

HIGH CURRENT MOTOR DRIVER ICs BRING AUTOMOTIVE MULTIPLEX CLOSER

by Riccardo Ferrari & Sandro Storti

Smart power ICs delivering up to 25A complete the family of power components needed in automotive multiplex systems, making it possible to drive even a windowlift motor directly. With these ICs the large-scale adoption of partial multiplex schemes moves much closer.

One of the essential prerequisites for the large-scale introduction of multiplex wiring systems for vehicles is the availability of high power ICs capable of driving lamps, motors, solenoids and relays. These ICs must be able to survive in an exceptionally hostile environment, they must be highly reliable and -- since so many are needed in each vehicle -- they must be inexpensive.

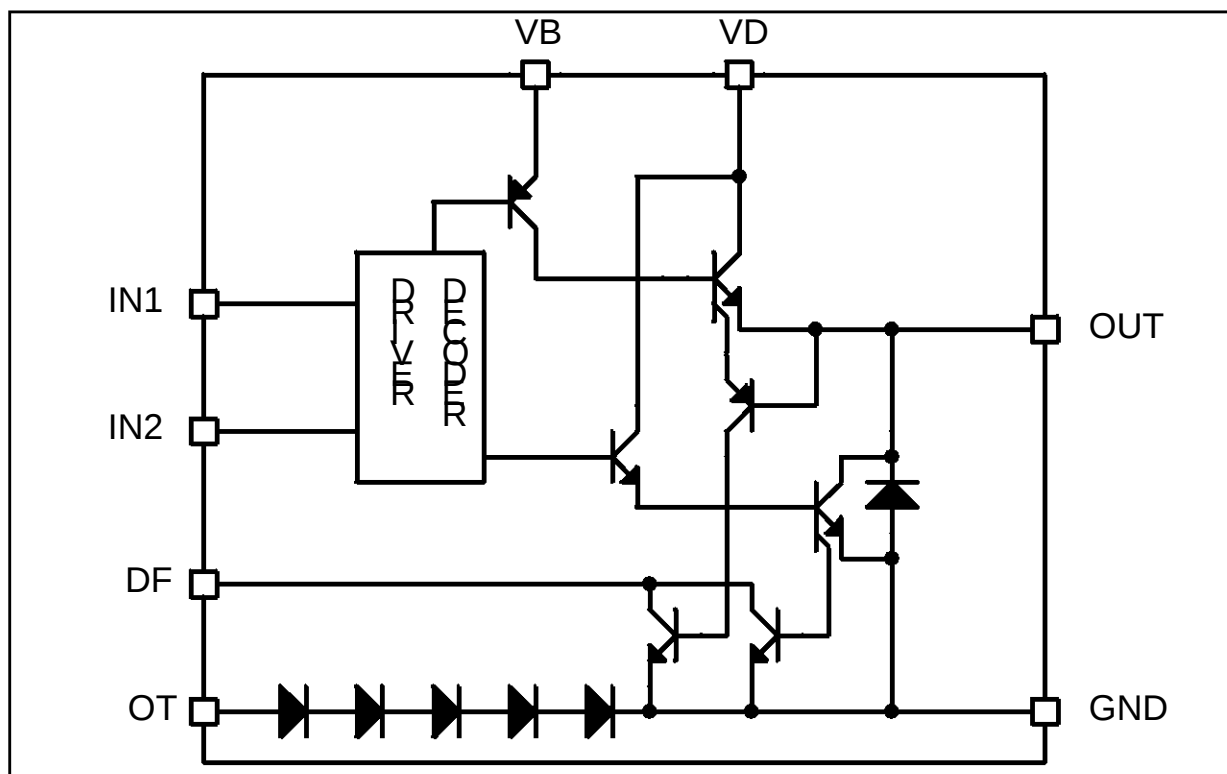
Many power ICs suitable for this emerging market have already been introduced, but a gap was left at the high current end of the range, where ICs delivering 20A or more are needed to drive loads like windowlift motors.

Today SGS-THOMSON has filled this gap with

new power ICs that exploit technologies that make it possible to build very high current ICs that are both reliable and economical. Two such ICs are the L9936 half-bridge motor driver and the L9937 full bridge motor driver.

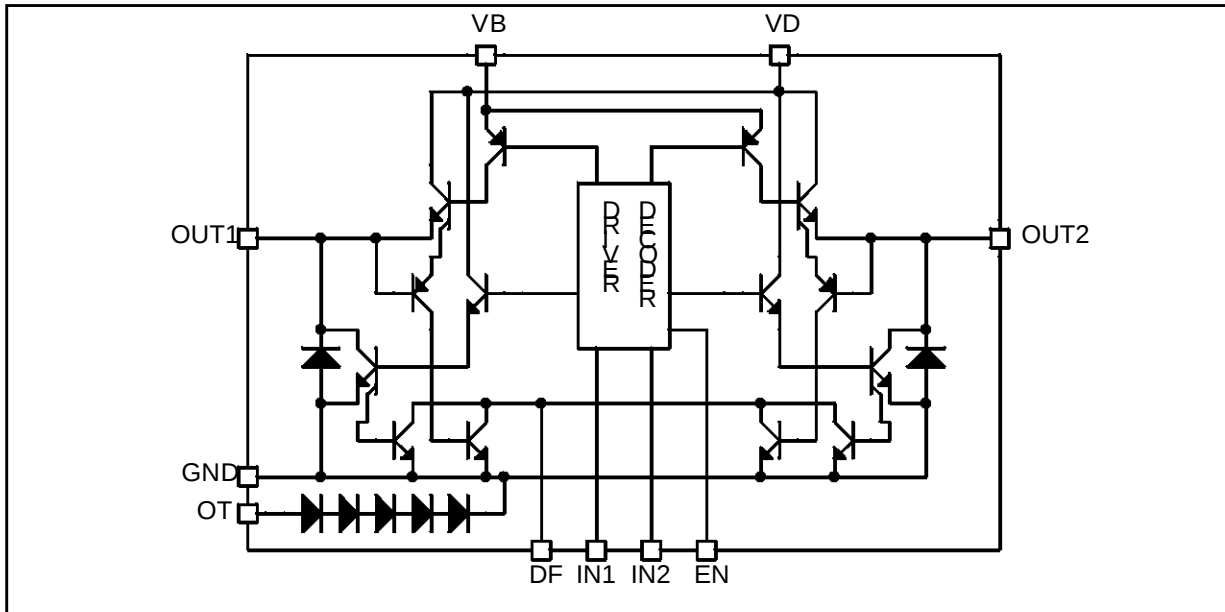
The L9936 (figure 1a) contains a half-bridge circuit capable of delivering 20A dc current, which is sufficient to drive directly a windowlift motor. Since the motor is bidirectional two of these devices are used to make a complete drive stage. Designed for lighter loads, the L9937 (figure 1b) contains a full bridge delivering up to 6A continuous (12A peak for starting). A single L9937 device drives a bidirectional dc motor.

Figure 1a: Capable of delivering 25A, the L9936 half bridge driver is a smart power IC suitable for driving windowlift motors in automotive multiplex wiring systems.



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Figure 1b: A full bridge driver, the L9937 delivers 6A (10A peak) and is used in motor driving applications such as doorlock driving.



Both of these ICs are fabricated using an enhanced bipolar power process and a new mixed bonding technology. Bipolar technology has been adopted for these circuits -- rather than the "BCD" mixed bipolar/CMOS/DMOS technology used for other multiplex switches -- for several reasons. First of all, when very high currents are involved the resistance of the silicon is no longer dominant -- half of the series resistance is caused by the metallization tracks on the surface of the chip and the bonding wires. Consequently there is nothing to be gained by using DMOS technology to further reduce the output transistor resistance. Fig-

ure 2 shows the contributions to the saturation resistance of a power NPN transistor in the BHP20 process used for these ICs. The use of thick metal (6 microns) significantly reduces voltage drop with high load currents in this technology.

Another reason for using bipolar technology is that the substrate currents generated in the substrate when 20A load current recirculates would affect low-level CMOS logic. In the L9936 and L9937 high-level bipolar logic is used in the control stages to avoid this danger, giving excellent noise immunity. Interfacing to this high-level logic is performed in the bus interface chip which will

AUTOMOTIVE MULTIPLEX WIRING SYSTEMS

Multiplex wiring is the system where a conventional wiring harness is replaced partly or completely by a single, common bus which carries power and control signals throughout the vehicle. Each load is equipped with an electronic switch that recognizes commands on the control bus and returns status information.

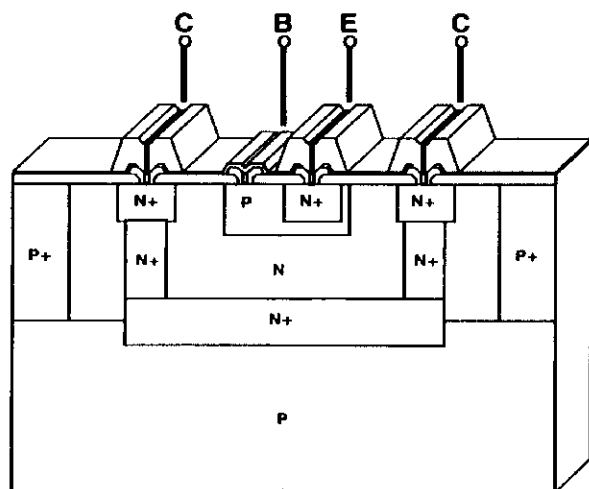
There are many different standards for the multiplex bus, of which the simplest is a three-wire scheme having one wire for the battery, one for control data and a common ground. Extra wires are sometimes added for more reliable transmission.

In a typical operation sequence, such as turning on a lamp, the control switch will cause a suitable command to be transmitted on the bus. The smart switch controlling the lamp will recognize the command and attempt to turn on the lamp. A signal indicating successful or unsuccessful completion is then returned on the bus.

Advantages of multiplex wiring are weight reduction, easier assembly, greater reliability and simpler fault diagnosis & repair. The simplicity of multiplex wiring is particularly important in critical points such as the connection between the driver's door and the rest of the body; in one case 27 wires were reduced to just three by the adoption of a multiplex subsystem.

Crucial to the success of multiplex wiring is the availability of electronic switches that can guarantee the necessary reliability and performance. Multiplex wiring is already used in small scale trials and will be adopted on volume produced vehicles in 1991.

Figure 2: In very high current ICs the voltage drop of the metallization and the bonding wires becomes significant. This example, a power transistor realized with the BHP20 process (used for the L9936 and L9937) indicates typical values. Because of this problem it is more important to optimize the metal resistances than that of the silicon.



POWER NPN
ISOLATED AREA = 5.7 mm²

MAXIMUM CURRENT = 20A
 $R_{SAT} = 30\text{ m}\Omega$

CONTRIBUTION TO R _{SAT}	
• WIRES	6 mΩ
• METAL	10 mΩ
• SILICON	14 mΩ

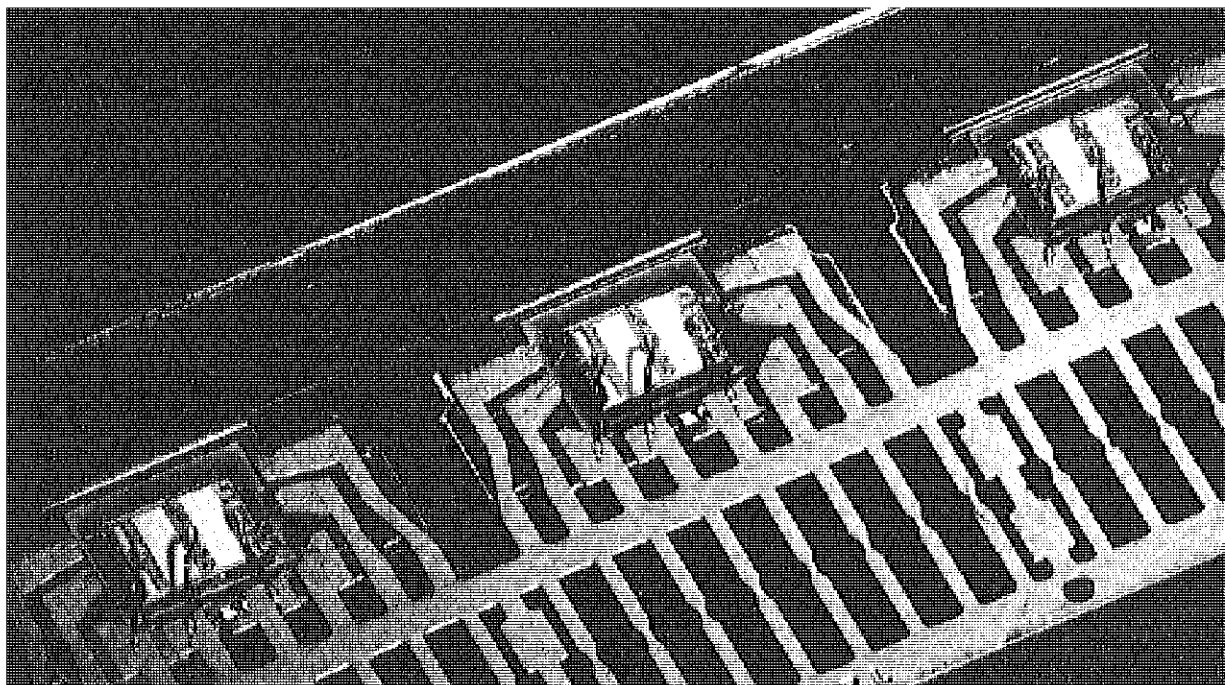
THIS IS OBTAINED BY:

- **USING DOUBLE METAL THICKNESS ($0.7 + 5 \mu\text{m}$)**

be placed between the L9936/7 and the multiplex bus. Since these interface chips are system dependent they are always developed for a specific application, rather than being standard parts like the power ICs.

The mixed wire bonding technology used in the new ICs is clearly visible in the photo, figure 3. Because of the high current it is not possible to use the standard thin gold wires employed in standard ICs. Thick gold wires are out of the

Figure 3: The mixed bonding technology used in the L9936 -- shown here after bonding but before encapsulation -- reconciles the conflicting requirements of current and silicon area. Thick aluminum wires are used for the power connections; thin gold wires for the signal connections.



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question, partly because of cost, but also because they are too rigid to bond to the chip without damaging it.

One alternative, widely used in simple power ICs, is to use thick aluminum wires. However, a thick aluminum bonding wire needs a large bonding pad on the die. In a simple device like a 3-terminal regulator this is not a problem because there are few such pads, but for more complex ICs with eight or more connections the wasted silicon area would be excessive.

Another alternative, still used by some companies, is to use two or more thin gold wires in parallel for each power connection. This solution, however, is costly because more gold wire is needed and it is prone to reliability problems because it is extremely difficult to verify each bond. Moreover, for the currents used in multiplex applications so many parallel wires would be needed this method would be totally impractical.

SGS-THOMSON has developed and industrialized a different solution: a mixed bonding technology where thin gold wires (50 μ m) are used for signal connections and thick aluminum wires (250 μ m) are used for power connections. The two bonding wire types can be clearly seen in figure 3. Note also that the bonding pads for the aluminum wires are oriented in the direction of the wire to avoid needless waste of silicon area.

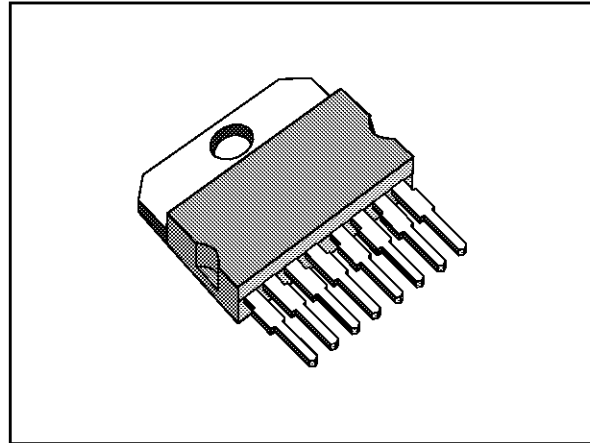
Because gold and aluminum are bonded using different techniques this has necessitated a two-step bonding operation. Moreover, because of the combination of different bonding metals the lead-frame has to be plated with a special gold alloy. This plating is selective, being applied only to the bond area, partly for economy and partly to avoid gold on the external leads, which could contaminate soldering baths, causing reliability problems on PC boards.

Different bonding techniques are used to weld the two types of wire to the surface of the chip. For the thin gold wires the thermosonic method is used where an electric discharge first creates a small ball on the free end of the wire; this ball is then pressed onto the bonding pad and vibrated rapidly (in the ultrasonic range), causing the gold ball and silicon surface to weld together.

The thicker aluminum wires are bonded using the simpler ultrasonic method, where the wire is simply pressed onto the surface of the chip then vibrated rapidly to weld the wires to the pad. Because more vigorous vibrations are used in this technique the aluminum wires are bonded first, followed by the gold wires.

To guarantee automotive-level reliability the bonds are pull tested on a sample of parts. In this test the wires are pulled to determine their breaking strength. Gold wires must resist a force of at least 15g; aluminum wires must resist a pull of 130g. Moreover, the wire must break leaving the

Figure 4: After molding and cropping the finished part looks like this. This eight-lead version of the Multiwatt package -- first developed by SGS-THOMSON in 1979 -- has wider lead spacing to suit the large high current PCB tracks.



bonds intact -- if a bond detaches before the wire breaks the part fails the test.

The L9936 is housed in a new eight-lead version of the successful Multiwatt package, originally developed by SGS-THOMSON in 1979 (figure 4). This version has eight leads in line at 0.1" centers, rather than the usual two rows of leads. This makes the Multiwatt-8 package suitable for very high current devices where wide PCB tracks are needed. An 11-lead Multiwatt package is used for the L9937.

The new package also has a larger die flag -- to accommodate today's large chip sizes -- which has necessitated the addition of new antistress features in the frame design. These features ensure a dependable adhesion between frame and resin -- essential for humidity resistance -- and isolate the die flag mechanically from the external tab to ensure that the die is not damaged if the tab is deformed during mounting.

In a typical application both the L9936 and L9937 are used with a customer specific interface chip which handles bus interface and protocol handling functions. Two different approaches at the system level are used today (figure 5). In the first case each load has its own interface, connected directly to the multiplex bus. An alternative is to combine several load units into a single module; this approach is very attractive in situations like door multiplex where there is a high concentration of loads in a distinct and fairly compact assembly.

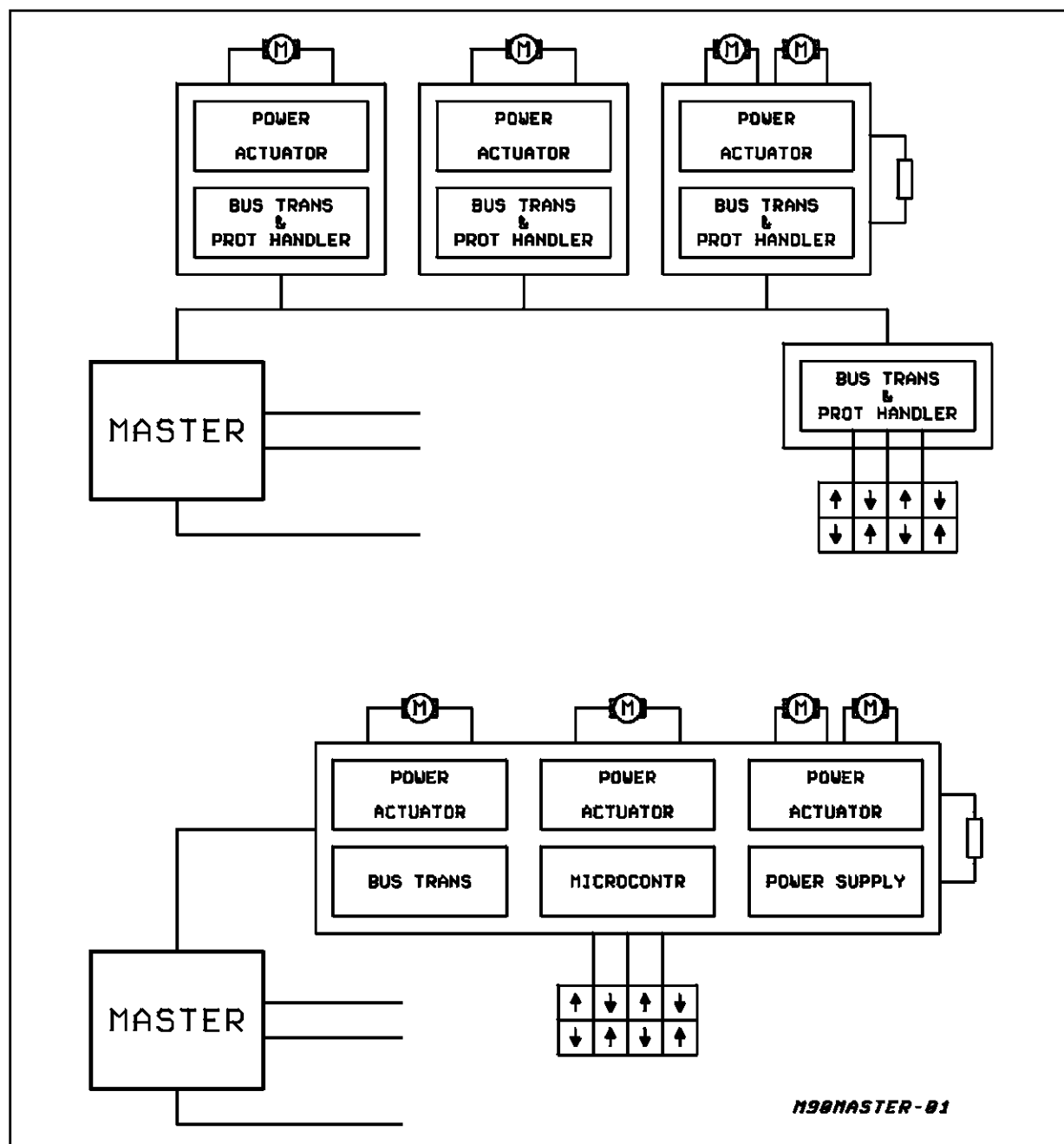
Figure 6 shows a generic door multiplex solution of the second type, illustrating the role of the new high current bipolar driver ICs. In this example an L9937 drives the door lock motor, two L9936's drive the windowlift motor, a VN02 high side driver IC drives a hazard warning light (the light

on the edge of the door that turns on whenever the door is opened) and an L9946 multiple half-bridge IC drives the three rear-view mirror motors (two for mirror adjustment and one for "folding" of the whole mirror unit for car washes and so on) and the mirror de-icing heater. All of these integrated circuits are available today.

Pure bipolar technology is used only for the very

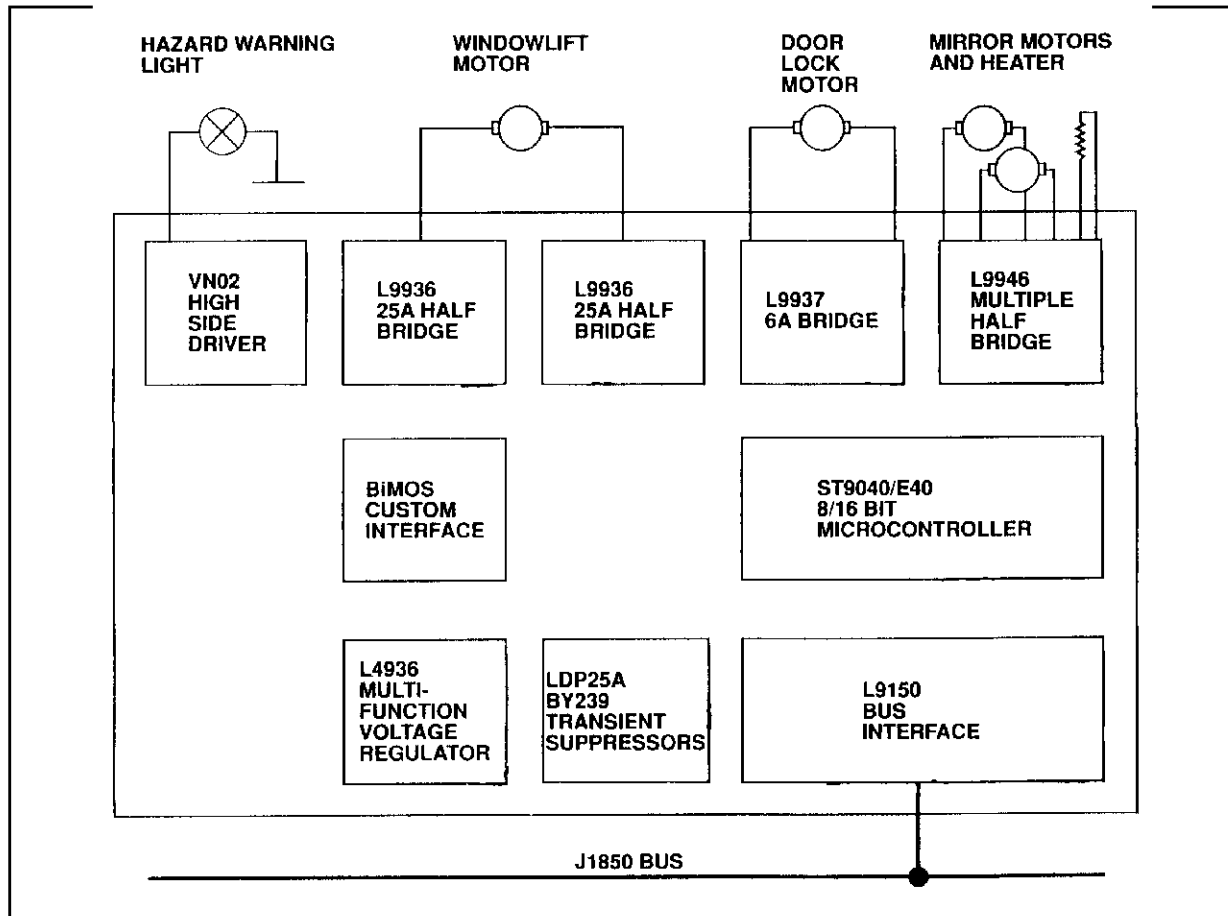
high current ICs. For all of the other parts a mixed bipolar+CMOS+DMOS technology has been chosen because of the higher efficiency of DMOS power stages and because it allows the integration of complex parts. The L9946 multiple half bridge, for example, has a four high power half bridges plus a microprocessor interface all on the same chip.

Figure 5: Two approaches are being used for multiplex systems. In the first each load has its own bus interface; in the second loads are grouped together and share a common electronics module. This approach is used in door multiplex systems, where the loads are all close together and multiplex wiring used primarily to reduce the number of wires passing from the body to the door.



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Figure 6: A typical door multiplex solution will use a mixture of high current bipolar power ICs and BCD power ICs. Solutions of this type will be on production models in 1991.



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