



## Next-generation Audi MMI System

Audi is introducing the next generation of its Multi Media Interface (MMI) infotainment system. Highlights are speech control with a new complete-word input capability, three-dimensional map displays and a music jukebox on the system's internal hard disk drive. Control by touch has been greatly simplified with the adoption of a joystick integrated into the central MMI control knob. Although the control concept still relies on the well-proven 'MMI genes', first launched by Audi in 2002, the system is totally new in its technical concept, at the heart of which is a central media and communication computer installed in the vehicle's centre console.

## 1 Introduction

An immediately visible highlight in the new MMI infotainment system is its high-resolution 7-inch TFT display with four times the number of pixels (800 x 480) compared with the previous MMI generation. The high contrast range and LED back-light ensure that the image is absolutely sharp even in poor lighting conditions, with brilliant colours against a deep black background. Together with the high-resolution driver information display, the overall impression is of high-quality graphics worthy of a luxury car.

Slightly more discrete is the new MMI joystick which permits scrolling in eight directions to speed up and simplify map-based destination input. This input function is also essential for operation of DVD video menus.

At the heart of the system is a central media and communication computer, the 'Main Unit 3G', installed in the vehicle's centre console. This extremely compact computer unit controls all of the infotainment functions and combines the previously separate units for navigation, universal mobile phone preparation, Bluetooth® car phone, speech control and media in a single 1-DIN standard housing, with integral DVD drive and a 40 GB hard disk. A hinged cover conceals the card reader for two SD cards and an optional SIM telephone card. If the optional Audi Music Interface is installed to extend the system, USB memory sticks, an Apple iPod® player and other mobile media players can be connected to the central computer, thus offering customers who are also music enthusiasts a wide variety of playback options.

To permit computationally-intensive applications such as navigation, speech control, Bluetooth® telephony, DVD video playback and the MP3 audio player to be used simultaneously, a duo consisting of an 800-MHz SH4A RISC processor from the Japanese chip manufacturer Renesas and a 500MHz DM642 digital signal processor from the American chip specialist Texas Instruments supply the necessary high computing performance. This enables premium speech control such as the input of a navigation destination as a complete word without the chore of having to spell it out letter by letter, as well as the simple selection by voice of a name in the imported telephone directory. The signal processor also permits the playback of DVD video sound in Dolby 5.1 digital and DTS audio quality.

With the EMP1 3D graphics processor from the Californian 3D leader NVIDIA, the Audi MMI enters the third dimension. The impressive graphical performance of this chip makes it possible for the first time for Audi to provide a genuine in-car three-dimensional map display in the form of a digital topographical model for the whole of Europe and

North America. In addition, 3D building models make orientation easier in many city centres. Last but not least, the graphics processor enables a classy graphical user interface, with free-flowing animation and superimposition effects of the highest resolution and presentation quality. The Audi MMI thus sets new standards for the graphical design and performance of modern high-end infotainment systems.

## 2 Topology

The MMI 3G infotainment system, like its predecessor, is a networked system based on the MOST (Media Oriented Systems Transport) standard, whereby the major system components are interconnected via a high speed optical bus using plastic optical fibres (Figure 1). The system uses three newly developed components as a basis: the 'Main Unit' with CD/DVD memory, SD card reader, navigation and telephone as integrated functions, the new high-resolution display (7", WVGA) and the 'Radio Unit' installed at the rear. This combines the new phase-diversity AM/FM tuner, digital radio (DAB) and a basic amplifier or 6-channel Audi Sound System. The infotainment system is connected to other vehicle networks by a secure central gateway, so that a wide variety of vehicle functions can be operated from a single screen. Additional optional components include: a CD changer, a TV tuner and a premium Bang & Olufsen audio amplifier.



Figure 1: MMI 3G topology

## 3 Operating Concept

The new MMI 3G system offers a host of new functions and the intuitive MMI operating concept has evolved to control them. Particularly notable examples are the innovative speech control capabilities and the newly integrated media and navigation functions.

### 3.1 New MMI Design

A clearly visible change is the revised design of the user menus. The guiding principle was to offer the user an attractive, 3D-based graphic display and

in this way to make operation of the system even more self-evident. This has been an evolutionary process in the sense that the basic principles familiar from the previous Audi MMI have been retained. They include colour coding of the function-groups, representation of the main control knob (Figure 2) on the display and division throughout into main groups (hardkeys) with corresponding control elements (softkeys).



Figure 2: MMI control unit with integrated joystick

### 3.2 Speech Control

The new speech control system facilitates operation of the main functions such as navigation, telephone and directory. Town and street names can now be entered as a navigation destination without having to be spelled out tediously letter by letter; they are now entered directly and conveniently by speaking the complete word, (Figure 3). A similar complete-word principle applies when making a telephone call to someone listed in the integrated directory: only the 'Call' command followed by the name as a complete word need to be input in order to make the connection with the subscriber concerned. In order to make the voice input more natural, the system recognises a number of synonyms that can also be used. An example might be input of the word 'Telephone' instead of 'Call', followed by the name.



Figure 3: Speech control – entering place names directly into the navigation system as complete spoken words

As a further improvement, the MMI will inform the user by means of a symbol of the current status of the speech control system, so that he or she is always aware during a dialogue when the system is expecting a spoken command.

### 3.3 Media

In the media sector in particular, a variety of new features are now available. In addition to audio CDs or MP3 data CDs, the user can play back his or her own music from the integrated hard disk jukebox or from interchangeable storage media such as SD cards or USB memory sticks. The popular Apple iPod® line of music players can also be comfortably operated via the MMI system.

Although the various music sources that can be played through the MMI differ widely, the system is able to show them all on the control screen. A file browser always provides access to the music selection in a consistent way, regardless of the data medium on which it is recorded. The jukebox also provides many forms of filter, for instance sorting according to performer's name, album or type of music. Support for memorised 'playlists' enables the play order to be customized to suit individual tastes, (Figure 4).

A further example to illustrate how the operating concept has been extended without abandoning the overall MMI control and display logic is the new browser integrated into the system. This is used to display HTML-based content, for example the vehicle user manual stored on the hard disk. Here too the principle of continuity in the operating and display logic has been adhered to. The operating changes resulting from the extended scope (for instance, the ability to jump back page by page) have been realised by extension of the GUI where appropriate.



Figure 4: Operation of the jukebox

### 4 3D Map Navigation

The navigation function on the MMI 3G also introduces a large number of innovations. The navigation map is now shown in three dimensions for the first time, as a true 3D topographical model with

colour distinctions according to height, thus communicating the familiar impression of a typical printed map (Figure 5). A further enhancement is the inclusion of 3D models for a large number of cities, with important buildings shown in near authentic detail (Figure 6). These features would not have been possible without increased onboard storage in the form of a 2.5-inch automotive hard disk and support for high-performance graphics, including the industry-standard OpenGL ES (Open Graphics Library for Embedded Systems) powered by an NVIDIA graphics chip.

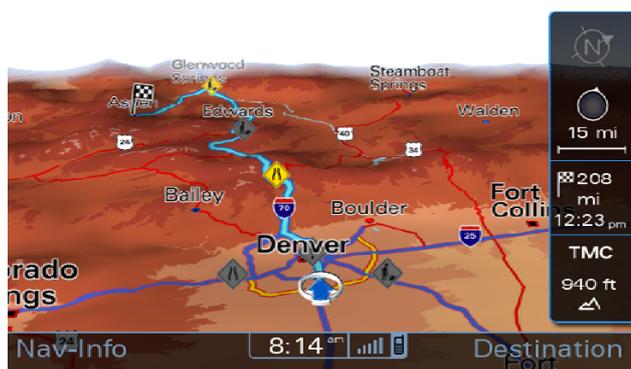


Figure 5: 3D map with topographical terrain model



Figure 6: 3D city model including textured buildings and points of interest



Figure 7: Route display with turn and incident information

For route guidance, the 3D motorway exit views and route information already familiar from Audi's Navigation Plus (RNS-E) infotainment system have been further improved. As illustrated, information relating to the current route is also superimposed on the map (Figure 7). The content includes upcoming

turns as well as any traffic incidents, which are in each case accompanied by time and distance data. A new safety and convenience feature is the addition of lane-level guidance to the 3D motorway exit display (Figure 8). For many exits this lane information is already contained in the navigation database stored in the system's hard disk drive. Future map updates will continue to improve coverage across the United States and Canada.



Figure 8: 3D motorway exit display with lane-level guidance

With efficiency in mind, a new route option, 'Economical' has been added to the 'Fast' and 'Short' algorithms of the current system. The MMI quickly computes all three route options simultaneously, allowing the customer to preview and subsequently choose the most suitable one according to its impact on arrival time and distance.

A powerful onboard search engine is able to locate special destinations, such as points of interest, on the basis of a keyword or a complete name. Adding to the system's flexibility, addresses from the user's mobile phone directory can also be adopted as destinations for the navigation system. Provided that the phone is connected to the MMI the system will interpret postal addresses stored on the phone and convert them into geographical coordinates for routing.

The navigation system is operated using the familiar central MMI control knob, but is greatly assisted by the newly integrated joystick already popular in the Asian variant of the current generation MMI. With its ability to scroll in eight independent directions this feature greatly simplifies and speeds up panning and destination input on the map.

For those customers who would rather use speech control, the new MMI has an absolute treat: the destination can simply be spoken to the system, and no longer has to be spelled out letter by letter, since destinations for many countries are conveniently understood as complete words.

Not only speech control but also spoken messages and route recommendations have been considerably improved in quality. The user can, for instance, choose between a compact and a complete spoken

message mode, the main difference being the breadth of spoken information. In the complete mode, for example, the message “In 400 metres, turn right” is extended to include the name of the street (“In 400 metres, turn right at Pennsylvania Avenue”).

## 5 Telephone

Unlike the preceding MMI generation which used a separate control unit for Bluetooth® Hands-Free telephone functionality, the new MMI 3G directly incorporates the latest Bluetooth® chipset directly in the Main Unit (Figure 9). Support for the newest Bluetooth® profiles (Hands-Free Profile 1.5 and Phonebook Access Profile 1.0 and SIM Access Profile) for the first time enables standardised access to the directories and call lists of the mobile phones connected to the system. Integrated software for Bluetooth® device management makes it possible for the car to establish the optimal Bluetooth® connection with each phone depending on which Bluetooth® profile it supports, and to seamlessly switch between several mobile phones.



Figure 9: Bluetooth® phone architecture

Phone directory listings are now easily viewed on the MMI - the contacts from the customer's mobile phone as well as the local contacts stored on the vehicle can be seen on a joint list. Up to five telephone numbers, two navigation destinations and additional information can all be stored and organised as a contact under a single name (Figure 10). Memory capacity for up to 2000 contacts per phone is reserved by the system and altogether, the MMI's directory can manage contacts from up to five different devices.

If supported by the mobile phone's network provider, convenient features such as call brokering and conference calls can now be comfortably used in the car. For select mobile phones, optional adapters are also available which charge the mobile phone's battery and provide a connection to the roof-mounted antenna.

Intensive ongoing Bluetooth® interoperability tests conducted by Audi and the mobile phone manufacturers ensure that Audi is able to support a very wide range of mobile phones.



Figure 10: Stored telephone contact



Figure 11: Typical jukebox screen

## 6 Media

### 6.1 Track Memory

To ensure that the MMI 3G is state-of-the-art in new media, Audi set itself the target of supporting the largest possible number of external memory devices and players – despite the high degree of complexity entailed by the variety of different manufacturers and standards. The system has two slots for flash-based memory cards, and accepts not only the currently popular SD (Secure Digital) cards and newer high capacity SDHC cards (for capacities up to 32 GB), but also the older MMC (Multi Media Card) standard. Up to 4,000 tracks may be saved to each memory card, in either MP3 or WMA (up to and including Version 9) format and, with AAC (Advanced Audio Coding), as M4A encoded music titles. The user can also use play lists created with the aid of suitable tools in either PLS or M3U formats.

Aside from supporting memory cards, the new MMI system uses its internal hard disk drive as a jukebox. The customer can save up to 2,000 tracks on the drive and all tracks imported to the jukebox are visualised by means of their track information in an intuitive screen display, so that orientation is easy even if the volume of data is very large. The tracks can be sorted according to artist, album or type of music. Figure 11

shows a typical screen where 'Artist' has been selected as a filter criterion.

Handling such a variety of media with thousands of tracks is a fundamental challenge to the operating concept. For this reason, a 'fast scrolling' feature, has been introduced. If the MMI's rotary pushbutton is turned rapidly, the display switches to a smaller scale with a position indicator (Figure 12). The number of tracks to be jumped over depends on the speed with which the knob is turned. If an entry is selected or if a timeout occurs, the display reverts to the usual style.



Figure 12: Fast scrolling

When saving tracks to the jukebox on the hard disk, the memory cards and CDs or DVDs (both of which can be played back via the DVD drive) are all possible import sources. In addition, media stored on USB memory devices can be imported if the Audi Music Interface is installed.

The Audi Music Interface, with its 30-pin connecting socket, provides a universal means for connecting a very wide variety of external devices to the MMI. If the appropriate adapter cables are used, Apple iPod® (fourth generation or newer), USB mass storage devices (USB 1.0, 2.0) and external audio sources can all be connected to the MMI. Apple iPod® operation has been fully integrated into the MMI interface. As with MP3 media, all of the iPod®'s song titles and other artist and track information can be viewed via the centre console or driver displays and the MMI can even search through all music directories and play lists (Figure 13). For music reproduction on USB devices, as with SD cards, up to 4,000 tracks are supported, in MP3, WMA and AAC formats, and PLS and M3U for play lists.

Other music players can also be connected to the system via a standard AUX-IN connection. If the optional Audi Music Interface has not been ordered, the AUX-IN socket is still available and can be found in the vehicle's centre console. Although no direct control of the player is possible via the AUX-IN connection, the MMI settings allow the customer to select a suitable volume range for each player so as to safely account for the varying output volumes of different manufacturers.



Figure 13: Apple iPod® control via the Audi Music Interface

## 7 Radio

### 7.1 Radio Unit

The MMI 3G Radio Unit attains new performance heights for the Audi model line-up, both in terms of reception quality as well as functionality. It was Audi's aim, to further enhance the radio listening experience with as little audio interference as possible, especially while the vehicle is in motion. As a result, the signal processing capability of the reception modules has been steadily improved over a number of successive equipment generations.

The radio unit is a fixed element in all next-generation MOST systems. It contains an Analog/Digital reception module and a six-channel audio amplifier with digital signal processing (DSP). The reception module integrates AM/FM reception as well as Digital Satellite Radio (SDARS). FM-reception quality represents a new benchmark for the automotive industry, owing to a truly high-tech three-tuner reception concept with digital signal processing, dynamic selection and permanent dual-antenna phase diversity.

This new three-tuner concept has several advantages:

- Previous solutions switch to a single-tuner mode if the reception is moderate to good, so that one tuner is released to search the waveband for new radio stations and traffic message information. In the MMI radio unit, on the other hand, the phase-diversity regulating algorithm is not interrupted by mode changeovers. The permanent use of two tuners achieves a stereo quality that was previously not possible with mobile equipment.
- Tuner 1 and Tuner 2, together, generate an audio signal that is reproduced by the car's sound system. The two tuners can remain in phase diversity mode all the time, thereby ensuring excellent sound quality.
- Tuner 3 does not generate an audio signal, but renders the manual station search obsolete. This tuner is dedicated to permanently finding, rating and sorting all receivable stations as well as undertaking an alternative frequency search with optimised RDS sensitivity. This ensures that the

user is presented with an optimal list of available stations at all times.

### 7.2 Satellite Radio

In recent years, most analog transmission formats have gradually been superseded by digital processes (telephone, TV, satellite). Keeping with the times, the MMI 3G for the United States and Canada, includes an SDARS (satellite digital audio radio service) system that is fully integrated in the MMI 3G Radio Unit, providing up to 223 commercial free audio channels that are available nationwide (Figure 14).



Figure 14: Sirius Satellite Radio

With the MMI 3G Radio Unit, Audi is one of the first automakers to include a dual SDARS tuner. While the first tuner ensures an enhanced digital audio experience, the second tuner is used to collect up-to-date traffic information that is also broadcast nationwide via satellite. This information, which includes speed, flow and traffic incidents, is invaluable for the MMI 3G's navigation software as it dynamically re-routes the driver around obstacles or delays. An easy snapshot of the traffic situation along, around and ahead of the current route is also presented to the driver on the navigation screen (Figure 15).

A 180-day free on air subscription for satellite audio and traffic services is standard for all Audi Customers after purchase of the vehicle. Hence, the customer is able to fully experience both the listening experience as well as the convenience of always up-to-date traffic information. After expiration of the free trial, the MMI's user interface indicates the necessary steps for the customer to further subscribe to the services he or she wants to use in the future.

The SDARS user interface also received a thorough update to further increase customer satisfaction. Besides displaying the current song title or album (where available), for the first time, a so called "look around mode" has been implemented, which allows the user to listen to a channel while browsing through the channel list and looking for available content on other channels. You can really "see", what's going on in other channels without having to tune to them!

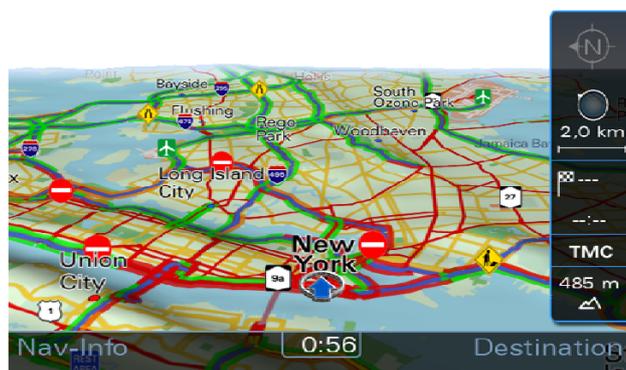


Figure 15: Display of traffic information

### 8 Sound Systems

Audi offers a wide selection of sound systems customized for each vehicle, (Figures 16 and 17). Taking Audi's all new Q5 compact crossover vehicle as an example, up to four different sound systems are available for different markets worldwide. The basic equipment version has two channels with 2x20W and 200mm speakers in the front doors, supplemented by 32mm tweeters in the dash panel. To provide both front- and rear-seat occupants with a full sound range, the Basic Plus version is available with a total amplifier output rating of 80W and four additional speakers (2 x 168mm low mid-range speakers, 2 x 25mm tweeters) in the rear doors.



Figure 16: Overview of available Audi Q5 sound systems



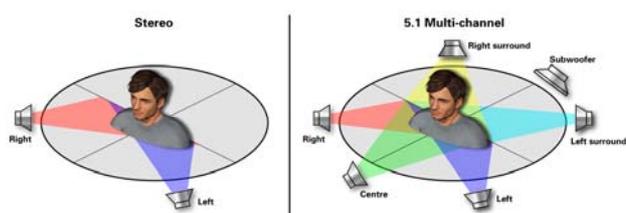
Figure 17: Speaker locations

The high end Audi Sound System has six active amplifier channels with a total output rating of 180W. As a complement to the 40W low mid-range speakers in the front doors, a 15-litre sub-woofer in the spare wheel well reproduces even very low frequencies with an output rating of 40W. To improve the audio stage effect, a centre-fill mid-range speaker driven by a 25W amplifier channel is located in the dash panel. Following the MMI Main Unit's trend towards high-level integration of electronics, the complete amplifier electronics and radio tuners fit tightly in a 1-DIN housing, taking up very little space in the vehicle.

At the very premium end, the Bang & Olufsen Sound System consists of 14 high-grade speakers with acoustically optimised Neodym drivers from ten amplifier channels, the total output rating of which is 505W. The system's digital amplifier adapts the individual channels optimally to the acoustical properties of the vehicle's interior.

Mid-range reproduction is by way of two 25W, 80mm mid-range units and an 80mm centre-fill speaker. The tweeters are in the front door quarter triangles and thus help to create an optimised audio stage for the driver and front-seat passenger. This premium sound system is completed by 80mm surround speakers in the vehicle D-panel. All 80mm mid-range units have high-grade fabric diaphragms that reproduce music without discoloration. Two 40W, 168mm low mid-range units and 25mm tweeters in the rear doors add to this high-end system architecture. Bass frequencies are supplied at a total amplifier output rating of 300W from two 200mm woofers (150W) in the front doors and a 150W sub-woofer in the spare wheel well. To maintain this high level of music reproduction in all driving situations, the digital amplifier analyses audible interference in the vehicle's interior by means of a microphone and adapts music reproduction optimally to the current acoustic environment.

Among the most outstanding features of the Bang & Olufsen system is its ability to reproduce DVD media with DolbyDigital 5.1 or DTS quality. In contrast with a CD which carries only two discrete sources (left and right channels, as shown in **Figure 18 left**), six different source signals have to be processed in this case and their reproduction is individually optimised for each of the vehicle's occupants, (**Figure 18 right**).



**Figure 18:** Comparison of CD and DVD audio reproduction