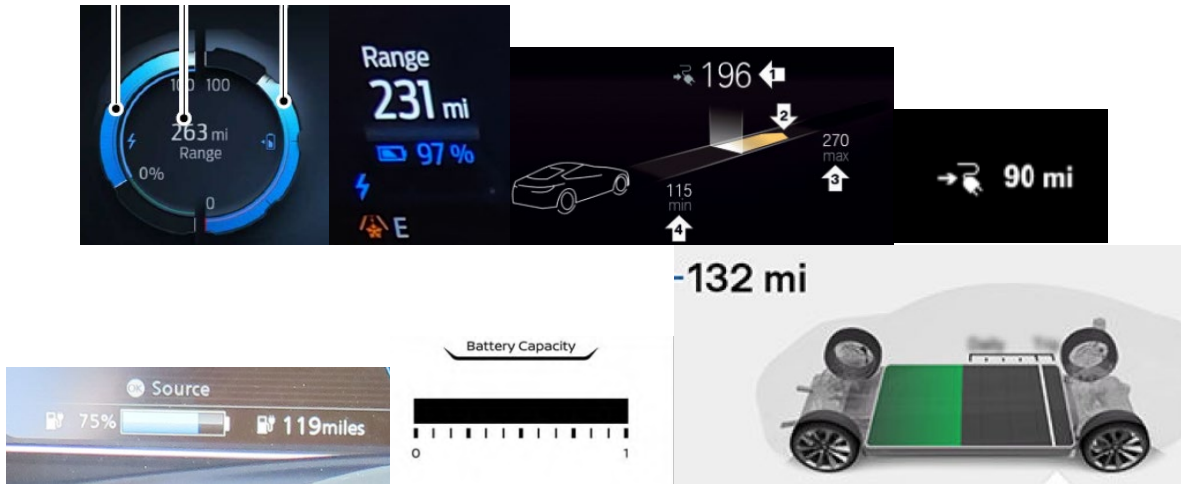
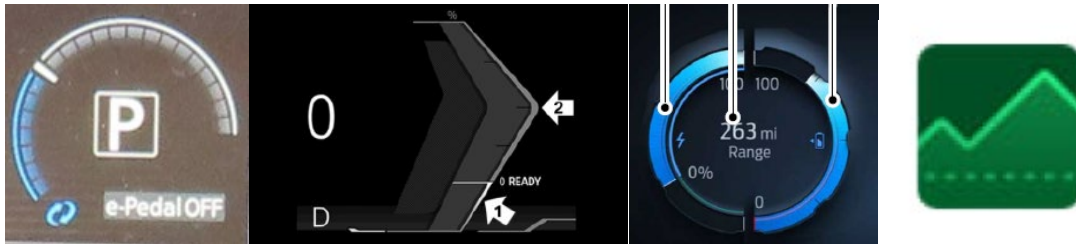Figure 55. Examples of range displays for electric vehicles.

Figure 56. Examples of power meter/gage displays for electric vehicles.

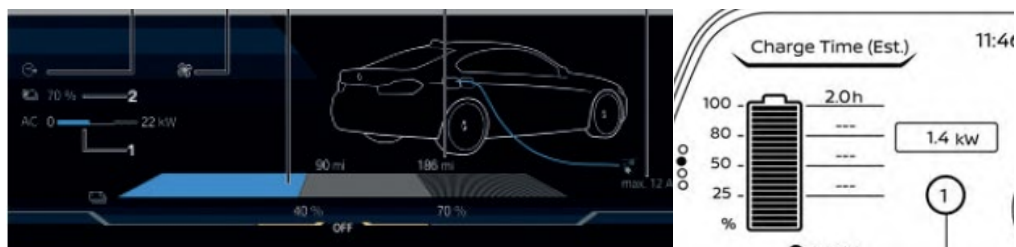Figure 57. Examples of battery/motor temperature displays for electric vehicles.

Figure 58. Examples of charging information displays for electric vehicles.
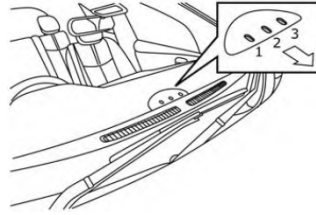
Figure 59. Illustration of Nissan Leaf charging indicators visible from inside or outside the vehicles.

Ignition, Wipers, Lighting, Turn Signal Controls, Windows, Locks

In most vehicles, left and right stalks mounted to the steering column are used to control wipers, lighting, and turn signals. Some vehicles also have lighting controls on the lower left dashboard. Most vehicles also have push-button ignition switches located on the lower right dashboard or on the left side of the center console. This section highlights vehicles where this is not the case.

The Isuzu NRR (a Class 5 Crew Cab) has door lock controls on the left dashboard rather than the door, and only has window controls on the door. F150 has mirror control on lower left dashboard, as does the Mitsubishi Mirage.

Several vehicles included in this study use a key ignition, although most of the manuals indicate that a push button ignition is available for other models.

Teslas adjust mirrors using the infotainment system and scroll on left steering wheel. For the Tesla Plaid, wipers are operated with a button and scroll on right steering wheel, while lights are operated by a button and scroll on right steering wheel.

Technologies Not Addressed

The following technologies could not be documented in detail in the current scope of the project. However, we note their availability for future reference.

- Driver alert/attention/sway warning/monitoring
- Parking Assist, self parking, remote parking
- Hill start, downhill brake control
- Auto idle stop (for fuel economy)
- Automatic brake hold
- Multiple camera options
- Rear cross path warning/cross traffic assist
- Highway driving assist
- Intersection collision avoidance support
- Acceleration suppression
- Frontal Cross Traffic Alert, Moving object detection, Cross traffic braking, Side Collision Mitigation, Evasion Assistant

- Reverse automatic braking

- Pre-collision throttle management

- Auto idle stop/ Auto start stop, Intermittent stop & go

- Rear Occupant alert system

- E-Pedal (Nissan), One Pedal (Ford)-drive with only accelerator?

- Hands-free driving

- Rear-End Collision Preparation

- Curve Speed Control

Appendix A. Photos of Vehicle Instrument Panels

Underlined names are included in the vehicle survey

Audi/VW/Porsche

Audi Q3 SUV

Audi Q5 SUV

Audi Q7 SUV

Porsche Cayenne SUV

Porsche Macan SUV

Volkswagen Atlas SUV

Volkswagen Taos SUV

Volkswagen Tiguan SUV

Volkswagen Atlas Sport SUV

Volkswagen Jetta Sedan

BMW/Mini

BMW 3-Series Sedan

BMW 4-Series Sedan

BMW 5-Series Sedan

BMW 7-series Sedan

BMW X3 SUV

BMW X5 SUV

BMW X7 SUV

Mini Cooper Sedan

Chrysler/Dodge/Jeep/AlfaRomeo/Fiat

Alfa Romeo Stelvio SUV

Alfa Romeo Giulia Sedan

Fiat 500X Sedan

Chrysler 300 Sedan

Chrysler Pacifica Minivan

Dodge Challenger Sedan

Dodge Charger Sedan

Jeep Cherokee SUV

Jeep Grand Cherokee SUV

Jeep Compass SUV

Jeep Wagoneer SUV

Jeep Gladiator Pickup

Jeep Wrangler SUV

Jeep Renegade SUV

Dodge Durango SUV

Ram Pickup 1500 Pickup

Ram Pickup 1500 HD Pickup

Ram Pickup 2500 Pickup

Ram Pickup 3500 Pickup

Ram Chassis Pickup

Ram ProMaster Van

Ford/Lincoln

Ford Bronco SUV

Ford Bronco Sport SUV

Ford EcoSport SUV

Ford Edge SUV

Ford Escape SUV

Ford Expedition SUV

Ford Explorer SUV

Ford Mustang Sedan

Lincoln Aviator SUV

Lincoln Corsair (previously MKC) SUV

Ford Mustang Mach E Sedan

Lincoln MKX/Nautilus SUV

Ford F-150 Pickup

Ford Maverick Pickup

Ford F-150 Lightning Pickup

Ford Ranger Pickup

Ford E-Series Van

Ford SuperDuty Pickup

Ford Transit Van

Ford Transit Connect Van

GM/GMC/Chevrolet/Buick/ Cadillac

Chevrolet Bolt Sedan

Chevrolet Camaro Sedan

Chevrolet Corvette Sedan

Cadillac XT4 SUV

Cadillac XT5 SUV

Cadillac XT6 SUV

95

Buick Enclave SUV

Buick Encore GX SUV

Buick Envision SUV

Cadillac Escalade SUV

Cadillac Lyriq SUV

Chevrolet Blazer SUV

Chevrolet Equinox SUV

Chevrolet Suburban SUV

Chevrolet Tahoe SUV

Chevrolet TrailBlazer SUV

Chevrolet Traverse SUV

Chevrolet Trax SUV

GMC Acadia SUV

GMC Terrain SUV

GMC Yukon SUV

Chevrolet Colorado Pickup

Chevrolet Silverado 1500 Pickup

Chevrolet Silverado HD Pickup

GMC Canyon Pickup

GMC Sierra 1500 Pickup

GMC Sierra HD Pickup

Chevrolet Express Van

GMC Hummer EV SUV

GMC Savana Van

Honda/Acura

Acura Integra Sedan

Acura TLX Sedan

Acura MDX SUV

Honda Accord Sedan

Honda Civic Sedan

Acura RDX SUV

Honda Passport SUV

Honda CR-V SUV

Honda Pilot SUV

Honda HR-V SUV

Honda Ridgeline Pickup

Honda Odyssey Minivan

Hyundai/Genesis

Hyundai Venue SUV

Hyundai Kona SUV

Hyundai Tucson SUV

Hyundai Santa Cruz Pickup

Hyundai Santa Fe SUV

Hyundai Palisade SUV

Hyundai Ioniq5 SUV

Hyundai Elantra Sedan

Hyundai Sonata Sedan

Genesis G70 Sedan

Genesis G80 Sedan

Genesis G90 Sedan

Genesis GV60 SUV

Genesis GV70 SUV

Genesis GV80 SUV

Isuzu

Isuzu NRR Heavy truck

Jaguar/Range Rover

Land Rover Range Rover SUV

Range Rover Sport SUV

Range Rover Velar SUV

Range Rover Evoque SUV

Range Rover Discovery SUV

Range Rover Discovery Sport SUV

Range Rover Defender SUV

Jaguar F-Pace SUV

Jaguar F-type Sedan

Jaguar XF Sedan

Jaguar E-Pace SUV

Jaguar I-Pace SUV

Kia

Kia Forte Sedan

Kia K5 Sedan

Kia Stinger Sedan

Kia Niro SUV

Kia Rio Sedan

Kia Seltos SUV

Kia Sorento SUV

Kia Telluride SUV

Kia Soul Sedan

Kia Carnival SUV

Kia Sportage SUV

Mazda

Mazda 3 Sedan

Mazda CX-30 SUV

Mazda CX-5 SUV

Mazda CX-50 SUV

Mazda CX-9 SUV

Mazda MX-5 Sedan

Mercedes

Mercedes-Benz C-Class Sedan

Mercedes-Benz E-Class Sedan

Mercedes-Benz S-Class Sedan

Mercedes-Benz EQS Sedan

Mercedes-Benz GL/GLS-Class SUV

Mercedes-Benz GLB SUV

Mercedes-Benz GLC/GLK-Class SUV

Mercedes-Benz GLE-Class SUV

Mercedes-Benz Sprinter Van

Mitsubishi

Mitsubishi Outlander PHEV SUV

Mitsubishi Outlander SUV

Mitsubishi Outlander Sport SUV

Mitsubishi Eclipse Cross SUV

Mitsubishi Mirage Sedan

Nissan/Infiniti

Nissan Kicks Sedan

Nissan Murano SUV

Nissan Rogue SUV

Nissan Pathfinder SUV

Nissan Ariya SUV

Nissan Armada SUV

Nissan Versa Sedan

Nissan Maxima Sedan

Nissan Sentra Sedan

Nissan LEAF Sedan

Nissan Altima Sedan

Nissan Z Sedan

Nissan Frontier Pickup

Nissan Titan Pickup

Infiniti Q50 Sedan

Infiniti Q60 Sedan

Infiniti QX50 SUV

Infiniti QX55 SUV

Infiniti QX60 SUV

Infiniti QX80 SUV

Subaru

Subaru Ascent SUV

Subaru CrossTrek SUV

Subaru Forester SUV

Subaru Solterra SUV

Subaru Impreza Sedan

Subaru Legacy Sedan

Subaru Outback SUV

Subaru BRZ Sedan

Subaru WRX Sedan

Tesla

Tesla Model 3 Sedan

Tesla Model Y SUV

Tesla Model X SUV

Toyota/Lexus

Lexus Ux Hybrid SUV

Lexus RZ SUV

Lexus GX SUV

Lexus LX SUV

Lexus IS Sedan

Lexus ES Sedan

Lexus LS Sedan

Lexus NX SUV

Lexus RX SUV

Toyota 4Runner SUV

Toyota bz4x SUV

Toyota C-Hr SUV

Toyota Corolla Sedan

Toyota Corolla Cross SUV

Toyota GR86 Sedan

Toyota GR Corolla Sedan

Toyota Prius Family Sedan

Toyota GR Supra Sedan

Toyota RAV4 SUV

Toyota Highlander SUV

Toyota Sienna Minvan

Toyota Mirai Sedan

Toyota Sequoia SUV

Toyota Tacoma Pickup

Toyota Tundra Pickup

Toyota Venza SUV

Volvo

Volvo XC40 SUV

Volvo Xc40 Recharge SUV

Volvo XC60 SUV

Volvo XC60 Recharge SUV

Volvo XC90 SUV

Volvo XC90 Recharge SUV

Volvo C40 Recharge SUV

V60 Recharge Sedan

v60 Cross Country Sedan

V90 Cross Country Sedan

Volvo S60 Sedan

Volvo S90 Sedan