



Automotive Electronics Engineering

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First Edition, 2011

ISBN 978-93-81157-05-3

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Published by:

The English Press

4735/22 Prakashdeep Bldg,

Ansari Road, Darya Ganj,

Delhi - 110002

Email: info@wtbooks.com

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Car Audio

Car audio/video (car AV), mobile audio, 12-volt and other terms are used to describe the sound or video system fitted in an automobile. While 12-volt audio and video systems are also used, marketed, or manufactured for marine, aviation, and buses, here we focus on cars as the most common application. From the earliest days of radio, enthusiasts had adapted domestic equipment to use in their cars. In the 1960s, tape players using reel to reel equipment, Compact Cassettes, and then 8-track cartridges were introduced for in-car use.

A stock car audio system refers to the OEM application that the vehicle's manufacturer specified to be installed when the car was built. A large after market industry exists where the consumer can at their desire replace many or all components of the stock system. In modern cars, the primary control device for an audio system is commonly referred to as a head unit, and is installed in the center of the dash panel between the driver and the passenger. In older vehicles that had audio components as an option, such devices were mounted externally to the top of or underneath the dash. Car speakers often use space-saving designs such as mounting a tweeter directly over a woofer or using non-circular cone shapes. Subwoofers are a specific type of loudspeaker for low frequency reproduction. Extremely loud sound systems in automobiles, which have been nicknamed "boom cars", may violate the noise ordinance of some municipalities.

Motorcycles have been utilized with similar equipment since they also have the so-called "car audio" experience. Even pedal bicycles, as well as homemade boomboxes have utilized sealed lead-acid batteries (or 12V power supplies) for applications outside of motor vehicle use, likewise the store displays which mount in demo models prior to aftermarket purchases for installation.

History

1930s



Early 1970s tractor with a radio/8-track system

From the earliest days of radio, enthusiasts had adapted domestic equipment to use in their cars. The commercial introduction of the fitted car radio came in the 1930s from the Galvin Manufacturing Corporation. Galvin Manufacturing was owned and operated by Paul V. Galvin and his brother Joseph E. Galvin. The Galvin brothers purchased a battery eliminator business in 1928 and the corporation's first product was a battery eliminator that allowed vacuum tube battery-powered radios to run on standard household electric current. In 1930, the Galvin Corporation introduced one of the first commercial car radios, the Motorola model 5T71, which sold for between \$110 and \$130 (2009: \$1,700) and could be installed in most popular automobiles. Founders Paul Galvin and Joe Galvin came up with the name 'Motorola' when his company started manufacturing car radios. A number of early companies making phonographs, radios, and other audio equipment in the early 20th century used the suffix "-ola," the most famous being Victrola; RCA made a "radiola"; there was also a company that made jukeboxes called Rock-Ola, and a film-editing device called a Moviola. The Motorola prefix "motor-" was chosen because the company's initial focus was in automotive electronics.

In Germany Blaupunkt fitted their first radio to a Studebaker in 1932 and in the United Kingdom Crossley offered a factory fitted wireless in their 10 hp models from 1933. The

early car radio receivers used the battery voltage (6.3 volts at the time) to run the vacuum tube filaments, and generated the required high voltage for the plate supply using a vibrator to drive a step-up transformer. The receivers required more stages than the typical home receiver in order to ensure that enough gain was available to allow the AGC to mask signal fading as the car was driven. When cars switched to 12-volt batteries, the same arrangement was used, with tubes with 12-volt heaters. In 1952 Blaupunkt became the first maker to offer FM receivers.

1950s

A common feature of modern car radios is the "seek" function which allows tuning from one station to the next at the push of a button. This was a popular option on some Ford products in the 1950s. It was known as the "Town & Country" radio since it used a pair of switches marked "Town" and "Country." Pressing the Town button actuated a motor to rotate the tuning mechanism while the receiver sensitivity was reduced so that only local (stronger) signals would be received. When a station was tuned, the motor stopped. Pressing the Country button had the same effect except that full sensitivity was enabled so that the very next available station would be selected. In addition, for repeated seeking operations, pressing a foot switch on the driver's floor up to the left where the "dead pedal" is located on modern cars would reactivate the Seek at whatever sensitivity was last selected.

1960s-1970s

The introduction of semiconductors (transistors) allowed the output stage to change to a transistor, which soon led to the elimination of the vibrator, and the use of "space charge" tubes that only required 12 volts on their plates without a high voltage plate power supply (typical example was the 6GM8/ECC86). Advances in electronics allowed additions to the basic radio and Motorola offered 16 2/3 rpm disc players fitted to some Chryslers known as "Hiway HI FI" from as early as 1956 and ran through 1958. Records were produced under license by Comumbia "Special Products division and sold exclusively through Chrysler dealers. The 45 rpm record player was introduced in 1959 and ran through the early 60"s under the RCA and ARC brand. Earl "Mad Man Muntz" introduced the "4 track" tape player in the early 60's using a continuous loop cartridge and was the first commercially available "car stereo. Tape players using reel to reel equipment followed, but their bulk ensured limited popularity. This changed in 1964 when Philips launched the Compact Cassette. During the '60s Lear invented and introduced the 8track cartridge in competition with the cassette system. Other early manufacturers and enthusiasts began building extra audio amplifiers to run on 12 volts (the standard voltage in automotive electrical systems). Jim Fosgate, later to become the founder of Rockford Fosgate, was one such pioneer. The company *a/d/s* also brought an amplifier to market in 1978.

1980s-1990s

In 1983, Zed Audio became the first company to build a 200 watt per channel car amplifier, which was invented by company founder Steven Mantz. At first, speakers from the home audio and professional markets were simply installed into vehicles. However, they were not well suited to the extremes of temperature and vibration which are a normal part of the environment of an automobile. Different manufacturing techniques, and different component materials were used in construction to adapt to these conditions.

Car audio competitions started in the early 1980s. The first known occurred in 1981 in Bakersfield, CA and evolved into an annual event, The Summertime Sound Off, which at its height drew upwards of 300 contestants and continued into the 1990s. Like the Summertime Sound Off, some competitions during the 1980s were judged based on sound and installation quality, particularly those hosted in California. But most were simply held to find the loudest and/or most outrageous installations. Perhaps the most well known vehicle of this time was the Wayne Harris modified 1960 Cadillac Hearse; featuring three 24-inch subwoofers as well as eight 12-inch subwoofers. During the late '80s, several interests in the car stereo industry promoted the formation of sanctioning organizations to provide common rules and to move the focus to sound quality.

The most important of these were CAN (formed by Alpine) and NACA (supported by shop owners and amp manufacturers). Both organizations sanctioned countrywide regional events and hosted National Championship events in the late 1980s. They merged to form IASCA in 1990. Despite the move to "quality" based judging, volume was still a significant portion of most early 1990s competitions. Since then, the two styles—SPL vs. sound quality—have become almost mutually exclusive. The loudness competitions have become known as dB drag racing. Currently, MEASQ conducts Sound Quality Competitions nationally in Australia. This back to basics competition format was developed by Marc Rushton, the founder of one of the largest enthusiast organizations known as Mobile Electronics Australia.

Common components and terms

Stock unit

A *stock* car audio system refers to the OEM application that the vehicle's manufacturer specified to be installed when the car was built and nowadays at least includes a CD-radio, with MP3 player and an aux-in. A large after market industry exists where the consumer can at their desire replace or complement many or all components of the stock system (i.e. kits to include a USB port and bluetooth to the stock radio-CD).

Head unit



A Panasonic single DIN head unit, combining radio, CD and MP3

In modern cars, the primary control device for an audio system is commonly referred to as a head unit, and is installed in the center of the dash panel between the driver and the passenger. In older vehicles that had audio components as an option, such devices were mounted externally to the top of or underneath the dash.

The headunit itself is usually a multi-purpose device that houses multiple types of components in its housing. The most common components are a radio receiver/tuner usually with AM and FM bands, and a small amplifier for driving an audio signal to speakers. Other possible components include various media devices, such as (in older vehicles) a tape player (either 8-track or cassette), CD player, DVD player, Minidisc, USB flash memory, and even a hard disk drive typically used in notebook computing. Many head units also feature a DSP component, and equalization component (such as bass and treble controls), or a control interface for another feature on the car (such as a back-up/parking camera, navigation system, trip odometer, etc).

Due to auto manufacturing differences over the years, aftermarket headunit products are manufactured in multiple form factors. The primarily used size is mostly referred to by its legacy name of DIN, which refers to ISO 7736. DIN headunits come as single DIN or

double DIN. A third less common standard is used mostly by Chrysler group and for a time Mitsubishi in their OEM devices.

Speakers



A set of speaker drivers removed from a passenger vehicle.

Car **speakers** are largely functionally identical to any other loudspeaker design with key components specialized for use in mobile environments, and generally serve an identical purpose. One major key design difference is multi-axial mounting of different types of loudspeakers in the same footprint, such as a tweeter directly mounted over a woofer. Another key difference is non-circular cone shapes, such as square, oval, or even triangular. Both of these features reflect a significant reduction in space and size that a speaker may occupy in a vehicle cabin.

Material construction may also include more exotic and hearty components more suitable to mobile use. Marine speakers may have plating for corrosion resistance. Cones may be coated with a substance to resist expansion and contraction under high vehicle cabin temperatures, known to reach 140 °F (60 °C) in the sun. Subwoofers may also be found in mobile audio applications where a cabin speaker may lack the desired low frequency response on its own.

Before stereo radio was introduced, the most common speaker location was in the middle of the dashboard pointing through perforations towards the front windshield. In most modern applications, speakers are mounted certain common locations including the front

deck (or dash), the rear deck (or parcel shelf), the kick panel (located in the footwell below the A-pillar,) or the doors. In the case of subwoofers, mountings are usually under the seat or in the trunk. Each position has certain strengths and limitations from both a quality of sound, and a vehicle manufacturing perspective.

5.1 and even 7.1 channel surround sound systems, as well as THX II Certified, are now being integrated into some cars by both aftermarket enthusiasts and car manufacturers themselves. These systems include the full complement of front left, right and center speakers along with rear right and left surround speakers.

Amplifiers



A car audio amplifier.



Blaupunkt Class T amplifier

Basically a mobile audio amplifier, a car 'amp' is a term used to refer to a dedicated electronic amplifier separated from the other components of the system. Though most head units have an amplifier, some do not, or lack the desired power or additional features (e.g., equalization controls or crossover systems). External amplification is available and most often used when existing amplification is insufficient. External amplifiers can be mounted in a different part of the car than the "head unit"; in many cases, an additional amp is mounted in the trunk. This is usually the case when powering a subwoofer, where desired wattage may be several multiples more compared to other cabin speakers.

Though less common, OEM external amplification can be found in 'premium' audio packages, or in luxury cars. More common is aftermarket amplification installed later to satisfy the expansion of an existing system in some way. During operation, it is common for a vehicle's charging system to fluctuate, so a regulated amplifier will maintain its power output regardless of voltage fluctuation. Amplifiers rated at 100 watts at 14.4 volts can not be regarded equal as to an amplifier that can maintain 100 watts at 12 volts. Outside of certain standards, it is not uncommon for manufacturers to list a 14.4 rating and not post a 12 volt value.

Subwoofers

Subwoofers are a specific type of loudspeaker for low frequency reproduction. Mobile 'subs' are not very different from any other application of sub in terms of construction. However it is more common in aftermarket that visual aesthetics take on a more significant role in design than other types of sub drivers, including high contrast paint schemes, grill covers, translucent or refractive materials. Typical subwoofer drivers range in size from an 8" diameter to 10", 12" or 15"; more rarely, some car systems may have 18", 21", 22", 24" or even 32" subwoofers.

A subwoofer is used when existing low frequency production is unsatisfactory, either in frequency range or in volume. Design goals have led to subwoofer, both driver's alone and whole packages, with some extreme difference from one another. Space conscious design has reduced some driver depth to 2" or less, or enclosure depth to 3". Pure loudness through increasing sound pressure has led to some drivers with excursions as great as 4" and vented components to cool the "motor" of the speaker. Quality and clarity has led to driver enclosures being tuned by construction to resonate or neutralize certain frequencies.

Capacitors

Capacitors are used to store energy for the amplifier to draw on demand. They come in many different sizes ranging from 0.5 farad to well over 100 farads and their intended function is to temporarily cover the short-burst electrical demands of a car audio system that have exceeded the general electrical capabilities of the vehicle. There is little evidence to suggest they impart any benefit to the system, however, due to their low energy storage (compared with the battery) and exponential nature of capacitor voltage decay.



A powerful after-market audio system installation in a Toyota

Damping

Sound deadening material is often used in the door cavities and boot/trunk area to damp excess vibration of the panels in the car in response to loud subwoofer bass tones, especially the boot/trunk. The most common type of deadening is either butyl or rubberized asphalt, a product which has an adhesive quality and can be applied by simply pressing it into place with a roller and using a heat gun (or hair dryer). Other types of deadening can be sprayed on, but they are less common because of the additional installation difficulties.



Uniden BCT-15 radio scanner installed with aftermarket head unit

Other components

Other components that make up high-end car audio installations may include:

- Multiple-CD Changer
- amplifiers
- audio processors
- cables
- crossovers
- equalizers
- mobile video (VCRs, television, DVD and navigation)

- Controls, including on steering wheel interface, as well as remote controls
- Car computer, fully functional computer (i.e. Internet, Music, games) that is operable from the interface.
- Gaming consoles – passenger entertainment

Legal problems

Extremely loud sound systems in automobiles may violate the noise ordinance of some municipalities. Some cities have even outlawed so called "boom cars", vehicles containing loud stereo systems that emit low frequency sound, usually with an intense amount of bass. A number of organizations and websites are dedicated to lobbying for tougher restrictions on boom cars, citing that they disturb the peace and cause documented health problems. Noise Free America, a 501(c)(3) non-profit group, cites boom cars as one of the most problematic sources of noise pollution. In 2007, the U.S. Department of Justice issued a guide to police officers on how to deal with problems associated with boom cars.

Automotive Navigation System



A taxi equipped with GPS navigation device

An **automotive navigation system** is a satellite navigation system designed for use in automobiles. It typically uses a GPS navigation device to acquire position data to locate the user on a road in the unit's map database. Using the road database, the unit can give directions to other locations along roads also in its database. Dead reckoning using distance data from sensors attached to the drivetrain, a gyroscope and an accelerometer can be used for greater reliability, as GPS signal loss and/or multipath can occur due to urban canyons or tunnels.

Some sorts can be taken out of the car and used hand-held while walking.

History

Automotive navigation systems were the subject of extensive experimentation, including some efforts to reach mass markets, prior to the availability of commercial GPS.

Most major technologies required for modern automobile navigation were already established when the microprocessor emerged in the 1970s to support their integration and enhancement by computer software. These technologies subsequently underwent extensive refinement, and a variety of system architectures had been explored by the time practical systems reached the market in the late 1980s. Among the other enhancements of the 1980s was the development of color displays for digital maps and of CD-ROMs for digital map storage.

However, there is some question about who made the first *commercially available* automotive navigation system. There seems to be little room for doubt that Etak was first to make available a digital system that used map-matching to improve on dead reckoning instrumentation. Etak's systems, which accessed digital map information stored on standard cassette tapes, arguably made car navigation systems practical for the first time. However, Japanese efforts on both digital and analog systems predate Etak's founding.

Steven Lobbezoo developed the first commercially available satellite navigation system for cars. It was produced in Berlin from start 1984 to January 1986. Publicly presented first at the Hannover fair in 1985 in Germany, the system was shown in operation on the evening news (item in the Hannover fair) from the first German television channel in that year. It used a modified IBM PC, a large disc for map data and a flat screen, built into the glove compartment. It was called Homer (after the device from a James Bond movie).

Alpine claims to have created the first automotive navigation system in 1981. However, according to the company's own historical timeline, the company claims to have *co-*developed an analog automotive navigation product called the Electro Gyrocator, working with Honda. This engineering effort was abandoned in 1985. Although there are reports of the Electro Gyrocator being offered as a dealer option on the Honda Accord in 1981, it's not clear whether an actual product was released, whether any customers took delivery of an Electro Gyrocator-equipped Accord, or even whether the unit appeared in any dealer showrooms; Honda's own official history appears to pronounce the Electro Gyrocator as not practical.

Honda claims to have created the first navigation system starting in 1983, and culminating with general availability in the 1990 Acura Legend. The original analog Electro Gyrocator system used an accelerometer to navigate using inertial navigation, as the GPS system was not yet generally available. However, it appears from Honda's concessions in their own account of the Electro Gyrocator project that Etak actually trumped Honda's analog effort with a truly practical digital system, albeit one whose

effective range of operation was limited by the availability of appropriately digitized street map data.

[...] progress in digital technology would not stop simply because Honda had turned its attention to analog. In 1985, for example, the U.S. company ETAK introduced its own digital map navigation system. Although the system's effective range-the area of geographical coverage-was limited, the announcement was a dour one for Nakamura and his staff. Therefore, ultimately the development of a practical analog system was shelved. The staff experienced indescribable feelings of disappointment. The development of [Honda's] digital map navigation system resumed in 1987, following a three-year hiatus.

Both Mitsubishi Electric and Pioneer claim to be the first with a GPS-based auto navigation system, in 1990. Also in 1990, a draft patent application was filed within Digital Equipment Co. Ltd. for a multi-function device called PageLink that had real-time maps for use in a car listed as one of its functions.

Magellan, a GPS navigation system manufacturer, claims to have created the first GPS-based vehicle navigation system in the U.S. in 1995.

In 1995, Oldsmobile introduced the first GPS navigation system available in a production car, called GuideStar. There also was an Oldsmobile navigation system available as an option as early as 1994 called the Oldsmobile Navigation/Information System. It was an option on the Oldsmobile Eighty Eight.

However it was not until 2000 that the United States made a more accurate GPS signal available for civilian use.

Technology

Visualization

Navigation systems may (or may not) use a combination of any of the following:

- top view for the map
- top view for the map with the map rotating with the automobile (so that "up" on the map always corresponds to "forward" in the vehicle)
- bird's-eye view for the map or the next curve
- linear gauge for distance, which is redundant if a rotating map is used
- numbers for distance
- schematic pictograms
- voice prompts

Road database

Contents

The road database is a vector map of some area of interest. Street names or numbers and house numbers are encoded as geographic coordinates so that the user can find some desired destination by street address.

Points of interest (waypoints) will also be stored with their geographic coordinates. Point of interest specialties include speed cameras, fuel stations, public parking, and "parked here" (or "you parked here").

Contents can be produced by the user base as their cars drive along existing streets (Wi-Fi) and communicating via the internet, yielding a free and up-to-date map.

Map formats

Formats are almost uniformly proprietary; there is no industry standard for satellite navigation maps, although NAVTEQ are currently trying to address this with S-Dal (see below).

The map data vendors such as Tele Atlas and NAVTEQ create the base map in a standard format GDF, but each electronics manufacturer compiles it in an optimized, usually proprietary format. GDF is not a CD standard for car navigation systems. GDF is used and converted onto the CD-ROM in the internal format of the navigation system.

CARiN

CARiN Database Format (CDF) is a proprietary navigation map format created by Philips Car Systems (this branch was sold to Mannesman VDO, VDO/Dayton in 1998, to Siemens VDO in 2002, and Continental in 2007.) and is used in a number of navigation-equipped vehicles. The 'CARiN' portmanteau is derived from **Car** Information and Navigation.

S-Dal

This is a proprietary map format published by NAVTEQ, who released it royalty free in the hope that it would become an industry standard for digital navigation maps. Vendors currently using this format include:

- Microsoft
- Magellan
- Pioneer
- Panasonic
- Clarion
- InfoGation

The format has not been very widely adopted by the industry.

Physical Storage Format

The Physical Storage Format (PSF) initiative is an industry grouping of car manufacturers, navigation system suppliers and map data suppliers whose objective is the standardization of the data format used in car navigation systems, as well as allow a map update capability. Standardization would improve interoperability, specifically by allowing the same navigation maps to be used in navigation systems from 19 manufacturers. Companies involved include BMW, Volkswagen, Daimler, Renault, ADIT, Aisin AW, Alpine Electronics, Navigon, Bosch, DENSO, Mitsubishi, Harman Becker, Panasonic, PTV, Continental AG, Clarion, NAVTEQ, Tele Atlas and Zenrin.

Media

The road database may be stored in solid state read-only memory (ROM), optical media (CD or DVD), solid state flash memory, magnetic media (hard disk), or a combination. A common scheme is to have a base map permanently stored in ROM that can be augmented with detailed information for a region the user is interested in. A ROM is always programmed at the factory; the other media may be preprogrammed, downloaded from a CD or DVD via a computer or wireless connection (bluetooth, Wi-Fi), or directly used utilizing a card reader.

Some navigation device makers provide free map updates for their customers. These updates are often obtained from the vendor's website, which is accessed by connecting the navigation device to a PC.

Real-time data

Some newer systems can not only give precise driving directions, they can also receive and display information on traffic congestion and suggest alternate routes. These may use either TMC, which delivers coded traffic information using radio RDS, or by GPRS/3G data transmission via mobile phones.

One key type of real-time data is traffic information, which includes:

- Real-time data about free/full parkings;
- Nearest public transport lines and prices, to go to a destination, when there is a jam.

Other real-time data includes weather broadcasting, etc.

Integration and other functions

- The color LCD screens on some automotive navigation systems can also be used to display television broadcasts or DVD movies.

- A few systems integrate (or communicate) with mobile phones for hands-free talking and SMS messaging (i.e., using Bluetooth or Wi-Fi).
- Automotive navigation systems can include personal information management for meetings, which can be combined with a traffic and public transport information system.

Controversy

Safety features

Vehicles produced by Subaru and Lexus, as well as Lexus' parent company, Toyota, lock out many of the features when the vehicle is in motion. The manufacturers claim this is a safety feature to avoid the driver being distracted. Many users have complained that passengers are not able to enter destinations while in motion, even though it is safe to do so. Additionally, drivers have complained that it is often more dangerous to pull off a highway and stop than it would be to enter a destination into the system.

Misdirection

A number of road accidents in the UK have been attributed to misdirection by satellite navigation systems. On May 11, 2007, a driver followed satellite navigation instructions in the dark and her car was hit by a train on a rail crossing that was not shown on the system. In Exton, Hampshire, the County Council erected a sign warning drivers to ignore their "sat nav" system and to take another route, because the street was too narrow for vehicular traffic and property damage resulted from vehicles getting stuck.

On March 25, 2009, a man drove down a steep mountain path and almost off of a cliff after he was allegedly directed by his portable GPS system. He was finally stopped by a wire fence.

Misdirection can also occur when a road is altered either permanently or temporarily, such as during road re-construction.

GPS vs speed camera accuracy

In July 2007, an Australian man successfully overturned a speeding conviction after evidence from a GPS navigational track proved that he did not exceed the speed limit.

Other functions

- Golf Carts may have integrated GPS rangefinders tailored to specific golf courses, providing interactive course maps and live readings of distance measurements to the green.
- Many systems can give information on nearby points of interest (POIs), such as restaurants, cash machines and gas stations. Some navigation devices use this feature to store the location of known speed traps or speed cameras, and can alert

the driver in much the same way as a radar detector. GPS may also be integrated into actual radar detection devices to enhance accuracy, and in some cases, implement a logic system where the system only alerts if the driver is traveling above the speed limit or in the direction to be 'caught.' Unlike radar detectors, GPS-based speed trap warnings are currently legal in many countries.

- Some systems feature internet connectivity, either via Bluetooth to a mobile phone (in which case the device can typically also be used for hands-free calling), or with a built in GSM SIM card. This connectivity can be used for up-to-date traffic information, to find fuel prices, as well as to search for local distances. Such devices include the TomTom LIVE series, and the Garmin nüvi 1690.
- The radio dispatching of taxicabs have been phased out in several countries in favor of GPS technology plus some form of mobile networking with on board computers. The central dispatch computer keeps track of all vehicles in its fleet, and automatically selects the nearest cab to respond to a passenger request.
- Advanced car security vehicle tracking systems can relay the vehicle's location via cellular phone services in case of loss or theft. The technology can also be used to manage fleet vehicles, in which case it's known as automatic vehicle location.
- A very basic form of GPS navigation is used on public buses in Taipei, where the location and sequence of bus stops for a particular route are programmed. The computer announces the approaching and upcoming bus stops and repeats the information on a dot-matrix display, all without intervention from the driver. This service was once provided based on tire revolutions and odometer mileage, which is not nearly as reliable as a GPS enabled system.

Retrofitting of GPS

A vehicle can be retrofitted with a GPS navigation device unit if it did not originally have one. There are three approaches that can be taken here:

Portable GPS

This type of GPS navigation device is not permanently integrated into the vehicle, having only a simple bracket to mount the device on the surface of the dashboard and powered via the car cigarette lighter. This class of GPS unit does not require professional installation and can typically be used as handheld device, too.

Benefits of this type of GPS unit include low cost as well as the ability to move them easily to other vehicles. Their portability means they are easily stolen if left inside the vehicle. Furthermore, not having a compass, accelerometer or inputs from the vehicle's speed sensors, means that they cannot navigate as accurately by dead reckoning as some built-in devices when there's no GPS signal. More modern portable devices such as the TomTom 920, have an inbuilt accelerometer to try to address this.

A portable automotive navigation system kit generally includes:

- Mini-USB sync cable
- AC adaptor
- Car charger
- Car mount kit
- Pouch
- Wrist band
- External antenna (optional by model)
- Stylus
- Battery pack
- Document kit
- SD card with preload map (sometimes capable of shuffling MP3 playlists)
- Companion CD-ROM
- Navigation software CD-ROM



Early Factory Navigation System (as fitted to 1997 UK Specification Ford Mondeo)

Original factory equipment

Many vehicle manufacturers offer a GPS navigation device as an option in their vehicles. Customers whose vehicles did not ship with GPS can therefore purchase and retrofit the original factory-supplied GPS unit. In some cases this can be a straightforward "plug-and-play" installation if the required wiring harness is already present in the vehicle.

However, with some manufacturers, new wiring is required, making the installation more complex.



Modern Factory Navigation System (as fitted to a 2009 U.S. Honda Accord)

The primary benefit of this approach is an integrated and factory-standard installation. Many original systems also contain a gyrocompass or accelerometer and may accept input from the vehicle's speed sensors, thereby allowing them to navigate via dead reckoning when a GPS signal is temporarily unavailable. However, the costs can be considerably higher than other options. In some cases, it may even be more economical to buy a similar vehicle that already has a factory-fitted GPS.

Aftermarket

A number of manufacturers supply aftermarket GPS navigation devices that can be integrated permanently into the vehicle. A typical location for such an installation is the

DIN slot for the radio/tape/CD. However, in extreme cases, the dashboard may also be remodeled to accommodate the unit.

This approach can be considered a tradeoff between the previous two options. Benefits include a more secure and better cosmetic finish than a portable device, and lower cost compared to the installation of an original factory-supplied GPS.

Alternatives

Smartphones with GPS, and other navigation devices, may also be used without installing in a car.

SMS

Establishing points of interest in real-time and transmitting them via GSM cellular telephone networks using the Short Message Service (SMS) is referred to as Gps2sms. Some vehicles and vessels are equipped with hardware that is able to automatically send an SMS text message when a particular event happens, such as theft, anchor drift or breakdown. The receiving party (e.g., a tow truck) can store the waypoint in a computer system, draw a map indicating the location, or see it in an automotive navigation system.

Example systems



Navigon

- Acer e300 series
- Clarion
- EB street director
- Garmin
- Gizmondo
- Hertz Neverlost
- iGo (software)
- MapmyIndia
- Kenwood DNX-5120
- Magellan Navigation
- Master Navigator Software (Sapper Oy)
- Mio Technology
- Navigon
- Navmii
- NDrive
- Navman iCN series
- Ovi Maps
- Pioneer
- TomTom
- VDO Dayton
- Wayfinder Navigator
- Sygic Mobile Maps/Tele Atlas
- Mireo
- Teletype Software
- VIETMAP

Chapter- 3

I-Drive

iDrive is a computer system which is used to control most secondary vehicle systems in many current BMW cars. iDrive's user interface consists of a LCD panel mounted in the dashboard and a controller knob mounted on the center console.

iDrive allows the driver and front-seat passenger (in recent cars it is available to back-seat passengers as well) to control such amenities as the climate (air conditioner and heater), the audio system (radio and CD player), the navigation system and communication system.

iDrive Generations

iDrive (1st Gen)

Debuted in September 2001 with the 7-Series and was based on Microsoft Windows CE for Automotive.

This can easily be seen when the system reboots or restarts after a software crash displaying a "Windows CE" logo.

iDrive Business (M-ASK)

M-ASK stands for MMI Audio System controller and is manufactured by Becker. This is a limited version of the iDrive computer with a small 6.6" display and is only found on 5th, 6th and 7th-series, and the X5 or X6, without the navigation option.

In addition it can optionally be ordered in Europe on the 1-series and 3-series as "Business navigation", which has basic navigation abilities. Early versions of the Business navigation could only display directional arrows, but the latest version can also display 2D maps. iDrive Business Navigation uses a different map DVD than iDrive Professional Navigation. In addition because only one optical drive is available you cannot use both navigation and listen to a CD simultaneously.

When iDrive Professional is ordered the M-ASK system is replaced by either the CCC or CIC in addition to a larger display.

iDrive Business is available on the following cars;

- iDrive Business Navigation (optional)
 - 1-Series E81/E82/E87/E88
 - 3-Series E90/E91/E92/E93
- iDrive Business (default when navigation is not ordered)
 - 5-Series E60/E61
 - 6-Series E63/E64
 - 7-Series E65/E66/E67/E68
 - 7-Series F01/F02
 - X5 E70
 - X6 E71

Note that the above list can vary depending on the region. For instance North American 7-series come by default with CCC or CIC.

iDrive Professional Navigation (CCC)



iDrive Controller on BMW X5



iDrive controller on BMW 530d

Debuted in 2003 with the E60/E61 5-Series and is based on Wind River VxWorks, a real-time operating system. CCC stands for Car Communication Computer and uses a larger 8.8" wide-screen display. It was available on the following cars as an option;

- 1-Series E81/E82/E87/E88 manufactured until March 2007
- 3-Series E90/E91/E92/E93 manufactured until March 2007
- 5-Series E60/E61 manufactured until March 2007
- 6-Series E63/E64 manufactured until March 2007
- 7-Series E65/E66/E67/E68 from September 2004

CCC based systems use a map DVD from Navteq in a dedicated DVD drive.

CCC - update 1

This is a minor update to iDrive Professional debuted in March 2007. It adds additional programmable buttons in the dashboard to directly access frequent functions and it

removes the haptic feedback from the iDrive controller. It is available on the following cars as an option;

- 1-Series E81/E82/E87/E88 manufactured between March 2007 and September 2008
- 3-Series E90/E91/E92/E93 manufactured between March 2007 and September 2008
- 5-Series E60/E61 manufactured between March 2007 and March 2010
- 6-Series E63/E64 manufactured between March 2007 and September 2009
- X5 E70
- X6 E71

CCC - update 2

This is a minor update debuted in September 2008 to iDrive Professional equipped cars that did not get the new CIC based system. These cars get the new iDrive controller that is also used on cars with CIC. The actual iDrive computer (CCC) remains the same. This update is available on the following cars;

- 5-Series E60/E61 manufactured from September 2008
- 6-Series E63/E64 manufactured from September 2008

iDrive Professional Navigation (CIC)

Debuted in September 2008 with F01/F02 7-Series. CIC stands for Car Infotainment Computer and is manufactured by Becker, utilizing the QNX operating system. It is available on the following cars as an option;

- 1-Series E81/E82/E87/E88 manufactured from September 2008
- 3-Series E90/E91/E92/E93 manufactured from September 2008
- 5-Series F07/F10/F11 manufactured from September 2009
- 6-Series E63/E64 manufactured from September 2009
- 7-Series F01/F02 manufactured from September 2008

The CIC system is a major update to iDrive, replacing the display, computer and the controller. The display is of a higher resolution, and is generally more responsive than CCC, to address one of the common complaints of iDrive. Internet access is also supported.

CIC-based systems use maps from TeleAtlas which are installed on an internal 2.5" 40GB Hard Disk Drive (HDD). This HDD can also store up to 8GB of music files for playback. For facilitating the uploading of music files to the HDD, a USB port is provided in the glove box.

Following 2009 LCI production, all CIC-based iDrive systems will support DVD video. This, however, is only operational when the vehicle is in the "Park" position.

Rationale

The design rationale of iDrive is to replace a confusing array of controls for the above systems with an all-in-one unit. The controls necessary for vehicle control and safety, such as the headlights and turn signals, are still located in the immediate vicinity of the steering column. iDrive also allows the On-Board Diagnostics computer to provide detailed information to the driver and service technicians in plain-text, rather than limited and confusing symbology, such as a "Check Engine" light.

Since the climate, audio, navigation and communication systems are adjusted only occasionally, they were moved into an easy-to-use, central location. However, iDrive was filled with controversy and many disapproved of it, as it was considered to be difficult to use .

Controversy and Critics

iDrive has caused significant controversy among users, the automotive media, and critics. Many reviewers of BMWs in (automobile) magazines disapprove of the system. Criticisms of iDrive include its steep learning curve and its tendency to cause the driver to look away from the road too much . Most users report that they adapt to the system after about one hour of practice, and the advent of voice controls has reduced the learning curve greatly.

A new iDrive system (CIC) was introduced in September 2008 to address most of the complaints.

Influence

Despite the criticisms of iDrive, the concept of a computer-oriented interface has grown in the luxury segment of the industry:

- MMI, Audi
- Comand APS, Mercedes-Benz
- Remote Touch, Lexus

As such, the significance of iDrive in auto history is predicated more on its pioneering value as a first mover into a new feature space than on the success of its application or particular interpretation of how to execute the idea in design. Generally speaking, the single touch-point for an increasingly broad array of controls is becoming a standard functionality and, like other features that were once only found in luxury vehicles (power windows, air conditioning, air bags) this single touch-point, if it remains a strong selling feature, will likely trickle down to higher-production, more affordable model lines.

How It Works

The *iDrive* M-ASK and CCC systems are based around the points of a compass (north, south, east, west) with each direction corresponding with a specific area. These areas are also colour coded providing identification as to which part of the system is currently being viewed.

- North (blue) for communication
- East (green) for navigation (In some models without navigation, this option is replaced by the On Board Computer)
- South (yellow) for entertainment
- West (red) for climate control

Also, at the *iDrive* home screen, the control knob can be pushed downwards to provide access to the car's control panel (*iMenu*), which gives access to a variety of operational parameters:

- date/time settings
- System language localization (generally, English (US/UK) and native language of the vehicle's location is provided.)
- Bluetooth settings
- Flat tire sensor settings,
- lighting behavior, etc.
- custom steering wheel buttons
- Power Output (BMW M series, for example, 400 hp, 500 hp).

Starting in 2007, perhaps in response to critics, *iDrive* added programmable buttons (6 USA/Japan, 8 in Europe) to the dashboard, breaking tradition of having the entire system operated via the control knob. Each button can be programmed to instantly access any feature within *iDrive* (such as a particular navigation route, or your favorite radio station). In addition, a dedicated AM/FM button, and a Mode button (to switch between entertainment sources) were added (only USA)

iDrive is controlled by manipulating the control knob. This can be pushed north, south, east, west; pushed inwards (down), nudged left and right, or rotated left and right. The control knob contains an element of 'force feedback' so the knob can not be rotated further than there are options on the screen. It will also kick back slightly as it scrolls through options. This makes it easier to use while driving and keeping your eyes on the road.

From the home screen, each option can be reached by pushing the control knob in the desired direction. From any other screen, pushing the knob in the desired direction and holding in place for a few seconds will jump to that new area. (For example, in the *Entertainment* screen, pushing the control knob to the right for a few seconds before letting it go will jump straight to the *Navigation* area). The *iDrive* system includes a

button marked *Menu* behind the control knob which provides quick access to the home screen.

iDrive is unique among its competitors by using a widescreen display that is split into a 2/3 main window, and 1/3 "Assistance Window". This allows the driver to use any function or menu, while simultaneously maintaining secondary information. For example, if the driver is not in the Navigation menu, he can still see a map on the assistance window. Other information that can be displayed includes navigation route directions and a trip computer.

The latest generation of the BMW iDrive in the 2009 BMW 7-Series features a large 10.2 inch high resolution LCD panel with a 1280x480 resolution. It has a full featured web browser that connects to the internet via BMW ConnectedDrive using EDGE.

Chapter- 4

Multi Media Interface



the MMI controls (to the rear of the gear lever) on a left-hand drive Audi Q7

The Audi **Multi Media Interface**, commonly abbreviated to **MMI**, is an in-car user interface system developed by Audi, and implemented in most of its latest series of cars/automobiles since 2004.

Concept

MMI consists of a single interface, which controls a variety of devices and functions of the car, thus minimizing the vast array of buttons and dials normally found on a dashboard. The system consists of the MMI terminal and the MMI display screen.

Like in the mentioned iDrive the central element of the MMI terminal is the control dial. This dial can be rotated, to navigate up and down through menus, and pressed to activate a selected highlighted function. Four or eight function buttons surround the control dial (dependent on MMI specification installed in the car), which can be used to call up a corresponding on-screen menu. The MMI screen is available as a 5-inch monochrome black & red or 7-inch 16:9 full colour display, depending on the variation of MMI fitted in the car. MMI uses Media Oriented Systems Transport (MOST) technology to interconnect the various systems. Harman Becker manufactures the system, utilizing QNX Neutrino's Real Time Operating System (RTOS) software.

Variations



a right-hand drive 2005 Audi A6 (C6), showing the Multi Media Interface (MMI) controls



a left-hand drive 2007 Audi S6 (C6), showing the MMI controls, and the display screen in the dashboard

On the A6 and S6, MMI comes in a choice of 3 systems, **MMI Basic**, **MMI Basic Plus** and **MMI** . The features of the 3 varieties are as follows:

- **MMI basic**
 - 5-inch monochrome display (red and black)
 - optional CD-ROM based satellite navigation (with single country street-level maps)
 - radio tuner (with RDS Traffic Programme (TP))
 - single CD player
- **MMI basic plus** - all features of MMI basic, plus:
 - DSP 10-speaker sound system
 - ability to store (TIM) RDS Traffic Announcement messages (TA)
- **MMI** - the features of MMI basic plus, and the addition of:
 - 7-inch 16:9 full-colour display
 - 6 CD Changer

- optional DVD-ROM based satellite navigation (with Europe-wide/United States-wide street-level maps, and TMC)
- optional TV Tuner

For the current A8 and S8 and Q5, the MMI only comes as a complete "one size fits all" package.

On the current Q7, it is available in two specifications, the standard **MMI** (with 8 speakers, monochrome display, and radio/CD player, and 4 function keys), and the optional **MMI High** (7" hi-res colour monitor, double tuner extended radio, DSP sound system, and separate CD changer - but NO navigation, which is an extra option).

The latest version, due to appear in 2010 on the new A8, can recognize handwriting inputs for the phone and navigation system.

Functions

MMI operates a large number of in car entertainment components, car electronics, and other functions. The list below indicates the scope of systems controllable by MMI. However, depending on the actual car model, along with which version was specified (MMI basic, MMI High, etc), only some, and not all functions will be applicable or available.

- Satellite Navigation, including traffic management (TMC)
- Radio tuner
- CD Changer
- TV Tuner
- Telephone & Directory
- heating, ventilation, air conditioning / Climate Control, and seat heating
- Car Setup (e.g. central locking and convenience function (coming home/leaving home, power sunroof and windows) options, global audio settings, suspension settings etc.)
- Driver Information (e.g. fuel economy statistics (often encompassed by "trip computer" functions), battery level, tire-pressure monitoring, etc.)
- User Manual (full on-board car user manual, displayed on screen)

Cars

Audi models featuring MMI are:

- A1
- A4 (B8) 2008 onwards
- A5
- A6 (C6) 2005 onwards
- S6 (C6) 2006 onwards
- A8 (D3) from the 2005 facelift onwards

- S8 (D3) 2006 onwards
- Q5
- Q7

Criticisms

While intuitive and user-friendly, MMI can be difficult to operate when driving. A sequence of menus may need to be accessed in order to change a particular setting, such as radio station, rather than having a dedicated button designated to such a function. This can make changing a setting both time-consuming and arguably hazardous under certain circumstances, where the driver is distracted from the road. It must be said, however, that this concern can also apply to other dashboard interfaces and even conventional dashboards.

Software Updates

- The MMI systems firmware can be updated, either by a dealer, or by a more recent release of navigation software. Bug-fixes, and enhancements can be added in this process, and on first installing a new navigation DVD, the firmware version is updated and system altered.
- MMI featuring DVD based navigation has a DVD disc drive located in the boot/trunk. This is used exclusively for navigation and contains the navigation software DVD.

Verify that the software level in 07 - Display control unit is 1070. ▪ If this is not the case, contact the Audi Technical Assistance Center for further instruction.

Version History

European / ROW (Rest of the World) versions:

- 0890 (0.8.90) -
- 1190 (1.1.90) -
- 1200 (1.2.00) -
- 2120 (2.1.20) - {Update CD p/n 4E0 906 961 L}
- 3460 (3.4.60) - {Update CD p/n 4E0 906 961 T}
- 4220 (4.2.20) - {Update CD p/n 4E0 906 961 AA}
- 5150 (5.1.50) - {Update CD p/n 4F0 906 961 AB}
- 5170 (5.1.79) -
- 5570 (5.5.70) - {Update CD set p/n 4L0 998 961 (A6/A8/Q7) or p/n 8K0 998 961 (A4 B8/A5)}

North America versions:

- 0600 (0.6.00) -
- 1190 (1.1.90) -

- 2750 (2.7.50) - version 2750 and below have to be upgraded to 3360 before upgrading to a higher version
- 3310 (3.3.10) -
- 3360 (3.3.60) - {Update CD p/n 4F0 906 961AB}
- 4140 (4.1.40) - {Update CD p/n 4L0 906 961 H}
- 4610 (4.6.10) - {Update CD set p/n 4F0 998 961}

Pseudo-MMI

Certain Audi cars have a "pseudo" type of MMI. These are the A3, A4 (B6 and B7), the TT and the R8 - when fitted with the RNS-E DVD based "Audi Navigation Plus" system. Whilst appearing to be a similar layout, and operating in a similar manner, these two systems are very different, are unable to share mapping discs or software, and are not able to control non-ICE functions (such as Climate, convenience or suspension settings).

Competing Technologies

Other car manufacturers use similar technologies in their car, including BMW with its iDrive system and Mercedes-Benz with its COMAND system; Lexus uses a mouse-based Remote Touch system; Ford uses a product called Sync.

Subwoofer



a 12" subwoofer driver without an enclosure

A **subwoofer** (or simply "sub") is a woofer, or a complete loudspeaker typically between 8" and 21" in diameter, which is dedicated to the reproduction of low-pitched audio frequencies (the "bass"). The typical frequency range for a subwoofer is about 20–200 Hz for consumer products, below 100 Hz for professional live sound, and below 80 Hz in

THX-approved systems. Because of their limited frequency range, most subwoofers are used to augment the output of loudspeakers covering higher frequency bands.

Subwoofers are made up of one or more woofers in a well-braced wood or plastic loudspeaker enclosure, in one of a variety of designs, including bass reflex (with a port or tube in the enclosure), infinite baffle, horn-loaded, and bandpass designs, each of which has advantages and disadvantages in efficiency, size, distortion, cost, and power handling. Passive subwoofers have a subwoofer driver and enclosure and they are powered by an external amplifier. Active subwoofers include a built-in amplifier.

The first subwoofers were developed in the 1960s to add bass response to home stereo systems. Subwoofers came into greater popular consciousness in the 1970s with the introduction of Sensurround in movies such as *Earthquake*, which produced loud low-frequency sounds through large subwoofers. With the advent of the compact cassette and the compact disc in the 1980s, the easy reproduction of deep *and* loud bass was no longer limited by the ability of a phonograph record stylus to track a groove, and producers could add more low frequency content to recordings. As well, during the 1990s, DVDs were increasingly recorded with "surround sound" processes that included a Low Frequency Effects (LFE) channel, which could be heard using the subwoofer in home theater systems. During the 1990s, subwoofers also became increasingly popular in home stereo systems, custom car audio installations, and in PA systems. By the 2000s, subwoofers became almost universal in sound reinforcement systems in nightclubs and concert venues.

History

The very first subwoofer was developed during the 1960s by Ken Kreisel, the former president of the Miller & Kreisel Sound Corporation in Los Angeles. When Kreisel's business partner, Jonas Miller, who owned a high-end audio store in Los Angeles, told Kreisel that some purchasers of the store's high-end electrostatic speakers had complained about a lack of bass response in the electrostatics, Kreisel designed a powered woofer that would reproduce only those frequencies that were too low for the electrostatic speakers to convey. Infinity's full range electrostatic speaker system that was developed during the 1960s also used a woofer to cover the lower frequency range that its electrostatic arrays did not handle adequately.

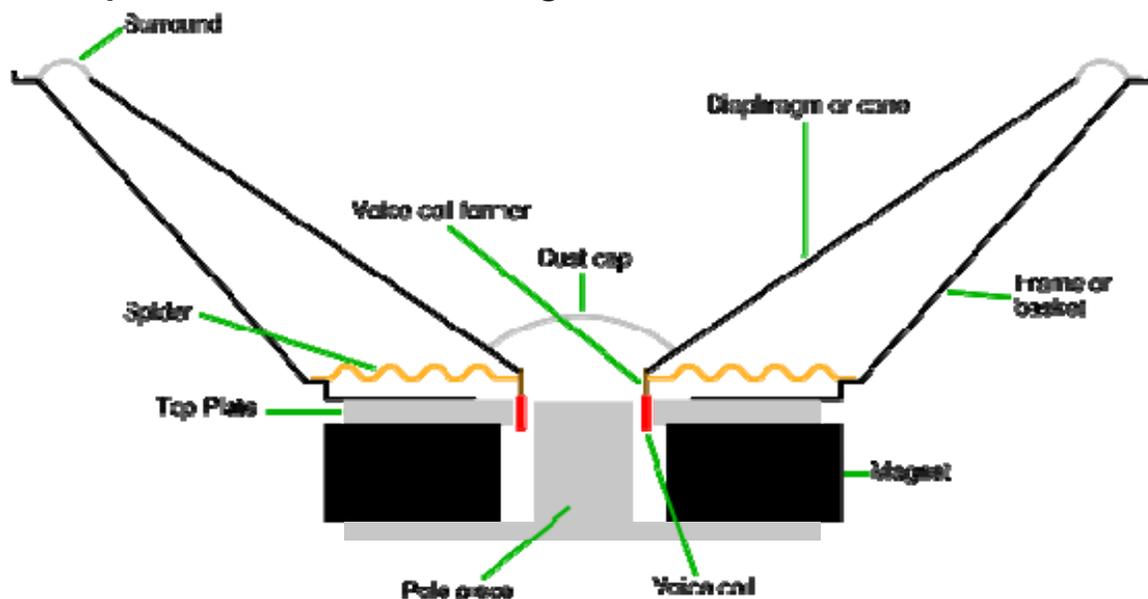
The first use of a subwoofer in a recording session was in 1973 for mixing the Steely Dan album *Pretzel Logic* when recording engineer Roger Nichols arranged for Kreisel to bring a prototype of his subwoofer to Village Recorders. Further design modifications were made by Kreisel over the next ten years, and in the 1970s and 1980s by engineer John P. D'Arcy; record producer Daniel Levitin served as a consultant and "golden ears" for the design of the crossover network (used to partition the frequency spectrum so that the subwoofer would not attempt to reproduce frequencies too high for its effective range, and so that the main speakers would not need to handle frequencies too low for their effective range).

Subwoofers received a great deal of publicity in 1974 with the movie *Earthquake* which was released in Sensurround. Initially installed in 17 U.S. theaters, the Sensurround system used large subwoofers which were driven by racks of 500 watt amplifiers which were triggered by control tones printed on one of the audio tracks on the film. Four of the subwoofers were positioned in front of the audience under (or behind) the film screen and two more were placed together at the rear of the audience on a platform. Powerful noise energy in the range of 17 Hz to 120 Hz was generated at the level of 110–120 decibels of sound pressure level, abbreviated dB(SPL). The new low frequency entertainment method helped the film become a box office success. More Sensurround systems were assembled and installed. By 1976 there were almost 300 Sensurround systems leapfrogging through select theaters. Other films to use the effect include the WW II naval battle epic *Midway* in 1976 and *Rollercoaster* in 1977.

For owners of 33 rpm LPs and 45 singles, loud *and* deep bass was limited by the ability of the phonograph record stylus to track the groove. Some hi-fi aficionados solved the problem by using reel-to-reel tape players which were capable of delivering accurate, naturally deep bass from acoustic sources, or synthetic bass not found in nature. With the popular introduction of the compact cassette and the CD, it became possible to add more low frequency content to recordings, and satisfy a larger number of consumers. Home subwoofers grew in popularity, as they were easy to add to existing multimedia speaker setups and they were easy to position or hide.

Construction and features

Loudspeaker and enclosure design



Cross-section of a subwoofer drive unit. *Image not to scale.*

Subwoofers use speaker drivers (woofers) typically between 8" and 21" in diameter. Some uncommon subwoofers use larger drivers, and single prototype subwoofers as large as 60" have been fabricated. On the smaller end of the spectrum, subwoofer drivers as small as 4" may be used, depending on the design of the loudspeaker enclosure, the desired sound pressure level, the lowest frequency targeted and the level of permitted distortion. The most common subwoofer driver sizes used for sound reinforcement are 10-, 12-, 15- and 18-inch models. The largest available sound reinforcement subwoofers, 21" drivers, are less commonly seen.

The efficiency of a speaker driver is given by:

$$\eta_0 = \left(\frac{4\pi^2 F_s^3 V_{as}}{c^3 Q_{es}} \right) \times 100 \%$$

Where the variables are Thiele/Small parameters. Deep low frequency extension is a common goal for a subwoofer and small box volumes are also considered desirable. Hoffman's Iron Laws therefore mandate low efficiency under those constraints, and indeed most subwoofers require considerable power, much more than other individual drivers.

So for the example of a sealed speaker box, the box volume to achieve a given Q_{ts} is proportional to V_{as} :

$$V_b = \frac{V_{as}}{\alpha} \quad \text{Where:} \quad \alpha = \frac{Q_{tc}^2}{Q_{ts}} - 1$$

Therefore a decrease in box volume and the same F_3 will decrease the efficiency of the sub woofer. Similarly the F_3 of a speaker is proportional to F_s :

$$F_c = \frac{(Q_{tc} F_s)}{Q_{ts}}$$

As the efficiency is proportional to F_s^3 , small improvements in low frequency extension with the same driver and box volume will result in very significant reductions in efficiency. For these reasons, subwoofers are typically very inefficient at converting electrical energy into sound energy. This combination of factors accounts for the higher power output of subwoofer amplifiers, and the requirement for greater power handling for subwoofer drivers. Enclosure variations (e.g., bass reflex designs) are sometimes used for subwoofers to increase the efficiency of the driver/enclosure system, helping to reduce the amplifier power requirement.



Subwoofer mounted in a sealed enclosure

Subwoofers have been designed using a number of enclosure approaches: bass reflex, acoustic suspension, infinite baffle, horn loaded, tapped horn, transmission line and bandpass. Each enclosure type has advantages and disadvantages in efficiency increase, bass extension, cabinet size, distortion, and cost. Subwoofers are typically constructed by mounting one or more woofers in a cabinet of medium-density fibreboard (MDF), oriented strand board (OSB), plywood, plastic or other dense materials. Because of the high power they use, subwoofers often require strong internal crossbracing to add strength and reduce box resonances.

There is a great deal of variety in the size of enclosures and, in the case of bass reflex systems, vent designs. When two or more subwoofers are placed in the same enclosure, they work together to move a greater mass of air, resulting in lower frequency extension.

For example, if a single 12" subwoofer enclosure can go down to 40 Hz, a larger enclosure with four of these 12" drivers may be able to go to 30 Hz.

The smallest subwoofers are typically those designed for home theater users with limited space. The largest common subwoofer enclosures are those used for concert sound reinforcement systems or nightclub sound systems. An example of a large concert subwoofer enclosure is the 1980s-era ElectroVoice MT-4 "Bass Cube" system, which used four 18" drivers. An example of a subwoofer that uses a bass horn is the Bassmaxx B-Two, which loads an 18" driver onto an 11-foot (3.4 m) long folded horn. Folded horn-type subwoofers can typically produce a deeper range with greater efficiency than the same driver in an enclosure that lacks a horn. Some experimental fixed-installation subwoofer horns have been constructed using brick and concrete to produce a very long horn that allows a very deep sub-bass extension.

Subwoofer output level can be increased by increasing cone surface area or by increasing cone excursion. Since large drivers require undesirably large cabinets, most subwoofer drivers have large excursions. Unfortunately, high excursion, at high power levels, tends to produce more distortion from inherent mechanical and magnetic effects in electro-dynamic drivers (the most common sort). The conflict between assorted goals can never be fully resolved; subwoofer designs are necessarily compromises. Hoffman's Iron Law (the efficiency of a woofer system is directly proportional to its cabinet volume and to the cube of its cutoff frequency) applies to subwoofers just as to all loudspeakers.

Frequency range and frequency response

The typical frequency range for a subwoofer is between 20–200 Hz. Professional concert sound system subwoofers typically operate below 100 Hz, and THX-approved systems in movie theaters operate below 80 Hz. The frequency response specification of a speaker "attempts to describe the range of frequencies or musical tones a speaker can reproduce, measured in Hertz" Subwoofers vary in terms of the range of pitches that they can reproduce, depending on a number of factors such as the size of the cabinet and the construction and design of the enclosure and driver(s). Specifications of frequency response depend wholly for relevance on an accompanying amplitude value—measurements taken within a wider amplitude range will give any loudspeaker a wider frequency response. For example, the JBL 4688 TCB Subwoofer System, a now-discontinued system which was designed for movie theaters, had a frequency response of 23–350 Hz when measured within a 10-decibel boundary (0 dB to -10 dB) and a narrower frequency response of 28–120 Hz when measured within a six-decibel boundary (± 3 dB).

As well, subwoofers vary in regards to the sound pressure levels achievable and the distortion levels they can produce over their range. The Abyss subwoofer, for example can reproduce pitches from 18 Hz (which is about the pitch of the lowest rumbling notes on a huge pipe organ with 32-foot (9.8 m) bass pipes) to 120 Hz (± 3 dB). Nevertheless, even though the Abyss subwoofer can go down to 18 Hz, its lowest frequency and maximum SPL with a limit of 10% distortion at 2 meters in a large room is 35.5 Hz at

79.8 dB. This means that a person choosing a subwoofer needs to consider more than just the lowest pitch that that sub can reproduce.

Amplification

'Active subwoofers' include their own dedicated amplifiers within the cabinet. Some also include user-adjustable equalization that allows boosted or reduced output at particular frequencies; these vary from a simple "boost" switch, to fully parametric equalizers meant for detailed speaker and room correction. Some such systems are even supplied with a calibrated microphone to measure the subwoofer's in-room response, so the automatic equalizer can correct the combination of subwoofer, subwoofer location, and room response to minimize effects of room modes and improve low frequency performance.

'Passive subwoofers' have a subwoofer driver and enclosure, but they do not include an amplifier. They sometimes incorporate internal passive crossovers, with the filter frequency determined at the factory. These are generally used with third-party power amplifiers, taking their inputs from active crossovers earlier in the signal chain. While few high-end home-theater systems use passive subwoofers, this format is still popular in the professional sound industry. Using a passive subwoofer adds flexibility for the user, because the user can select which type of amplifier (Class AB or Class D, for example); brand of amplifier; or features (e.g., limiting to prevent distortion) that they want to use with their speaker or speakers.

Equalization

Equalization can be used to adjust the in-room response of a subwoofer system. Designers of active subwoofers sometimes include a degree of corrective equalization to compensate for known performance issues (e.g., a steeper than desired low end roll-off rate). In addition, many amplifiers include an adjustable low-pass filter, which prevents undesired higher frequencies from reaching the subwoofer driver. For example, if a listener's main speakers are usable down to 80 Hz, then the subwoofer filter can be set so the subwoofer only works below 80. Realizable filter behavior does not permit such sharp cutoffs, so some overlap is to be expected and must be compensated for. Digital crossover filters can produce sharper and more precise cutoff characteristics than analog filters. The crossover section may also include a high-pass "infrasonic" filter which prevents the subwoofer driver from attempting to reproduce frequencies below its safe capabilities.

Some systems use parametric equalization in an attempt to correct for room frequency response irregularities. Equalization is often unable to achieve flat frequency response at all listening locations in part because of the resonance (i.e., standing wave) patterns at low frequencies in nearly all rooms. Careful positioning of the subwoofer within the room can also help flatten the frequency response. Multiple subwoofers can manage a flatter general response since they can often be arranged to excite room modes more evenly than a single subwoofer, allowing equalisation to be more effective.

Phase control

Changing the relative phase of the subwoofer with respect to the woofers in other speakers may or may not help to minimize unwanted destructive acoustic interference in the frequency region covered by both subwoofer and main speakers. It may not help at all frequencies, and may create further problems with frequency response, but is even so generally provided as an adjustment for subwoofer amplifiers. Phase control circuits may be a simple polarity reversal switch or a more complex continuously variable circuits.

Continuously variable phase control circuits are common in subwoofer amplifiers, and may be found in crossovers and as do-it-yourself electronics projects. Phase controls allow the listener to change the arrival time of the subwoofer sound waves relative to the same frequencies from the main speakers (i.e., at and around the crossover point to the subwoofer). A similar effect can be achieved with the delay control on many home theater receivers. The subwoofer phase control found on many subwoofer amplifiers is actually a polarity inversion switch. It allows users to reverse the polarity of the subwoofer relative to the audio signal it is being given. This type of control allows the subwoofer to either be in phase with the source signal, or 180 degrees out of phase.



Back panel of a Polk subwoofer. Notice consumer line-level and speaker-level inputs, the polarity switch and the crossover frequency control.

Servo subwoofers

Some active subwoofers use a servo feedback mechanism based on cone movement which modifies the signal sent to the voice coil. The servo feedback signal is derived from a comparison of the input signal to the amplifier versus the actual motion of the cone. The usual source of the feedback signal is a few turns of voice coil attached to the cone or a microchip-based accelerometer placed on the cone itself. An advantage of a well-implemented servo subwoofer design is reduced distortion making smaller enclosure sizes possible. The primary disadvantages are cost and complexity.

Servo controlled subwoofers are not the same as Servodrive subwoofers whose primary mechanism of sound reproduction avoids the normal voice coil and magnet combination in favor of a high-speed belt-driven servomotor. The Servodrive design increases output power, reduces harmonic distortion and virtually eliminates the loss of loudspeaker output that results from an increase in voice coil impedance due to overheating of the voice coil (called *power compression*.) This feature allows high power operation for extended periods of time. Intersonics was nominated for a TEC Award for its Servo Drive Loudspeaker (SDL) design in 1986 and for the Bass Tech 7 model in 1990.

Applications

Home audio

The use of a subwoofer augments the bass capability of the main speakers, and allows them to be smaller without sacrificing low frequency capability. A subwoofer does not necessarily provide superior bass performance in comparison to large conventional loudspeakers on ordinary music recordings due to the typical lack of very low frequency content on such sources. However, there are recordings with substantial low frequency content that most conventional loudspeakers are ill-equipped to handle without the help of a subwoofer, especially at high playback levels, such as music for pipe organs with 32' bass pipes (16 Hz), very large bass drums on symphony orchestra recordings and electronic music with extremely low synth bass parts.

Low frequencies are not easily localized; hence many stereo and multichannel audio systems feature only one subwoofer channel and a single subwoofer can be placed off-center without affecting the perceived sound stage, since the sound produced is difficult to localize. The intention in a system with a subwoofer is often to use small main ("satellite") speakers (of which there are two for stereo and five or more for surround sound or movie tracks) and to hide the subwoofer elsewhere (e.g. behind furniture or under a table), or to augment an existing speaker to save it from having to handle woofer-destroying low frequencies at high levels.

Some users add a subwoofer because high levels of low bass are desired, even beyond what is in the original recording, as in the case of house music enthusiasts. Thus, subwoofers may be part of a package that includes satellite speakers, may be purchased separately, or may be built into the same cabinet as a conventional speaker system. For

instance, some floor standing tower speakers include a subwoofer driver in the lower portion of the same cabinet. Physical separation of subwoofer and "satellite" speakers not only allows placement in an inconspicuous location, but since sub-bass frequencies are particularly sensitive to room location (due to room resonances and reverberation 'modes'), the best position for the subwoofer is not likely to be where the "satellite" speakers are located.



The 1987 Bose Acoustimass 5 stereo bass driver contained one six-inch (152 mm) driver per channel and provided crossover filtering for its two satellites

For greatest efficiency and best coupling to the room's air volume, subwoofers can be placed in a corner of the room, far from large room openings, and closer to the listener. This is possible since low bass frequencies have a long wavelength; hence there is little difference between the information reaching a listener's left and right ears, and so they cannot be readily localized. All low frequency information is sent to the subwoofer. However, unless the sound tracks have been carefully mixed for a single subwoofer channel, it's possible to have some cancellation of low frequencies if bass information in one channel is out of phase with another.

The physically separate subwoofer/satellite arrangement has been popularized by multimedia speaker systems such as Bose Acoustimass Home Entertainment Systems, Polk Audio RM2008 Series and Klipsch Audio Technologies ProMedia. Low-cost "home theater in a box" systems advertise their integration and simplicity.

Particularly among low cost "Home Theater in a Box" systems and with "boom boxes", however, inclusion of a subwoofer may be little more than a marketing device. It is unlikely that a small woofer in an inexpensively-built compact plastic cabinet will have better bass performance than well-designed conventional (and typically larger) speakers in a plywood or MDF cabinet. Mere use of the term "subwoofer" is no guarantee of good or extended bass performance. Many multimedia "subwoofers" might better be termed "bass drivers" as they are too small to produce deep bass.

Further, poorly designed systems often leave everything below about 120 Hz (or even higher) to the subwoofer, meaning that the subwoofer handles frequencies which the ear can use for sound source localization, thus introducing an undesirable subwoofer "localization effect". This is usually due to poor crossover designs or choices (too high crossover point or insufficient crossover slope) used in many computer and home theater systems; localization also comes from port noise and from typically large amounts of harmonic distortion in the subwoofer design. Home subwoofers sold individually usually include crossover circuitry to assist integration into an existing system.

Car audio



A number of subwoofers in a car hatchback

Automobiles are well suited to the "hidden" subwoofer approach due to space limitations in the passenger compartments. It is not possible, in most circumstances, to fit such large drivers and enclosures into doors or dashboards, so subwoofers are installed in the trunk or back seat space. Some car audio enthusiasts compete to produce very high sound pressure levels in the confines of their vehicle's cabin; sometimes dangerously high. The "SPL wars" have drawn much attention to subwoofers in general, but subjective competitions in sound quality ("SQ") have not gained equivalent popularity. Top SPL cars are not able to play normal music, or perhaps even to drive normally as they are designed solely for competition. Many subwoofers are capable of generating high levels in cars due to the small volume of a typical car interior. High sound levels can cause hearing loss and tinnitus if one is exposed to them for an extended period of time.



A homemade car audio subwoofer speaker box with a 15 inch Boss Audio subwoofer and an empty space for a second driver

In the 2000s, several car audio manufacturers have produced subwoofers using non-circular shapes from manufacturers, including Kicker, Sony, Bazooka, and X-Tant. These shapes typically carry some sort of distortion penalties. In situations of limited mounting space they provide a greater cone area and assuming all other variables are constant, greater maximum output. An important factor in the "square sub vs round sub" argument

is the effects of the enclosure used. In a sealed enclosure, the maximum displacement is determined by

$$V_d = x_{\max} \times S_d$$

where

- V_d stands for volume of displacement (in m^3)
- x_{\max} to the amount of linear excursion the speaker is mechanically capable of (in m)
- S_d to the cone area of the sub woofer (in m^2).

These are some of the Thiele/Small parameters which can either be measured or found with the driver specifications.

Cinema sound

After the introduction of Sensurround, movie theater owners began installing permanent subwoofer systems. Dolby Stereo 70 mm Six Track was a six channel film sound format introduced in 1976 that used two subwoofer channels for stereo reproduction of low frequencies. In 1981, Altec introduced a dedicated cinema subwoofer model tuned to 20 Hz: the 8182. Starting in 1983, THX certification of the cinema sound experience quantified the parameters of good audio for watching films, including requirements for subwoofer performance levels and enough isolation from outside sounds so that noise did not interfere with the listening experience. This helped provide guidelines for multiplex cinema owners who wanted to isolate each individual cinema from its neighbors, even as louder subwoofers were making isolation more difficult. Specific cinema subwoofer models appeared from JBL, Electro-Voice, Eastern Acoustic Works, Kintek, Meyer Sound Laboratories and BGW Systems in the early 1990s. In 1992, Dolby Digital's six-channel film sound format incorporated a single low-frequency effects (LFE) channel, the "point one" in 5.1 surround sound.

Tom Horral, a Boston-based acoustician, blames subwoofers for louder cinema sound in general. He says that before subwoofers made it possible to have loud, relatively undistorted bass, movie sound levels were limited by the distortion in less capable systems at low frequency and high levels.

Sound reinforcement



Each stack of speakers in this sound reinforcement setup consists of two EAW SB1000 direct radiating subwoofers (each contains two 18" drivers) and two EAW KF850 full range cabinets for the mid and high frequencies.

Professional audio subwoofers must be capable of very high output levels. This is reflected in the design attention given in recent years to the subwoofer applications for sound reinforcement, public address systems, dance club systems and concert systems. Consumer applications (as in home use) are considerably less demanding due to much smaller listening space and lower playback levels. Subwoofers are now almost universal in professional sound applications such as live concert sound, churches, nightclubs, and theme parks. Movie theatres certified to the THX standard for playback always include high capability subwoofers. Some professional applications require subwoofers designed

for very high sound levels, using multiple 12", 15", 18" or 21" drivers. Drivers as small as 10" are occasionally used, generally in horn loaded enclosures.

The number of subwoofer enclosures used in a concert depends on a number of factors, including the size of the venue, whether it is indoors or outdoors, the amount of low-frequency content in the band's sound, the desired volume of the concert, and the design and construction of the enclosures (e.g., direct-radiating versus horn-loaded. A small bar may use a single direct-radiating 15-inch sub cabinet. A large dance club may have a row of four or five twin 18-inch subwoofer cabinets, or more). In the largest stadium venues, there may be a very large number of subwoofer enclosures. For example, the 2009–2010 U2 360° Tour uses 24 Clair Brothers BT-218 subwoofers (a double 18" box) around the perimeter of the central circular stage, and 72 proprietary Clair Brothers cardioid S4 subwoofers placed underneath the ring-shaped "B" stage which encircles the central main stage.

The main speakers may be 'flown' from the ceiling of a venue on chain hoists, and 'flying points' (i.e., attachment points) are built into many professional loudspeaker enclosures. Subwoofers can be flown or stacked on the ground near the stage. There can be more than 50 double-18-inch cabinets in a typical concert system. Just as consumer subwoofer enclosures can be made of Medium-density fibreboard (MDF), Oriented strand board (OSB), plywood, plastic or other dense material, professional subwoofer enclosures can be built from the same materials. MDF is commonly used to construct subwoofers for permanent installations as its density is relatively high and weatherproofing is not a concern. Other permanent installation subwoofers have used very thick plywood: the Altec 8182 (1981) used 7-ply 28 mm birch-faced oak plywood. Touring subwoofers are typically built from 18–20 mm thick void-free Baltic birch (*Betula pendula* or *Betula pubescens*) plywood from Finland, Estonia or Russia; such plywood affords greater strength for frequently transported enclosures. Not naturally weatherproof, Baltic birch is coated with carpet, thick paint or spray-on truck bedliner to give the subwoofer enclosures greater durability.

Touring subwoofer cabinets are typically designed with features that facilitate moving the enclosure (e.g., wheels, a "towel bar" handle and recessed handles), a protective grill for the speaker (in direct radiating-style cabinets), metal or plastic protection for the cabinets to protect the finish as the cabinets are being slid one on top of another, and hardware to facilitate stacking the cabinets (e.g., interlocking corners) and for "flying" the cabinets from stage rigging.

Full-range system

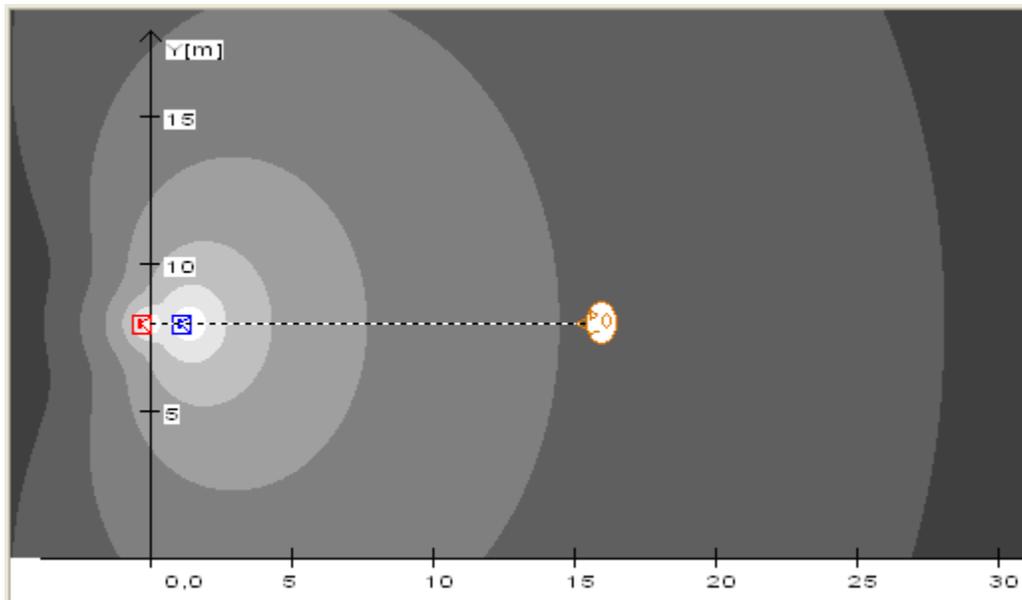
In professional concert sound system design, subwoofers can be incorporated seamlessly with the main speakers into a stereo or mono full-range system by using an active crossover. Such a system receives its signal from the main mono or stereo mixing console mix bus and amplifies all frequencies together in the desired balance. If the main sound system is stereo, the subwoofers can also be in stereo. Otherwise, a mono subwoofer

channel can be derived within the crossover from a stereo mix, depending on the crossover make and model.

Aux-fed subwoofers

Instead of being incorporated into a full-range system, concert subwoofers can be supplied with their own signal from a separate mix bus on the mixing console; often one of the auxiliary sends ("aux" or "auxes") is used. This configuration is called "aux-fed subwoofers", and has been observed to significantly reduce low frequency "muddiness" that can build up in a concert sound system which has on stage a number of microphones each picking up low frequencies and each having different phase relationships of those low frequencies. The aux-fed subs method greatly reduces the number of sources feeding the subwoofers to include only those instruments that have desired low frequency information; sources such as kick drum, bass guitar, samplers and keys. This simplifies the signal sent to the subwoofers and makes for greater clarity and low punch. Aux-fed subs can even be stereo, if desired, using two auxiliary mix buses.

Directional bass



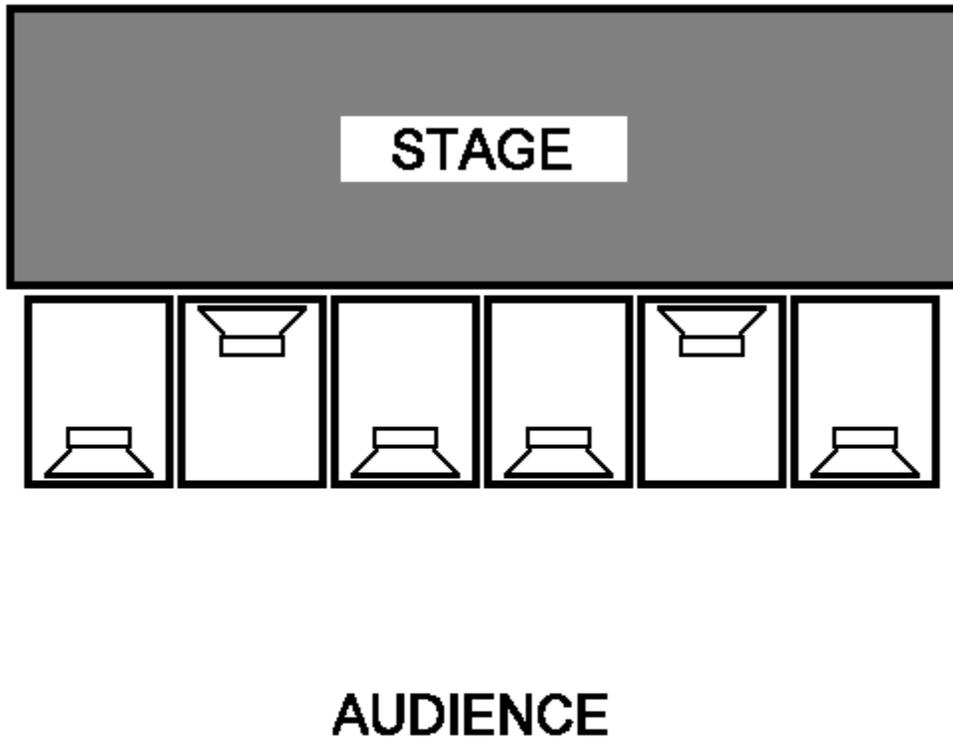
Cardioid dispersion pattern of two end-fire subwoofers placed one in front of the other. The enclosure nearest the listener is delayed by a few milliseconds.

In order to keep low frequency energy focused on the audience area and not on the stage, and to keep low frequencies from bothering people outside of the event space, a variety of techniques have been developed in concert sound to turn the naturally omnidirectional radiation of subwoofers into a more directional pattern. These techniques include setting up subwoofers in a vertical array; using combinations of delay and polarity inversion; and setting up a delay-shaded system.

Vertical array

Stacking or rigging the subwoofers in a vertical array focuses the low frequencies forward to a greater or lesser extent depending on the physical length of the array. Longer arrays have a more directional effect at lower frequencies. The directionality is more pronounced in the vertical dimension, yielding a radiation pattern that is wide but not tall. This helps reduce the amount of low frequency sound bouncing off the ceiling indoors and assists in mitigating external noise complaints outdoors.

Rear delay array



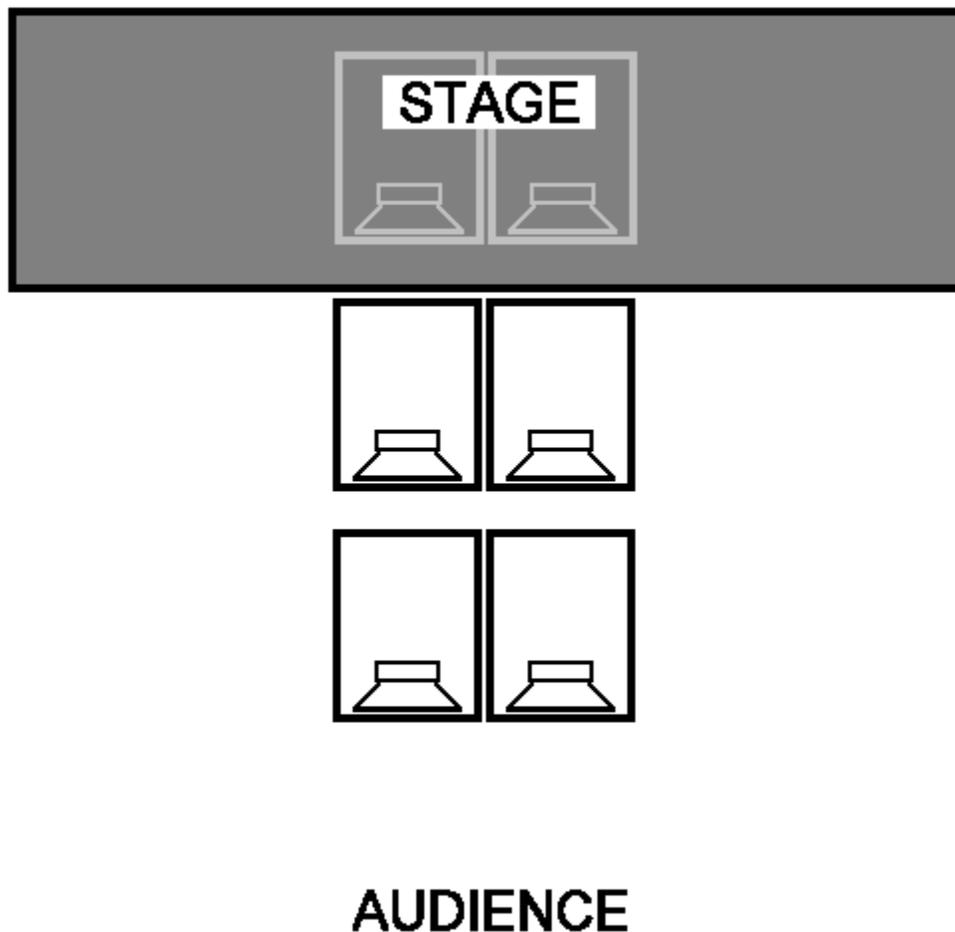
CSA: Six subwoofers arranged for less bass energy on stage. Signal going to the reversed enclosures is delayed a few milliseconds.

Another cardioid subwoofer array pattern can be used horizontally, one which takes few channels of processing and no change in required physical space. Often called "cardioid subwoofer array" or "CSA", though the pattern of all directional subwoofer methods is cardioid, the method inverts the polarity of one out of every three subwoofers across the front of the stage, and delays those enclosures for maximum cancellation of the target

frequency on stage. Polarity inversion can be implemented electronically, or by physically placing the enclosure to face rearward. This method reduces forward output relative to a tight-packed, flat-fronted array of subwoofers, but can solve problems of unwanted low frequency energy coming into microphones on stage. Compared to the end-fire array, this method has less on-axis energy but more even pattern control throughout the audience, and more predictable cancellation rearward. The effect spans a range of slightly more than one octave.

A second method of rear delay array combines end-fire topology with polarity reversal, using two subwoofers positioned front to back, the drivers spaced one-quarter wavelength apart, the rear enclosure inverted in polarity and delayed by a few milliseconds for maximum cancellation on stage of the target frequency. This method has the least output power directed toward the audience, compared to other directional methods.

End-fire array



End-fire array using three rows of subwoofers. Each row is delayed a few milliseconds more than the previous row.

The end-fire subwoofer method, also called "forward steered arrays", places subwoofer drivers co-axially in one or more rows, using destructive interference to reduce emissions to the sides and rear. This can be done with separate subwoofer enclosures positioned front to back with a spacing between them of one-quarter wavelength of the target frequency, the frequency that is least wanted on stage or most desired in the audience. Each row is delayed beyond the first row by an amount related to the speed of sound in air; typically a few milliseconds. The arrival time of sound energy from all the subwoofers is near-simultaneous from the audience's perspective, but is canceled out to a large degree behind the subwoofers because of offset sound wave arrival times. Directionality of the target frequency can achieve as much as 25 dB rear attenuation, and the forward sound is coherently summed in line with the subwoofers. The positional technique of end-fire subwoofers came into widespread use in European live concert sound in 2006.

The end-fire array trades a few decibels of output power for directionality, so it requires more enclosures for the same output power as a tight-packed, flat-fronted array of enclosures. Sixteen enclosures in four rows were used in 2007 at one of the stages of the Ultra Music Festival, to reduce low frequency interference to neighboring stages. Because of the physical size of the end-fire array, few concert venues are able to implement it. The output pattern suffers from comb-filtering off-axis, but can be further shaped by adjusting the frequency response of each row of subwoofers.

Delay-shaded array

A long line of subwoofers placed horizontally along the front edge of the stage can be delayed such that the center subs fire several milliseconds prior to the ones flanking them, which fire several milliseconds prior to *their* neighbors, continuing in this fashion until the last subwoofers are reached at the outside ends of the subwoofer row. This method helps to counteract the extreme narrowing of horizontal dispersion pattern seen with a horizontal subwoofer array. Such delay shading can be used to virtually reshape a loudspeaker array.

Directional enclosure

Some subwoofer enclosure designs rely on drivers facing to the sides or to the rear in order to achieve a degree of directionality. End-fire drivers can be positioned within a single enclosure that houses more than one driver.

Bass instrument amplification

In rare cases, sound reinforcement subwoofer enclosures are also used for bass instrument amplification by electric bass players and synth bass players. For most bands and most small- to mid-size venues (e.g., nightclubs and bars), standard bass guitar speaker enclosures or keyboard amplifiers will provide sufficient sound pressure levels for onstage monitoring. Since a regular electric bass has a low "E" (41 Hz) as its lowest note, most standard bass guitar cabinets are only designed with a range that goes down to

about 40 Hz. However, in some cases, performers wish to have extended sub-bass response that is not available from standard instrument speaker enclosures, so they use subwoofer cabinets. Just as some electric guitarists add huge stacks of guitar cabinets mainly for show, some bassists will add immense subwoofer cabinets with 18" woofers mainly for show, and the extension sub cabinets will be operated at a lower volume than the main bass cabinets.

Bass guitar players who may use subwoofer cabinets include performers who play with extended range basses that include a low "B" string (about 31 Hz); bassists who play in styles where a very powerful sub-bass response is an important part of the sound (e.g., funk, Latin, gospel, R & B, etc.); and/or bass players who perform in stadium-size venues or large outdoor venues. Keyboard players who use subwoofers for on-stage monitoring include electric organ players who use bass pedal keyboards (which go down to a low "C" which is about 33 Hz) and synth bass players who play rumbling sub-bass parts that go as low as 18 Hz. Of all of the keyboard instruments that are amplified onstage, synthesizers can produce some of the lowest pitches, because unlike a traditional electric piano or electric organ, which have as their lowest notes a low "A" and a low "C", respectively, a synth does not have a fixed lowest octave. A synth player can add lower octaves to a patch by pressing an "octave down" button, which can produce pitches that are at the limits of human hearing.

Several concert sound subwoofer manufacturers suggest that their subs can be used for bass instrument amplification. Meyer Sound suggests that its 650-R2 Concert Series Subwoofer, a 14-square-foot (1.3 m²) enclosure with two 18-inch drivers, can be used for bass instrument amplification. While performers who use concert sound subwoofers for onstage monitoring may like the powerful sub-bass sound that they get onstage, sound engineers may find the use of large subwoofers (e.g., two 18" drivers) for onstage instrument monitoring to be problematic, because it may interfere with the "Front of House" sub-bass sound.

Bass shakers

Since much very low bass is felt, sub-bass can be 'augmented' using tactile transducers. Unlike a typical subwoofer driver, which produces audible vibrations, tactile transducers produce low-frequency vibrations that are designed to be felt by individuals who are touching the transducer or indirectly through a piece of furniture or a wooden floor. Tactile transducers have recently emerged as a device class, called variously "bass shakers", "butt shakers" and "throne shakers". They are attached to a seat, for instance a drummer's stool ("throne") or gamer's chair, car seat or home theater seating, and the vibrations of the driver are transmitted to the body then to the ear in a manner similar to bone conduction. They connect to an amplifier like a normal subwoofer. They can be attached to a large flat surface (for instance a floor or platform) to create a large low frequency conduction area, although the transmission of low frequencies through the feet is not as efficient as the seat.

The advantage of tactile transducers used for low frequencies is that they allow a listening environment that is not filled with loud low frequency waves. This helps the concert drummer to monitor his or her kick drum performance without "polluting" the stage with powerful low frequency waves from a 15" subwoofer monitor. By not having a subwoofer monitor, a bass shaker also enables a drummer to lower the sound pressure levels that he is exposed to during a performance. For home cinema or videogame use, bass shakers help the user avoid disturbing others in nearby apartments or rooms, because even powerful sound effects such as explosion sounds in a war videogame or the simulated rumbling of an earthquake in an adventure film will not be heard by others. However, some critics argue that the felt vibrations are disconnected from the auditory experience, and they claim that that music is less satisfying with the "butt shaker" than sound effects. As well, critics have claimed that the bass shaker itself can rattle during loud sound effects, which can distract the listener.

World record claims

With varying measures upon which to base claims, several subwoofers have been said to be the world's largest, loudest or lowest.

Matterhorn

The Matterhorn is a subwoofer model completed in March 2007 by Danley Sound Labs in Gainesville, Georgia after a U.S. military request for a loudspeaker that could project infrasonic waves over a distance. The Matterhorn was designed to reproduce a continuous sine wave from 15 to 20 Hz, and generate 94 dB at a distance of 250 meters (820 ft), and more than 140 dB for music playback measured at the horn mouth. It can generate a constant 15 Hz sine wave tone at 140 dB for 24 hours a day, seven days a week with extremely low harmonic distortion. The subwoofer has a flat frequency response from 15 to 80 Hz, and is down 3 dB at 12 Hz. It was built within an intermodal container 20 feet (6.1 m) long and 8 by 8 feet (2.4 × 2.4 m) square. The container doors swing open to reveal a tapped horn driven by 40 long-throw 15-inch speaker drivers each powered by its own 1000-watt amplifier. The manufacturer claims that 53 13-ply 18 mm 4-by-8-foot (1.2 × 2.4 m) sheets of plywood were used in its construction, though one of the fabricators wrote that double-thickness 26-ply sheets were used for convenience. A diesel generator is housed within the enclosure to supply electricity when external power is unavailable. Of the constant tone output capability, designer Tom Danley wrote that the "target 94 dB at 250 meters is not the essentially fictional 'burst' or 'peak SPL' nonsense in pro sound, or like the 'death burp' signal used in car sound contests." At the annual National Systems Contractors Association (NSCA) convention in March 2007, the Matterhorn was barred from making any loud demonstrations of its power because of concerns about damaging the building of the Orange County Convention Center. Instead, using only a single 20 amp electrical circuit for safety, visitors were allowed to step inside the horn of the subwoofer for an "acoustic massage" as the fractionally powered Matterhorn reproduced low level 10–15 Hz waves.

Royal Device custom installation

Another subwoofer claimed to be the world's biggest is a custom installation in Italy made by Royal Device primarily of bricks, concrete and sound-deadening material consisting of two subwoofers embedded in the foundation of a listening room. The horn-loaded subwoofers each have a floor mouth that is 2.2 square meters (24 sq ft), and a horn length that is 9.5 meters (31 ft), in a cavity 1 meter (3 ft 3 in) under the floor of the listening room. Each subwoofer is driven by eight 18-inch subwoofer drivers with 100 millimeters (3.9 in) voice coils. The designers assert that the floor mouths of the horns are additionally loaded acoustically by a vertical wooden horn expansion and the room's ceiling to create a 10 Hz "full power" wave at the listening position.

Concept Design 60-inch

A single 60-inch (1,500 mm) diameter subwoofer driver was designed by Richard Clark and David Navone with the help of Dr. Eugene Patronis of Georgia Institute of Technology. The driver was intended to break sound pressure level records when mounted in a road vehicle, calculated to be able to achieve more than 180 dB SPL. It was built in 1997, driven by DC motors connected to a rotary crankshaft somewhat like in a piston engine. The cone diameter was 54 inches (1,400 mm) and was held in place with a 3-inch (76 mm) surround. With a 6-inch (150 mm) peak-to-peak stroke, it created a one-way air displacement of 6,871 cubic inches (112,600 cm³). It was capable of generating 5–20 Hz sine waves at various DC motor speeds—not as a response to audio signal—it could not play music. The driver was mounted in a stepvan owned by Tim Maynor but was too powerful for the amount of applied reinforcement and damaged the vehicle. MTX's Loyd Ivey helped underwrite the project and the driver was then called the MTX "Thunder 1000000" (one million). Still unfinished, the vehicle was entered in an SPL competition in 1997 at which a complaint was lodged against the computer control of the DC motor. Instead of using the controller, two leads were touched together in the hope that the motor speed was set correctly. The drive shaft broke after one positive stroke which created an interior pressure wave of 162 dB. The Concept Design 60-inch was not shown in public after 1998.

MTX Jackhammer

The largest production subwoofer intended for use in automobiles is the MTX Jackhammer by MTX Audio which has a 22-inch (560 mm) diameter cone. The Jackhammer can take a total of 6000 watts sent to dual voice coils moving within a 900-ounce (26 kg) strontium ferrite magnet. The Jackhammer weighs 369 pounds (167 kg) and has an aluminum heat sink. The Jackhammer has been featured on the television show Pimp My Ride.

Kenwood DNX-5120

The **Kenwood DNX-5120** Navigation Receiver is a "full-featured Entertainment and Navigation system with USB Direct Control for iPods or other portable music devices." It features built-in Garmin GPS navigation and includes maps of the United States, Canada, and Puerto Rico. Other prominent features include a 6.1" LCD touchscreen, variable-color illumination of the front panel controls, and two RCA 2V Preouts for system expansion. The majority of this post also applies to the DNX-5220 which is the european equivalent model.

General features

- in-dash DVD/CD player with internal amplifier (22 watts RMS/50 peak x 4 channels)
- fits double-DIN (4" tall) dash openings with surrounds available for many cars such as VW/Seat/Skoda etc.
- 6.1" LCD 16:9 touchscreen display with a TFT active matrix system (resolution of 480 x 234 with 336,960 total pixels - 480H x 234V x RGB). The screen is non-glare and smudge-resistant.
- Front-loading disc-slot.
- Built-in Garmin Navigation Board with USA, Canada, PR, Alaska and Hawaii Mapping - turn-by-turn navigation with spoken street names, and over 6 million of Points of Interest (maps use built-in memory and do not require a disc or other media to be inserted to use). The Garmin navigation interface is very similar to that of other Garmin devices such as the Garmin nuvi. (5120)
- Built-in Garmin Navigation Board with European map - Garmin North Europe City Navigator - turn-by-turn directions with spoken street names with full postcode lookup, traffic avoidance and mapping. (5220)
- Advanced GUI with Variable Illumination and Customizable Start-up
- USB Direct Control - allows connection of a thumb drive, hard drive, or other USB storage device

- iPod Ready - allows direct, speedy control of an iPod, allowing access to music and video (claimed to be the fastest Access to iPod Audio/Video) (requires optional KCA-iP300V cable)
- 2 2V RCA Preouts (F,R/Sub)
- Front Aux Input
- Rear audio/video input
- Rear reverse camera input (if desired, the unit can automatically switch to the rear camera when the car is put into reverse)
- Bluetooth Hands-Free Unit Ready (Requires Optional KCA-BT200 unless the unit model name has 'BT' suffix)
- Satellite Radio Ready (Requires Optional CA-SR20V + Sirius SC-C1 Tuner or KCA-XM100V + XM Mini Tuner) (5120 only)
- HD Radio Ready (requires optional HD radio adapter) (5120 Only, 5220 allows for European DAB connection)
- live traffic and weather data available with optional TMC receiver (5120)
- Built in TMC traffic using RAC traffic data (5220)
- plays DVD-Video, DVD-R/RW, DVD+R/RW, DVD-/+R DL, CD-Audio, CD-R/RW, CD-ROM, DTS-CD, and VCD discs
- plays AAC-LC (.M4a), MP3, WMA, JPEG, MPEG (MPEG1 or MPEG2) files
- allows viewing of JPEGs on CD, DVD, or USB
- 3-band EQ with six preset tone curves - the EQ may be set individually for different audio or video sources
- outputs: 4-channel preamp outputs (front, rear), A/V output, standard speaker outputs
- compatible with most factory steering wheel audio controls (adapter required)
- New units come with a 1 year warranty if purchased from an authorized Kenwood dealer
- Display has adjustable brightness and automatically dims with the vehicle headlights are turned on (if the unit is installed properly by connecting the dimmer wire lead to the vehicle dimmer wire) or at a specified time of day determined by the GPS (if installed)
- Allows Customized Background images
- The unit includes 3 buttons in the front of the unit labeled "NAV," "SRC," and "FNC." The unit also includes a rotary-dial along the left edge of the screen which can be pressed or turned.
- Button illumination can be manipulated to preset or custom colors.
- The unit may be programmed security code. Once the unit has been programmed with a security code, the code must be entered to use the unit after it has been disconnected from power.
- The front and rear channels may be independently set to separate sources ("Dual Zone"). Volume can be adjusted for each zone independently.
- The GPS antenna includes an attached 16.5' cable
- Using an optional FM Traffic Receiver, the navigation system can display and utilize traffic information in select cities. (5220 built in)
- Optional remote control is available

- Advanced Crossover system allows tailoring of system with selectable crossover points for all channels

Firmware and Map Software

- Kenwood released an update to the DNX-5120/DNX-5220 firmware on April 5, 2010. The current firmware version is 3.1, and the firmware can be downloaded from Kenwood's website [here](#).
- Kenwood released an update to the DNX-5120/DNX-5220 firmware on February 26, 2009. The current firmware version is 2.4.0, and the firmware can be downloaded from Kenwood's website [here](#).
- Garmin released an update to the Navigation software for the DNX-5120 on January 26, 2009. The current map firmware version is 2.60, and the firmware can be downloaded [here](#).
- Garmin released the 2009 map update called "City Navigator North America NT 2009", which can be ordered from the Garmin website [here](#). The updates come on DVD media which is inserted into the DNX-5120 unit which automatically updates after the required activation (an activation code must be entered by entering information into the appropriate fields on the Garmin activation webpage. The map update process takes over one hour to complete.
- Garmin has released the 2010 map update named "City Navigator North America NT 2010", which can be ordered from the Garmin website [here](#).
- Users of the optional KCA-BT200 bluetooth module (released in cooperation with Parrot) may download and install the latest firmware, version 1.70 using the links at the bottom of the page [here](#).
- The BT200 firmware has been updated to version 3.12 and can be downloaded [here](#).

Issues, tips, and workarounds

USB support

According to the Kenwood website, the DNX-5120 has the following limitations on files and folders stored on USB devices:

- Maximum number of folder layers: 8
- Maximum number of folders (per device): 126
- Maximum number of files (per folder): 255
- Maximum number of files (per device): 15000
- Maximum number of files per playlist: 7000

Folders outside of this limit are inaccessible and appear in the folder list, but they cannot be selected. This limitation does not appear to apply to iPods.

In addition to data volume limitations, there are also hardware compatibility limitations for USB devices used with the DNX5120:

- Utilizes standard USB 1.1 and USB 2.0 connection types
- Data transfer Speeds of up to 12Mbps
- USB class Mass storage class (MSC device)
- USB subclass SCSI
- Can operate on a maximum supply of 500 mA

Some users have also had issues with the USB device being recognized on startup. If the device is attached when the car is turned on, the device is sometimes not recognized.

Another issue with USB playback is that the device currently does not allow fast-forward or rewind of the current playing track (this is possible during playback on other media, such as CD or DVD). Full tracks may be advanced or reviewed; however, the seeking is not enabled through the currently playing track.

It should also be noted the maximum drive size is 32gb, formatted with FAT32. Unlike the documentation states, the unit displays files in the order they were written to the drive, not alphabetical as Kenwood claims.

Album Art

Album art for MP3 and WMA files will be displayed on the DNX-5120 if the album art files are embedded as ID3 metadata tags on the audio files. A jpeg picture file in the folder with the audio files is not required.. Many music organization or mp3 tag editing software packages can encode the album art this way, and users have reported that MediaMonkey and Tagclinic as working solutions.

Video Size and Framerate

According to the Kenwood website, the DNX-5120 has the following size and bitrate limitations on video file playback

- For MPEG1: Picture size of 352×240 or 352×288 ; Max bitrate of 1.5 Mbit/s.
- For MPEG2: Picture size of 720×480 or 720×576 ; Max bitrate of 2.0 Mbit/s.

However, users have found the following limitations to be more accurate:

- For MPEG2: 3000 kbit/s ("at 3500 I started stuttering").
- CBR vs VBR seems to make a difference. $720 \times 480 @ 3$ kbit/s CBR "worked fine." $480 \times 480 @ 5$ kbit/s CBR "worked fine too".

Safe Mode for navigation and viewing video

Because of traffic safety laws that have been adapted by most of the continental United States, the DNX-5120 includes a safe mode feature which disables on-screen video as well as access to manually entering destinations in the navigation source unless the vehicle's parking brake is engaged.

Custom backgrounds

You can customize the DNX-5210 with your own wallpaper / image by entering the "User Interface" option in the Setup menu. All you need to do is put the image you would like to use on a USB flash drive and plug it into the 5210's USB port, the image must be JPEG and stored in a folder on the drive. The DNX-5120 will not warp images to meet the resolution size of the screen. It will, however, raster the image to meet either the vertical or horizontal screen resolution; whichever is closest to the images' size ratio. In order to meet the full resolution of the screen an image will need to be manually resized to 480x250 pixels. Although the actual resolution is 480 x 234, if you load a graphic at the exact resolution, you will see bars at the top and bottom of the screen.

To display your background image only and none of the user interface buttons, select the audio source you wish to listen to. Then press the src button on the left hand side of the head unit. Now press and hold the select source soft button in the top left hand of the screen. Your user interface should disappear and all that will be displayed will be your background image. To get your user interface buttons back, simply tap the screen anywhere.

USB Hubs

USB Hubs cannot be used with the DNX-5120. However, a USB Hub can be used to allow the connection of an iPod as well as a USB storage device simultaneously, however the DNX-5120 will not actively read data from multiple devices at the same time..

HD radio presets

When using the HD Radio adapter (KTC-HR200), some users have reported that the radio presets are not saved when the car is turned off and back on again. Kenwood attributes this problem to outdated software that can not be updated at home. Unit can be sent in to a service center to be updated and resolve preset loss problem..

Mini-USB port

The mini-USB port found on the back of the DNX-5120 is used to connect the GTM-10 FM receiver navigation traffic module. The mini usb at the rear of the device can be used as an efficient way to upload custom maps to the garmin system. This can only be done using the mapsource software from Garmin

Settings Amnesia

Setting data loss can occur on navigation and main unit software if the power level drops too low or is interrupted when the unit is in a certain state. This can be caused when starting your engine - particularly Diesels. The settings for the main unit software and sound stage settings can be memorised and reset when this happens. If this happens to the navigation module, it will revert the user back to the initial setup, i.e. country and

language selection and your recent finds etc will be lost. - there are no options to store preferences in a backup file for this part. The Navigation or Main Unit software can lock up independently. i.e. menu or display frozen but playback or navigation continues. To avoid this every happening, simply turn the unit off before you start the engine. -Its the hesitation on startup for the glow-plugs heating that tends to make this worse on Diesels.

5120 and 5220 Differences

The majority of the system is the same, the firmware is identical and the connections are the same across these models. The largest noticeable difference is that XM Radio is not available in the UK or Europe, instead the 'equivalent' system for these services is DAB (digital audio broadcasting). This leads to different hardware requirements because DAB is land-based like FM rather than satellite based which would have been far better. The 5220 has FM traffic built-in to the navigation module, but are otherwise the same.

Custom Points of Interest

You can use Garmin POI editor to enter custom POI's or convert them from those used by TOMTOM etc. Its possible to convert complete police cash point databases that warn you for zones and particular cameras.

Chapter- 7

FM Transmitter



Belkin TuneCast transmitter, for use with any device which has a 3.5mm headphone jack. Frequency range is 88.1 - 88.3 - 88.5 - 88.7 MHz



Belkin TuneCastII FM Transmitter with a modified antenna connected to a fifth generation iPod video.

An **FM transmitter** is a portable device that plugs into the headphone jack or proprietary output port of a portable audio or video device, such as a portable media player, CD player, or satellite radio system. The sound is then broadcast through the transmitter, and plays through an FM broadcast band frequency. Purposes for an FM transmitter include playing music from a device through a car stereo, or any radio.

The FM-transmitter plugs into the audio output of audio devices and converts the audio output into an FM radio signal, which can then be picked up by appliances such as car or portable radios. Most devices on the market typically have a short range of up to 30 feet (9 meters) with any average radio (up to about 75 feet (23 meters) with a very good radio under perfect conditions) and can broadcast on any FM frequency from 76.0 to 108.0 MHz (or 88.1 to 107.9 in the US). Some lower-cost transmitters are hard-wired to the 87.7–91.9 MHz band allocated to educational broadcasts in the United States, or a certain other smaller range of frequencies.

FM transmitters are usually battery driven, but some use the cigarette lighter socket in cars, or draw their power from the device itself. They are typically used with portable

audio devices such as CD or MP3 players, but are also used to broadcast other outputs (such as that from a computer sound card) throughout a home or other building.

Limitations

- The relatively low power output of FM transmitters sometimes makes it unsuitable for use in some large urban areas because of the number of other radio signals. This is compounded by the fact that strong FM signals can bleed over into neighboring frequencies making the frequencies unusable with the transmitter. Removing a car's radio antenna has been found to significantly improve transmitter reception.
- Some models which connect via ports other than the headphone jack have no means of controlling the volume, which can force the sound to transmit out from the device harshly (causing over modulation, audio distortion and possible radio interference), or too low. In theory a device could use an automatic level control or audio limiter circuit to overcome this problem although there are few (if any) devices with such a facility available out on the market yet.

European legality of FM transmitters

The European Union's Radio Spectrum body the ERO (European Radiocommunications Office) has recently introduced a recommendation document (Table/Annex 13) for Member States to include Transmitters in the FM Band for Music Devices. The underlying specification suggests that the radio transmitter will only emit a maximum of 50 nanowatts Effective radiated power. It is not known what the current "iTrip" device emits although it is known that some devices supposedly manufactured to the US "FCC Part 15" standard emit considerably more. It also has to be ratified and entered into law in each European State, meaning that consultation will normally take place with the users of the spectrum in each country, a protracted and sometimes lengthy process. Until the recommendation is put in place and the law in the country of residence changed, an FM transmitter remains illegal to operate in many EU countries. Due to the minuscule range of these devices the existing legislation is rarely enforced against end users, although retailers in some jurisdictions have been threatened with prosecution.

Within the European Radiocommunications Office in the case the of the Members States that also belong to the European Union the situation is as follows. In 2006, the legislative powers for harmonisation of the technical conditions for use of spectrum for a wide variety of short-range devices, including applications such as alarms, local communications equipment, door openers and medical implants were transferred from the EU Member States to the European Union by Decision of the European Commission 2006/771/EC. Therefore European States no longer have legislative powers in this field, but the powers to police and impose sanctions for non-respect of this EU acts remain in the hands of the Member States. Following the recommendation of the European Radiocommunications Office, by Decision of the European Commission 2009/381/CE amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by short-range devices , in the frequencies of 87,5-108 MHz, it is allowed to use micro FM

transmitters of less than 50 nanowatts Effective radiated power. Since then, these FM transmitters are automatically allowed to enter and being marketed in the territory of the European Union for the use of consumers, as long as they have the CE mark. For countries that belong to the European Radiocommunications Office but are not Member States of the European Union, national law applies and reference has to be made to legal procedures of each country.

UK legality developments

Regulations to legalise the use of certain types of FM transmitter came into force on 8 December 2006. From the end of 2006 the iTrip and other FM transmitters can be used without licence in the United Kingdom. To be legal, it must carry a CE mark which indicates their approval for sale in the European Union. Some FM transmitters have been manufactured for sale and use specifically in the US. These devices do not carry a CE mark and will remain illegal to use in the UK.

The new Regulations set out the technical specifications for legal devices. This is to minimise the risk of interference to other radio devices. In particular, the Regulations set a 50 nanoWatts power limit for legal devices, which limits the distance at which they can broadcast to up to 8 metres.

The changes to the Wireless Telegraphy Act 1949 were announced in a statement from Ofcom.

Use of FM transmitters is now governed by Wireless Telegraphy Exemption Regulations

Models

There are several universal models, as well as those specifically designed for and by certain leading brands; for instance, Griffin Technology manufactures the iTrip which can exclusively be used on iPods. Other examples of FM transmitters are Whole House FM Transmitter, Arkon's SoundFeeder, My FM Station's models, or Belkin's FM TuneCast. Belkin manufactures a premium FM transmitter for iPods called the TuneBase FM with ClearScan. This device mounts an iPod on a sturdy flexible arm (which encases the fm transmitter and power connectors) and allows the iPod to be charged from a car cigarette lighter or power outlet.



Fourth-generation iPod with iTrip.

Most electronic retail stores sell several different models of FM transmitter, including generic brands, which may vary greatly in price, even though quality of audio is indistinguishable. However, the signal strength varies. Even though several models of MP3 player have built-in FM receivers; other models have had built-in FM transmitters to eliminate the need for a separate device. Some cheaper brand units can exhibit very poor audio quality with sibilance (distorted T and S sounds) and poor stereo imaging.

Telematics

Telematics typically is any integrated use of telecommunications and informatics, also known as ICT (Information and Communications Technology). Hence the application of telematics is with any of the following:



Lexus Gen V navigation system

- The technology of sending, receiving and storing information via telecommunication devices in conjunction with effecting control on remote objects.

- The integrated use of telecommunications and informatics, for application in vehicles and with control of vehicles on the move.
- Telematics includes but is not limited to Global Positioning System technology integrated with computers and mobile communications technology in automotive navigation systems.
- Most narrowly, the term has evolved to refer to the use of such systems within road vehicles, in which case the term **vehicle telematics** may be used.

In contrast *telemetry* is the transmission of measurements from the location of origin to the location of computing and consumption, especially without effecting control on the remote objects. Telemetry is typically applied in testing of flight objects.

Although the majority of devices that integrate telecommunications and information technology are not vehicles but rather mobile phones and the like, their use is not included in telematics.

Vehicle telematics

The etymology of *telematics*, as determined by Automotive Telematics author and academic Dennis Foy, is from the Greek "tele" ('far away', especially in relation to the process of producing or recording) and ~Matos (a derivative of the Greek machinari, or contrivance, usually taken in this context to mean 'of its own accord'). As combined, the term "telematics" describes the process of long-distance transmission of computer-based information. It was first introduced in French by Simon Nora and Alain Minc in *L'informatisation de la Société* (La Documentation Française, 1978)

Telematics —

1. The convergence of telecommunications and information processing, the term later evolved to refer to automation in automobiles, such as the invention of the emergency warning system for vehicles. GPS navigation, integrated hands-free cell phones, wireless safety communications and automatic driving assistance systems all are covered under the telematics umbrella.
2. The science of **Tele**communications and **Informatics** applied in wireless technologies and computational systems. 802.11p, the IEEE standard in the 802.11 family and also referred to as Wireless Access for the Vehicular Environment (WAVE), is the primary standard that addresses and enhances Intelligent Transportation System.
3. Emad Isaac, CTO of the Morey Corporation defines Telematics as "The potential for collection, aggregation, and storage of pertinent data that can be digested locally, or post-processed remotely." While this definition suggests a more universally applicable technology as a superset of M2M (Machine to Machine) connectivity, and as part of an "intelligent network of connected things", the term is rare outside the vehicle market.

Practical applications of vehicle telematics

When used in a commercial environment vehicle telematics can potentially be a powerful and valuable tool to improve the efficiency of an organization. Some practical applications of vehicle telematics include;

Telematics education

A project entitled the European Automotive Digital Innovation Studio (EADIS) has been awarded 400,000 Euros from the European commission under its Leonardo programme. EADIS will use a virtual work environment called the Digital Innovation Studio to train and develop professional designers in the automotive industry in the impact and application of ‘vehicle telematics’ so that they may integrate new technologies into future products within the automotive industry.

Leonardo da Vinci is a European Community programme which aims to support national training strategies through funding a range of transnational partnership projects aimed at improving quality, fostering innovation and promoting the European dimension in vocational training. The programme promotes transnational projects based on co-operation between the various players in vocational training - training bodies, vocational schools, universities, businesses, chambers of commerce, etc. - in an effort to increase mobility, to foster innovation and to improve the quality of training. The Leonardo da Vinci programme aims at helping people improve their skills throughout their lives.

“The European automotive industry is losing competitiveness as challengers from lower-cost economies have increased their share of world automotive markets” (CLEPA, European Association of automotive supplier’s White paper 2005). As a European solution to this problem, EADIS will develop training and infrastructure to enable European companies to operate more innovatively and efficiently.

This project is executed in partnership with:

- Coventry University (CEPAD), UK
- Oulu University of Applied Sciences, Finland
- Munster University of Applied Sciences, Germany
- Turin Polytechnic, Italy
- Technical University of Delft, the Netherlands

An Advisory panel made up of industry representatives including RDM automotive, Ricardo and MIRA has been set up to evaluate the project. All the partners are looking forward to developing the project and using it as a platform for building relationships and collaborating internationally with other universities and industry partners.

Vehicle tracking

Vehicle tracking is a way of monitoring the location, movements, status and behaviour of a vehicle or fleet of vehicles. This is achieved through a combination of a GPS(GNSS) receiver and an electronic device (usually comprising a GSM GPRS modem or SMS sender) installed in each vehicle, communicating with the user (dispatching, emergency or co-ordinating unit) and PC- or web-based software. The data are turned into information by management reporting tools in conjunction with a visual display on computerised mapping software. Vehicle tracking systems may also use odometry or dead reckoning as an alternative or complementary means of navigation.

Trailer tracking

Trailer tracking is the technology of tracking the movements and position of an articulated vehicle's trailer unit, through the use of a location unit fitted to the trailer and a method of returning the position data via mobile communication network or geostationary satellite communications, for use through either PC- or web-based software.

Cold store

Cold store freight trailers that are used to deliver fresh or frozen foods are increasingly incorporating telematics to gather time-series data on the temperature inside the cargo container, both to trigger alarms and record an audit trail for business purposes. An increasingly sophisticated array of sensors, many incorporating RFID technology, are being used to ensure that temperature throughout the cargo remains within food-safety parameters.

Fleet management

Fleet management is the management of a company's vehicle fleet. Fleet management includes the management of ships and or motor vehicles such as cars, vans and trucks. Fleet (vehicle) Management can include a range of Fleet Management functions, such as vehicle financing, vehicle maintenance, vehicle telematics (tracking and diagnostics), driver management, fuel management and health & safety management. Fleet Management is a function which allows companies which rely on transportation in their business to remove or minimize the risks associated with vehicle investment, improving efficiency, productivity and reducing their overall transportation costs, providing 100% compliancy with government legislation and Duty of Care obligations. These functions can either be dealt with by an in-house Fleet Management department or an outsourced Fleet Management provider.

The Association of Equipment Management Professionals (AEMP) successfully developed the industry's first Telematic Standard.

In 2008, AEMP brought together the major construction equipment manufacturers and telematics providers in the heavy equipment industry to discuss the development of the industry's first telematics standard. Following agreement from Caterpillar, Volvo CE, Komatsu, and John Deere Construction & Forestry to support such a standard, the AEMP formed a standards development subcommittee, chaired by Pat Crail CEM, to develop the standard. This committee consisted of developers provided by the Caterpillar/Trimble joint venture known as Virtual Site Solutions, Volvo CE, and John Deere. Will McFadyen of McFadyen & Associates provided expertise derived through years of integrating telematics data from various providers into a wide variety of customer fleet management, estimating, and accounting systems. This group worked from February 2009 through September 2010 to develop the industry's first standard for the delivery of telematics data.

The result, the AEMP Telematics Data Standard V1.1, was released in 2010 and officially went live on October 1st, 2010. As of November 1, 2010, Caterpillar, Volvo CE, John Deere Construction & Forestry, OEM Data Delivery, and Navman Wireless are able to support customers with delivery of basic telematics data in a standard xml format. Komatsu, Topcon, and others are finishing beta testing and have indicated that they will be able to support customers before the end of 2010.

The AEMP's telematics data standard was developed to allow end users to integrate key telematics data (operating hours, location, fuel consumed, and odometer reading where applicable) into their existing fleet management reporting systems. As such, the standard was primarily intended to facilitate importation of these data elements into enterprise software systems such as those used by many medium to large construction contractors. Prior to the standard, end users had few options for integrating this data into their reporting systems in a mixed-fleet environment consisting of multiple brands of machines and a mix of telematics-equipped machines and legacy machines (those without telematics devices where operating data is still reported manually via pen and paper). One option available to machine owners was to visit multiple websites to manually retrieve data from each manufacturer's telematics interface and then manually enter it into their fleet management program's database. This option was cumbersome and labor-intensive.

A second option was for the end user to develop an API (Application Programming Interface), or program, to integrate the data from each telematics provider into his or her database. This option was quite costly, as each telematics provider had a different procedure for accessing and retrieving the data and the data format varied from provider to provider. This option automated the process, but because each provider required a unique, custom API to retrieve and parse the data, it was an expensive option. In addition, another API had to be developed any time another brand of machine or telematics device was added to the fleet.

A third option for mixed-fleet integration was to replace the various factory-installed telematics devices with devices from a third party telematics provider. Although this solved the problem of having multiple data providers requiring unique integration methods, this was by far the most expensive option. In addition

to the expense, many of the third-party devices available for construction equipment are unable to access data directly from the machine's electronic control modules (ECMs), or computers, and as such are more limited than the device installed by the OEM (Cat, Volvo, Deere, Komatsu, etc) in the data they are able to provide. In some cases, these devices are limited to location and engine run time, although they are increasingly able to accommodate a number of add-on sensors to provide additional data.

The AEMP Telematics Data Standard provides a fourth option. By concentrating on the key data elements that drive the majority of fleet management reports (hours, miles, location, fuel consumption), making those data elements available in a standardized xml format, and standardizing the means by which the document is retrieved, the standard allows the end user to use one API to retrieve data from any participating telematics provider. Because one API can retrieve data from any participating telematics provider, as opposed to the unique API for each provider that was required previously, integration development costs are greatly reduced.

Satellite navigation

Satellite navigation in the context of vehicle telematics is the technology of using a GPS and electronic mapping tool to enable the driver of a vehicle to locate a position, then route plan and navigate a journey.

Mobile data and mobile television

Mobile data is use of wireless data communications using radio waves to send and receive real time computer data to, from and between devices used by field based personnel. These devices can be fitted solely for use while in the vehicle (Fixed Data Terminal) or for use in and out of the vehicle (Mobile Data Terminal).

Mobile data can be used to receive TV channels and programs, in a similar way to mobile phones, but using LCD TV devices.

Wireless vehicle safety communications

Wireless vehicle safety communications telematics aid in car safety and road safety. It is an electronic sub-system in a car or other vehicle for the purpose of exchanging safety information, about such things as road hazards and the locations and speeds of vehicles, over short range radio links. This may involve temporary ad hoc wireless local area networks.

Wireless units will be installed in vehicles and probably also in fixed locations such as near traffic signals and emergency call boxes along the road. Sensors in the cars and at the fixed locations, as well as possible connections to wider networks, will provide the information, which will be displayed to the drivers in some way. The range of the radio links can be extended by forwarding messages along multi-hop paths. Even without fixed units, information about fixed hazards can be maintained by moving vehicles by passing

it backwards. It also seems possible for traffic lights, which one can expect to become smarter, to use this information to reduce the chance of collisions.

Further in the future, it may connect directly to the adaptive cruise control or other vehicle control aids. Cars and trucks with the wireless system connected to their brakes may move in convoys, to save fuel and space on the roads. When any column member slows down, all those behind it will automatically slow also. There are also possibilities that need less engineering effort. A radio beacon could be connected to the brake light, for example.

Network ideas are scheduled for test in fall 2008, in Europe where radio frequency bandwidth has been allocated. The 30 MHz allocated is at 5.9 GHz, and unallocated bandwidth at 5.4 GHz may also be used. The standard is IEEE 802.11p, a low latency form of the Wi-Fi local area network standard. Similar efforts are underway in Japan and the USA.

Emergency warning system for vehicles

Telematics technologies are self-orientating open network architecture structure of variable programmable intelligent beacons developed for application in the development of intelligent vehicles — with target intent to accord (blend, or mesh) warning information with surrounding vehicles in the vicinity of travel, intra-vehicle, and infrastructure. Emergency warning system for vehicles telematics particularly developed for international harmonisation and standardisation of vehicle-to-vehicle — infrastructure-to-vehicle — and vehicle-to-infrastructure real-time Dedicated Short Range Communication (DSRC) systems.

Telematics most commonly relate to computerised systems that update information at the same rate as they receive data, enabling them to direct or control a process such as an instantaneous autonomous warning notification in a remote machine or group of machines. By use of telematics as applied to intelligent vehicle technologies, instantaneous direction travel cognizance of a vehicle may be transmitted in real-time to surrounding vehicles traveling in the local area of vehicles equipped (with EWSV) to receive said warning signals of danger.

Intelligent vehicle technologies

Telematics comprise electronic, electromechanical, and electromagnetic devices — usually silicon micromachined components operating in conjunction with computer controlled devices and radio transceivers to provide precision repeatability functions (such as in robotics artificial intelligence systems) emergency warning validation performance reconstruction.

Intelligent vehicle technologies commonly apply to car safety systems and self-contained autonomous electromechanical sensors generating warnings that can be transmitted within a specified targeted area of interest, say within 100 meters of the emergency

warning system for vehicles transceiver. In ground applications, intelligent vehicle technologies are utilized for safety and commercial communications between vehicles or between a vehicle and a sensor along the road.

On November 3, 2009 the most advanced Intelligent Vehicle concept car was demonstrated in New York City. A 2010 Toyota Prius became the first LTE Connected Car. The demonstration was provided by the NG Connect project, a collaboration of automotive telematic technologies designed to exploit in-car 4G wireless network connectivity.

Car clubs

Telematics technology has allowed car clubs to emerge, such as City Car Club in the UK. Telematics-enabled computers allow organisers to track members' usage and bill them on a pay-as-you-drive. Car Clubs such as Australia's Charter Drive use telematics to monitor and report on vehicle use within pre-defined geofence areas, in order to demonstrate the reach of their transit media car club fleet.

Auto insurance

The basic idea of telematic auto insurance is that a driver's behavior is monitored directly while the person drives and this information is transmitted to an insurance company. The insurance company then assesses the risk of that driver having an accident and charges insurance premiums accordingly. A driver who drives long distance at high speed, for example, will be charged a higher rate than a driver who drives short distances at slower speeds.

Telematic auto insurance was independently invented and patented by a major U.S. auto insurance company, Progressive Auto Insurance U.S. Patent 5,797,134 and a Spanish independent inventor, Salvador Minguijon Perez (European Patent EP0700009B1). The Progressive patents cover the use of a cell phone and GPS to track movements of a car. The Perez patents cover monitoring the car's engine control computer to determine distance driven, speed, time of day, braking force, etc. Ironically, Progressive is developing the Perez technology in the US and European auto insurer Norwich Union is developing the Progressive technology for Europe.

Trials conducted by Norwich Union in 2005 have found that young drivers (18 to 23 year olds) signing up for telematic auto insurance have had a 20% lower accident rate than average.

Recent theoretical economic research on the social welfare effects of Progressive's telematics technology business process patents have questioned whether the business process patents are pareto efficient for society. Preliminary results suggest that it is not, but more work is needed.

Chapter- 9

Car Alarm



Car alarm siren

A **car alarm** is an electronic annoyance device installed in a vehicle in an attempt to discourage theft of the vehicle itself, its contents, or both. Car alarms work by emitting high-volume sound (usually a siren, klaxon, pre-recorded verbal warning, the vehicle's own horn, or a combination thereof) when the conditions necessary for triggering are met, as well as by flashing some of the vehicle's lights, and (optionally) notifying the car's owner via a paging system and interrupting various electrical circuits necessary for the car to start.

Features

Car alarms should not be confused with immobilizers; although the purpose of both may be to deter car theft, they operate in a dissimilar fashion. An immobilizer generally will not offer any audible or visual theft deterrence, nor require any additional input from the driver than from the driver of a non-immobilizer car.

Car alarms can be divided into two categories:

- OEM (built-in to the vehicle at the factory)
- Aftermarket (installed at any time after the car has been built, such as by the new car dealer, an auto accessories store, or the vehicle's owner)

Alarms come with a mix of features. Remote car alarms typically consist of an additional radio receiver that allows the owner to wirelessly control the alarm from a key fob. Remote car alarms typically come equipped with an array of sensors along with immobilizers and motion detectors.

Keyless remote car alarms are typically based on strong cryptography authentication methods:

- Radio receiver
- Immobilizer
- Motion detector
- Wireless USB

Arming and disarming of car alarms

OEM alarms

Almost all OEM alarms are typically armed and disarmed with the vehicle's keyless entry remote. These devices often allow owner to honk or make other high frequency noises for no apparent reason. On many vehicles the key cylinders in the driver or front passenger door activate switches, so that when a key is used in the door the alarm will arm or disarm. Some vehicles will arm when the power door lock switch is pressed with the driver's door open, and the door is subsequently closed. Some vehicles will disarm if the ignition is turned on; often when the vehicle is equipped with a key-based immobilizer and an alarm, the combination of the valid key code and the ignition disarms the system.

Aftermarket alarms

Like OEM alarms, aftermarket systems are usually armed and disarmed via remote. Usually they do not have provisions for external disarming from the key cylinder, but will typically have an override switch mounted in a hidden location.

Alarm triggers

The individual triggers for a car alarm vary widely, depending on the make and model of the vehicle, and the brand and model of the alarm itself (for aftermarket alarms). Since aftermarket alarms are designed to be universal (i.e., compatible with all 12 volt negative ground electrical systems as opposed to one carmaker's vehicles), these commonly have trigger inputs that the installer/vehicle owner chooses not to connect, which additionally determines what will set the alarm off.

OEM alarm triggers

Generally, OEM alarms monitor the doors and trunk/hatch for unauthorized entry. On some vehicles this is done through pin switches, mercury switches, or microswitches integrated into the latch. On others, the doorlock mechanisms have switches built into them. Some OEM alarms additionally will trigger if the hood is opened, or if the ignition is turned on. Additionally a few systems have a shock sensor which will trigger upon a significant impact to the vehicle's body.

Aftermarket alarm triggers

The simplest aftermarket alarms are one-piece units with a siren and control module. Such a unit will typically contain a shock sensor and two wires (12 volt constant power and ground) which are connected to the car's battery. This type of alarm is triggered by vibration transferred to the shock sensor, or by voltage changes on the input (the alarm assumes that a sudden change in voltage is due to a door or trunk being opened, or the ignition being turned on); however it is very prone to false triggers on late-model vehicles with many electronic control modules, which can draw current with the ignition off. For this last reason these alarms are increasingly becoming obsolete.

More sophisticated aftermarket alarms are wired in to the vehicle's electronics individually. Typically, these alarms have inputs for power and ground, as well as for positive- and negative-switched door open circuits, negative trunk and/or hood circuits, and ignition-switched circuits to detect the ignition being turned on; aftermarket alarms also usually have a shock sensor which may be built into the control module or external to it.

In addition, some aftermarket alarms have provisions for optional sensors which can sense the vehicle being tilted (this alerts against unauthorized towing), glass breakage (which can sometimes be done without an impact sufficient to trigger the shock sensor),

or motion inside or immediately outside the vehicle (this is a concern on convertibles). Microwave detectors are frequently used for this

The sensors mentioned here are usually adjustable in order to avoid false alarms - for example a shock sensor will sometimes vibrate due to a loud noise in the area, or an accidental bump to the car from a passerby. This can cause the alarm to falsely sense an attempted break-in.

Some alarms will bypass some or all of the inputs at times by design. For example, Directed Electronics alarms have a feature called "Nuisance Prevention Circuitry" which ignores any input which has triggered 3 times within 1 hour, unless the car owner turns the ignition on to reset it.

Other alarms can bypass some of their inputs via a button combination on the remote, or when remote starting (if the alarm supports this feature).

Effectiveness of car alarms



Vehicle with broken window.

Since most car alarms are triggered accidentally (frequently because of high sensitivity settings), people often ignore alarms. The New York City Police Department claims that car alarms are actually making the crime problem worse because false alarms are so common that people simply ignore them.

Because of the large number of false alarms with car alarms, many vehicle manufacturers no longer factory-fit simple noise-making alarms, instead offering silent—but effective—immobilizers. Alternatively, an aftermarket vehicle tracking system can enable the police to trace stolen vehicles. Most police tracking systems require the user to pay a recurring fee, whereas factory immobilizers are included in the purchase price of the vehicle. GPS locating systems enable the owner of the vehicle to lock and unlock, track, and disable the starter of the vehicle online.

Frequently, false alarms occur because car alarm owners use high sensitivity settings. This is the main reason why loud bass frequency sound (loud music, other cars or motorcycles with loud exhaust systems, thunderstorms, etc.) can set off car alarms. The second possible reason is that some parts of the alarm system may be improperly installed. For example, a typical mistake is that the microwave sensor is not pointed upward as intended. A third possible reason is that the shock sensor is mounted to bad surface, where all the vibrations caused by sound leads to shock sensor. If reducing sensitivity doesn't help, then another way to solve this problem is to place foam (or another soft material that absorbs vibrations/sounds) under the shock sensor or even covering/surrounding the whole shock sensor with foam. It can also become necessary to consider other methods to mount the shock sensor instead of using metal screws. Also, some of the window breakage sensors(the sensors that use microphones to detect broken windows) can false detect window breaking, for example, if someone detonates loud fireworks near the car, causing car windows to rattle.

Yet another class of security covers aftermarket car alarms that include 2-way paging controllers. Some 2-way systems have an LCD icon display that can pinpoint the actual part of the vehicle being threatened, and many alert the user with beeps or silent vibration.

Chapter- 10

Automotive Electronics

Power window

Power windows or **electric windows** (American English) as well as electric or power window **lifts** (British English) are automobile windows which can be raised and lowered by depressing a button or switch, as opposed to using a hand-turned crank handle.

History



Typical window switches with remote disable control on driver's door (1993 Jeep Grand Cherokee).



Window controls on center console between front seats (2005 Saab 9-5).

Packard introduced the first power windows (along with automotive air-conditioning systems) in the 1940 Packard 180 series. This was a hydro-electric system. In 1941, the Ford Motor Company followed quickly with power windows on the Lincoln Custom (only the limousine and seven-passenger sedans). Cadillac had a straight-electric divider window (but not side windows) on their series 75 limousines immediately prior to World War II.

Power assists originated in the need and desire to move convertible body-style tops up and down by some means other than human effort. The earliest power assists were vacuum-operated and were offered on Chrysler Corporation vehicles, particularly the low-cost Plymouth convertibles in the late 1930s.

Shortly before World War II, General Motors developed a central hydraulic pump for working convertible tops. This system was introduced on 1942 convertibles built by GM. Previously, GM had used a vacuum system which did not have the power to handle increasingly larger and complex (four side-windows vs. only two) convertible top mechanisms.

The June and July 2010 issues of "The Self-Starter", the official magazine of the International Cadillac-LaSalle Club, contain references to the use of various types of power window mechanisms in pre-WWII specially modified Cadillac sedans. These Cadillac-built (as opposed to private coachbuilder) models used three types of power mechanisms - straight electric, straight vacuum (much as the power antenna mechanisms used on Cadillacs through 1955) and the soon-to-be-standard electro-hydraulic system. The July 2010 edition also references a 1941 specially modified Cadillac Model 6219 four-door sedan built for the Chairman of the GM Board, Alfred P. Sloan, that had power window mechanisms, although the type is not specified.

Chief Engineer of the Buick Division, Charles A. Chayne, "...had introduced an electrically controlled hydraulic system into the 1946 Buick convertibles that provided fingertip operation of the top, door windows, and front seat adjustment". Apparently Chayne was a pioneer in these types of systems. These systems were based on major hydraulic advances made in military weapons (tanks, aircraft) in preparation for World War II.

The "Hydro-Lectric" system (windows, front seat adjustment and convertible top) was standard on 1947 model year. It was probably standard on the 1946 models; however, no definite source documentation has been located. The seat and window assists were optional on closed cars (standard on some Cadillac Series 75 models). The full system was standard only on the high-end GM convertibles made by Oldsmobile, Buick, and Cadillac. It was only available as a package; that is, power assisted windows, front seat and convertible top (where applicable). This feature can be identified in 1948 and later General Motors model numbers with an "X" at the end, such as the 1951 Cadillac Sixty Special sedan, model 6019X.

Ford also had a similar electro-hydraulic system on higher-end convertibles (Mercury and Lincoln) by 1951. These systems were used by other luxury car models (Imperial and Packard) until Chrysler introduced the all-electric operation on the 1951 Imperial. General Motors also followed with full electric operation in 1954. This included four-way and then six-way seats, which were introduced in 1956. Chevrolet introduced the oddity of power front windows (only) in the 1954 model. Ford also introduced full four-door power windows in 1954.

Electrically-operated vent windows were introduced on 1958 Cadillacs. Some luxury cars in the 1970s and 1980s had as many as fourteen switches on the driver's door for windows (four vent, four main), driver seats (three switches), power door locks, mirror adjustment, power door lock-out, cigarette lighter, and other items.

Modern heavy-duty highway tractors frequently have an option for power window controls; however, these are generally what is referred to as "straight air". That is, the compressed air system used for air brakes is also used for the windows. These types of trucks have long used compressed air cylinders for seat height adjustment. In a similar fashion to the electro-hydraulic system, the compressed air is merely released to lower the window and/or seat. The compressed air is then admitted to the respective cylinder to raise the window or seat.

In a typical auto/light truck installation, there is an individual switch at each window and a set of switches in the driver's door or a-frame pillar, so the driver can operate all the windows. These switches took on many different appearances, from heavy chrome plate to inexpensive plastic.

However, some models like Saab and Holden have used switches located in the center console, where they are accessible to all the occupants. In this case, the door-mounted switches can be omitted.

Operation

Power windows are usually inoperable when the car is not running as the electrical system is not 'live' once the ignition has been turned off. The Hydro-Lectric system; however, could lower the windows at rest, since pressure from the hydraulic system was merely released to lower the window. Raising the windows required the pump to operate (at a fairly high noise level) and introduce pressure at each cylinder. These hydraulic systems also required pressure lines to each cylinder (door, seat and top) and tended to leak.

Many modern cars have a time delay feature, first introduced by Cadillac in the 1980s, called **retained accessory power**. This allows operation of the windows and some other accessories for ten minutes or so after the engine is stopped. Another feature is the **express-down** window, which allows the window to be fully lowered with one tap on the switch, as opposed to holding the switch down until the window retracts. Many luxury vehicles during the 1990s expanded on this feature, to include **express-up** on the driver's window, and recently, some manufacturers have added the feature on all window switches for all passengers convenience. This is done by activating the switch until a "click" response is felt.

Power windows have become so common that by 2008, some automakers eliminated hand cranks from all models. So many vehicles have power windows that some people no longer understand the (formerly) common sign from another driver of using their hand to simulate moving a window crank to indicate that they wish to speak with someone (stopped at a light or in a parking lot).

Safety

Power windows have come under some scrutiny after several fatal accidents in which children's necks have become trapped, leading to suffocation. Some designs place the switch in a location on a hand rest where it can be accidentally triggered by a child climbing to place his or her head out of the window. To prevent this, many vehicles feature a driver-controlled lockout switch, preventing rear-seat passengers (usually smaller children) from accidentally triggering the switches. This also prevents children from using them as toys and pets riding with their heads out windows from activating the power window switch.

Starting with the 2008 model year, U.S. government regulations required automakers to install power window controls that are less likely to be accidentally activated by children. However, the rules do not prevent all potential injuries to a hand, finger, or even a child's head, if someone holds the switch when the window is closing. In 2009, the U.S. auto safety administration tentatively decided against requiring all cars to have automatic reversing power windows if they sense an obstruction while closing. Proposed requirements concern "one-touch" up window systems, but most vehicles with this feature already have automatic-reversing. The federal government made a written contract that all automakers should make the lever switches (as opposed to the rocker and toggle switches) standard on all new vehicles by 1 October 2010.

Power door locks

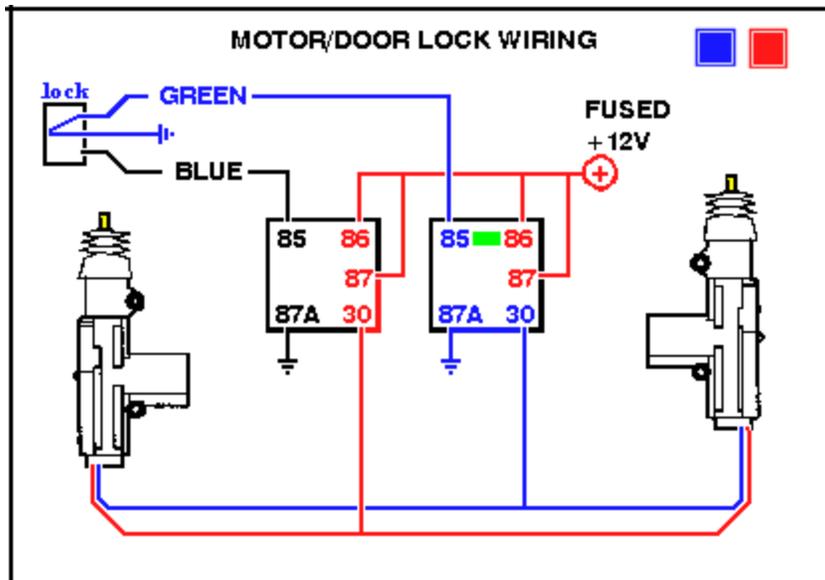
Power door locks (also known as electric door locks or **central locking**) allow the driver or front passenger to simultaneously lock or unlock all the doors of an automobile or truck, by pressing a button or flipping a switch.

Power door locks were introduced on the luxury Scripps-Booth in 1914, but were not common on luxury cars until Packard reintroduced them in 1956. Nearly every car model today offers this feature as at least optional equipment.

Early systems locked and unlocked only the car doors. Many cars today also feature systems which can unlock such things as the luggage compartment or fuel filler cap door.

It is also common on modern cars for the locks to activate automatically when the car is put into gear or reaches a certain speed. Automatic unlocking when the car is parked is usually also featured on such systems.

Power lock system : (Simple relay operation,how it works)



Remote and handsfree



Pressing a button on the key unlocks all of the car doors. Another button locks the car.

Today, many cars with power door locks also have a radio frequency remote keyless system, which allows a person to press a button on a remote control key fob.

In 1980, Ford Motor Company introduced an external keypad-type keyless entry system, wherein the driver entered a numeric combination -- either pre-programmed at the factory or one programmed by the owner -- to unlock the car without the key. Early- to mid-1980s Nissan Maximas could also be installed with a keypad, which would also retract the windows and moonroof once the car was successfully unlocked by pushing a specific button on the keypad.

Currently, many luxury makers also allow the windows to be opened or closed by pressing and holding a button on the remote control key fob, or by inserting the ignition key and holding it in the lock or unlock position in the external driver's door lock. During the early 1990s, Subaru offered infra-red keyless entry on the Japanese Domestic Market Legacy, installing the transmitter in the ignition key. The Legacy could also be opened by pulling the drivers external door handle a specific number of times to enter a passcode number that would unlock the driver's door only.

This system confirms successful (un)locking through either a light or a horn signal, and usually offers an option to switch easily between these two variants. Both provide almost the same functionality, though light signals are more discreet while horn signals might create a nuisance in residential neighborhoods and other busy parking areas (e.g. short-term parking lots). Some manufacturers offer the ability to adjust the horn signal volume.

Other cars have a *proximity* system that is triggered if a keylike transducer (Advanced Key or handsfree) is within a certain distance of the car.

Carputer

Carputer is the predominant term used to describe a category of mobile computer designed or modified to specifically be installed and run in automobiles. Originally these were based on industrial personal computer technology, but as smartphones and PDAs have become more powerful, and have included useful technologies like GPS and Bluetooth, they have become the predominant base platform for developing carputers.

Many do-it-your-selfers have built carputers from laptops and small form factor computers like the Mac Mini.

The recent popularity of carputers has caused the creation of more advanced units that use touch screen interfaces, integrate with vehicles via OBD-II link, and offer a variety of other add-ons like rear-view cameras and GPS. It is now possible to find assembled carputers complete with wireless capabilities and built-in microphones for sale on the internet.

Band expander

An **FM Band Expander** (band converter, fm converter) is a device used on Japanese car stereo systems to enable them to receive international FM. Japanese radio bands are between 76-90 MHz whereas the international broadcast plan is between 87.0-108.0 MHz. The unit itself is connected inline between the radio and the antenna, and it downshifts the frequency of the broadcast by a predetermined amount (generally between 10-14 MHz).

It is powered from the ACC line that is also connected to the stereo unit so it is only operational when the radio is active. Because the Japanese broadcast bandwidth is a smaller range than the international scheme, the unit may have to downshift the same frequencies by 10 and 20 MHz simultaneously. This is to ensure both 'sets' of frequencies get included in the reduced bandwidth, but it can mean that some stations can become doubled up.

Handsfree



Hands-free mobile phone kit fitted to a Saab 9-5.

Handsfree is an adjective describing equipment that can be used without the use of hands (for example via voice commands) or, in a wider sense, equipment which needs only limited use of hands, or for which the controls are positioned so that the hands are able to occupy themselves with another task (such as driving) without needing to hunt far afield for the controls.

Devices that are typically used for handsfree communication use Bluetooth as its wireless technology. They still require a mobile phone or other device to initiate a call. These devices include Bluetooth headsets, hands-free car kits (HFCK), and personal navigation devices (PND). Originally introduced as optional features connected by a wire to mobile phones or other communication devices, they now generally are available with wireless technology.

Bluetooth handsfree options are now also easily found in any high end automotive as part of the vehicle's stereo system, or in after market stereo system units. This option utilizes the vehicle's speakers to transmit the caller's voice in the phone call and have an embedded microphone in the stereo unit itself, the steering wheel, or use a separate wired microphone that can be placed anywhere in the vehicle.

Mobile phones

Handsfree mobile phones are obligatory in many countries for use of a mobile phone while driving. However, studies have shown that even with a hands-free unit, the added distraction to the driver, and the increase in accident rates, are almost as substantial as when driving and talking on a normal mobile phone.

In the United Kingdom, as of 2003, it is illegal to use a handheld mobile phone while driving. Similar laws have been adopted in many jurisdictions worldwide, and many make provisions for hands-free phone use.

Installation of Hands Free devices in the UK is governed by MPT 1362, which is now referred to as FCS 1362. A technical document created and updated by the Federation of Communication Services.

In the USA, several states have banned talking on a hand-held cellphone while driving.

Software Technologies

Since handsfree devices replace a phone's own speaker and microphone capability in a phone call, they now also must deal with the same issues that standard mobile phones and land phones deal with. The main acoustic issues are echo cancellation and noise suppression, although there are others as well. There have been many ways developed to cancel echo in phone calls and results range from poor to excellent.

These acoustic technologies must also remove or reduce the noise levels so that the caller is well understood. A person making a call from a handsfree device who is in a busy restaurant or while driving will introduce large levels of noise into the call. This situation is complicated as the software must not only remove the noise around him, but must transmit his voice clearly and loudly to whoever is connected to him.

The best software solutions combine both echo cancellation and noise cancellation into a single technology so that the caller has the freedom to use a handsfree device anywhere they please. Having an acoustic solution with only one feature will dramatically reduce its flexibility.

Head unit



A panasonic head unit, combining radio, CD and MP3



Installing a head unit



Activated head unit

A **head unit** is a component of a stereo system either in a vehicle or home cinema system which provides a unified hardware interface for the various components of an electronic media system.

The head unit is the centerpiece of the car's sound system. Typically located in the center of the dashboard, modern head units are densely integrated electronic packages housed in detachable face plates. As high-end head units are common targets for theft, many head units are typically integrated into the vehicle's alarm system.

Head units give the user control over the vehicle's entertainment media: AM/FM radio, satellite radio, CDs, cassette tapes (although these are now uncommon), MP3, GPS navigation, Bluetooth, etc. Many audio-only head units afford the user precise control over detailed audio functions such as volume, band, frequency, speaker balance, speaker fade, bass, treble, EQ and so on.

Several OEMs such as General Motors are integrating more advanced systems into vehicle's head units such that they can control vehicular functions such as door chimes and even offer vehicle data such as trouble warnings and odometer information; such a head unit thus serves as a secondary instrument panel.

In as much as head units are a central part of a car's decor, they vary as widely in aesthetics as they do in functionality; in this regard they are analogous to skins.

With the advent of GPS and DVDs head units with video monitors have come on the market. Such features raise design, safety, and ergonomic issues.

The most standard sizes in vehicles are Single DIN ISO 7736 (178x53 mm) in Europe, South America and Australasia and Double DIN (178x106 mm) in Japan, the UK and North America.

Typically, the 8-pin ISO 10487 connector is used for connecting the head unit to the car's electrical system.

Kia UVO

Kia UVO is an in-car infotainment system with advanced voice- and touch-activated features. Kia UVO, short for 'Your Voice,' provides simple and quick access to vehicle's multimedia and infotainment systems. It is much like Ford Sync and is developed by Microsoft and Kia and will be available on the 2011 Kia Sorento. It will only be available with a 4.3" inch touch screen with reversing camera unlike Ford's Sync which is available with out a touch screen.

Features

- **Advanced Speech Technology:** Integrate speech recognition and synthesis technology from Microsoft.
- **Natural Interface Advancements :** A full-color, in-dash monitor allows occupants to quickly scroll through media and mobile device content through intuitive voice and touch-screen commands.
- **Custom Media Experiences with MyMusic :** UVO's "Jukebox" function features a hard drive for media storage, allowing users to rip music from CDs or an MP3 player into personal MyMusic folders and store songs sorted by title and/or artist - all through voice commands. The system can shuffle through an MP3 player or AM/FM and SIRIUS radio stations and instantly identify what's playing all through simple voice commands.
- **Rear Backup Camera :** When the vehicle is put in reverse, a built-in rear backup camera uses UVO's in-dash display to provide images of the environment behind the car assisting the driver to identify certain objects that otherwise may be difficult to see.
- **Ability to Continuously Update Features and Services**

MyFord Touch

MyFord Touch is an in-car communications and entertainment system developed by the Ford Motor Company and Microsoft. The technology comes factory installed with Ford's product offerings and is based on the Microsoft Auto 4.0 software platform. It is regarded as the next-generation of Ford Sync. Announced in January 2010, at the Consumer Electronics Show (CES), the technology will launch with the 2011 Ford Edge. MyFord Touch will be branded as MyLincoln Touch on Ford Motor Company's Lincoln brand products.

Overview

MyFord Touch enables drivers of Ford's car offerings to seamlessly utilize nearly all mobile phones, PDAs and digital media players into their cars. Operation of these devices, utilizing advanced Ford Sync functionality is performed using voice commands, touch-screen inputs, the vehicle's steering wheel, radio controls, Bluetooth and Wi-Fi connectivity.

MyFord Touch enables users to operate various portable devices (e.g. MP3 players, Bluetooth enabled phones and USB devices) using simple voice commands. MyFord Touch is capable of receiving text messages and reading these text messages aloud to occupants of the car.

As a stand-alone option, the MSRP is \$1,000. Purchasers of this option, on Ford brand products, get the MyFord Touch system with two driver-configurable 4.2" color LCD displays in the gauge cluster, one 8" color LCD touch screen in the center stack, a media hub with 2 USB ports, SD card reader, RCA video input jacks and 5-way controls located on steering wheel; Sync voice activated communications and entertainment system (Free three year pre-paid subscription for 911 Assist, Vehicle Health Reports, traffic reports, GPS-based turn by turn driving directions and information services).

MyFord Touch was recognized by PC Magazine.

Features

- *Traffic, Directions and Information:* Improved visual presentation of the SYNC traffic, directions and information applications.
 - Traffic Alerts — provided by INRIX.
 - Map-based navigation application via an optional SD card — provided by TeleNav.
 - SD card navigation includes services like weather maps, gas prices, and movie listings — via SIRIUS Travel Link.
- *Vehicle Health Report:* Vehicle Report provides a personalized online report for the vehicle showing vehicle diagnostics, scheduled maintenance and any recall information. Vehicle Health Report allows users to schedule car service online,

- directly with the users' preferred car dealer, directly from the personalized online report.
- *911 Assist*: In the event of a serious road accident (airbag deployed) and, on certain vehicles, where the emergency fuel pump shut-off is activated, 911 Assist puts the occupant(s) of the car directly in touch with a 911 operator. 911 Assist provides a 10-second window where occupants have the option to cancel the call before dialing. Where occupants of the car are unable to speak, 911 Assist delivers an emergency message to the 911 operator.
 - *Media Hub*:
 - 2 USB 2.0 inputs;
 - SD card slot;
 - A/V Input Jacks — RCA type.
 - *Internet Connectivity*: MyFord Touch provides full Wi-Fi capability, with a built-in web browser for use while the car is parked. The technology also includes hotspot connectivity enabling other devices to share the MyFord Touch system's internet connection.
 - Supports on-screen and USB-connected keyboards.
 - RSS feed aggregator and text-to-voice reader.
 - In-car Wi-Fi hot-spot capability through USB mobile broadband modem or USB-installed Aircard. That does not work on any Canadian Aircards (US models unknown at this time). Nor is there currently support from Ford to assist on finding a compatible model. This feature is not usable in its current state until more reports are found about working Aircards or a compatibility list is made available from Ford.
 - *Media Player Support*: MyFord Touch provides compatibility with USB-connected MP3 players.
 - AM/FM/CD, Sirius Satellite Radio, HD Radio capability.
 - Media player equipped with new Podcast category.
 - Enhanced Bluetooth audio support.

MyFord Touch availability

The following vehicles have been announced as being MyFord Touch capable (provided as a standard or optional feature). Note: MyFord Touch typically available only on medium to high end trim packages.

2011 model year

- Ford Edge — 2011 Model Year
- Lincoln MKX — 2011 Model Year
- Ford Explorer — 2011 Model Year

2012 model year

- Ford Focus

Anti-hijack system

An **anti-hijack system** is an electronic system fitted to motor vehicles to deter criminals from hijacking them. Although these types of systems are becoming more common on newer cars, they have not caused a decrease in insurance premiums as they are not as widely known about as other more common anti-theft systems such as alarms or steering locks. It can also be a part of an alarm or immobiliser system.

Technology

There are three basic principles on which the systems work.

Lockout

A lockout system is armed when the driver turns the ignition key to the *on* position and carries out a specified action, usually flicking a hidden switch or depressing the brake pedal twice. It is activated when the vehicle drops below a certain speed or becomes stationary, and will cause all of the vehicles doors to automatically lock, to prevent against thieves stealing the vehicle when it is stopped, for example at a traffic light or pedestrian crossing.

Transponder

A transponder system is a system which is always armed until a device, usually a small RFID transponder, enters the vehicle's transmitter radius. Since the device is carried by the driver, usually in their wallet or pocket, if the driver leaves the immediate vicinity of the vehicle, so will the transponder, causing the system to assume the vehicle has been hijacked and disable it.

As the transponder itself is concealed, the thief would not be aware that such a system is active on a vehicle until they had ejected the driver and moved the vehicle out of range of the driver (usually only a couple of meters). This is probably the most common anti-hijack system and a central locking system which uses the same concept was demonstrated by Jeremy Clarkson on an old episode of the BBC Top Gear program where he teased a butler by asking him to put his bags in a Mercedes-Benz S600 but didn't give the RFID transponder.

The butler was confused when the S600 doors wouldn't open when he tried, but when Jeremy approached with the transponder in his pocket, the system acknowledged this and unlocked the car, allowing Jeremy to simply pull the door handle to gain entry to the vehicle.

Microswitch

A microswitch system is always armed and is usually activated if one of the vehicle doors is opened and closed again while the vehicle's engine is running. Once the system has been activated, the driver will have a set time limit to disarm it by entering a code before the vehicle takes measures.

If the system is not disarmed in the time window, it will warn the driver by sounding the vehicle's horn once every 10 seconds for 30 seconds, at which point the system will start sounding the horn at much shorter intervals and will usually activate the vehicle's hazard lights.

At this point the immobiliser circuit will also start rapidly pulsing for 40 seconds, completely disabling the engine and eventually bringing the vehicle to a stop. If the thief switches the ignition to the *off* position and back to the *on* position again, the horn will restart and operate constantly and the hazard lights will flash for 60 seconds.

The immobiliser circuit will close for 15 seconds and will rapidly pulse for 15 seconds before re-opening the circuit, allowing the vehicle to be driven to a safe location before once again being immobilised. The hazard lights will continue to flash, and on every subsequent attempt to start the vehicle will cause the horn to operate for 30 seconds, but the immobilizer circuit will not open, so the vehicle will not start and the hazard lights will keep flashing until the vehicle's battery is drained or the system is disarmed.

Vehicle tracking system

A **vehicle tracking system** combines the installation of an electronic device in a vehicle, or fleet of vehicles, with purpose-designed computer software at least at one operational base to enable the owner or a third party to track the vehicle's location, collecting data in the process from the field and deliver it to the base of operation. Modern vehicle tracking systems commonly use GPS or GLONASS technology for locating the vehicle, but other types of automatic vehicle location technology can also be used. Vehicle information can be viewed on electronic maps via the Internet or specialized software. Urban public transit authorities are an increasingly common user of vehicle tracking systems, particularly in large cities.

Active versus passive tracking

Several types of Vehicle Tracking devices exist. Typically they are classified as "Passive" and "Active". "Passive" devices store GPS location, speed, heading and sometimes a trigger event such as key on/off, door open/closed. Once the vehicle returns to a predetermined point, the device is removed and the data downloaded to a computer for evaluation. Passive systems include auto download type that transfer data via wireless download. "Active" devices also collect the same information but usually transmit the

data in real-time via cellular or satellite networks to a computer or data center for evaluation.

Many modern vehicle tracking devices combine both active and passive tracking abilities: when a cellular network is available and a tracking device is connected it transmits data to a server; when a network is not available the device stores data in internal memory and will transmit stored data to the server later when the network becomes available again.

Common uses

Vehicle tracking systems are commonly used by fleet operators for fleet management functions such as fleet tracking, routing, dispatch, on-board information and security. Along with commercial fleet operators, urban transit agencies use the technology for a number of purposes, including monitoring schedule adherence of buses in service, triggering changes of buses' destination sign displays at the end of the line (or other set location along a bus route), and triggering pre-recorded announcements for passengers. The American Public Transportation Association estimated that, at the beginning of 2009, around half of all transit buses in the United States were already using a GPS-based vehicle tracking system to trigger automated stop announcements. This can refer to external announcements (triggered by the opening of the bus's door) at a bus stop, announcing the vehicle's route number and destination, primarily for the benefit of visually impaired customers, or to internal announcements (to passengers already on board) identifying the next stop, as the bus (or tram) approaches a stop, or both. Data collected as a transit vehicle follows its route is often continuously fed into a computer program which compares the vehicle's actual location and time with its schedule, and in turn produces a frequently updating display for the driver, telling him/her how early or late he/she is at any given time, potentially making it easier to adhere more closely to the published schedule. Such programs are also used to provide customers with real-time information as to the waiting time until arrival of the next bus or tram/streetcar at a given stop, based on the nearest vehicles' actual progress at the time, rather than merely giving information as to the *scheduled* time of the next arrival. Transit systems providing this kind of information assign a unique number to each stop, and waiting passengers can obtain information by entering the stop number into an automated telephone system or an application on the transit system's website. Some transit agencies provide a virtual map on their website, with icons depicting the current locations of buses in service on each route, for customers' information, while others provide such information only to dispatchers or other employees.

Other applications include monitoring driving behavior, such as an employer of an employee, or a parent with a teen driver.

Vehicle tracking systems are also popular in consumer vehicles as a theft prevention and retrieval device. Police can simply follow the signal emitted by the tracking system and locate the stolen vehicle. When used as a security system, a Vehicle Tracking System may serve as either an addition to or replacement for a traditional Car alarm. Some

- **Stolen Vehicle Recovery:** Both consumer and commercial vehicles can be outfitted with RF or GPS units to allow police to do tracking and recovery. In the case of LoJack, the police can activate the tracking unit in the vehicle directly and follow tracking signals.
- **Fleet Management:** When managing a fleet of vehicles, knowing the real-time location of all drivers allows management to meet customer needs more efficiently. Whether it is delivery, service or other multi-vehicle enterprises, drivers now only need a mobile phone with telephony or Internet connection to be inexpensively tracked by and dispatched efficiently.
- **Asset Tracking:** Companies needing to track valuable assets for insurance or other monitoring purposes can now plot the real-time asset location on a map and closely monitor movement and operating status.
- **Field Service Management:** Companies with a field service workforce for services such as repair or maintenance, must be able to plan field workers' time, schedule subsequent customer visits and be able to operate these departments efficiently. Vehicle tracking allows companies to quickly locate a field engineer and dispatch the closest one to meet a new customer request or provide site arrival information.
- **Field Sales:** Mobile sales professionals can access real-time locations. For example, in unfamiliar areas, they can locate themselves as well as customers and prospects, get driving directions and add nearby last-minute appointments to itineraries. Benefits include increased productivity, reduced driving time and increased time spent with customers and prospects.
- **Trailer Tracking:** Haulage and Logistics companies often operate lorries with detachable load carrying units. The part of the vehicle that drives the load is known as the cab and the load carrying unit is known as the trailer. There are different types of trailer used for different applications, e.g., flat bed, refrigerated, curtain sider, box container.
- **Surveillance:** A tracker may be placed on a vehicle to follow the vehicle's movements.
- **Transit Tracking:** This is the temporary tracking of assets or cargoes from one point to another. Users will ensure that the assets do not stop on route or do a U-Turn in order to ensure the security of the assets.

Vehicle Tracking Systems are widely used worldwide. Components come in various shapes and forms but most utilize GPS technology and SMS Messaging. While most will offer real-time tracking, Others record real time data and store it to be read, similar to data-loggers. Systems like these track and record and allow reports after certain points have been saved.

Non conventional uses

Industries not traditionally known to use vehicle tracking systems (logistics and transportation industries are the ones that have traditionally incorporated vehicle tracking system into their operations) have started to use it in creative ways to improve their processes or businesses.

The hospitality industry have caught on to this technology to improve customer service. For example, a luxury hotel in Singapore have been known to install vehicle tracking system in their limousines to ensure they can welcome their VIPs when they reach the hotel.

Vehicle tracking systems have also been used in food delivery and car rental companies.