THE XK8 BODY ELECTRONICS CONTROL SYSTEM

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Introduction

The XK8 being a new design gave the opportunity to introduce fresh concepts utilising the latest available technology whilst largely retaining the customer controls familiarity of the XJ saloon range.

The requirements of any program are to improve quality, minimise cost, weight and the number of parts/derivatives whilst maximising feature content and refinement. In addition the market is dictating that the development time of programs must become shorter to remain competitive. The production volumes for a luxury car are lower than other sectors of the market which means that the development costs are critical and opportunities to utilise existing developed technologies must be utilised.

Historically the increased feature content of cars has lead to an increase of hardware and wiring such that packaging space is now at a premium. This is particularly so in the case of Jaguar's cars, which being located in the luxury sector of the market, must fulfil the associated expectations.

The timing of the XK8 program meant Jaguar was able to take advantage of developments within its parent company, the Ford Motor Company. In particular, a multiplex control system developed specifically for automotive applications (Standard Corporate Protocol) and associated microprocessor based control modules.

These developments formed the basis of the XK8 body system to meet the above criteria i.e. to reduce wiring with the associated reduction in cost, weight and packaging space; refinement of feature operation and the flexibility to modify; reduced part count and associated production costs; and lower development costs.

What is a Body Electronic Control System ?

The body system can be loosely defined as non-driving functions operated by the driver or passengers. The functions controlled by the body system are :-

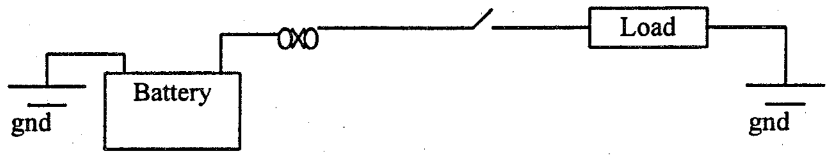
- Lighting (Interior and exterior);
- Wipers & washers including headlamp power-wash;
- Window control including entry/exit glass drop, one touch down window operation;
- Control of the Door Mirrors, Seats and Steering Column;
- Memorisation of two driving positions for the Door Mirrors, Seats and Steering Column;
- Locking, Security and Immobilisation;
- Convertible Hood operation; Warnings and Convenience features.

What is Meant by Multiplexing ?

Multiplexing is NOT a feature of the vehicle, but an enabling technology, the operation of which the car's users should not be aware of. Multiplexing allows microprocessor based modules to transfer complex information over a single communications link, comprised of one or two wires.

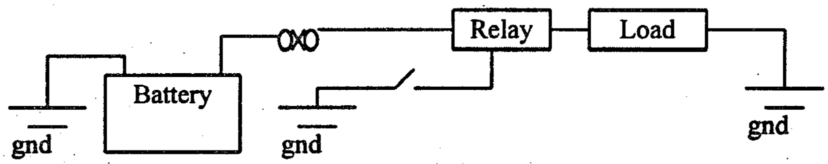
Over the last twenty years the approach to controlling electrical systems on cars has changed dramatically. The simplest form of control is for a switch to be in series with the load. The switch and harness wires then carry all the current required to operate the devise. This is known as High Current Switching.

Figure A: High Current Switching:



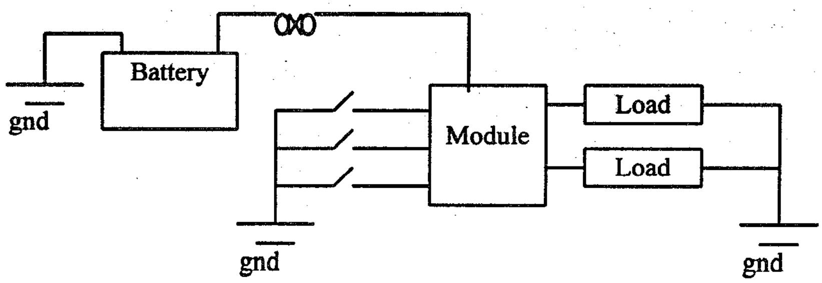
The first development was to Low Current Switching, where the switch operated a relay which sourced the current to operate the device, thus enabling smaller & less expensive switches to be used.

Figure B: Low Current Switching:



For more complicated systems requiring multiple switches & with multiple outputs, single chip microprocessor based modules were then used, with all the necessary switches and loads being hardwired to a single controlling module. This is known as Functional Partitioning.

Figure C: Low Current Switching via a Module:



The addition of a multiplexed link between these modules allows information to be shared whilst REDUCING the number of harness wires required (see figure F, later in paper). Once a switch or load is wired to one module, the status or control of that wire is available to all the other modules on the network via the multiplexed link.

An example of this is the Door Ajar Switch. On the XK8, this is hard wired to the module in the door. This Door Module broadcasts the state of the switch to the other modules on the link to control such features as interior lighting, instrument cluster door open warning, the security system and many other functions. The signal is used by nearly every module on the multiplexed link, but it is connected to only one!

The amount of information that can be transferred via a multiplexed link varies depending on the speed of the multiplexed bus or "protocol" used. A low speed system will operate at less than 10kbits/second, whilst the fastest real time systems can go up to around 1 Mega bit/second.

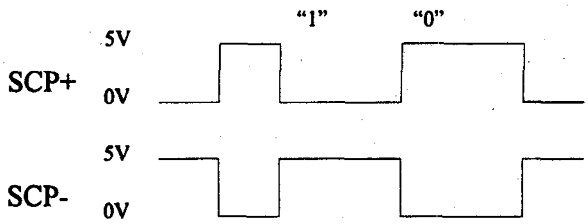
The XK8 Body System modules use the Ford Standard Corporate Protocol (SCP), which is a mid range system, operating at around 50 kbits/second. This translates to a maximum of 700 messages/second.

Ford's Standard Corporate Protocol (SCP)

The SCP complies with the requirements of the Society of Automotive Engineer's requirements for automotive multiplexed links, the SAE J1850 specification.

SCP uses TWO wires, twisted in to a pair. However, the system will operate fully with only a single wire intact. As shown in figure D, the SCP- line rests at five volts & is driven to ground, whilst the SCP+ line rests at ground & is driven to five volts. These steps increase the robustness of the link whilst reducing the risk of radiated electro-magnetic emissions.

Figure D: SCP + & - Line Configuration



The link is used as a star network (see figure E). There is no controlling module, a system of non-destructive arbitration & message priorities is used to determine access to the bus. The format of these messages is pre-defined and is controlled by a standardised Ford world-wide data-base.

To avoid increasing the processing burden on the control modules own microprocessors, SCP adds a Hosted Bus Controller Chip (HBCC) to each module on the bus. The HBCC takes care of all the overheads of transmitting & receiving messages of the SCP network. The HBCC together with the SCP interface and termination components (which together make-up what is called the "Physical Layer") represent all the hardware additions necessary for a module to communicate via SCP.

For Body System applications messages are sent on an EVENT, such as a door being opened. With the robustness of the design preventing messages from being lost, the message is not repeated until the event occurs again. This reduces the number of messages sent, allowing the system to operate at it's lower bus speed. The exception to this are the critical messages, where periodic messages are used.

The XK8 SCP system does not exceed 20% bus loading, even during the busiest periods of normal operation.

With modules being permanently powered, action is necessary to reduce the load on the battery when the engine is not running & the ignition is off. To do this, any or all of the modules may enter a "sleep mode" during periods of inactivity. These sleep modes reduce the current drawn by the modules to as little as half a milliamp, which contributes to the vehicles requirement of a long term parking & starting capability.

The Body System Application to the XK8

The body system functions referred to are located or controlled in six areas, the two doors, the two front seats, the facia and boot. A module was allocated to each of these areas resulting in four module types being required i.e. Door Module, Seat Module, Body Processor Module (Facia) and Security & Locking Module (Boot). In comparison the XJS which was functionally less complex had eight modules and for example did not include windows or steering column control.

Microprocessor based modules were chosen to allow the flexibility of change, refinement of control and sophistication of functions desired. For the XK8 Jaguar implemented a program in conjunction with the Automotive Component Division of Ford who supplied the electronics.

Reference to figure E (below) shows the module locations and system interconnections.

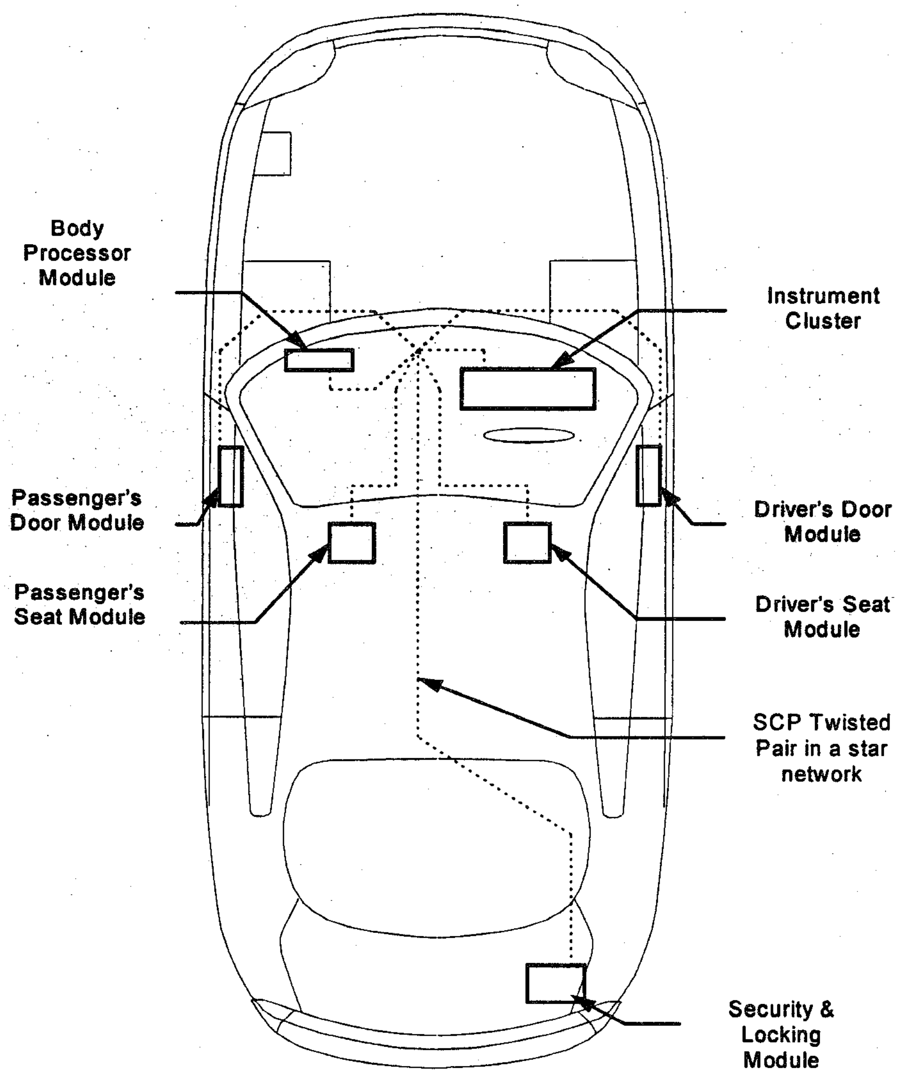


Figure E: Body System Module Location

In addition to the body system modules the SCP bus is also connected to the instrument cluster. The body system utilises the instrument cluster to obtain the status of the power train from the CAN networked information i.e. Gear Selector position, Engine running, Vehicle speed. The car has two other communication networks; the Controller Area Network (CAN) used for high speed communication within the power train system and an ISO 9141 data bus used for diagnostics communication to the small number of modules not on SCP or CAN (Ref. Appendix 1).

The Door, Seat and Security & Locking modules utilised an existing design with minor hardware changes and new software. The Body Processor module was a new unit developed especially for the XK8 but also to be utilised on the 98MY XJ saloon range and future programs. The requirement to minimise the number of part derivatives was satisfied by having only one variant of door, seat & body processor module and two variants of security and locking module. Model, market and feature level variants are controlled within the system software by end of build option programming on the production line. Driver and passenger side "identing" is carried via an "ident" connection for the seat module and by recognition of the number of window switches present for the door module. The security and locking module contains the remote control receiver, due to there being two operating frequencies across the world markets two part derivatives were required.

The system is delivered programmed to a set of default parameters with the variables located in the EEPROM section of the microprocessor. At the completion of the build all vehicle systems are programmed against the vehicle specification, the body system options being part of this process; for example the security system variants, locking system variants, memory or non memory, daytime running lighting (Scandinavia & Canada), hand of drive and convertible or coupe model. Disabling or enabling of software controlled convenience features can be carried out at a Jaguar dealer to satisfy customers individual preferences, e.g. reverse mirror dipping, chirps and light flashing upon locking/unlocking/arming etc.

The first stage of the application was the writing of the feature functional specification that defined the system operating philosophy. From this the functions and system operation were animated using computer functional modelling techniques (Ilogics Statemate). The specification and models were then circulated for review and comment within the company. The models provided a visual appreciation of the functions over a year before any representative vehicles were available and in good time for change to be made before software production had started. The modelling technology at that time had limitations which resulted in more conventional techniques being used during the production of the control module software.

The zonal partitioning was then carried out. As we are dealing with a system, functions are not constrained to be located in one specific module. A function's input/outputs are taken to/from the nearest module and likewise the software control of a function can be in several modules for thrift of code and reduction of bus messages. Taking as an example the security sub-system, figures F & G demonstrate the input & output partitioning and software partitioning respectively.

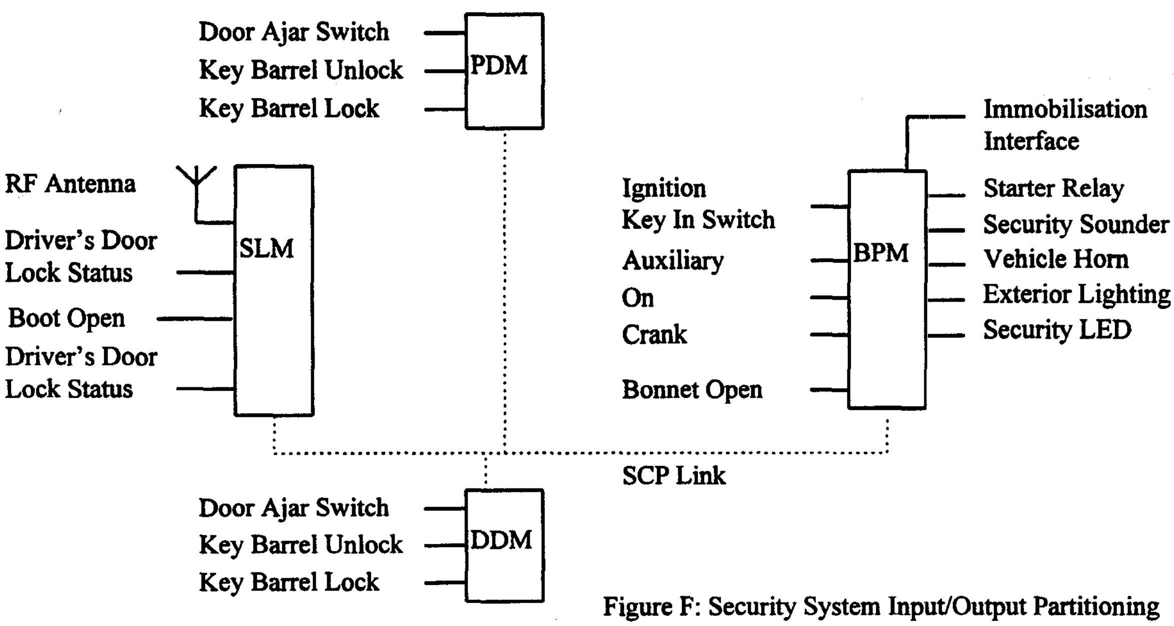
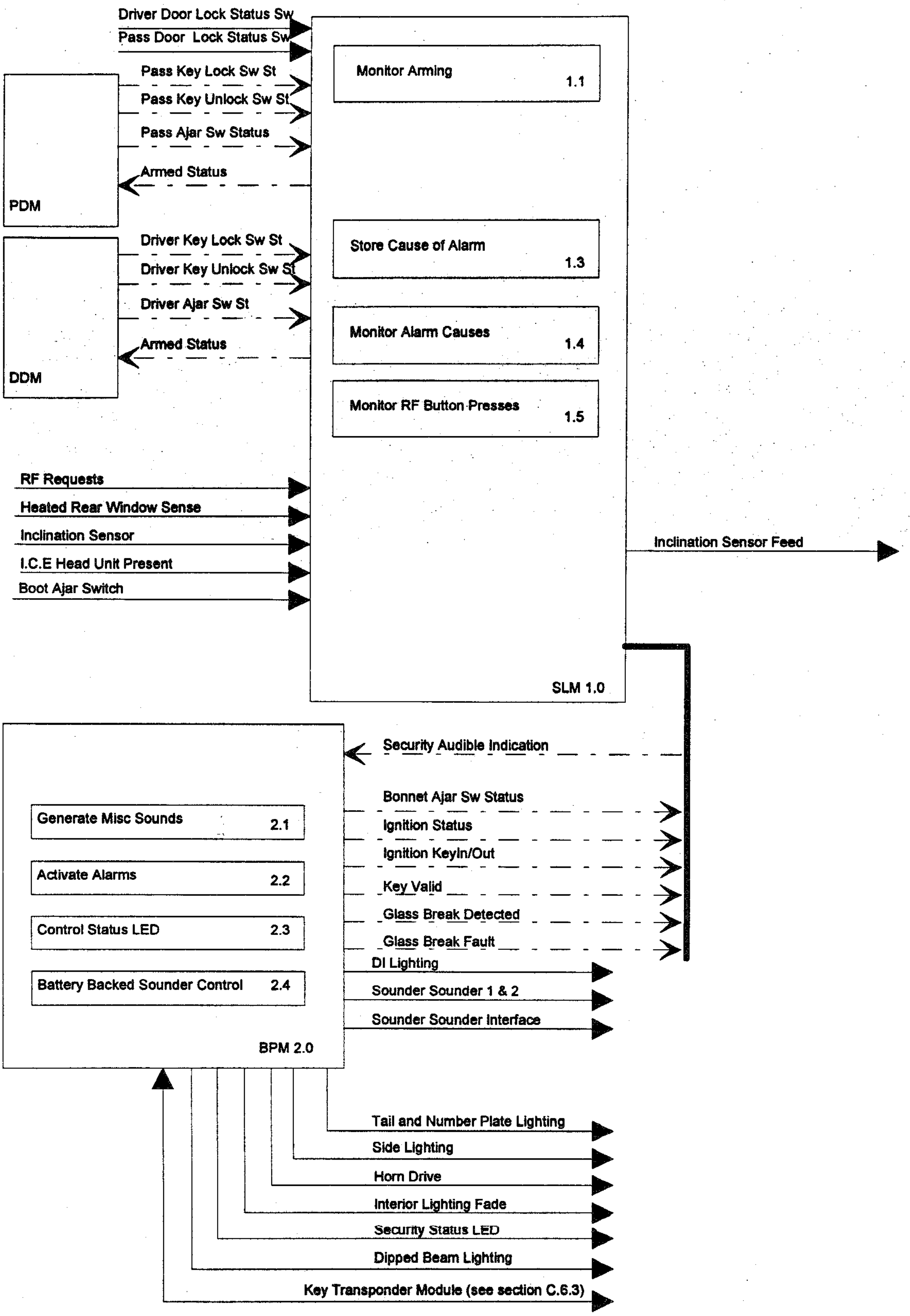


Figure F: Security System Input/Output Partitioning

A static buck (called the 'yellowboard') was constructed at Ford's premises for development and testing. This was a physical representation of the car on a yellow bench. The buck contained the body system and the associated vehicle components interfacing to the body system in approximately the representative car location and orientation i.e. harnessing and fuse boxes, lighting, seats components, door components, steering column components, facia components, instrument clusters etc. This was in parallel with the first stage of Jaguar prototype vehicles. Key areas of the buck were updated throughout the project as the rest of vehicle development progressed.

Figure G: Security System, Software Partitioning



Once vehicle hardware became available a continual process of evolution and testing was carried out. This continued from the early prototypes through to the pre-production builds. Functional, system, durability and "abuse" testing were carried out. In parallel, customer focused appraisals of functionality were also carried out.

The microprocessors used during these phases were One Time Programmable (OTP's) which allowed the flexibility of late software change, but incurred a higher piece price and availability penalties. The final stage was to freeze and release the software to proceed to a dedicated masked part with the resulting piece part reduction.

Examples of Sub-Systems Within the XK8 Body Control System

- Front Window Operation.

Entry and exit glass drop: As a door handle is operated with the window closed, the system automatically lowers the window a controlled amount to clear the door seals and closes the window upon door closure. This allows a seal profile to be used for minimum wind noise and increased in car comfort. The locking and security sub-systems have an input in that this does not take place if the car is locked or armed (i.e. door handle lifted whilst parked).

One touch window operation where by a momentary operation of the switch allows full downward travel. The next stage of refinement of the window position control, used during entry/exit, is the addition of one touch upward travel with the associated blockage sensing (anti-finger trap) and window reversal.

- Convertible Hood Control & Automatic Powered Latching

One of the major feature additions for the XK8 is the extension of the hood control sub-system to include the addition of automatic latching of the front edge of the convertible top to the top of the windscreen (the header rail).

The Security & Locking module, located in the boot near the hood pump & rear hydraulic rams, controls the movement of the soft top. This includes control of the header rail powered latching system, although in true multiplexed style, the header rail switches are all linked to the nearest module, that being the Body Processor module in the facia.

By a single maintained switch press, the driver first lowers the rear windows, then initiates the cycle that unlatches the hood and folds it away behind the rear seat. To protect the window seals, the cycle also lowers the front windows out of the way before moving the soft top.

To raise the hood, a single maintained press of the close switch reverses the process. The soft top is raised from it's stowed position and automatically latched to the header rail, before the rear windows are raised.

To make opening & closing the soft top even move convenient, these functions can also be operated by holding the door key barrel in the unlock or lock positions respectively.

- Vehicle Security & Immobilisation

The XK8 security & immobilisation sub-system is a development & refinement of the features offered by the award winning XJ6 saloon system, in which the multiplexed body system takes over from the functionally partitioned modules used on that vehicle.

The use of multiplexing to reduce the harness runs has been shown previously by figure F. Whilst the functional improvements include the increased encryption of the communications between the main immobilisation modules and the increased integration of the sub-system in to the electrical architecture of the vehicle.

Due to the need to cope with the convertible soft top, the ultrasonic intrusion sensing used on the saloon has been replaced by a new glass breakage sensor able to "hear" and identify the sound of the vehicles own glass being broken.

The overall vehicle security package has been approved by the Thatcham organisation, working for the ABI, and has achieved their "E" rating, as exceeding their requirements for a luxury car of this type.

The Benefits of the Multiplexed Body System to the XK8

The following are some of the benefits that the XK8 programme has gained by using an SCP multiplexed Body System:

- Reduced wiring runs, where possible a switch or load is connected to it's nearest module AND only to that one module.

- This has allowed the adoption of modular harnessing, with the boot, cabin & facia having separate harnesses.

- Multiplexing has encouraged software control of functions, reducing the piece cost of adding features.

- Reduced number of modules AND variants of modules, able to support all world markets via the increased use of option programming during vehicle build.

- Increased flexibility in the design of functions, with all signals & loads being available for all the Body Systems functions. This promotes more sophisticated design.

- Increased use of smart switching of module outputs to reduce the number of fuses & relays required in the vehicle.

- Improved vehicle diagnostics, with the ability to monitor module inputs & outputs during normal vehicle operation ("flight recording") AND increased use of Diagnostic Trouble Codes to capture intermittent concerns.

When grouped together, these benefits have allowed the XK8 body control system to support the programmes objectives of reduced vehicle cost & weight and to make the vehicle easier to assemble, reducing build times whilst supporting the level of functionality required for a luxury car.

APPENDIX 1

XK8 COMMUNICATION NETWORKS