<u>EHV-Unit-5</u>

Hybrid vehicle drive trains transmit power to the driving wheels for **hybrid vehicles**. A hybrid vehicle has multiple forms of motive power.

The term ***hybrid vehicle*** refers to a vehicle with at least two sources of power. A ***hybrid-electric vehicle*** indicates that ***one source of power*** is provided by an ***electric motor***. The ***other source of motive power*** can come from a number of different technologies, but is typically provided by an ***internal combustion engine*** designed to run on either gasoline or diesel fuel. As proposed by Technical Committee (Electric Road Vehicles) of the International Electrotechnical Commission, <u>***an HEV is a vehicle in which propulsion energy is available from two or more types of energy sources and at least one of them can deliver electrical energy***</u>. Based on this general definition, there are many types of HEVs, such as:

- the gasoline ICE and battery
- diesel ICE and battery
- battery and FC
- battery and capacitor
- battery and flywheel
- battery and battery hybrids.

Most commonly, the propulsion force in HEV is provided by a combination of electric motor and an ICE. The electric motor is used to improve the energy efficiency (improves fuel consumption) and vehicular emissions while the ICE provides extended range capability.

Architectures of Hybrid Electric Drive Trains

The architecture of a hybrid vehicle is defined as the connection between the components that define the energy flow routes and control ports. Traditionally, HEVs were classified into two basic types: series and parallel. It is interesting to note that, in 2000, some newly introduced EVs could not be classified into these kinds. Hence, HEVs are presently classified into four kinds—series hybrid, parallel hybrid, series–parallel hybrid, and complex hybrid—that are functionally shown in Figure 5.3 Scientifically, the classifications above are not very clear and may cause confusion. Actually, in an HEV, there are two kinds of energy flowing in the drive train: one is mechanical energy and the other is electrical energy. Adding two powers together or splitting one power into two at the power merging point always occurs with the same power type, that is, electrical or mechanical, not electrical and mechanical. So perhaps a more accurate definition for HEV architecture may be to take the power coupling or decoupling features such as an electrical coupling drive train, a mechanical coupling drive train, and a mechanical–electrical coupling drive train.

Figure 5.3a functionally shows the architecture that is traditionally called a series hybrid drive train. The key feature of this configuration is that two electrical powers are added together in the power converter, which functions as an electric power coupler to control the power flows from the batteries and generator to the electric motor, or in the reverse direction, from the electric motor to the batteries. The fuel tank, the IC engine, and the generator constitute the primary energy supply and the batteries function as the energy buffer.

Figure 5.3b is the configuration that is traditionally called a parallel hybrid drive train. The key of this configuration is that two mechanical powers are added together in a mechanical coupler. The IC engine is the primary power plant, and the batteries and electric motor drive constitute the energy bumper. The power flows can be controlled only by the power plants—the engine and electric motor.

Figure 5.3c shows the configuration that is traditionally called a series– parallel hybrid drive train. The distinguished feature of this configuration is the employment of two power couplers—mechanical and electrical. Actually, this configuration is the combination of series and parallel structures, possessing the major features of both and more plentiful operation modes than those of the series or parallel structure alone. On the other hand, it is relatively more complicated and may be of higher cost.

Figure 5.3d shows a configuration of the so-called complex hybrid, which has a similar structure to the series–parallel one. The only difference is that the electric coupling function is moved from the power converter to the batteries and one more power converter is added between the motor/generator and the batteries.

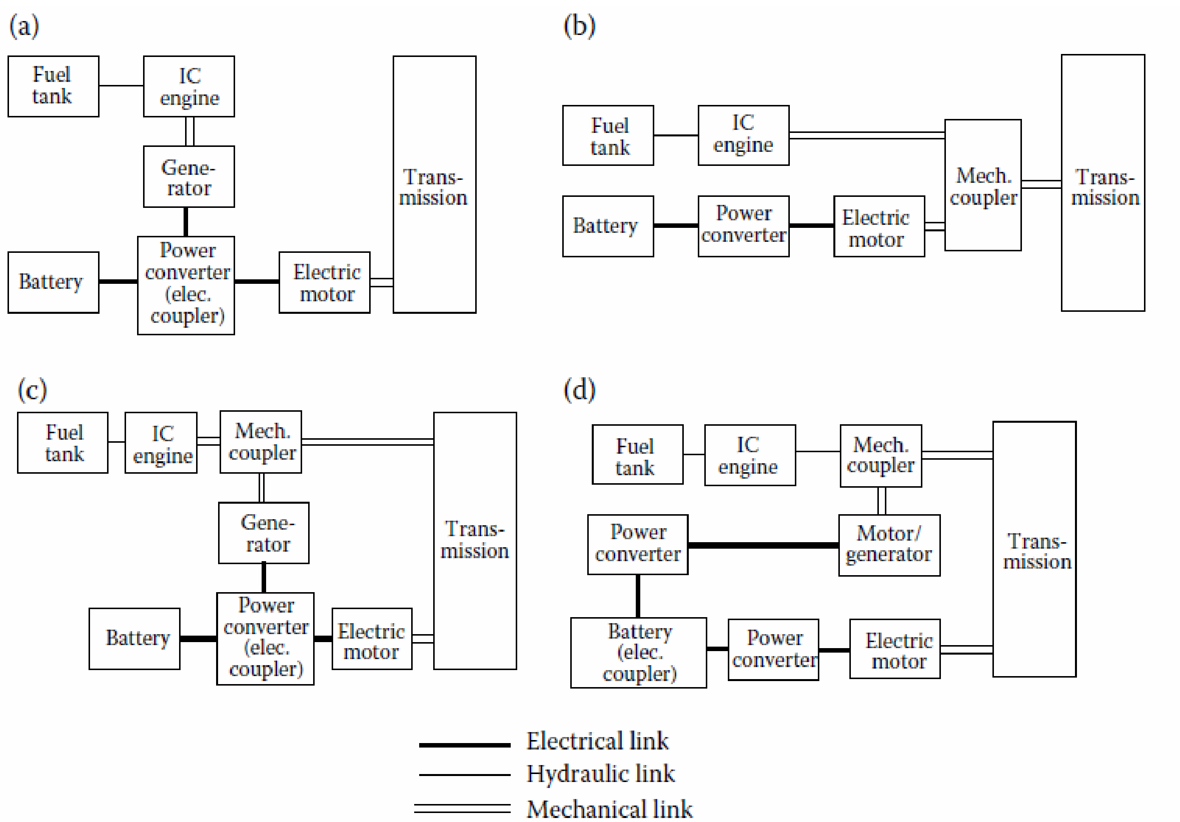

FIGURE 5.3 Classifications of hybrid EVs. (a) Series (electrically coupling), (b) parallel (mechanical coupling), (c) series–parallel (mechanical and electrical coupling), and (d) complex (mechanical and electrical coupling).

HYBRID/ELECTRIC VEHICLE SAFETY

Hybrid/electric vehicles have been sold in the U.S. since 2000. In 2012 434,000 hybrid/electric vehicles including passenger cars, SUVs and pickup trucks were sold in U.S. These vehicles incorporate a variety of configurations to combine a conventional combustion engine with an electric motor paired with a rechargeable battery to deliver enhanced performance, superior fuel economy and ultra low emissions.

The vehicles are equipped with sophisticated transmissions, regenerative braking and multiple controllers combined with numerous sensors to provide functionality and a driving experience only slightly different from a conventionally powered vehicle.

Operating Safety

In order to achieve a user-experience similar to what drivers are habituated, hybrid/electric vehicles must respond to driver inputs in a predictable and reliable manner. Computers control the combustion engine, electric motor, and multiple driver aids, including traction and stability control. The sophisticated systems commonly include several computer processors and many sensors. Failure of these systems can result in unexpected and unreliable vehicle performance that may cause a crash.

Battery charging occurs during regenerative braking or during recharging for a “plug in” type hybrid vehicle. The recharging is computer controlled to prevent over charging and overheating that can cause an electric shock hazard or fire.

Computer Controlled Transmission

A sophisticated computer controlled transmission is required to combine power from the combustion engine and the electric motor. The power split may range from electric only, a combination of electric and combustion engine, or solely combustion engine. Failure of proper power delivery can result in unwanted or inadequate acceleration and may cause a crash.

Battery

The battery state of charge and operating temperature are continuously monitored. Excessive temperatures can lead to vehicle fires. Short circuits can lead to vehicle fire even after the vehicle is shut off.

Brakes

The brakes may incorporate regenerative braking that recovers and stores electric energy. This may include the use of the electric motor as a generator in combination with conventional hydraulic brakes in order to slow the vehicle. The combining of the two systems is achieved with a sophisticated computer controlled system. Improper operation may cause inadequate braking and result in a crash.

Crashworthiness

Hybrid/electric vehicle must be designed and manufactured with additional crash safety features to protect the high energy battery pack and high voltage power electric circuits and components. Damage to these systems can cause electric shock and dangerous chemical exposure to occupants and emergency personnel.

Post Crash Safety

First responders must be trained to properly handle a damaged hybrid/electric vehicle. Vehicles are generally equipped with a master switch to de energize or isolate high voltage circuits that would pose a risk to emergency personnel.

Vehicle storage after a crash must be in an isolated location away from other vehicles and structures. For example, a damaged vehicle may have a slow coolant leak that can eventually cause a short circuit in the high voltage battery pack resulting in a vehicle fire.

<u>The major requirements of electric propulsion HEVs are summarized as follows:</u>

i. Very high instant power and a high power density.
ii. High torque at low speeds for starting and climbing, as well as a high power at high speed for cruising.
iii. Very wide speed range, including constant-torque and constant-power regions.
iv. Fast torque response.
v. High efficiency over the wide speed and torque ranges.
vi. High efficiency for regenerative braking.
vii. High reliability and robustness for various vehicle operating conditions, and
viii. Reasonable cost

Series Hybrid Electric Drive Trains (Electrical Coupling)

A series hybrid drive train is a drive train in which two electrical power sources feed a single electrical power plant (electric motor) that propels the vehicle. The configuration that is most often used is the one shown in Figure 5.4. The unidirectional energy source is a fuel tank and the unidirectional energy converter (power plant) is an IC engine coupled to an electric generator. The output of the electric generator is connected to a power DC bus through a controllable electronic converter (rectifier). The bidirectional energy source is a battery pack connected to the power DC bus by means of a controllable, bidirectional power electronic converter (DC/DC converter). The power bus is also connected to the controller of the electric motor. The traction motor can be controlled as either a motor or a generator, and in forward or reverse motion. This drive train may need a battery charger to charge the batteries by wall plug-in from a power grid. The series hybrid drive train originally came from an EV on which an additional engine–generator is added to extend the operating range that is limited by the poor energy density of the batteries.

The drive train needs a vehicle controller to control the operation and power flows based on the driver's operating command through accelerator and brake pedals and other feedback information from the components. The vehicle controller will control the IC engine through its throttle, electric coupler (controllable rectifier and DC/DC converter), and traction motor to produce the demanded propelling torque or regenerative braking torque with one of the following operation modes:

1. *Pure electric traction mode*: The engine is turned off and the vehicle is propelled only from the batteries.

2. *Pure engine traction mode*: The vehicle traction power comes only from the engine–generator, while the batteries neither supply nor accept any power from the drive train. The electric machines serve as an electric transmission from the engine to the driven wheels.

3. *Hybrid traction mode*: The traction powers are drawn from both the engine–generator and the batteries, merging together in the electrical coupler.

4. *Engine traction with battery charging mode*: The engine–generator supplies power to charge the batteries and to propel the vehicle simultaneously. The engine–generator power is split in the electric coupler.

5. *Regenerative braking mode*: The engine–generator is turned off and the traction motor is operated as a generator powered by the vehicle kinetic or potential energy. The power generated is charged to the batteries and reused in later propelling.

6. *Battery charging mode*: The traction motor receives no power and the engine–generator is operated only to charge the batteries.

7. *Hybrid battery charging mode*: Both the engine–generator and the traction motor operate as generators in braking to charge the batteries.

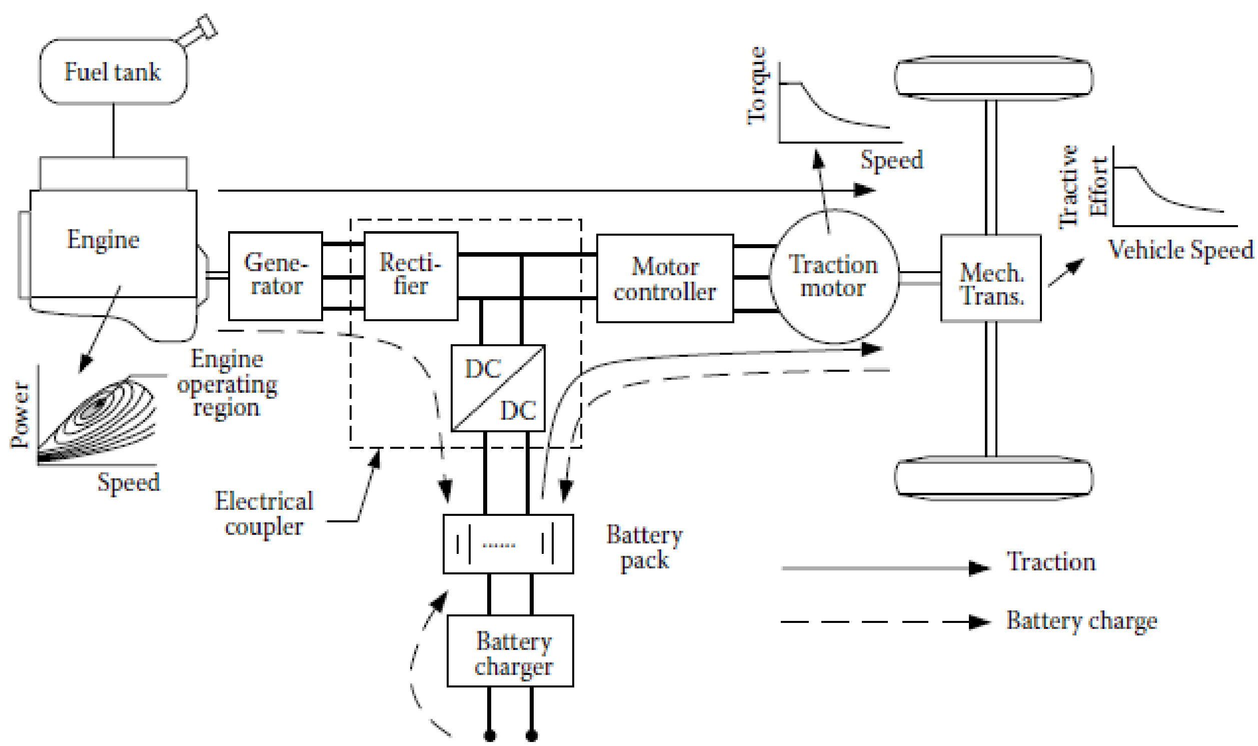

FIGURE 5.4 Configuration of a series hybrid electric drive train.

Series hybrid drive trains offer several advantages:

1. There is no mechanical connection between the engine and the driven wheels. Consequently, the engine can be potentially operated at any point on its speed–torque (power) map. This distinguished advantage, with a sophisticated power flow control, provides the engine with opportunities to be operated always within its maximum efficiency region, as shown in Figure 5.4. The efficiency and emissions of the engine in this narrow region may be further improved by some special design and control technologies, which is much easier than in the whole operating domain. Furthermore, the mechanical decoupling of the engine from the driven wheels allows the use of high-speed engines, where it is difficult to directly propel the wheels through a mechanical link, such as gas turbines or power plants that have slow dynamic responses (e.g., Stirling engine, etc.).

2. The drive train may not need multi gear transmission; therefore, the structure of the drive train can be greatly simplified and is of less cost. Furthermore, two motors may be used, each powering a single wheel, and the mechanical differential can be removed. Such an arrangement also has the following advantages of decoupling the speeds of two wheels, a similar function of a mechanical differential, and an additional function of anti slip similar to the conventional traction control. Furthermore, four in-the-wheel motors may be used, each one driving a wheel. In such a configuration, the speed and torque of each wheel can be independently controlled. Consequently, the drivability of the vehicle can be significantly enhanced. This is very important for off-road vehicles which usually operate on difficult terrain, such as ice, snow, and soft ground.

3. The control strategy of the drive train may be simple, compared to other configurations, because of its fully mechanical decoupling between the engine and wheels.

However, series hybrid electric drive trains have some disadvantages, such as the following:

1. The energy from the engine changes its form twice to reach its destination—driven wheels (mechanical to electrical in the generator and electrical to mechanical in the traction motor). The inefficiencies of the generator and traction motor may cause significant losses.

2. The generator adds additional weight and cost.

3. Because the traction motor is the only power plant propelling the vehicle, it must be sized to produce enough power for optimal vehicle performance in terms of acceleration and gradeability.

16

Comfort and safety

16.1 Seats, mirrors and sun-roofs

16.1.1 Introduction

Electrical movement of seats, mirrors and the sun-roof are included in one chapter as the operation of each system is quite similar. The operation of electric windows and central door locking is also much the same.

Fundamentally, all the above mentioned systems operate using one or several permanent magnet motors, together with a supply reversing circuit. A typical motor reverse circuit is shown in Figure 16.1. When the switch is moved, one of the relays will operate and this changes the polarity of the supply to *one* side of the motor. If the switch is moved the other way, then the polarity of the other side of the motor is changed. When at rest, both sides of the motor are at the same potential. This has the effect of regenerative braking so that when the motor stops it will do so instantly.

Further refinements are used to enhance the operation of these systems. Limit switches, position memories and force limitations are the most common.

16.1.2 Electric seat adjustment

Adjustment of the seat is achieved by using a number of motors to allow positioning of different parts of the seat. Movement is possible in the following ways.

- Front to rear.
- Cushion height rear.
- Cushion height front.
- Backrest tilt.
- Headrest height.
- Lumber support.

Figure 16.2 shows a typical electrically controlled seat. This system uses four positioning motors and one smaller motor to operate a pump, which controls the lumber support bag. Each motor can be considered to operate by a simple rocker-type switch that controls two relays as described above. Nine relays are required for this, two for each motor and one to control the main supply.

When the seat position is set, some vehicles have set position memories to allow automatic re-positioning if the seat has been moved. This is often combined with electric mirror adjustment. Figure 16.3 shows how the circuit is constructed to allow position memory. As the seat is moved a variable

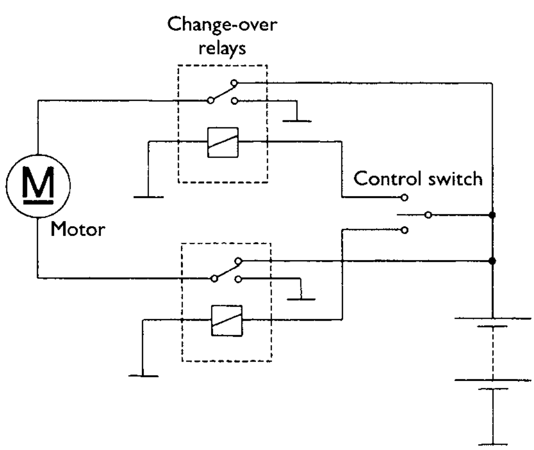

Figure 16.1 Typical motor reverse circuit

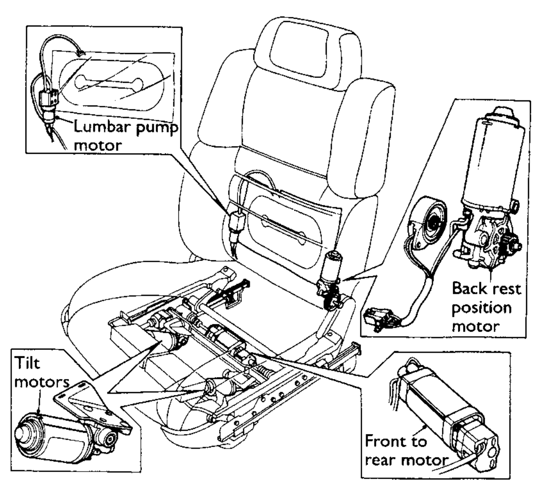

Figure 16.2 Electrically controlled seat

resistor, mechanically linked to the motor, is also moved. The resistance value provides feedback to an electronic control unit. This can be 'remembered' in a number of ways; the best technique is to supply the resistor with a fixed voltage such that the output relative to the seat position is proportional to position. This voltage can then be 'analogue-to-digital' converted, which produces a simple 'number' to store in a digital memory. When the driver presses a memory recall switch, the motor relays are activated by the ECU until the number in memory and the number fed back from the seat are equal. This facility is often isolated when the engine is running to prevent the seat moving into a dangerous position as the car is being driven. The position of the seats can still be adjusted by operating the switches as normal.

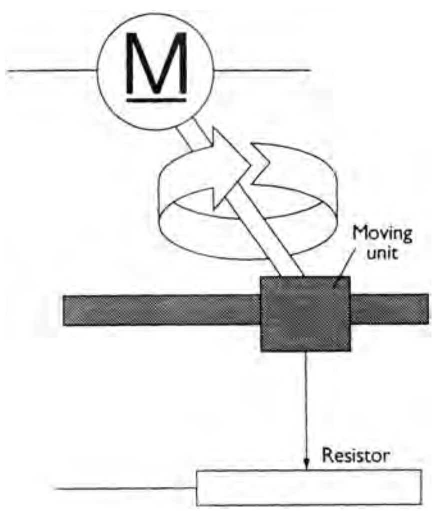

Figure 16.3 Position memory for electric seats

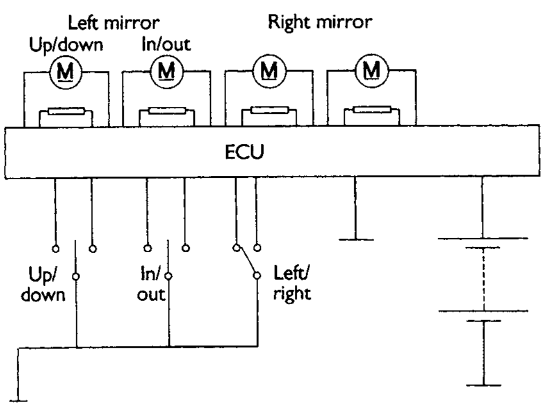

Figure 16.4 Feedback resistors for positional memory and the circuit

16.1.3 Electric mirrors

Many vehicles have electric adjustment of mirrors, particularly on the passenger side. The system used is much the same as has been discussed above in relation to seat movement. Two small motors are used to move the mirror vertically or horizontally. Many mirrors also contain a small heating element on the rear of the glass. This is operated for a few minutes when the ignition is first switched on and can also be linked to the heated rear window circuit. Figure 16.4 shows an electrically operated mirror circuit, which includes feedback resistors for positional memory.

16.1.4 Electric sun-roof operation

The operation of an electric sun-roof is similar to the motor reverse circuit discussed earlier in this chapter. However, further components and circuitry are needed to allow the roof to slide, tilt and stop in the closed position. The extra components used are a micro switch and a latching relay. A latching relay works in much the same way as a normal relay except that it locks into position each time it is energized. The mechanism used to achieve this is much like that used in ball-point pens that use a button on top.

The micro switch is mechanically positioned such as to operate when the roof is in its closed position. A rocker switch allows the driver to adjust the roof. The circuit for an electrically operated sun-roof is shown in Figure 16.5. The switch provides the supply to the motor to run it in the chosen direction. The roof will be caused to open or tilt. When the switch is operated to close the roof, the motor is run

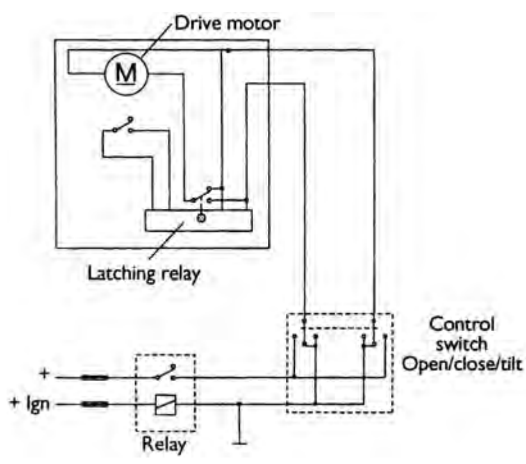

Figure 16.5 Sun-roof circuit

in the appropriate direction until the micro switch closes when the roof is in its closed position. This causes the latching relay to change over, which stops the motor. The control switch has now to be released. If the switch is pressed again, the latching relay will once more change over and the motor will be allowed to run.

16.2 Central locking and electric windows

16.2.1 Door locking circuit

When the key is turned in the driver's door lock, all the other doors on the vehicle should also lock. Motors or solenoids in each door achieve this. If the system can only be operated from the driver's door key, then an actuator is not required in this door. If the system can be operated from either front door or by remote control, then all the doors need an actuator. Vehicles with sophisticated alarm systems often lock all the doors as the alarm is set.

Figure 16.6 shows a door locking circuit. The main control unit contains two change-over relays (as in Figure 16.1), which are actuated by either the door lock switch or, if fitted, the remote infrared key. The motors for each door lock are simply wired in parallel and all operate at the same time.

Most door actuators are now small motors which, via suitable gear reduction, operate a linear rod in either direction to lock or unlock the doors. A simple motor reverse circuit is used to achieve the required action. Figure 16.7 shows a typical door lock actuator.

Infrared central door locking is controlled by a small hand-held transmitter and an infrared sensor receiver unit as well as a decoder in the main control unit. This layout will vary slightly between different manufacturers. When the infrared key is operated by pressing a small switch, a complex code is transmitted. The number of codes used is well in excess of 50 000. The infrared sensor picks up this code and sends it in an electrical form to the main control unit. If the received code is correct, the relays are triggered and the door locks are either locked or unlocked. If an incorrect code is received on three consecutive occasions when attempting to unlock the doors, then the infrared system will switch itself off until the door is opened by the key. This will also reset the system and allow the correct code to operate the locks again. This technique prevents a scanning type transmitter unit from being used to open the doors. Figure 16.8 shows a flow diagram representing the operation of a system that uses a 'rolling code' (MAC stands for Message Authentication Code).

16.2.2 Electric window operation

The basic form of electric window operation is similar to many of the systems discussed so far in this chapter; that is, a motor reversing system that is operated either by relays or directly by a switch.

More sophisticated systems are now becoming more popular for reasons of safety as well as improved comfort. The following features are now available from many manufacturers:

- One shot up or down.
- Inch up or down.
- Lazy lock.
- Back-off.

The complete system consists of an electronic control unit containing the window motor relays, switch packs and a link to the door lock and sun-roof circuits. This is represented in the form of a block diagram in Figure 16.9.

When a window is operated in one-shot or one-touch mode the window is driven in the chosen direction until either the switch position is reversed, the motor stalls or the ECU receives a signal from the door lock circuit. The problem with one-shot operation is that if a child, for example, should become trapped in the window there is a serious risk of injury. To prevent this, the back-off feature is used. An extra commutator is fitted to the motor

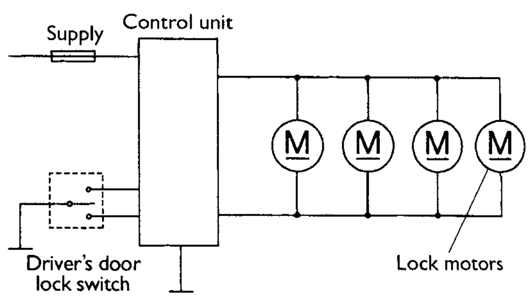

Figure 16.6 Door lock circuit

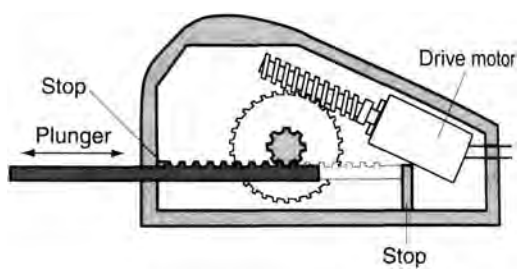

Figure 16.7 Door lock actuator

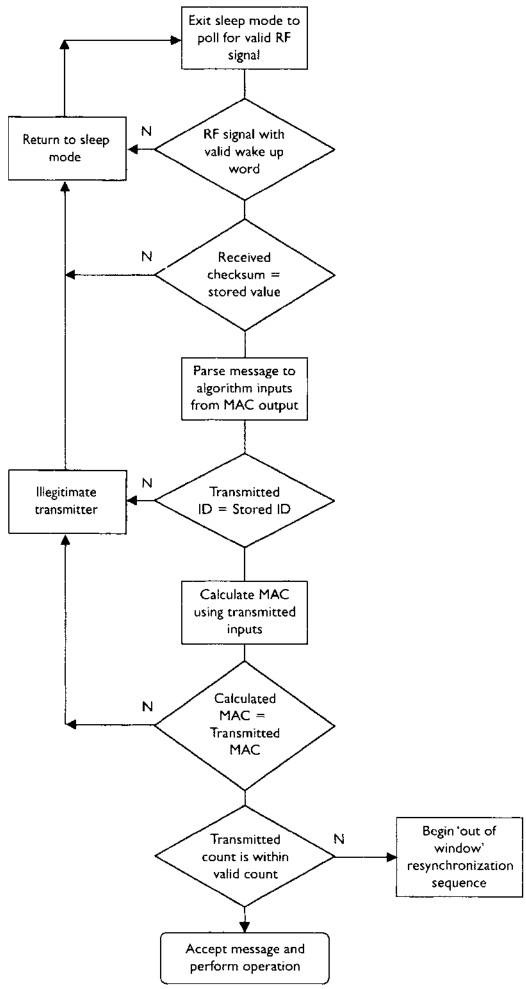

Figure 16.8 Flow diagram representing the 'Rolling code' system

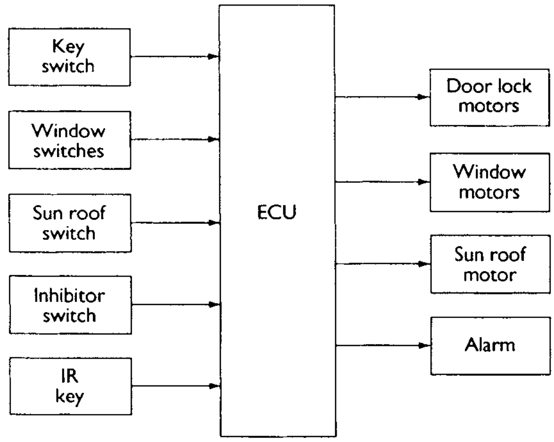

Figure 16.9 Block diagram showing links between door locks, windows and sun-roof – controlled by an infrared key

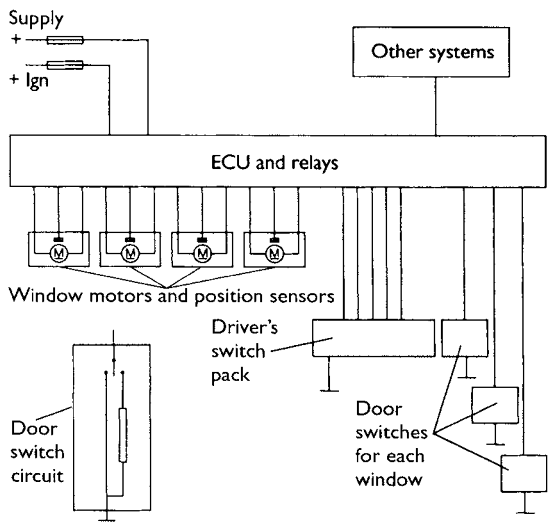

Figure 16.10 Electric window control circuit

armature and produces a signal via two brushes, proportional to the motor speed. If the rate of change of speed of the motor is detected as being below a certain threshold when closing, then the ECU will reverse the motor until the window is fully open.

By counting the number of pulses received, the ECU can also determine the window position. This is important, as the window must not reverse when it stalls in the closed position. In order for the ECU to know the window position it must be initialized. This is often done simply by operating the motor to drive the window first fully open, and then fully closed. If this is not done then the one-shot close will not operate.

On some systems, Hall effect sensors are used to detect motor speed. Other systems sense the current being drawn by the motor and use this as an indication of speed.

The lazy lock feature allows the car to be fully secured by one operation of a remote infrared key. This is done by the link between the door lock ECU and the window and sun-roof ECUs. A signal is supplied and causes all the windows to close in turn, then the sun-roof, and finally it locks the doors. The alarm will also be set if required. The windows close in turn to prevent the excessive current demand that would occur if they all tried to operate at the same time.

A circuit for electric windows is shown in Figure 16.10. Note the connections to other systems such as door locking and the rear window isolation switch. This is commonly fitted to allow the driver to prevent rear window operation for child safety, for example.

Figure 16.11 Window lift motor for cable or arm-lift systems

Figure 16.11 shows a typical window lift motor used for cable or arm-lift systems.

16.3 Cruise control

16.3.1 Introduction

Cruise control is the ideal example of a closed loop control system. Figure 16.12 illustrates this in the form of a block diagram. The purpose of cruise control is to allow the driver to set the vehicle speed and let the system maintain it automatically.

The system reacts to the measured speed of the vehicle and adjusts the throttle accordingly. The reaction time is important so that the vehicle's speed does not feel to be surging up and down.

Other facilities are included such as allowing the speed to be gradually increased or decreased at the touch of a button. Most systems also remember the last set speed and will resume this again at the touch of a button.

To summarize and to add further refinements, the following is the list of functional requirements for a good cruise control system.

- Hold the vehicle speed at the selected value.
- Hold the speed with minimum surging.
- Allow the vehicle to change speed.
- Relinquish control immediately the brakes are applied.
- Store the last set speed.
- Contain built in safety features.

16.3.2 System description

The main switch turns on the cruise control, this in turn is ignition controlled. Most systems do not retain the speed setting in memory when the main switch has been turned off. Operating the 'set' switch programs the memory but this normally will only work if conditions similar to the following are met.

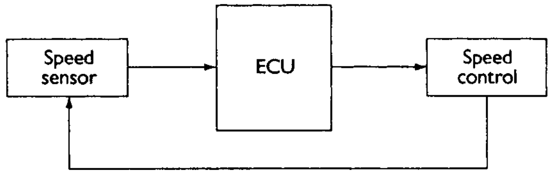

Figure 16.12 Cruise control closed loop system

- Vehicle speed is greater than 40 km/h.
- Vehicle speed is less than 12 km/h.
- Change of speed is less than 8 km/h/s.
- Automatics must be in 'drive'.
- Brakes or clutch are not being operated.
- Engine speed is stable.

Once the system is set, the speed is maintained to within about 3–4 km/h until it is deactivated by pressing the brake or clutch pedal, pressing the 'resume' switch or turning off the main control switch. The last 'set' speed is retained in memory except when the main switch is turned off.

If the cruise control system is required again then either the 'set' button will hold the vehicle at its current speed or the 'resume' button will accelerate the vehicle to the previous 'set' speed. When cruising at a set speed, the driver can press and hold the 'set' button to accelerate the vehicle until the desired speed is reached when the button is released.

If the driver accelerates from the set speed to overtake, for example, then when the throttle is released, the vehicle will slow down until it reaches the last set position.

16.3.3 Components

The main components of a typical cruise control system are as follows.

Actuator

A number of methods are used to control the throttle position. Vehicles fitted with driven by-wire systems allow the cruise control to operate the same actuator. A motor can be used to control the throttle cable or, in many cases, a vacuum-operated diaphragm is used which is controlled by three simple valves. This technique is shown in Figure 16.13. When the speed needs to be increased, valve 'x' is opened allowing low pressure from the inlet manifold to one side of the diaphragm. The atmospheric pressure on the other side will move the diaphragm and hence the throttle. To move the other way, valve 'x' is closed and valve 'y' is opened allowing

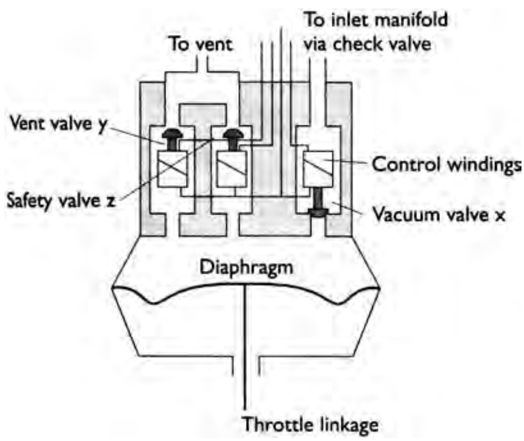

Figure 16.13 Cruise control 'vacuum' actuator

atmospheric pressure to enter the chamber. The spring moves the diaphragm back. If both valves are closed then the throttle position is held. Valve 'x' is normally closed and valve 'y' normally open; thus, in the event of electrical failure cruise control will not remain engaged and the manifold vacuum is not disturbed. Valve 'z' provides extra safety and is controlled by the brake and clutch pedals.

Main switch and warning lamp

This is a simple on/off switch located within easy reach of the driver on the dashboard. The warning lamp can be part of this switch or part of the main instrument display as long as it is in the driver's field of vision.

Set and resume switches

These are fitted either on the steering wheel or on a stalk from the steering column. When the switches are part of the steering wheel, slip rings are needed to transfer the connection. The 'set' button programs the speed into memory and can also be used to increase the vehicle and memory speed. The 'resume' button allows the vehicle to reach its last set speed or temporarily to deactivate the control.

Brake switch

This switch is very important, as it would be dangerous braking if the cruise control system was trying to maintain the vehicle speed. This switch is normally of superior quality and is fitted in place or as a supplement to the brake light switch activated by the brake pedal. Adjustment of this switch is important.

Clutch or automatic gearbox switch

The clutch switch is fitted in a similar manner to the brake switch. It deactivates the cruise system to prevent the engine speed increasing if the clutch is pressed. The automatic gearbox switch will only allow the cruise to be engaged when it is in the 'drive' position. This is again to prevent the engine over-speeding if the cruise control tried to accelerate to a high road speed with the gear selector in the '1' or '2' position. The gearbox will still change gear if accelerating back up to a set speed as long as it 'knows' top gear is available.

Speed sensor

This will often be the same sensor that is used for the speedometer. If not, several types are available – the most common produces a pulsed signal, the frequency of which is proportional to the vehicle speed.

16.3.4 Adaptive cruise control

Conventional cruise control has now developed to a high degree of quality. It is, however, not always very practical on many European roads as the speed of the general traffic varies constantly and traffic is often very heavy. The driver has to take over from the cruise control system on many occasions to speed up or slow down. Adaptive cruise control can automatically adjust the vehicle speed to the current traffic situation. Figure 16.14 shows the operation of the system. The system has three main aims.

- Maintain a speed as set by the driver.
- Adapt this speed and maintain a safe distance from the vehicles in front.
- Provide a warning if there is a risk of collision.

The main components of basic and more complex adaptive cruise systems are shown in Figure 16.15. Note the main extra components are the 'headway' sensor and the steering angle sensor; the first of these is clearly the most important. Information on steering angle is used to enhance further the data from the headway sensor by allowing greater discrimination between hazards and spurious signals. Two types of the headway sensor are in use, the *radar* and the *lidar*. Both contain transmitter and receiver units. The radar system uses microwave signals at about 35 GHz, and the reflection time of these gives the distance to the object in front. Lidar uses a laser diode to produce infrared light signals, the reflections of which are detected by a photodiode.

These two types of sensors have advantages and disadvantages. The radar system is not affected by rain and fog but the lidar can be more selective by recognizing the standard reflectors on the rear of the vehicle in front. Radar can produce strong reflections from bridges, trees, posts and other normal

Figure 16.14 Adaptive cruise control operation

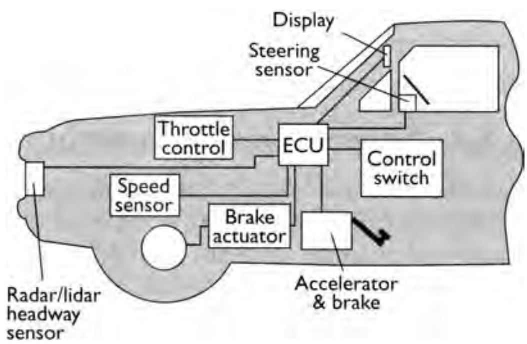

Figure 16.15 Adaptive cruise control

Figure 16.16 Headway sensor fitted at the front of a vehicle

roadside items. It can also suffer loss of signal return due to multipath reflections. Under ideal weather conditions, the lidar system appears to be the best but it becomes very unreliable when the weather changes. A beam divergence of about 2.5° vertically and horizontally has been found to be the most suitable whatever headway sensor is used. An important consideration is that signals from other vehicles fitted with this system must not produce erroneous results. Figure 16.16 shows a typical headway sensor. Fundamentally, the operation of an adaptive cruise system is the same as a conventional system except when a signal from the headway sensor detects an obstruction, in which case the vehicle speed is decreased. If the optimum stopping distance cannot be achieved by just backing off the throttle, a warning is supplied to the driver. A more complex system can also take control of the vehicle transmission and brakes but this, while very promising, is further behind in development. It is important to note that adaptive cruise control is designed to relieve the burden on the driver, not take full control of the vehicle!

16.4 In-car multimedia

16.4.1 Introduction

These days it would be almost unthinkable not to have at least a radio cassette player in our vehicles. It does not seem too long ago, however, that these were an optional extra. Looking back just a little further, the in-car record player must have been interesting to operate – it was evidently quite successful in large American cars in the US but left a bit to be desired in British vehicles and on British roads. Figure 16.17 shows a typical high quality in-car entertainment (ICE) system with a multi-CD changer.

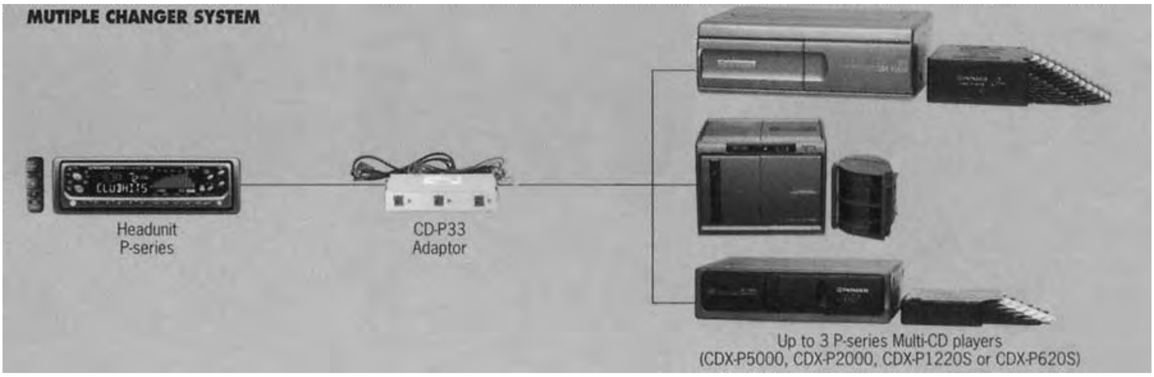

Figure 16.17 ICE system

We now have ICE systems fitted to standard production cars, which are of good hi-fi quality. Facilities such as compact disc players and multiple compact disc changers together with automatic station search and re-tune are popular.

We have seen the rise and fall of the CB radio and the first car telephones – which were so large the main unit had to be fitted in the car boot. 'Hands-free' car telephones, which allow both hands to be kept free to control the car, are in common use and voice activation of other systems is developing.

The 'In-car PC' or the 'Auto PC' is an emerging technology that will soon become the 'norm'. The 'digital' automobile is here!

16.4.2 Speakers

Good ICE systems include at least six speakers, two larger speakers in the rear parcel shelf to produce good low frequency reproduction, two front door speakers for the mid-range and two front door tweeters for high frequency notes. Figure 16.18 shows a Pioneer sub-woofer speaker.

Speakers are a very important part of a sound system. No matter how good the receiver or CD player is, the sound quality will be reduced if inferior speakers are used. Equally, if the speakers are of a lower power output rating than the set, distortion will result at best, and damage to the speakers at worst. Speakers generally fall into the following categories.

- Tweeters – high frequency reproduction.
- Mid-range – middle range frequency reproduction (treble).
- Woofers – low frequency reproduction (bass).
- Sub-woofers – very low frequency reproduction.

Figure 16.19 shows the construction of a speaker.

Figure 16.18 Pioneer sub-woofer

16.4.3 ICE

Controls on most ICE sets will include volume, treble, bass, balance and fade. Cassette tape options will include Dolby filters to reduce hiss and other tape selections such as chrome or metal. A digital display, of course, will provide a visual output of the operating condition. This is also linked into the vehicle lighting to prevent glare at night. Track selection and programming for one or several compact discs is possible.

Many ICE systems are coded to deter theft. The code is activated if the main supply is disconnected and will not allow the set to work until the correct code has been re-entered. Some systems now include a plug-in electronic 'key card', which makes the set worthless when removed.

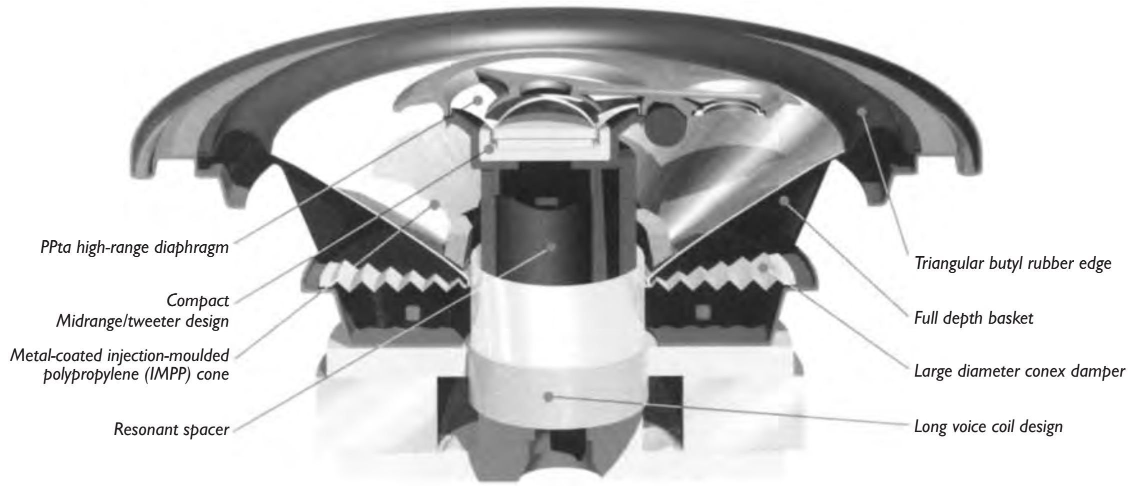

Figure 16.19 Speaker construction

16.4.4 Radio data system (RDS)

RDS has become a standard on many radio sets. It is an extra inaudible digital signal, which is sent with FM broadcasts in a similar way to how teletext is sent with TV signals. RDS provides information so a receiver can appear to act intelligently. The possibilities available when RDS is used are as follows.

- The station name can be displayed in place of the frequency.
- Automatic tuning is possible to the best available signal for the chosen radio station. For example, in the UK, a journey from the south of England to Scotland would mean the radio would have to be re-tuned up to ten times. RDS will do this without the driver even knowing.
- Traffic information broadcasts can be identified and a setting made so that whatever you are listening to at the time can be interrupted.

RDS has six main features, which are listed here with a brief explanation.

1. Programme identification to allow the re-tune facility to follow the correct broadcasts.
2. Alternative frequencies, again to allow the receiver to try other signals for re-tuning as required.
3. Programme service name for displaying the name of the station on the radio set.
4. Traffic information, which provides for two codes to work in conjunction with route finding equipment.
5. Traffic programme, which allows the set to indicate that the station broadcasts traffic information.
6. A traffic announcement is transmitted when an announcement is being broadcast. This allows the receiver either to adjust the volume, switch over from the cassette during the announcement, lift an audio mute or, of course, if the driver wishes it, to do nothing.

16.4.5 Radio reception

There are two main types of radio signal transmitted; these are amplitude modulation (AM) and frequency modulation (FM). Figure 16.20 shows the difference between AM and FM signals.

Amplitude modulation is a technique for varying the height, or amplitude, of a wave in order to transmit information. Some radio broadcasts still use amplitude modulation. A convenient and efficient means of transmitting information is by the propagation of waves of electromagnetic radiation. Sound waves in the audible range, such as speech and music, have a frequency that is too low for efficient transmission through the air for significant distances. By the process of modulation, however, this low-frequency audio information can be impressed on a carrier wave that has a much higher frequency and can propagate through space for great distances. The transmitter at a radio station generates a carrier wave having constant characteristics, such as amplitude and frequency. The signal containing the desired information is then used to modulate the carrier.

This new wave, called the modulated wave, will contain the information of the signal. In AM, it is the amplitude of the carrier wave that is made to vary so that it will contain the information of the signal. When the modulated wave reaches a radio

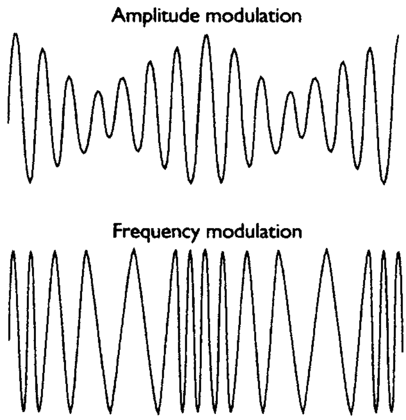

Figure 16.20 Difference between AM and FM signals

receiver tuned to the proper frequency, it is demodulated, which is essentially the opposite of modulation. The set can then reproduce the desired sound via an amplifier and the loudspeakers. AM radio is still a popular form of radio broadcasting, but it does have a number of disadvantages. The quality of reproduction is relatively poor because of inherent limitations in the technique and because of interference from other stations and other electrical signals, such as those produced by lightning or by electronic devices – of which the car has more than its fair share. Some of these drawbacks can be overcome by using FM.

Frequency modulation is a method of modulation in which the frequency of a wave is varied in response to a modulating wave. The wave in which frequency is varied is called the carrier, and the modulating wave is called the signal. Frequency modulation requires a higher-frequency carrier wave and a more complex method for transmitting information than does AM; however, FM has an important advantage in that it has constant amplitude; it is therefore much less susceptible to interference from both natural and artificial sources. Such sources cause static in an amplitude-modulated radio.

Both types of modulation, however, are used in radio broadcasting. FM radio is generally a far better source of high fidelity music. This is because the quality of AM reception, as well as the problems outlined above, is limited by the narrow bandwidth of the signal. During the winter months, reception of AM signals becomes worse due to changes in the atmosphere. FM does, however, present problems with reception when mobile. As most vehicles use a rod aerial, which is omni-directional, it will receive signals from all directions. Because of this, reflections from buildings, hills and other vehicles can reach the set all at the same time. This can distort the signal and is heard as a series of clicks or signal flutter as the signal is constantly enhanced or reduced. The best FM reception is considered to be line-of-sight from the transmitter. In general, the coverage or footprint of FM transmitters is quite extensive and, especially with the advent of RDS, the reception when mobile is quite acceptable.

16.4.6 Radio broadcast data system (RBDS)

The Radio Broadcast Data System is an extension of the Radio Data System (RDS), which has been in use in Europe since 1984. The system allows the broadcaster to transmit text information at the rate of about 1200 bits per second. The information is transmitted on a 57 kHz suppressed sub-carrier as part of the FM multiplexed (MPX) signal.

RBDS was developed for the North American market by the National Radio Systems Committee (NRSC), a joint committee composed of the Electronic Industries Association (EIA) and the National Association of Broadcasters (NAB). The applications for the transmission of text to the vehicle are interesting.

- Song title and artist.
- Traffic, accident and road hazard information.
- Stock information.
- Weather.

In emergency situations, the audio system can be enabled to interrupt the cassette, CD or normal radio broadcast to alert the user.

16.4.7 Digital audio broadcast (DAB)

Digital Audio Broadcasting is designed to provide high-quality, multiservice digital radio broadcasting for reception by stationary and mobile receivers. It is being designed to operate at any frequency up to 3 GHz. A system is being demonstrated and extensively tested in Europe, Canada and the United States. It is a rugged and also a very efficient sound and data broadcasting system.

The system uses digital techniques to remove redundancy and perceptually irrelevant information from the audio source signal. It then applies closely controlled redundancy to the transmitted signal for error correction. All transmitted information is then spread in both the frequency and the time domains (multiplexed) so a high quality signal is obtained in the receiver, even under poor conditions.

Figure 16.21 Clarion DAB receiver

Frequency reallocation will permit broadcasters to extend services, virtually without limit, using additional transmitters, all operating on the same radiated frequency. A common worldwide frequency in the L band (around 1.5 GHz) is being considered, but some disagreement still exists. The possibilities make the implementation of DAB inevitable. Figure 16.21 shows the front panel of the Clarion system, capable of receiving digital broadcast signals.

16.4.8 Interference suppression

The process of interference suppression on a vehicle is aimed at reducing the amount of unwanted noise produced from the speakers of an ICE system. This, however, can be quite difficult. To aid the discussion, it is necessary first to understand the different types of interference. Figure 16.22 shows two signals, one clean and the other suffering from interference. The amount of interference can be stated as a signal-to-noise ratio. This is the useful field strength compared with the interference field strength at the receiver. This should be as high as possible but a value in excess of 22.1 for radio reception is accepted as a working figure. Interference is an electromagnetic compatibility (EMC) issue and further details can be found in Chapter 4.

There are two overall issues to be considered relating to suppression of interference on a vehicle. These are as follows.

1. Short range – the effect of interference on the vehicle's radio system.
2. Long range – the effect of the vehicle on external receivers such as domestic televisions. This is covered by legislation making it illegal to cause disturbance to radios or televisions when using a vehicle.

Interference can propagate in one of four ways.

- Line borne, conducted through the wires.
- Air borne, radiated through the air to the aerial.
- Capacitive coupling by an electric field.
- Inductive coupling magnetic linking.

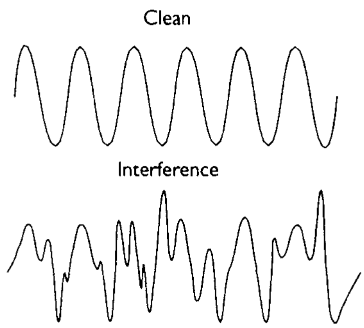

Figure 16.22 Two signals, one clean and the other suffering from interference

The sources of interference in the motor vehicle can be summarized quite simply as any circuit, which is switched or interrupted suddenly. This includes the action of a switch and the commutation process in a motor, both of which produce rapidly increasing signals. The secret of suppression is to slow down this increase. Interference is produced from four main areas of the vehicle.

- Ignition system.
- Charging system.
- Motors and switches.
- Static discharges.

The ignition system of a vehicle is the largest source of interference, particularly the high tension side. Voltages up to 30 kV are now common and the peak current for a fraction of a second when the spark plug fires can peak in excess of 100 A. The interference caused by the ignition system is mostly above 30 MHz and the energy can peak, for fractions of a second, of the order of 500 kW.

The charging system produces noise because of the sparking at the brushes. Electronic regulators produce little problems but regulators with vibrating contacts can cause trouble.

Any motor or switch, including relays, is likely to produce some interference. The most popular sources are the wiper motor and heater motor. The starter is not considered due to its short usage time.

The build-up of static electricity is due to friction between the vehicle and the air, and the tyres and the road. If the static on, say, the bonnet builds up more than the wing then a spark can be discharged. Using bonding straps to ensure all panels stay at the same potential easily prevents this. Due to the action of the tyres, a potential can build up between the wheel rims and the chassis unless suitable bonding straps are fitted. The arc to ground can be as much as 10 kV.

There are five main techniques for suppressing radio interference.

- Resistors.
- Bonding.
- Screening.
- Capacitors.
- Inductors.

Resistance is used exclusively in the ignition HT circuit, up to a maximum of about 20 kΩ per lead. This has the effect of limiting the peak current, which in turn limits the peak electromagnetic radiation. Providing excessive resistance is not used, the spark quality is not affected. These resistors effectively damp down the interference waves.

Bonding has been mentioned earlier, it is simply to ensure all parts of the vehicle are at the same electrical potential to prevent sparking due to the build-up of static.

Screening is generally only used for specialist applications such as emergency services and the military. It involves completely enclosing the ignition system and other major sources of noise, in a conductive screen, which is connected to the vehicle's chassis earth. This prevents interference waves escaping; it is a very effective technique but expensive. Often, a limited amount of screening – metal covers on the plugs for example – can be used to good effect.

Capacitors and inductors are used to act as filters. This is achieved by using the changing value of 'resistance' to alternating signals as the frequency increases. The correct term for this resistance is either capacitive or inductive reactance.

By choosing suitable values of a capacitor in parallel and or an inductor in series it is possible to filter out unwanted signals of certain frequencies.

The aerial is worth a mention at this stage. Several types are in use; the most popular still being the rod aerial, which is often telescopic. The advantage of a rod aerial is that it extends beyond the interference field of the vehicle. For reception in the AM bands the aerial represents a capacitance of 80 pF with a shunt resistance of about 1 MΩ. The set will often incorporate a trimmer to ensure the aerial is matched to the set. Contact resistance between all parts of the aerial should be less than 20 mΩ. This is particularly important for the earth connection.

When receiving in the FM range, the length of the aerial is very important. The ideal length of a rod aerial for FM reception is one quarter of the wavelength. In the middle of the FM band (94 MHz) this is about 80 cm. Due to the magnetic and electrical field of the vehicle and the effect of the coaxial cable, the most practical length is about 1 m. Some smaller aerials are available but whilst these may be more practical the signal strength is reduced. Aerials embedded into the vehicle windows or using the heated rear window element are good from the damage prevention aspect and insensitivity to moisture, but produce a weaker signal, often requiring an aerial amplifier to be included. Note that this will also amplify interference. Some top-range vehicles use a rod aerial and a screen aerial, the set being able to detect and use the strongest signal. This reduces the effect of reflected signals and causes less flutter.

Consideration must be given to the position of an external aerial. This has to be a compromise taking into account the following factors.

- Rod length – 1 m if possible.
- Coaxial cable length – longer cable reduces the signal strength.
- Position – as far away as reasonably possible from the ignition system.
- Potential for vandalism – out of easy reach.
- Aesthetic appearance – does it fit with the style of the vehicle?
- Angle of fitting – vertical is best for AM, horizontal for FM.

Most quality sets also include a system known as interference absorption. This is a circuit built into the set consisting of high quality filters.

Figure 16.23 shows a circuit of a typical ICE system. An electric aerial is included and also the connection to a multi compact disc unit via a data bus.

16.4.9 Mobile communications

If the success of the cellular industry is any indication of how much use we can make of the telephone, the future promises an even greater expansion. Cellular technology started to become useful in the 1980s and has continued to develop from then – very quickly!

The need and desire we perceive to keep in touch with each other is so great that an increasing number of business people now have up to five telephone numbers: home, office, pager, fax and cellular. But within the foreseeable future, high-tech digital radio technology and sophisticated telecommunications systems will enable all communications to be processed through a single number.

With personal numbering, a person carrying a pocket-size phone will need only one phone number. Instead of people calling places, people will call people – we will not be tied to any particular place. Personal numbering will make business people more productive because they will be able to reach, and be reached by, colleagues and clients, anywhere and anytime, indoors or outdoors. When travelling from home to office or from one meeting to the next, it will be possible to communicate with anyone, whenever the need arises.

But where does this leave communication systems relating to the vehicle? It is my opinion that 'in-vehicle' communication equipment for normal business and personal use will be by the simple pocket sized mobile phone and that there is no further market for the car telephone. Hands-free conversions will still be important.

CB radios and short-range two-way systems such as used by taxi firms and service industries will still have a place for the time being. However, even these may decline as the cellular network becomes cheaper and more convenient to use.

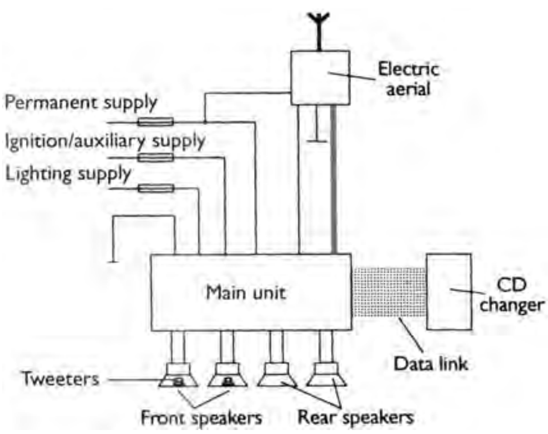

Figure 16.23 ICE system wiring

16.4.10 Auto PC

A revolution in the use of information technology in vehicles is taking place! Advanced computing, communications and positioning developments are being introduced in even the most basic vehicles. Figure 16.24 shows an Auto PC/Car Multimedia system. However, there were several barriers to the widespread use of such new technology.

- Not robust enough.
- Too costly.
- Difficult to install.
- Lack of common standards.
- Difficult to operate.

Most of these problems either have been resolved or are about to be, and other developments are also beneficial:

- Computers have become smaller.
- Prices have reduced.

Figure 16.24 Car multimedia

- Performance has improved.
- Standards are being agreed.

Many leading computer companies, including Microsoft, IBM, and Intel have identified the vehicle as their next big market place. Plans have been announced for in-vehicle computers with a range of integrated functions. Microsoft's Auto PC, for example, uses the Windows CE operating system, a cut-down version of Windows 95/98/2000.

Many suppliers of Windows programs are now committed to offering Windows CE versions of their programs for use in car computers and hand-held personal computers (PCs). Just like a desktop PC, the car computer supports a range of programs. A car computer that will give the driver spoken directions while passengers browse the Internet or watch football will be a reality.

The Auto PC will be able to run familiar desk-top programs whilst also offering the following.

- Spoken turn-by-turn navigation.
- Digital map database of useful sites, such as filling stations and cinemas.
- Voice memo system.
- Vehicle diagnostics program.
- Vehicle security and tracking system.
- Emergency roadside assistance service.

The unit could also be a high-performance stereo system capable of playing CDs and receiving FM radio. An optional communications interface will enable cellular phones to be controlled by spoken instructions, and traffic news received over a pager or cellular service. Intel, the largest computer chip manufacturer, envisages a car computer that is even more highly specified than Microsoft's Auto PC.

The Intel Connected Car PC has a full Windows operating system. As well as providing the driver with similar functions to the Auto PC, this also gives passengers access to a monitor for browsing the Internet or watching television programmes. IBM is working with car manufacturers to help them create networking capabilities in their vehicles.

Whether car computers ultimately succeed or not, there is little doubt that there will be much greater integration of all electronic systems in cars in the future. Efforts are underway in Europe, Japan and the United States to develop a standard databus system linking and powering non-safety related electronic systems in vehicles, such as CD players, positioning systems, air conditioning and electric windows. Adding electronic systems later would be by what is described as 'plug and play'.

Tying the computer in with the mobile communication system opens up even more possibilities. Cellular phone systems can provide an excellent means of tracking vehicles. Phone operators divide the country into separate cells and monitor phones as they move between them to ensure that each phone communicates through the best transmitter. Mobile communication systems will have a profound impact on how vehicles are used. Development work is underway on the exchange of information between vehicles and the road infrastructure.

(See also the section on 'Telematics' in Chapter 13.)

16.5 Security

16.5.1 Introduction

Stolen cars and theft from cars account for about a quarter of all reported crime. A huge number of cars are reported missing each year and over 20% are never recovered. Even when returned many are damaged. Most car thieves are opportunists, so even a basic alarm system can serve as a deterrent.

Car and alarm manufacturers are constantly fighting to improve security. Building the alarm system as an integral part of the vehicle electronics has made significant improvements. Even so, retrofit systems can still be very effective. Three main types of intruder alarm are used.

- Switch operated on all entry points.
- Battery voltage sensed.
- Volumetric sensing.

There are three main ways to disable the vehicle.

- Ignition circuit cut off.
- Starter circuit cut off.
- Engine ECU code lock.

A separate switch or IR transmitter can be used to set an alarm system. Often, they are set automatically when the doors are locked.

16.5.2 Basic security

To help introduce the principles of a vehicle alarm, this section will describe a very simple system, which can be built as a DIY retro-fit. First, the requirements of this particular alarm system.

- It must activate when a door is opened.
- The ignition to be disabled.
- The existing horn is used as the warning.
- Once triggered, the horn must continue even when the door is closed.
- It must reset after 15 seconds.

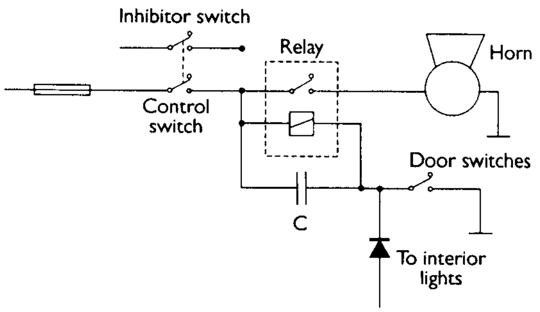

Figure 16.25 Simple alarm circuit the entry delay is made by using a CR circuit

The design will be based around a simple relay circuit. When a door is opened, the switches make an earth connection. This will be used to trigger the relay, which in turn will operate the horn. The delay must be built in using a capacitor, which will keep the relay energized even after the door closes, for a further 15 seconds. An external key switch is to be used to arm and disarm whilst isolating the ignition supply. Figure 16.25 shows a simple alarm circuit, which should achieve some of the aims. The delay is achieved by using a CR circuit; the 'R' is the resistance of the relay coil. Using the following data the capacitor value can be calculated.

- Time delay = 15 s.
- Relay coil = 120 Ω.
- Supply voltage = 12 V.
- Relay drop out = 8 V.

A capacitor will discharge to about 66% of its full value in *CR* seconds. The supply voltage is 12 V, so 66% of this is 8 V.

Therefore, if $CR = 15$, then, $C = 15/120$

$C = 125\,\text{mF}$

This seems an ideal simple solution – but it is not. As an assignment, find the problem and design a simple electronic circuit using a transistor, resistor and capacitor.

16.5.3 Top of the range security

The following is an overview of the good alarm systems now available either as a retro-fit or factory fitted. Most are made for 12 V, negative earth vehicles. They have electronic sirens and give an audible signal when arming and disarming. They are all triggered when the car door opens and will automatically reset after a period of time, often 1 or 2 minutes. The alarms are triggered instantly when an entry point is breached. Most systems can be considered as two pieces, with a separate control

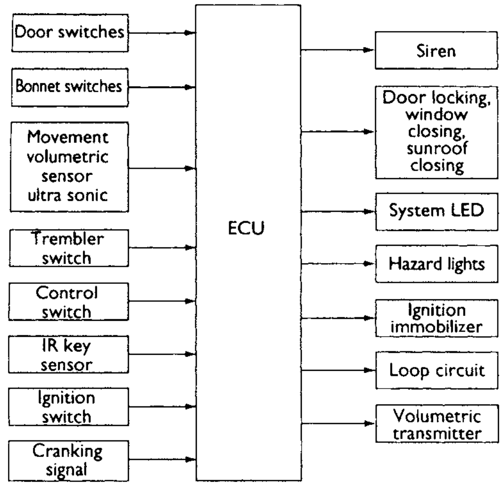

Figure 16.26 Block diagram of a complex alarm system

unit and siren; most will have the control unit in the passenger compartment and the siren under the bonnet.

Most systems now come with two infrared remote 'keys' that use small button-type batteries and have an LED that shows when the signal is being sent. They operate with one vehicle only. Intrusion sensors such as car movement and volumetric sensing can be adjusted for sensitivity.

When operating with flashing lights most systems draw about 5 A. Without flashing lights (siren only) the current drawn is less than 1 A. The sirens produce a sound level of about 95 dB, when measured 2 m in front of the vehicle.

Figure 16.26 shows a block diagram of a complex alarm system. The system, as is usual, can be considered as a series of inputs and outputs.

Inputs

- Ignition supply.
- Engine crank signal.
- Volumetric sensor.
- Bonnet switch.
- Trembler switch.
- IR/RF remote (Figure 16.27).
- Doors switches.
- Control switch.

Outputs

- Volumetric transmitter.
- System LED.
- Horn or siren.
- Hazard lights.
- Ignition immobilizer.
- Loop circuit.
- Electric windows, sun-roof and door locks.

Some factory fitted alarms are combined with the central door locking system. This allows the facility mentioned in a previous section known as lazy lock. Pressing the button on the remote unit, and as well as setting the alarm, the windows and sun-roof close, and the doors lock.

16.5.4 Security coded ECUs

A security code in the engine electronic control unit is a powerful deterrent. This can only be 'unlocked' to allow the engine to start when it receives a coded signal. Ford and other manufacturers use a special ignition key that is programmed with the required information. Even the correct 'cut' key will not start the engine. Citroën, for example, have used a similar idea but the code has to be entered via a numerical keypad.

Of course nothing will stop the car being lifted on to a lorry and driven away, but this technique will mean a new engine control ECU will be needed by the thieves. The cost will be high and also questions may be asked as to why a new ECU is required.

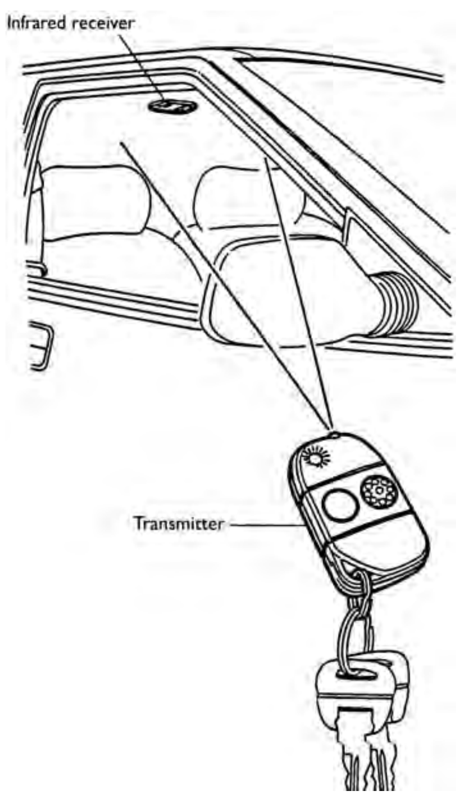

Figure 16.27 Alarm system with remote control

16.6 Airbags and belt tensioners

16.6.1 Introduction

A seat-belt, seat-belt tensioner and an airbag are, at present, the most effective restraint system in the event of a serious accident. At speeds in excess of 40 km/h the seat-belt alone is no longer adequate. Research after a number of accidents has determined that in 68% of cases an airbag provides a significant improvement. It is suggested that if all cars in the world were fitted with an airbag then the number of fatalities annually would be reduced by well over 50 000. Some airbag safety issues have been apparent in the USA where airbags are larger and more powerful. This is because in many areas the wearing of seat-belts is less frequent.

The method becoming most popular for an airbag system is that of building most of the required components into one unit. This reduces the amount of wiring and connections, thus improving reliability. An important aspect is that some form of system monitoring must be built-in, as the operation cannot be tested – it only ever works once. Figure 16.28 shows the airbags operating in a Peugeot.

16.6.2 Operation of the system

The sequence of events in the case of a frontal impact at about 35 km/h, as shown in Figure 16.29, is as follows.

1. The driver is in the normal seating position prior to impact. About 15 ms after the impact the

Figure 16.28 Don't be a crash test dummy!

vehicle is strongly decelerated and the threshold for triggering the airbag is reached. The igniter ignites the fuel tablets in the inflater.

2. After about 30 ms the airbag unfolds and the driver will have moved forwards as the vehicle's crumple zones collapse. The seat-belt will have locked or been tensioned depending on the system.
3. At 40 ms after impact the airbag will be fully inflated and the driver's momentum will be absorbed by the airbag.
4. About 120 ms after impact the driver will be moved back into the seat and the airbag will have almost deflated through the side vents, allowing driver visibility.

Passenger airbag events are similar to the above description. A number of arrangements are used with the mounting of all components in the steering wheel centre becoming the most popular. Nonetheless, the basic principle of operation is the same.

16.6.3 Components and circuit

The main components of a basic airbag system are as follows.

- Driver and passenger airbags.
- Warning light.
- Passenger seat switches.
- Pyrotechnic inflater.
- Igniter.
- Crash sensor(s).
- Electronic control unit.

The airbag is made of a nylon fabric with a coating on the inside. Prior to inflation the airbag is folded up under suitable padding that has specially designed break lines built-in. Holes are provided in the side of the airbag to allow rapid deflation after deployment. The driver's air has a volume of about 60 litres and the passenger airbag about 160 litres.

A warning light is used as part of the system monitoring circuit. This gives an indication of a potential malfunction and is an important part of the circuit. Some manufacturers use two bulbs for added reliability.

Consideration is being given to the use of a seat switch on the passenger side to prevent deployment when not occupied. This may be more appropriate to side-impact airbags mentioned in the next section.

The pyrotechnic inflater and the igniter can be considered together. The inflater in the case of the driver is located in the centre of the steering wheel. It contains a number of fuel tablets in a combustion chamber. The igniter consists of charged capacitors,

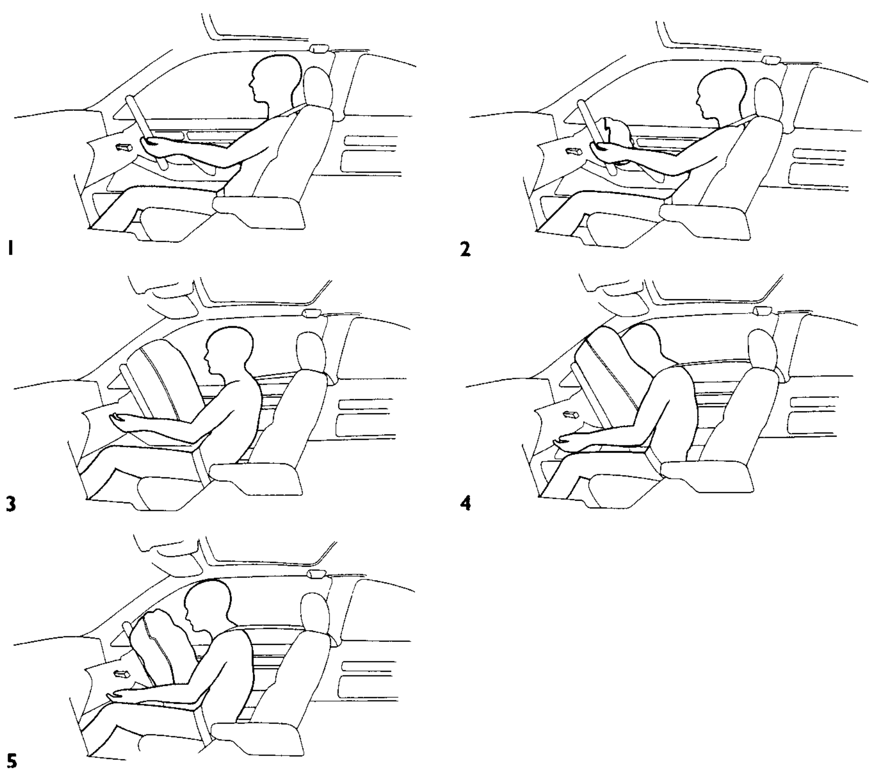

Figure 16.29 Airbag in action

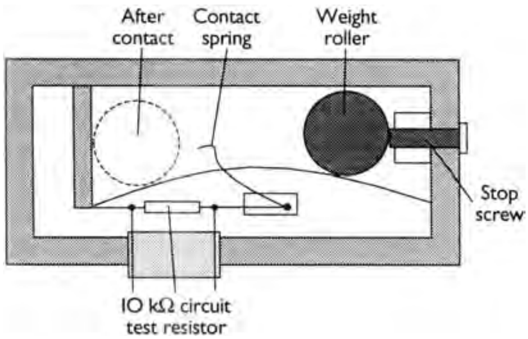

Figure 16.30 The mechanical impact sensor works by a spring holding a roller

which produce the ignition spark. The fuel tablets burn very rapidly and produce a given quantity of nitrogen gas at a given pressure. This gas is forced into the airbag through a filter and the bag inflates breaking through the padding in the wheel centre. After deployment, a small amount of sodium hydroxide will be present in the airbag and vehicle interior. Personal protection equipment must be used when removing the old system and cleaning the vehicle interior.

The crash sensor can take a number of forms; these can be described as mechanical or electronic. The mechanical system (Figure 16.30) works by a spring holding a roller in a set position until an impact above a predetermined limit, provides enough force to overcome the spring and the roller moves, triggering a micro switch. The switch is normally open with a resistor in parallel to allow the system to be monitored. Two switches similar to this may be used to ensure the bag is deployed only in the case of sufficient frontal impact. Note that the airbag is not deployed in the event of a roll over.

The other main type of crash sensor can be described as an accelerometer. This will sense deceleration, which is negative acceleration. Figure 16.31 is a sensor based on strain gauges.

Figure 16.32 shows two types of piezoelectric crystal accelerometers, one much like an engine knock sensor and the other using spring elements. A severe change in speed of the vehicle will cause an output from these sensors as the seismic mass moves or the springs bend. Suitable electronic circuits can monitor this and be pre-programmed to react further when a signal beyond a set threshold is reached. The advantage of this technique is that the sensors do not have to be designed for specific vehicles, as the changes can be software-based.

The final component to be considered is the electronic control unit or diagnostic control unit. When a mechanical-type crash sensor is used, in theory no electronic unit would be required. A

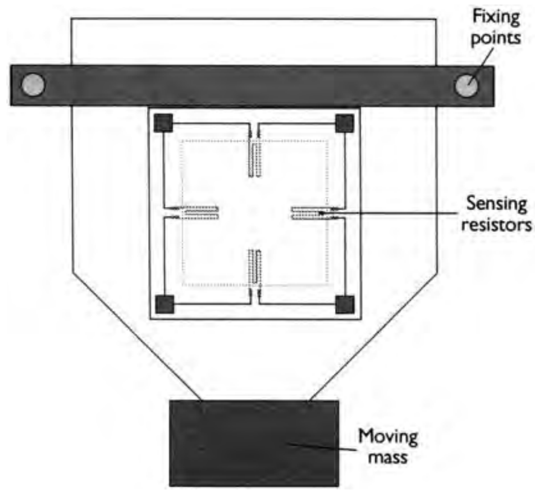

Figure 16.31 Strain gauges accelerometer

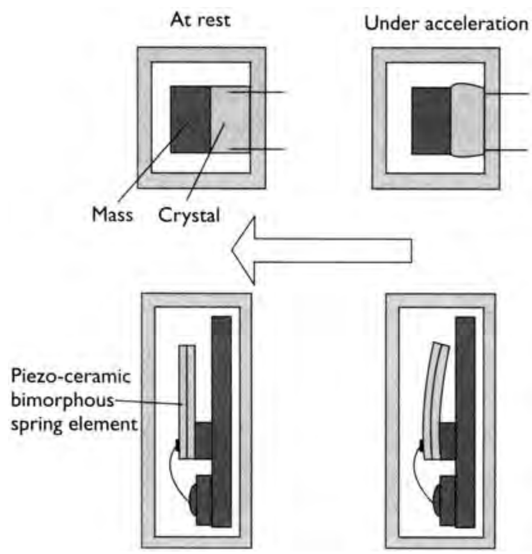

Figure 16.32 Piezoelectric crystal accelerometer

simple circuit could be used to deploy the airbag when the sensor switch was operated. However, it is the system monitoring or diagnostic part of the ECU, that is most important. If a failure is detected in any part of the circuit then the warning light will be operated. Up to five or more faults can be stored in the ECU memory, which can be accessed by blink code or serial fault readers. Conventional testing of the system with a multimeter and jump wires is not to be recommended as it might cause the airbag to deploy! Figure 16.33 shows an airbag ECU.

A block diagram of an airbag circuit is shown in Figure 16.34. Note the 'safing' circuit, which is a crash sensor that prevents deployment in the event of a faulty main sensor. A digital-based system using electronic sensors has about 10 ms at a vehicle

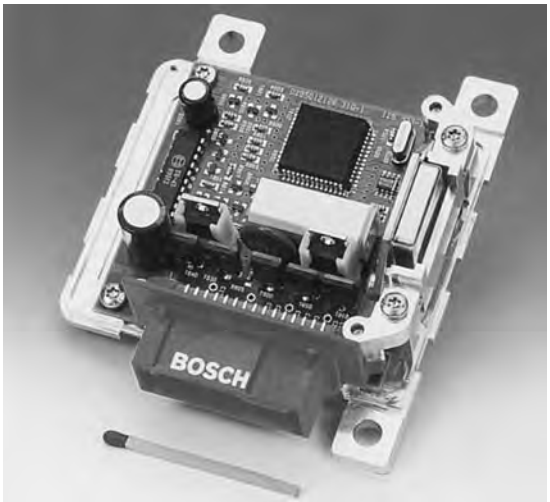

Figure 16.33 Airbag ECU

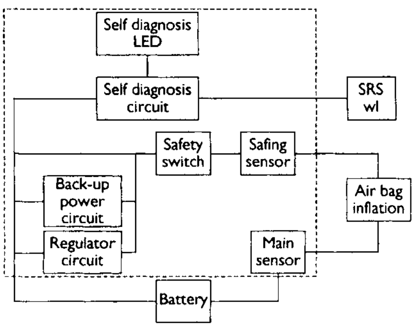

Figure 16.34 A block diagram of an airbag circuit

speed of 50 km/h, to decide if the restraint systems should be activated. In this time about 10 000 computing operations are necessary. Data for the development of these algorithms are based on computer simulations but digital systems can also remember the events during a crash, allowing real data to be collected.

16.6.4 Seat-belt tensioners

Taking the 'slack' out of a seat-belt in the event of an impact is a good contribution to vehicle passenger safety. The decision to take this action is the same as for the airbag inflation. The two main types of tensioners are:

- Spring tension.
- Pyrotechnic.

The mechanism used by one type of seat-belt tensioner is shown in Figure 16.35. When the explosive charge is fired, the cable pulls a lever on the seat-belt reel, which in turn tightens the belt. The

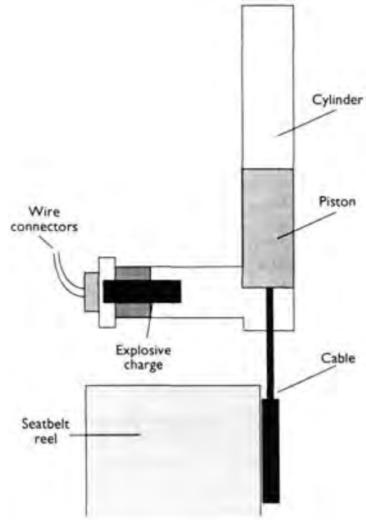

Figure 16.35 The mechanism used by one type of seat-belt tensioner

unit must be replaced once deployed. This feature is sometimes described as anti-submarining.

16.6.5 Side airbags

Airbags working on the same techniques to those described previously are being used to protect against side impacts. In some cases bags are stowed in the door pillars or the edge of the roof. Figure 16.36 shows this system.

Figure 16.37 shows a full seat-belt and airbag system used by Ford.

16.7 Other safety and comfort systems

16.7.1 Obstacle avoidance radar

This system, sometimes called collision avoidance radar, can be looked at in two ways. First, as an aid to reversing, which gives the driver some indication as to how much space is behind the car. Second, collision avoidance radar can be used as a vision enhancement system.

The principle of radar as a reversing aid is illustrated in Figure 16.38. This technique is, in effect, a range-finding system. The output can be audio or visual, the latter being perhaps most appropriate, as the driver is likely to be looking backwards. The audible signal is a 'pip pip pip' type sound, the repetition frequency of which increases as the car comes nearer to the obstruction, and becomes almost continuous as impact is imminent.

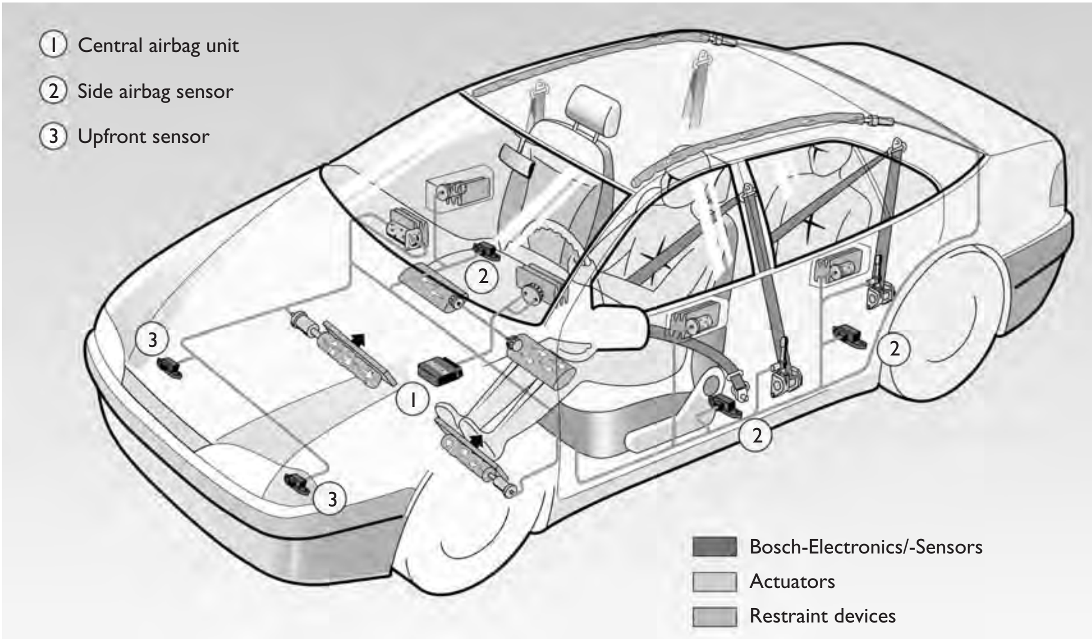

Figure 16.36 Optimized airbag control (Source: Bosch Press)

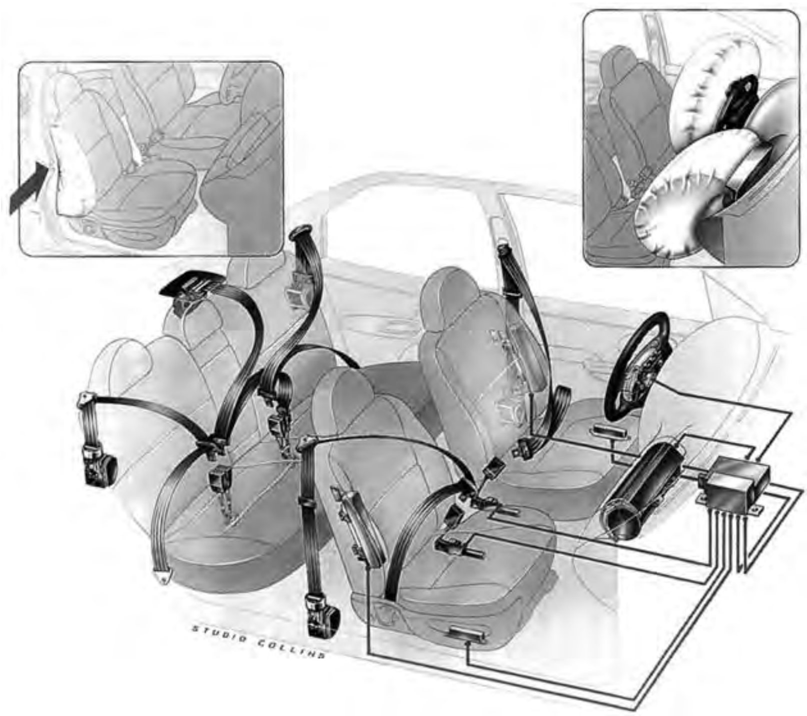

Figure 16.37 Seat-belt and airbag operation

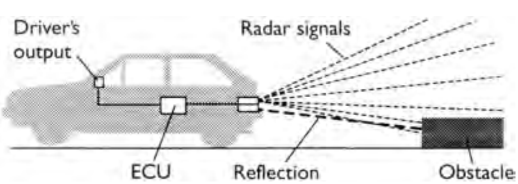

Figure 16.38 Obstacle avoidance radar

The technique is relatively simple as the level of discrimination required is fairly low and the radar only has to operate over short distances. The main problem is to ensure the whole width of the vehicle is protected.

Obstacle avoidance radar, when used as a vision enhancement system, is somewhat different.

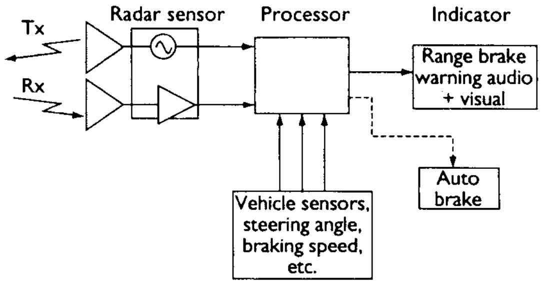

Figure 16.39 Block diagram of obstacle avoidance radar when used as a vision enhancement system

Figure 16.39 is a block diagram to demonstrate the principle of this system. In the future, this may be linked with adaptive cruise control, as discussed in an earlier section, but at this stage the two systems are separate. A frequency of 94 GHz has been used for development work; this frequency is known as millimetre waves.

A short look at the history and principle of radar at this stage will help with an overall understanding. Radar was the name given during World War II to an electronic system by which radio waves were bounced off an aircraft in order to detect its presence and locate its position. The term is an acronym, made from the fuller term 'radio detection and ranging'. A large number of researchers helped to develop the devices and techniques of radar, but the development of the earliest practical radar system is usually credited to Sir Robert Watson-Watt.

The operation of a basic radar system is as follows: a radio transmitter generates radio waves, which are then radiated from an antenna, 'lighting up' the airspace with radio waves. A target, such as another vehicle that is in this space, scatters a small portion of the radio energy back to a receiving antenna. This weak signal is amplified by an electronic amplifier and displayed, often on a cathode ray tube. To determine its position, the distance (range) and bearing must be measured. Because radio waves travel at a known constant velocity, the speed of light, which is 3×10^8 m/s, the range may be found by measuring the time taken for a radio wave to travel from transmitter to obstacle and back to the receiver.

For example, if the range were 150 m, the time for the round trip would be:

$$t = \frac{2d}{C}$$

where t = time, d = distance to object, and C = speed of light.

In this example:

$$t = \frac{2 \times 150}{3 \times 10^8}$$

Relative closing speed can be calculated from the current vehicle speed. The radar is actually transmitted in the form of pulses. This is done by frequency modulating the signal, maybe using a triangular wave with a frequency of the order of 100 MHz: this can also be used to trigger a display and for calculation of distance.

The bearing, if required, is given by the relative position on the display device. Radar for use in a vehicle must fulfil the following general requirements.

- Range to be at least 300 m in bad weather. This gives about 7 seconds warning at 160 k/h (100 mile/h).
- Objects greater than $0.1\,m^2$ must be detected.
- Data update greater than one per second.
- Beam spread of about 15° horizontal and vertical.
- The driver's display should not intrude on concentration and only act as a warning.

The type of display or output that may be used on a motor vehicle will vary from an audible warning to a warning light or series of lights and possibly a display screen.

16.7.2 Tyre pressure warning

A glance at the instrument panel should be enough to tell the driver that the tyre pressures are all correct. Bosch has developed an electronic tyre pressure monitoring system. Each wheel has its own pilot lamp, which lights up if the pressure falls below a set value. Poorly inflated tyres cause loss of control and worse fuel consumption. The idea is to give the driver warning of reduced pressure – as an instant deflation is generally apparent to the driver!

There are three basic components to the system. Mounted in the wheel rim is a pressure operated switch, the contacts of which close when pressure falls. This is recognized by a high frequency sender which the switch passes but does not contact as the wheel rotates. The high frequency sender transmits an appropriate pulse to the electronic evaluator. If the pressure drops below the set value then the switch contacts open, causing the high frequency sender to interrupt its stream of pulses to the evaluation circuit and the warning lamp comes on. The system measures the tyre pressure with an accuracy of ±50 mbar. The design of the switch is such that changes in temperature of the air in the tyre will not cause false readings.

If the tyre pressure warning system is used in conjunction with wheels fitted with 'limp-home' tyres, it will provide a reminder that the limp-home mode is in use.

Bosch is also developing another tyre pressure warning system using active analogue sensors in the tyre and wireless transmission of the signal from the wheel to the body. The advantage is that absolute values of pressure and temperature are measured continuously, even when the car is at rest. Values such as vehicle speed and load are also included in the calculation.

16.7.3 Noise control

The principle of adaptive noise control is that of using sound, which is identical and 180° out of phase, or in anti-phase, to cancel out the original source of noise. Figure 16.40 shows three signals, the original noise, the anti-phase cancelling waveform and the residual noise.

A microphone picks up the original noise. It is then inverted and amplified, and then replayed by a suitably positioned speaker. This effectively cancels out the noise. Whilst the theory is relatively simple, until recently it has not been particularly suitable for motor vehicle use. This is due to the wide range of noise frequencies produced, and the fast response time, which is needed to give acceptable results. Low frequency noise ($<$200 Hz), causes 'boom' in a vehicle, this is very difficult to reduce by conventional methods.

Much development time and money has been spent on reducing cabin noise levels. This can range from simple sound-deadening material to a special design of engine mountings, exhaust systems and using balance shafts on the engine. Even so, the demand still exists to reduce noise further and this is becoming ever more expensive.

Most vehicles today are susceptible to some low frequency boom in the passenger compartment, even when a large amount of sound deadening is used. The trend to produce lighter vehicles using thinner grade metal further exacerbates the problem. Conventional techniques solve the problem at certain frequencies, not all across the range.

To apply the adaptive noise control system to a car required the development of high-speed digital signal processors as well as a detailed understanding of noise generation dynamics in the vehicle. A typical four-cylinder engine running between 600 and 6000 rev/min has a firing frequency of about 20–200 Hz. There are several critical speeds at which the vehicle will display unpleasant boom. Low-profile tyres and harder suspension also generate considerable low frequency noise.

Lotus Engineering has developed a system which uses eight microphones embedded in the vehicle headlining to sample the noise. A digital signal processor measures the average sound pressure energy across the cabin and adjusts the phase and amplitude of the anti-noise signals. These are played through the in-car speaker system until, by measuring the error signal from the microphones, a minimum noise is achieved. The maximum active noise control can be achieved in about 70 ms. A quality loudspeaker system is needed which must be able to produce up to 40 W RMS per channel. This is not uncommon on many ICE systems. Figure 16.41 shows a typical layout of an adaptive noise control system. The greatest improvements are gained in

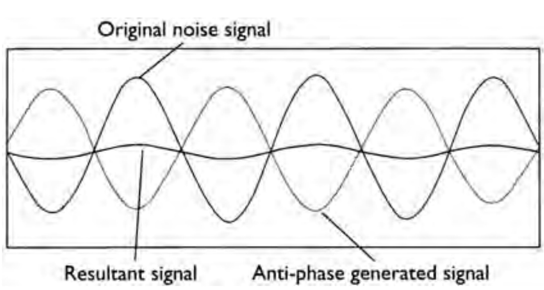

Figure 16.40 Three signals; the original noise, the anti-phase cancelling waveform and the residual noise

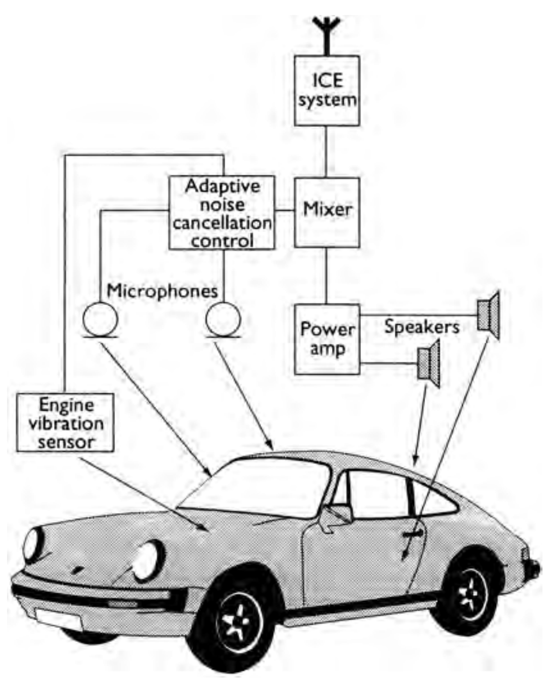

Figure 16.41 Layout of an adaptive noise control system and how it could be fitted

small vehicles where the perceived reduction is as much as 80%.

16.8 Case studies

16.8.1 Volvo safety

The following information is extracted from information relating to features on the Volvo S80. It shows the clear commitment of manufacturers in general, and perhaps Volvo in particular, to safety developments.

Safety is very much part of Volvo's soul and, as a result, it is always present (claims the company). It is an integral part of the first design work and a vital part at every stage of the development process. Active safety can be summarized as active accident avoidance, passive safety can be summed up in three words: passenger protection priority. One of Volvo's prerequisites is that every new Volvo has to be safer than the previous one. Figure 16.42 shows the Volvo S80 airbags.

When it comes to the Volvo S80, this is very much the case. One of the objectives when designing the Volvo S80 was to strengthen further Volvo's position as the world leader in the field of passenger protection. This aim has been realized. With two new and important technical features, the level of passenger protection has taken yet another step forward. It would perhaps be no exaggeration to say that the Volvo S80 is the safest passenger car on the market at present. Although safety developments in the automotive industry have progressed by leaps and bounds in recent years, there is still some truth in the statement that a large car is safer than a small one. Size is related to safety. This is part of the laws of nature. A larger, heavier car suffers the least damage in a collision with a smaller, lighter car, thus providing better protection for its occupants. Crumple zones and energy absorption are two vital parameters that can be more effectively designed if there is more space. A well-designed, rigid body structure is the perfect base on which to build.

Volvo has always claimed that the most important protective feature in a car is the seat-belt. The Volvo S80 has three-point belts on all five seating positions; all equipped with pyrotechnical pretensioners. The pretensioners automatically tighten the belts in a crash, eliminating the slack, which is normal in a belt. The front seat-belts are also equipped with force limiters, which control and regulate the roll speed of the belt webbing and provide more gentle restraint. The front seat-belts also have automatic belt height adjusters for optimum belt geometry. The belt system has been integrated with the airbag systems as these systems interact.

The passenger airbag is invisibly stored under the upper part of the dashboard and is designed to activate in a 'friendly' way in order to protect the passenger rather than being a risk. A belt sensor indicates whether or not the front seat passenger is wearing a seat-belt and adapts the airbag trigger level accordingly. This means that more crash energy is needed to trigger the bag when the passenger is wearing a seat-belt than when he is not.

In 1997, the Volvo Car Corporation presented the Whiplash Protection Study, WHIPS, which was an R&D project designed to produce a seat that would reduce the risk of whiplash injuries in rear-end collisions (Figure 16.43). Although they are most frequently caused at low speeds in relatively minor accidents, whiplash injuries are extremely painful, both physically and mentally, for the people who incur them, as well as being difficult to detect and define. They are also perhaps the single most expensive injury in insurance terms.

Since rear-end collisions often occur in city traffic, the WHIPS system is optimized to be most effective at speeds ranging from 15 to 30 km/h. The system consists of two elements. The first element of the WHIPS system is a brand new device that adjusts the angle between the seat cushion and the backrest. The system is activated in two phases.

1. The backrest of the seat is allowed to move backwards together with the occupant, reducing G-forces.

Figure 16.42 Volvo S80 airbags

Figure 16.43 Volvo S80 'WHIPS'

Figure 16.44 Volvo new SIPS airbag

2. The angle of the backrest folds backwards by up to 15 °, effectively catching the body and preventing a catapult effect.

The second element of WHIPS are six modified springs in the backrest with limiters that provide even support of the spine when pressed into the seat. The fixed head restraint, which remains close to the head, minimizes head movement and reduces forces on the neck. Consequently, the entire back is pressed against the backrest in a controlled manner. Tests conducted by Volvo during the development of the system reveal that the WHIPS system can reduce the acceleration forces in the neck by some 50%.

Passenger protection in side impacts is perhaps the most difficult area in terms of safety development, because of the lack of space and the minimal crumple zone, only 25–30 cm. Passengers sit very close to the point of impact. This must therefore be compensated for one way or another. The Side Impact Protection System (SIPS) structure has been extensively upgraded and its interacting components consist of the energy-absorbing elements in bottom rails, pillars, cross-members, roof and seats, plus energy-absorbing materials in the doors. This has been supplemented with more, further improved, padding in all the roof pillars and along the edges of the headliner. This material feels hard when it is touched, but it yields in a 'friendly' manner and absorbs energy when it is hit in an impact. The second step in the continued development of the SIPS system was the introduction of the SIPS bags in 1994 – now a standard item on all Volvo cars.

The Volvo side airbag (Figure 16.44) is located in the outer part of the backrest and is therefore always in the optimum protective position in relation to the occupant. The SIPS further reduces the risk of severe chest and pelvic injuries, as its function is to keep the occupant away from the side of the car. The side airbags are triggered by electronic sensors, one in the B pillar and one behind the rear door. Their position makes the reaction time from moment of impact to triggering the bag very short – a factor that is of vital importance in side impacts. However, padding and side airbags cannot completely make up for what can happen to the head when the car is hit from the side.

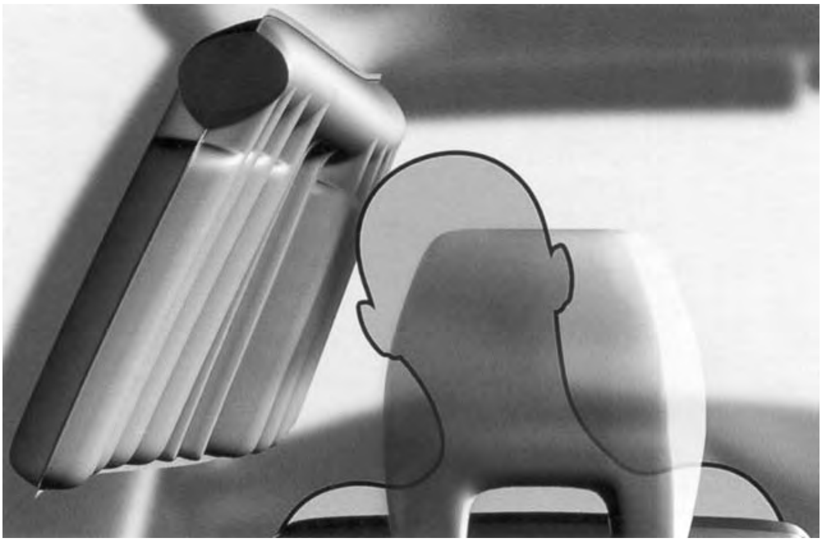

Figure 16.45 Volvo S80 inflatable curtain

The Inflatable Curtain (IC) was presented together with WHIPS an an R&D project in 1997, and is claimed to be the first technical system for this type of protection. The purpose of the system (Figure 16.45) is to reduce further injuries in a side impact by protecting the head and neck of the occupants both in the front and rear seats. The curtains, one on each side, are woven in one piece and hidden inside the roof lining. They cover the upper part of the interior, from the 'A' pillar to the rear side pillar. The same sensors as used with the SIPS bags activate the IC. They are 'slave' sensors to a central sensor, which determines where the impact is and which bag should be triggered in order to protect the occupants.

If only the rear sensor is affected, the IC is activated but not the SIPS bag. The curtain is filled within 2.5 ms and stays inflated about three seconds in order to provide maximum protection in complicated collisions. The ducts do not cover the entire surface of the curtain. Instead, they are concentrated in the areas that are most likely to be hit by the occupants' heads. As a result, the need for gas is limited and the activation time is minimal. The ducts act as controlled head restraints and prevent the head from hitting the inside of the car. The curtain also prevents the head from impacting on collision obstacles, such as lampposts and similar objects. The size of the curtain also provides support, keeping the passengers inside the car instead of being partially thrown out of the side windows.

The protective capacity of the IC remains the same, regardless of whether the window is open or closed. When the curtain is activated, it hardly touches the side window but expands inwards, moving closer to the heads of the occupants.

In order to permit the installation of a rear-facing child seat in the front passenger position, the passenger airbag can be switched on and off using a switch. This switch, which can be fitted only by a Volvo dealer, works via the ignition key. When the ignition is turned on, an indicator lamp on the switch comes on and shows whether or not the passenger airbag is activated. If the switch suffers electronic failure, the supplementary restraint system (SRS) lamp comes on, just as it does if any other defect occurs in the SRS system.

16.8.2 Rover electric windows

The circuit of the electric window system used by some Rover vehicles is shown in Figure 16.46. The windows will only operate when the ignition is switched on. When the ignition is switched on, the window lift relay is energized by the supply from fuse 18 in the passenger compartment fuse-box on the LG wire, which passes to earth on a B wire. With the relay energized, the battery supply from fusible link 4 on the N wire feeds the four window lift fuses on an N/U wire.

The driver's window can only be operated from the switchblock on the driver's door, which is supplied from fuse 30 in satellite fuse block 2, on an S/G wire. When the 'up' switch is pressed, the feed from the fuse crosses the window lift switch and provides a feed to the control unit on a B/Y wire. The control unit will now provide a positive supply to the window lift motor on a R/U wire and an earth path on an R/Y wire. The window will now move upwards until the switch is released or it reaches the end of its travel.

When the 'down' switch is pressed the supply from fuse 30 in satellite fuse block 2 provides a

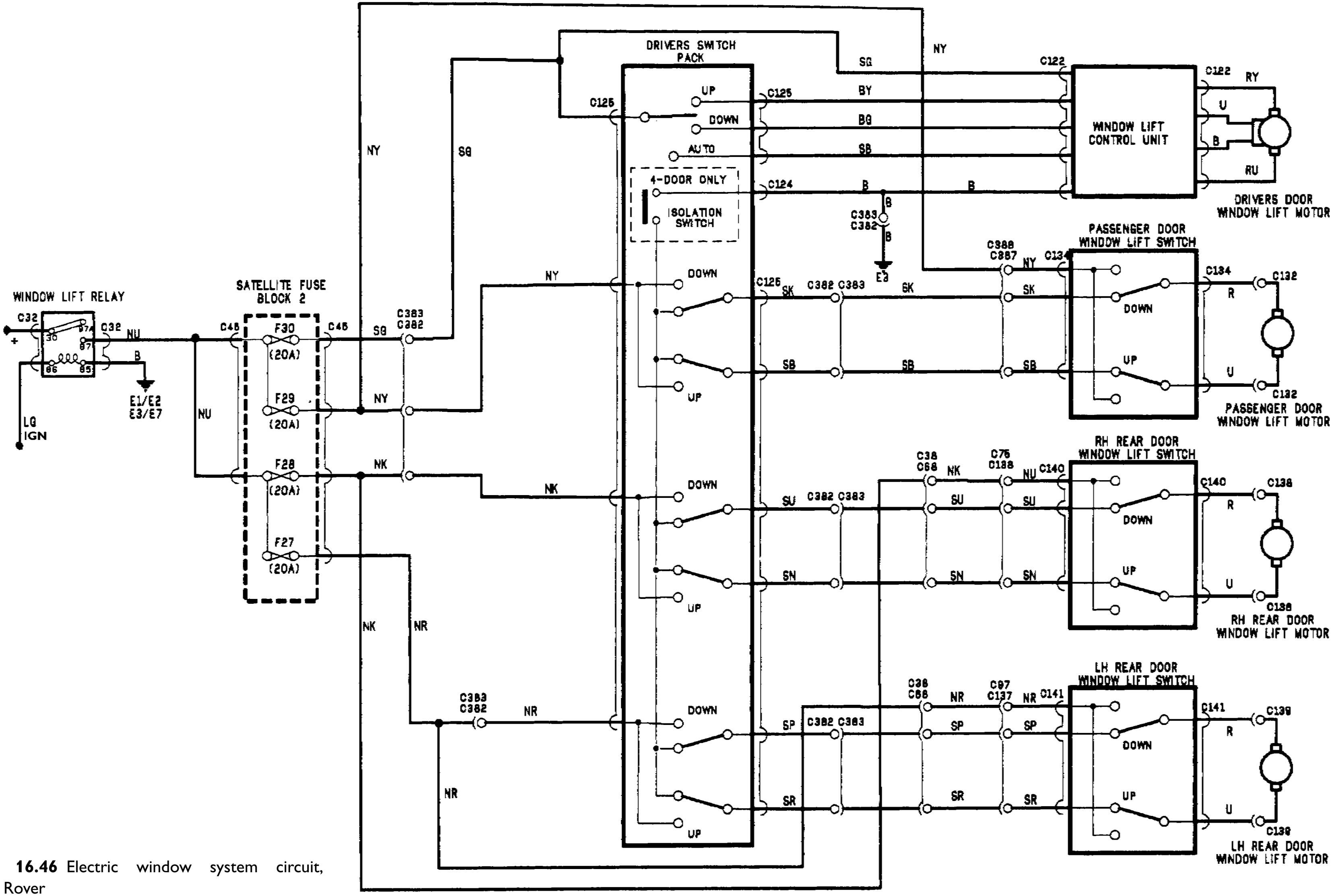

Figure 16.46 Electric window system circuit, used by Rover

feed to the control unit on an S/G wire. The control unit will now connect a positive feed to the window lift motor on an R/Y wire and an earth path on a R/U wire. The window will now move downwards until the switch is released or the window reaches the end of its travel.

The driver's door window may be fully opened by moving the driver's door window switch fully downwards then releasing it. This will allow a supply to cross the closed switch contacts and feed the control unit on an S/B wire. The control unit will now operate the window lift motor in the downward direction until the window reaches the end of its travel. The front passenger's window can be operated from the driver's door switchback or the passenger's door switchback.

When the 'up' switch is pressed, the supply from fuse 29 in satellite fuse block 2 on the N/Y wire crosses the window lift switch out to the passenger's window lift switch on an S/B wire, then onto the window lift motor on a U wire. The earth path for the window lift motor on an R wire crosses the passenger's window lift switch out to the driver's door master switch on an S/K wire, through the isolator switch and to earth on a B wire.

When the 'down' switch is pressed, the supply from fuse 29 in satellite fuse block 2 on an N/Y wire crosses the window lift switch out to the passenger's window lift switch on an S/K wire, then onto the window lift motor on an R wire. The earth path for the window lift motor on a U wire crosses the passenger's window lift switch out to the driver's door master switch on an S/B wire, through the isolator switch and to earth on a B wire.

When the 'up' switch is pressed, the supply from fuse 29 in satellite fuse block 2 supplies the passenger's window lift switch on an N/Y wire, then onto the window lift motor on a U wire. The earth path for the window lift motor on an R wire crosses the passenger's window lift switch out to the driver's door master switch on an S/K wire, through the isolator switch and to earth on a B wire.

When the 'down' switch is pressed, the supply from fuse 29 in satellite fuse block 2 supplies the passenger's window lift switch on an N/Y wire, then onto the window lift motor on an R wire. The earth path for the window lift motor on a U wire crosses the passenger's window lift switch out to the driver's door master switch on an S/B wire, through the isolator switch and to earth on a B wire.

Each rear window can be operated from the driver's door switchback or, provided that the isolation switch in the driver's door switchback has not been pressed, from the switch on each rear door. The operation of the rear windows is similar in operation to the front passenger's window.

16.8.3 Jaguar 'S' type audio, communications and telematics

The following information is extracted from information relating to features on the Jaguar 'S' (Figure 16.47). It shows the general trend and developments relating to 'communication' systems.

For the first time on a production car (Jaguar claims), optional voice-activated controls for the audio (radio/cassette/CD), phone and climate control systems, responding to the spoken instructions

Figure 16.47 Jaguar S-type

of the driver, provide safe, hands-free operation. The system responds to a wide diversity of English and North American accents, but also provides for training to recognize a specific voice.

A first for Jaguar is the optional, fully integrated on-board satellite navigation system using multilingual, digitized map data on CD-ROM. The system can point out useful landmarks and points of interest and links with the UK's Trafficmaster system to provide real-time data on traffic delays.

The 175 W, 12-speaker, premium sound system, features two active 'centre fill' speakers, an active sub-woofer enclosure and 6-disc CD auto-changer. Digital sound processing, working with Dolby, provides special audio effects and compensates for the number of vehicle occupants.

The premium specification Motorola portable GSM phone is a factory fit option, combining the advantages of vehicle integration, safety, convenience and performance with the versatility of a pocket phone.

16.8.4 Noise control developments

A hydraulic engine mount, which is electronically controlled in response to the engine vibration, can significantly reduce noise. Some manufacturers, however, are now using a much simpler version, which can switch between hard and soft settings. A system developed by Lotus is claimed to be as effective as about 45 kg of sound deadening material.

An exhaust company, 'Walker', has developed an active muffler for reducing exhaust noise. The heart of this system is a digital processor. Two inputs are used, a microphone to measure the noise from the tailpipe and an engine speed sensor. The system calculates the correct anti-noise and delivers this by means of special speaker drivers mounted on the exhaust system. The residual noise is measured and adjustments can be made. Because the system is self-learning it will adapt to the changing noises of an ageing engine.

The active muffler allows straight gas flow from the exhaust after the catalytic converter. This allows improved engine performance that can mean less fuel is used. An average reduction in fuel consumption of 5% is possible. Future EC directives are expected relating to exhaust noise, which are currently set at 77 dB (A) in Germany. Larger mufflers will be needed to comply, which means this system may well become quite popular.

16.8.5 Alarming developments!

Professional car thieves will always find ways around the latest alarm systems. However, the vehicle manufacturers strive to stay one jump ahead. Tracking devices can be built-in to an unknown part of the vehicle's chassis. This can be activated in the event of the car being stolen, allowing the police to trace the vehicle. A system popular in the UK is 'Tracker' and this works as follows.

1. The car is stolen.
2. Depending on the product, the owner tells 'Tracker' or 'Tracker' tell the customer.

Figure 16.48 Since 1993 'Tracker' has helped police forces throughout the UK recover more than £35 million worth of stolen vehicles

3. The ‘Tracker’ unit in the car is activated by powerful transmitters.
4. Police with tracking computers detect the silent homing signal.
5. The police recover the car.

The ‘Tracker’ unit is a radio transponder. When the vehicle is reported stolen the police are informed and the ‘Tracker’ unit is activated. The unit then broadcasts a unique reply code, which can be detected and decoded by police tracking computers, which are fitted in police cars, helicopters and fixed land sites. The police then track the vehicle, taking appropriate action. Figure 16.48 shows a stolen car recovery in action.

A ‘Tracker’ unit can be fitted to any self-propelled road vehicle that has a suitable location where the unit can be hidden. The system currently only operates in mainland Great Britain. It constantly draws power from the main vehicle battery but if this is disconnected, a re-chargeable back-up battery provides power for up to 2 days. The presence of the unit is not disclosed to the thief, which means there is a greater likelihood of rapid recovery and minimal damage. The unit is not transferable from one vehicle to another but the new owner need only pay for the network subscription. Most insurance companies offer additional discounts of up to 20% if this system is fitted.

16.8.6 ICE warning

The following is a description of a Blaupunkt ‘New York RDA 127’ ICE system.

This is a purely high-end system thanks to DSA, which is an automatic calibration program for linear frequency response in the car and the ‘psycho-acoustic masking’ of driving noises (DNC). An integrated high-end CD drive is included with an optional opto-changer.

The ‘Sub-Out’ and the many equalizer functions demonstrate its serious claim of sophistication among the high-end car hi-fi systems of today. The whole spectrum of new car audio technology is covered along with some fascinating options:

- FM, MW, LW
- TIM (Traffic Memo)
- Dual-tuner RDS
- RDS-EON-PTY
- Radiotext
- Travelstore
- CD 1 bit/8 × Over-sampling
- Disc Management System (DMS)
- Digital Signal Adaptation (DSA)
- Dynamic Noise Covering (DNC)
- Self-adjusting equalizer
- 4 × 23 watts RMS power
- 4 × 35 watts maximum power
- Digital-in
- Four-channel pre-amp output
- Sub-Out

This type of mobile multimedia seems to have everything! In spite of high-end performance, it all remains uncomplicated. Good sized, easily readable displays, menu-controlled operator prompting and an ergonomic, award-winning design make an important contribution to driving pleasure.

High-end sound technology automatically perfects the acoustics in the vehicle interior, masks undesirable driving noises and uses incredible dynamics and ‘spatiality’ to make listening to the audio system on the road a real experience.

16.8.7 Intelligent airbag sensing system

Bosch has developed an ‘Intelligent Airbag Sensing System’ which can determine the right reaction for a specific accident situation. The system can control a one- or two-stage airbag inflation process via a two-stage gas generator. Acting on signals from vehicle acceleration and belt buckle sensors, which vary according to the severity of the accident, the gas generator receives different control pulses, firing off one airbag stage (de-powering), both stages (full inflation), or staged inflation with a time interval.

Future developments will lead to capabilities for multistage inflation or a controllable sequence of inflation following a pattern determined by the type of accident and the position of the vehicle occupants. The introduction of an automotive occupancy sensing (AOS) unit that uses ultrasonic and infrared sensors will provide further enhancements. This additional module will detect seat and child occupancy and will be capable of assessing whether a passenger is in a particular position, such as feet on the dashboard!

Bosch hopes that the latest radar technology will assist the design of a pre-crash sensor capable of detecting an estimated impact speed prior to collision, and activating individual restraint systems, such as seat-belt pre-tensioners. Or, if necessary, all available restraint systems. Figure 16.49 shows a representation of this system.

16.8.8 ICE system – digital recordable radio

The Woodstock DAB 53 digital car radio from Blaupunkt contains some interesting features. Digital audio broadcasting (DAB) is now fully available. Compared to the paths of transmission used up to now, DAB provides considerably improved reception characteristics in terms of quality. It effectively eliminates the interference caused by multi-path reception or fluctuating signal strength.

The unit is equipped with an impressive new feature: while driving, the driver can record DAB programs at the touch of a button and play them back again. Blaupunkt selected the multimedia card (MMC), one of the smallest, most modern storage mediums currently available in the world, as the most suitable medium for the innovative new 'Recordable' feature. In addition, the multimedia card and the integrated CD audio/MP3 drive make it possible to play music in the MP3 format. This provides up to twelve hours of sounds from a single CD-ROM.

Figure 16.49 Intelligent airbag system

The set is fully digital and can be installed in the standard radio compartment of any vehicle. It is able to process all the audio signals of the DAB transmission system digitally and has been equipped to receive radio stations on the FM, MW and LW wavebands. For FM reception the digital tuner concept provides excellent sound quality and RDS (Radio Data System) makes sure that the radio always tunes into the best available frequency.

The Woodstock DAB 53 has been equipped with a 4×45 W output stage and a 4-channel preamp out. The radio can also be connected to a hands-free telephone system and is able to operate a CD changer. The front panel folds down to reveal the CD and MMC slots. As effective theft protection, the operating panel can be removed.

16.8.9 Reverse sensing/ parking aid

A Reverse Sensing System is a reverse only parking aid system that uses sensors mounted in the rear

Figure 16.50 Digital audio broadcast recordable radio (Source: Bosch)

bumper. Parking aid systems feature both front and rear sensors. As the vehicle approaches large objects, such as other vehicles or general obstacles, it beeps warning sounds. The frequency of beeping increases as the object is approached – until a solid tone is emitted at a distance of about 25 cm (10 inches).

Low-cost, high-performance ultrasonic range sensors are fitted to the vehicle. Generally, four intelligent sensors are used to form a detection zone as wide as the vehicle. A microprocessor monitors the sensors and emits audible beeps during slow reverse parking to help the driver back up or park the vehicle.

This leads to easier and convenient reversing and parking manoeuvres, especially for vehicles where drivers have limited view at the front, rear or corners of the vehicle.

16.8.10 Alarms and immobilizers

The anti-theft alarm circuit shown here is typical of many. As with all complex systems it can be considered as a black box with inputs and outputs. The inputs are signals from key and lock switches as well as monitoring sensors. The outputs are the alarm horn and the hazard lights but also starter inhibitor relays, etc.

Alarm system

This system can be operated by remote control or using the key in a door lock. When first activated, the system checks that the doors and tailgate are closed by monitoring the appropriate switches. If all is in order, the anti-theft system is then activated after a 20-second delay. The function indicator LED flashes rapidly during this time and then slowly once the system is fully active.

The alarm can be triggered in a number of ways:

- Opening a door, the tailgate or the bonnet/hood.
- Removal of the radio connector loop.
- Switching on the ignition.
- Movement inside the vehicle.

If the alarm is triggered the horn operates for 30 seconds and the hazard lights for 5 minutes. This stops if the remote key or door key is used to unlock the vehicle.

Passive anti-theft system (PATS)

This system is a vehicle immobilizer developed by Ford. It is activated directly through the ignition switch by means of an electronic code stored in a special key. Each key has a transponder that stores the code, which does not require a battery. The key code is read by the receiver (which is part of the

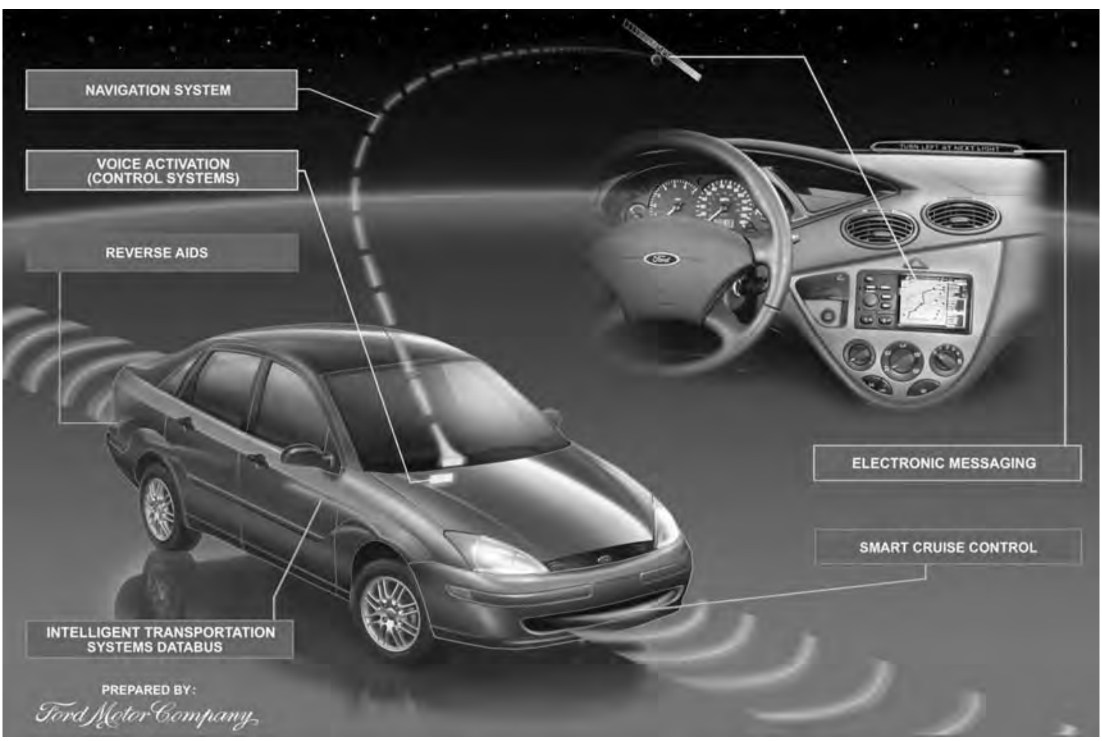

Figure 16.51 Reversing aid as part of a control system (Source: Ford)

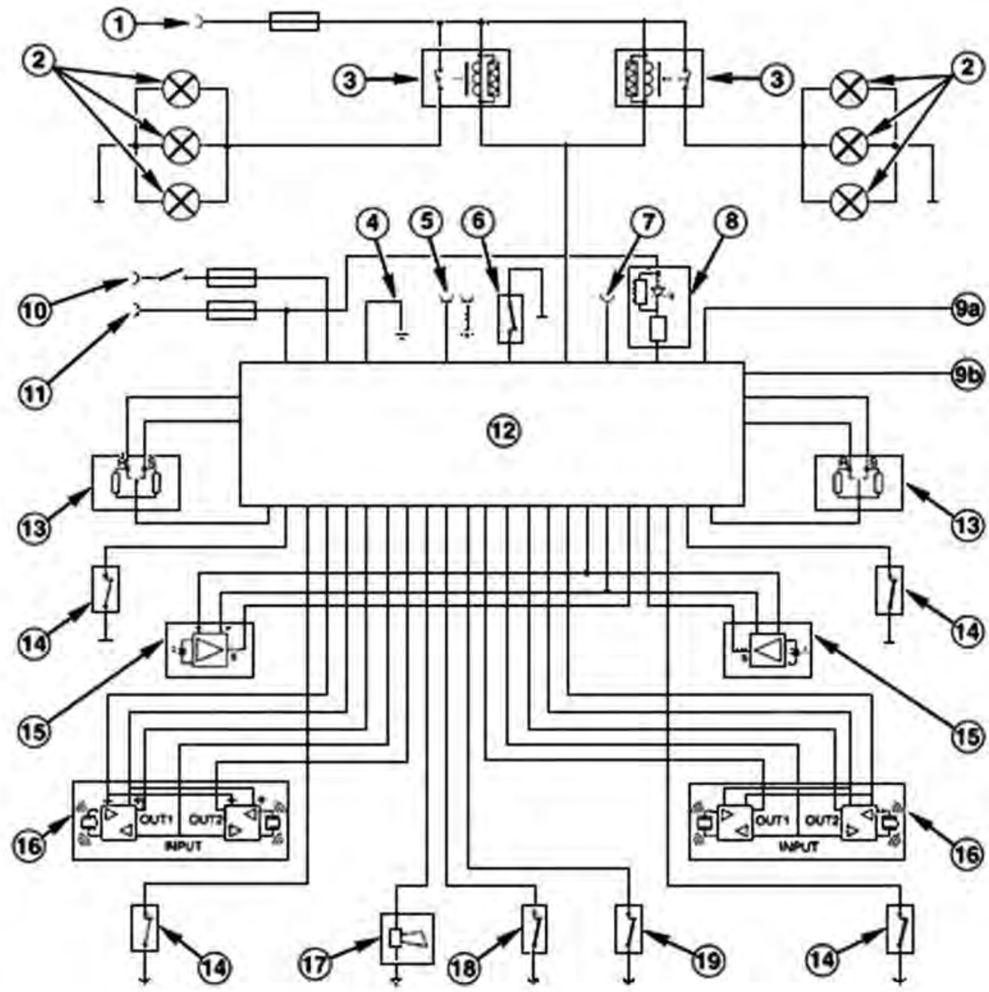

Figure 16.52 Anti-theft alarm system with remote control and interior monitoring (Source: Ford). 1. Battery supply. 2. Hazard lights. 3. Hazard lights alarm relay. 4. Earth/Ground. 5. Diagnostic connector. 6. Bonnet/Hood switch. 7. Connector for radio theft protection. 8. Function light. 9. Input signal locked/unlocked. 10. Ignition supply. 11. Battery supply. 12. Anti-theft alarm ECU. 13. Left/Right door key switch. 14. Door switches. 15. Infrared receiver. 16. Ultrasound sensors. 17. Horn. 18. Tailgate switch. 19. Tailgate key switch

ignition switch) when the key is turned from position 0 to 1 or 2 (usually marked as I or II). If the code matches the one stored in the module, then it allows the engine to start. These systems operate independently of the alarm.

Key programming

Some keys and/or remotes for later vehicles may need to be reprogrammed if, for example, the battery goes flat or a new key is required. There are several methods of programming remote keys. However, different manufacturers use various methods and it is therefore not possible to cover all of these. A few methods are described here as examples.

PATS key programming:

In earlier systems a red key is used as a master; it is exactly the same as the other keys apart from its colour. This key is the only one that can program new keys – if lost the whole system has to be reprogrammed by a dealer – and a new master supplied.

To program a red key system insert the master key into the ignition and turn it to position II. When the light on the clock goes out remove the key. The light will come back on if the master key was used. While the light is still on, insert the new key and turn to position II. The light will flash twice and the key is programmed.

To program a two key system both of the original keys are needed. Insert the keys one after the other in the ignition, turn to position II and then remove. After the second key is removed, insert the new un-programmed key, switch to position II and then remove it. The new key is now programmed.

Remember not to put an un-programmed PATS key in the ignition unless following the above

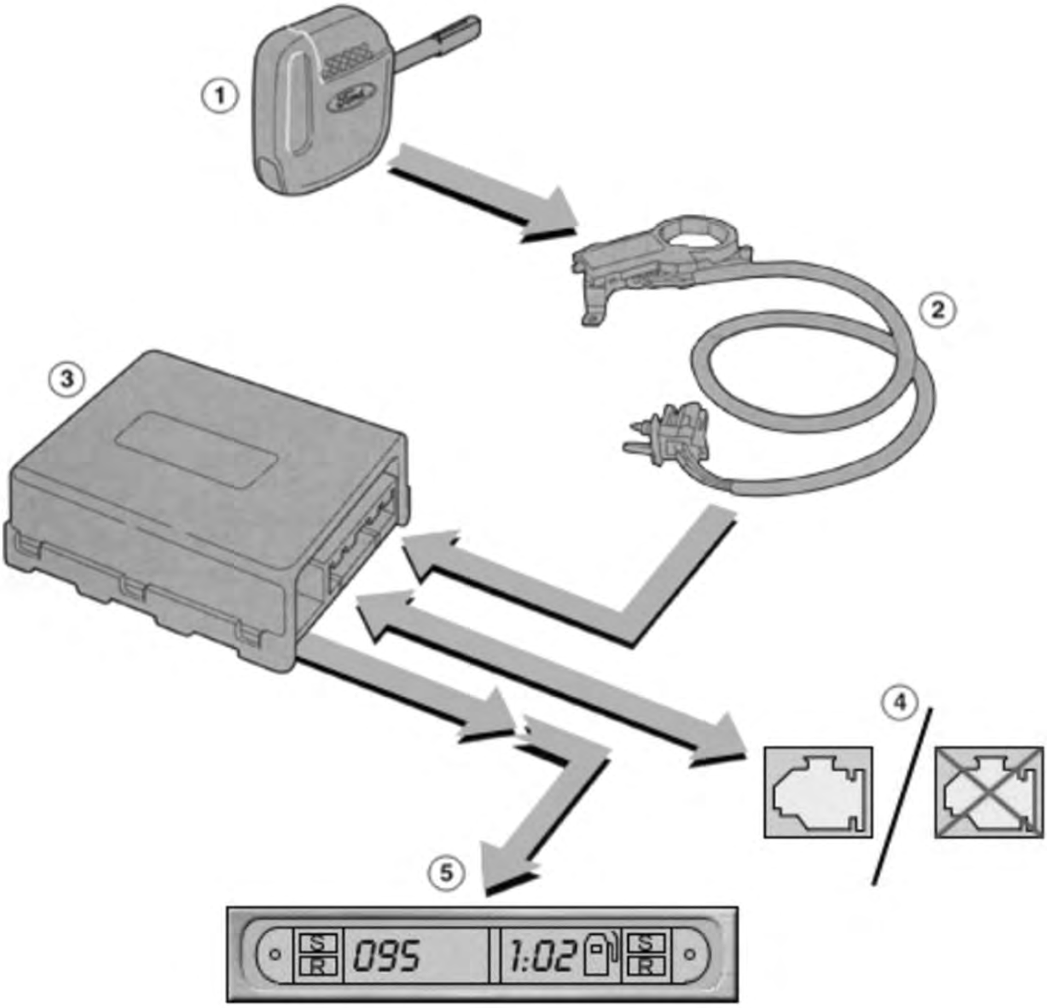

Figure 16.53 PATS components (Source: Ford). 1. Key with integrated transponder. 2. Transmitter/Receiver. 3. PATS module. 4. Engine start – yes/no. 5. Clock with integrated function indicator

procedure – it will immobilize the vehicle for 30 minutes!

Remote keys (example only):

Switch the ignition from I to II quickly 4 times – this illuminates the alarm warning light. Remove the key from the ignition and point it at the remote sensor (interior mirror usually). Press and hold one of the buttons until the light on the remote flashes. Keep holding the first button, press the other button 3 times and finally release both buttons. The light on the remote and the warning light will flash 5 times – the remote key is now programmed.

On some vehicles, switching the ignition from I to II quickly 4 times will activate a chime. Remove the key and press any of the buttons to activate another chime. Finally, replace the key and turn the ignition to position II – the remote key is now programmed.

A useful tip is that on many remotes changing the batteries within 15 seconds will mean they do not need to be reprogrammed.

Fault diagnosis

Many vehicle manufacturers use equipment connected to a diagnostic link connector (DLC) to check several systems, including alarms. This is the same DLC as used for engine management diagnostics. See the sections on OBD for more details. Test equipment is becoming available that can be used by independent repairers. However, it is not often cost effective to purchase this for specific vehicles.

As with others, an alarm system can be treated as a black box system. In other words, checking the inputs and outputs for correct operation means the complexity inside the ECU can be largely ignored. Note that most alarms will not set if the module

Table 16.1 Common symptoms and possible faults of comfort systems

Symptom	Possible fault
Radio interference	• Tracking HT components. • Static build-up on isolated body panels. • High resistance or open circuit aerial earth. • Suppression device open circuit.
Electric windows not operating	If all windows not operating: • Open circuit in main supply. • Main fuse blown. • Relay coil or contacts open circuit or high resistance. If one window is not operating: • Fuse blown. • Control switch open circuit. • Motor seized or open circuit. • Back-off safety circuit signal incorrect.
Cruise control will not set	• Brake switch sticking on. • Safety valve/circuit fault. • Diaphragm holed. • Actuating motor open circuit or seized. • Steering wheel slip ring open circuit. • Supply/earth/fuse open circuit.

is receiving an incorrect input signal when it is activated (door switch open/closed for example). A generic diagnostic procedure for an anti-theft alarm system is listed as follows (a circuit diagram helps but is not essential):

1. Check ignition and battery power supplies and earth/ground connections to the alarm module.
2. Test operation of all 'entry' switches at the module connector. Look for a low/high voltage as the switches are operated. If incorrect, trace the specific circuit after testing the switch itself.
3. Measure the voltage signals from the key switches as the key is turned in each lock.
4. Check the radio loop circuit for continuity.
5. Test continuity of ultrasonic sensor wiring if fitted.
6. The horn/siren can be tested using a fused jumper wire (disconnect it first).

Important: Only use a digital voltmeter for the tests because a lamp could overload a circuit in the module.

Remember, most electrical faults are simple – broken wires or connectors or open circuit switches. Don't be too hasty in condemning the ECU/module!

16.9 Diagnosing comfort and safety system faults

16.9.1 Introduction

As with all systems the six stages of fault-finding should be followed.

1. Verify the fault.
2. Collect further information.
3. Evaluate the evidence.
4. Carry out further tests in a logical sequence.
5. Rectify the problem.
6. Check all systems.

The procedure outlined in the next section is related primarily to stage 4 of the process. Table 16.1 lists just a few faults as examples for this chapter.

16.9.2 Testing procedure

The following procedure is very generic but with a little adaptation can be applied to any electrical system. Refer to the manufacturer's recommendations if in any doubt. The process of checking any system circuit is broadly as follows.

1. Hand and eye checks (loose wires, loose switches and other obvious faults) – all connections clean and tight.
2. Check battery (see Chapter 5) – must be 70% charged.
3. Check motor/solenoid/linkage/bulbs/unit – visual check.
4. Fuse continuity – (do not trust your eyes) voltage at both sides with a meter or a test lamp.
5. If used, does the relay click (if yes, jump to stage 8) – this means the relay has operated, but it is not necessarily making contact.
6. Supply to switch – battery volts.
7. Supply from the switch – battery volts.
8. Supplies to relay – battery volts.

9. Feed out of the relay – battery volts.
10. Voltage supply to the motor – within 0.5 V of the battery.
11. Earth circuit (continuity or voltage) – 0 Ω or 0 V.

16.9.3 ECU auto-diagnostic function

Many ECUs are equipped to advise the driver of a fault in the system and to aid the repairer in detection of the problem. The detected fault is first notified to the driver by a dashboard warning light. A code giving the details is held in RAM within the ECU. The repairer, as an aid to fault-finding, can read this fault code.

Each fault detected is memorized as a numerical code and can only be erased by a voluntary action. Only serious faults will light the lamp but minor faults are still recorded in memory. The faults are memorized in the order of occurrence.

Faults can be read as two-digit numbers from the flashing warning light by shorting a diagnostic wire to earth for more than 2.5 seconds but less than 10 seconds. Earthing this wire for more than 10 seconds will erase the fault memory as does removing the ECU constant battery supply. Earthing a wire to read fault codes should only be carried out in accordance with the manufacturer's recommendations. The same coded signals can be more easily read on many after-sales service testers. On some systems it is not possible to read the fault codes without a code reader.

16.9.4 Fault-finding by luck

If four electric windows stopped working at the same time, it would be very unlikely that all four motors had burned out. On the other hand, if just one electric window stopped working, then it may be reasonable to suspect the motor. It is this type of reasoning that is necessary when fault-finding. However, be warned, it is theoretically possible for four motors to burn out apparently all at the same time!

Using this 'playing the odds' technique can save time when tracing a fault in a vehicle system. For example, if both stop lights do not work and everything else on the vehicle is OK, I would suspect the switch (stages 1 to 3 of the normal process). At this stage though, the fault could be anywhere – even two or three blown bulbs. Nonetheless a quick test at the switch with a voltmeter would prove the point. Now, let us assume the switch is OK and it produces an output when the brake pedal is pushed down. Testing the length of wire from the front to the back of the vehicle further illustrates how 'luck' comes into play.

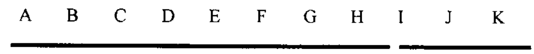

Figure 16.54 Representation of a wire with an open circuit between 'H' and 'I'

Figure 16.54 represents the main supply wire from the brake switch to the point where the wire 'divides' to each individual stop light (the odds say the fault must be in this wire). For the purpose of this illustration we will assume the open circuit is just before point 'I'. The procedure continues in one of the two following ways.

One

- Guess that the fault is in the first half and test at point F.
- We were wrong! Guess that the fault is in the first half of the second half and test at point I.
- We were right! Check at H and we have the fault … On test number *three*.

Two

- Test from A to K in a logical sequence of tests.
- We would find the fault … On test number *nine*.

You may choose which method you prefer!

16.10 Advanced comfort and safety systems technology

16.10.1 Cruise control and system response

Figure 16.55 shows a block diagram of a cruise control ECU. Many cruise control systems work by the proportional-integral control technique. Proportional control means that an error signal is developed via the feedback loop, which is proportional to the difference between the required and actual outputs. The final output of a cruise control system is the vehicle speed but this depends on the throttle position, which is controlled by the actuator. The system electronics must take into account the lag between throttle movement and the required change in vehicle speed.

If the system overreacts, then the vehicle speed would become too high and then an over-reaction would cause the speed to become too low and so on. In other words, the system is not damped correctly (under damped) and will oscillate, much like a

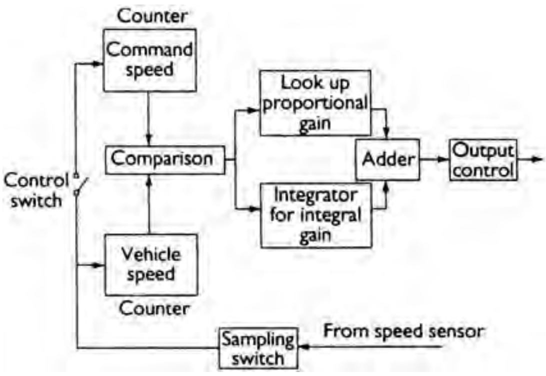

Figure 16.55 Cruise control system – detailed block diagram

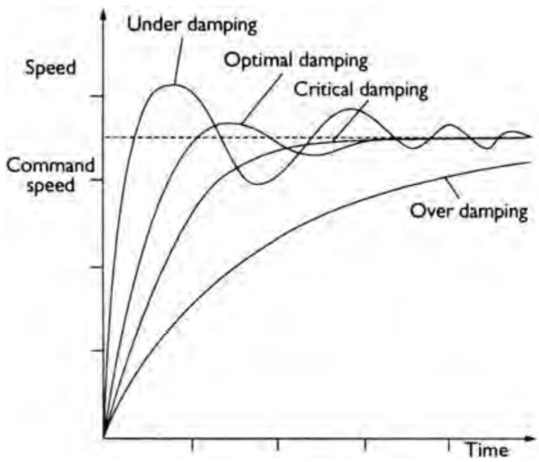

Figure 16.56 Damping factors

suspension spring without a damper. Proportional control alone is prone to this problem because of steady-state errors in the system. To improve on this, good system design will also include integral control. Thus, the final signal will be the sum of proportional and integral control signals. An integral controller produces a signal, which is a ramp, increasing or decreasing, proportional to the original error signal.

The use of integral control causes the final error signal to tend towards zero. The combination therefore of these two forms of control in the weighting given to each determines the damping factor of the control electronics. Figure 16.56 shows the effect on vehicle speed of different damping factors. These four responses are well known in engineering and electronics and can be modelled by mathematics to calculate the response of a system.

The above technique can be based on analogue or digital electronics. The principle is much the same in that for any system the proportional and integral control can be used. The theoretical values can be calculated prior to circuit design as follows:

$$G_i = \omega_n^2 M$$

$$G_p = (2d\omega_n M) - C$$

where G_i = integral gain, G_p = proportional gain, ω_n = natural frequency of the system ($2\pi f_n$), M = mass of the vehicle, C = experimentally determined frictional factor (mechanical), and d = damping coefficient.

16.10.2 Radio suppresser calculations

Capacitors and inductors are used to act as filters. This is achieved by using the changing value of 'resistance' to alternating signals as the frequency increases. The correct term for this resistance is either capacitive or inductive reactance. These can be calculated as follows:

$$X_C = \frac{1}{2\pi fC}$$

$$X_L = 2\pi fL$$

where X_C = capacitive reactance (ohms), X_L = inductive reactance (ohms), C = capacitance (farads), L = inductance (henrys), f = frequency of the interference (hertz).

Using the above formulae gives the following results with a 0.1 mF capacitor and a 300 mH inductor, first at 50 Hz and then at 1 MHz.

Frequency	100 Hz	1 MHz
Capacitive reactance	15.5 kΩ	1.6 Ω
Inductive reactance	0.18 Ω	1.9 KΩ

By choosing suitable values of a capacitor in parallel and or an inductor in series it is possible to filter out unwanted signals of certain frequencies. To home in on a specific or resonant frequency a combination of a capacitor and inductor can be used. The resonant frequency of this combination can be calculated:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

When the range of the interference frequency is known, suitable values of components can be determined to filter out its effect.

Figure 16.57 Standard key and remote transmitter

16.11 New developments in comfort and safety systems

16.11.1 Key words

Remote keyless entry (RKE)

Remote keyless entry has been a feature on many cars for a number of years. Remote keys work by transmitting either radio frequency or infrared signals. Door locking is controlled by a small handheld transmitter and a receiver unit, as well as a decoder in the main control unit. This layout varies slightly between different manufacturers.

When the remote key is operated (by pressing a small switch), a complex code is transmitted. The number of codes used is in excess of 50 000. The receiver sensor picks up this code and sends it in an electrical form to the main control unit. If the received code is correct, the relays are triggered and the doors are either locked or unlocked. On some systems, if an incorrect code is received on three consecutive occasions when attempting to unlock the doors, the system will switch itself off until the door is opened by the key. This action resets the system and allows the correct code to operate the locks again. This technique prevents a scanning type transmitter unit from being used to open the doors.

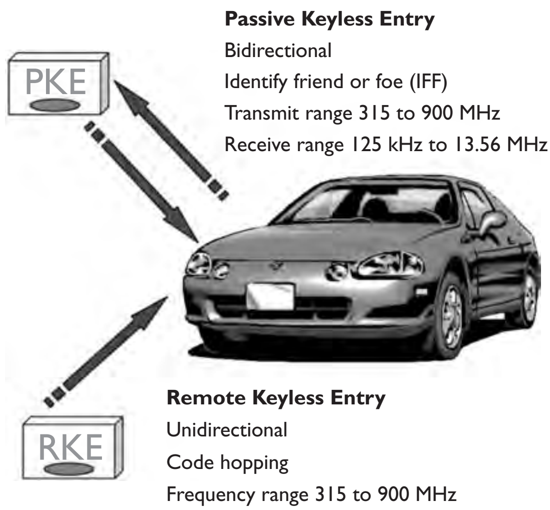

Figure 16.58 Remote and Passive Keyless Entry systems

Figure 16.59 Numerical keypad on the door (Source: Ford)

Passive keyless entry (PKE)

Passive keyless entry systems[1] mean the driver doesn't even need to press a button to unlock the vehicle! The electronic key is simply carried in a pocket, on a belt clip or in a bag. The controllers in the doors communicate with the key using radio frequency (RF). This action determines if the correct key is present and, if it is, the doors are unlocked.

[1] Joerge Becker, Passive Keyless Entry and Drive Systems, Auto Technology, June 2002

This communication event is triggered by lifting the door handle, or in some cases the vehicle will even unlock as the key holder approaches it.

PKE systems need the same level of security as any other remote locking method. Conventional RKE is a unidirectional process. In other words, signals are only sent from the key to the receiver. With PKE the communication is two-way. This is because the PKE system carries out an 'identity friend or foe' (IFF) operation for security purposes. The vehicle sends a random challenge to the key; the key encrypts this value and sends it back to the vehicle. The vehicle then performs the same encryption, compares the result with that sent by the key, and unlocks the doors if the values match.

Battery life is a critical issue for PKE. To obtain the required range of operation, 1.5 m (5 ft), the detection circuit in the key needs to be sensitive enough to detect just a few mV; this consumes significant power. There is also an issue with power consumption for the base station (vehicle) if the doors are designed to unlock as the key approaches. To achieve this the base station must poll continuously. In other words, it must keep looking for the key. This consumes battery power, which could be an issue if the vehicle was left for a long period. However, this method does have the advantage that the doors will always be locked unless a key is present.

If the method of lifting a handle is used as a trigger, then no power is consumed until needed. The down side of this method is that the user will want to feel the door unlock as the handle is lifted. However, Texas Instruments has developed a low-frequency RF chip. With a standby current of 5 μA and less than 10 mV peak-to-peak sensitivity, the chip therefore provides a long battery life. It comes in an industry-standard package small enough to fit into a key fob or credit card device. This type of system is likely to become very common. Some PKE systems can even be set up to recognize multiple keys. The car could even be programmed to 'know' who was driving and set seat and mirror positions automatically!

Passive keyless go and exit

When the driver enters a car the key remains in a 'pocket' or at least it will be inside the vehicle. This means assuming that the key is being recognized, engine starting can be by a simple start button. As the button is pressed the same authentication process that takes place for the door locks starts. The engine can only be started if the key is inside the car, which is a technical challenge for the designers. For example, the key could be in a jacket hanging above the back seat, or it could be in the jacket outside on the roof.

Philips Semiconductors have produced a system with receive signal strength identification (RSSI), which can detect whether the key is inside or outside the vehicle. After the occupants have left the vehicle, the doors can be locked by pressing a handle or as the driver leaves the vicinity. 'Inside/outside' detection is also necessary for this scenario so the key cannot be locked in the car.

Keypad entry

In vehicles equipped with a keypad entry system, the vehicle doors and the boot can be locked and unlocked without using a key. Before unlocking the boot or a passenger door, the driver's door must be unlocked. Usually, if more than five seconds pass between pressing numbers on the keypad, the system will shut down and the code has to be entered again.

To unlock the driver's door, the factory code or a personal code is entered. All codes have five numbers. After the fifth number is pressed, the driver's door unlocks. The passenger doors can then be unlocked by pressing the 3/4 button within five seconds of unlocking the driver's door. To unlock the boot, the 5/6 button must also be pressed within five seconds. If this time is exceeded, the code to open the driver's door must be re-entered.

The keypad can also be used to lock the doors. To lock all of the car doors at the same time, 7/8 and 9/0 need to be pressed at the same time. It is not necessary to enter the keypad code. This will also arm the anti-theft system if fitted.

16.11.2 GM Dialogue Manager

A new technology that 'knows' when drivers are too busy to receive certain information has been developed by GM-Saab. As drivers demand more information from their vehicles, manufacturers need to find ways to deliver it safely. The technology is designed to lessen attention demands on the driver and adjust certain vehicle information based on driver status and/or preference.

The system is designed to manage information flow to the driver based upon the current driving environment. To do this, the technology takes into account vehicle factors such as speed, wiper movement and other vehicle data. Based on these factors, the Dialogue Manager decides if it is a good time to relay messages to the driver via the information centre. If the 'vehicle' perceives that the driver is experiencing a demanding driving environment, the system will delay messages that aren't safety-critical until the car senses a less demanding situation.

Systems such as this are designed to reduce driver workload; a term for both physical and mental demands on a driver. GM researchers are already working on more sophisticated versions of the Dialogue Manager. These will take into account more vehicle factors and classify vehicle information into more categories.

One example of a more sophisticated version of the Dialogue Manager is that it would enable a vehicle to map out a travel route for the driver – without manual input of an address – based solely on the correct recognition of the driver and their personal calendar and appointments scheduled for that day. Eventually this technology would also be capable of identifying a delay in the original route, resulting in the vehicle modifying the route to achieve both energy and time efficiency. Another example could allow the vehicle to delay an incoming call from an embedded phone when demanding situations are identified.[2]

16.12 Self-assessment

16.12.1 Questions

1. State what is meant by active and passive safety.
2. Draw a simple motor reverse circuit and explain its operation.
3. Describe briefly six features of a high-end ICE system.
4. State five sources of radio interference.
5. Explain why fault-finding sometimes involves ‘playing the odds’.
6. Describe the operating sequence of a driver’s airbag.
7. Define ‘Latching relay’.
8. Describe, with the aid of a block diagram, the operation of a cruise control system.
9. State four advantages of an intelligent airbag.
10. Explain the key features of a top-end alarm system.

16.12.2 Assignment

Investigate the development of the ‘Auto PC’ with particular reference to:

- Digital map databases.
- Vehicle diagnostics programs.

Produce a report on some of the issues connected with these developments. A good technique for starting on this type of assignment is to ask the question: ‘Who gains and who loses?’

Consider also issues of updating and cost.

[1]GM, 2003, Press information

16.12.3 Multiple choice questions

An electric window has a Hall type sensor fitted. Technician A says this is used to determine the window position. Technician B says this is part of the ‘bounce back’ safety feature. Who is right?
1. A only
2. B only
3. Both A and B
4. Neither A nor B

A window lift motor drives through a worm gear because this:
1. increases speed and torque
2. reduces speed and torque
3. increases speed and reduces torque
4. reduces speed and increases torque

The frequency reproduction from a ‘tweeter’ type speaker would be described as:
1. high
2. middle range
3. low
4. very low

In order for a radio to interrupt listening and broadcast traffic announcements it will receive signals described as:
1. AM
2. RDS
3. CD
4. PC

When discussing ways in which to disable a vehicle to prevent theft, Technician A says two ways to do this are ignition circuit cut-off and fuel system cut-off. Technician B says starter circuit cut-off and engine ECU code lock. Who is right?
1. A only
2. B only
3. Both A and B
4. Neither A nor B

Which of the following would provide an input signal to an alarm system:
1. volumetric sensor
2. volumetric transmitter
3. ignition immobilizer
4. unbroken loop circuit

Which of the following would be regarded as a passive safety feature:
1. airbag
2. seat-belt
3. belt tensioner
4. all of the above