



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**11.09.2002 Bulletin 2002/37**

(51) Int Cl.7: **G08B 3/10**, F02P 3/055,  
H02P 7/29

(21) Application number: **02251515.9**

(22) Date of filing: **05.03.2002**

(84) Designated Contracting States:  
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU  
MC NL PT SE TR**  
Designated Extension States:  
**AL LT LV MK RO SI**

(72) Inventor: **LLoyd, Tim**  
**Broom, Warwickshire B50 4GZ (GB)**

(74) Representative: **Tranter, Andrew David**  
**Barker Brettell**  
**138 Hagley Road**  
**Edgbaston**  
**Birmingham B16 9PW (GB)**

(30) Priority: **08.03.2001 GB 0105655**

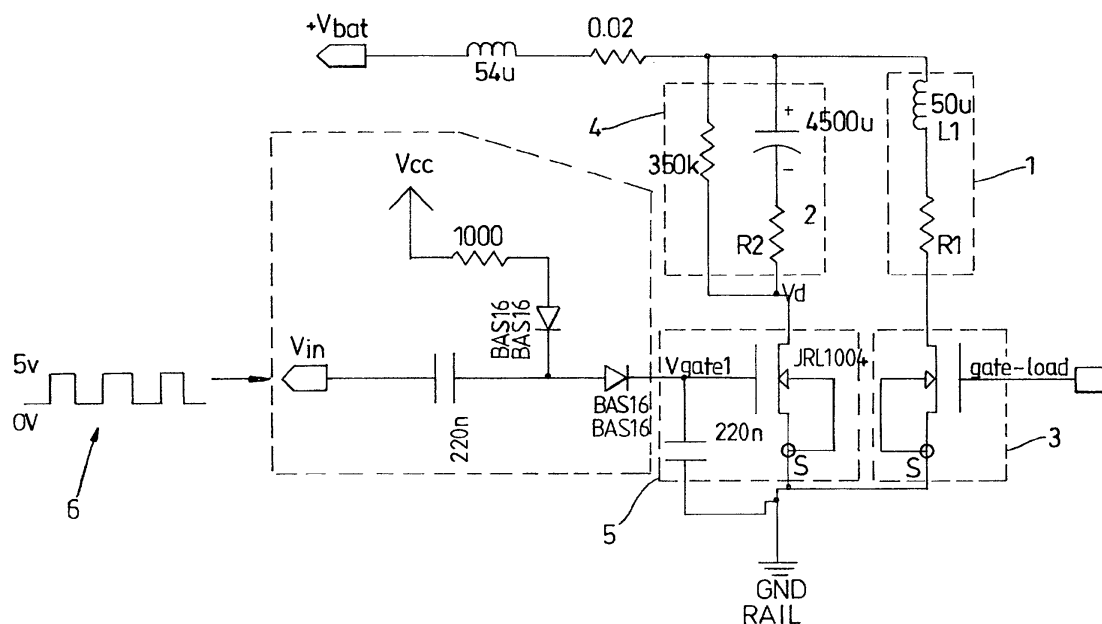
(71) Applicant: **Lucas Industries Limited**  
**West Midlands B90 4LA (GB)**

(54) **An electronic circuit**

(57) An electronic circuit suitable for connection to a voltage source (6) such as a vehicle battery comprises an electrical load (1), such as a motor, a first connection provided between an input node of the load (1) and the voltage source (6), a second connection provided between an output node of the load and a ground rail, at least one smoothing capacitor (4) connected in parallel with the load (1) between the input node and the ground rail, a switching device (3) connected in series between

the at least one smoothing capacitor (4) and the ground rail which is normally closed during operation of the load, and a control circuit (5) which is operative to open the switching device to isolate the at least one capacitor from the ground when the load is inoperative thereby reducing the quiescent current drawn by the circuit when the load is inoperative.

To be accompanied, when published, by Figure 1 of the drawings.



**Fig. 1**

## Description

**[0001]** This invention relates to improvements in electronic circuits, and in particular to an electronic circuit in which an electrical load, such as an electric motor in a vehicle automotive system, is connected to a battery driven electrical supply.

**[0002]** A wide variety of automotive systems have been developed which employ electronic actuators to perform essential functions of the vehicle. Examples of such systems are electric power assisted steering system in which an electric motor applies assistance torque to a steering shaft, and electric braking systems in which the brakes of a wheel are applied directly by an electric motor in response to a user-generated control signal. Both these systems replace hydraulic circuits and as such offer considerable advantages in terms of both packaging and weight when compared with their hydraulic equivalents.

**[0003]** A further development is the use of an electronic circuit to control the movement of fluid into and out of the vehicle dampers allowing the suspension of the vehicle to be actively controlled. This application requires a fast responding pump that is driven by an electric motor. To drive the volume and pressure of fluid requires a relatively high power electric motor.

**[0004]** To cope with the increased demands of the complex electronic circuits of modern vehicles it has been proposed to increase the supply voltage from the traditional 12 volt battery supply to a higher 42 volt (or similar) supply. Nevertheless, the electric motor required for an active suspension system may still need to draw a current of 60 Amps or more at full power.

**[0005]** For convenience of assembly and installation, the electric systems are often self-contained units having two terminals for connection to the positive supply and an earth point respectively. To suppress transients which can arise when the load presented by the system is varied, a smoothing capacitor is typically connected between the two terminals. This is usually an integral part of the self-contained unit.

**[0006]** One problem which arises in automotive applications is that whilst a high current must be available at times of peak demand from a load it is essential to minimise the quiescent current flowing in the circuit when the load is not operating. If the quiescent current is too high the battery will be quickly drained when the vehicle is left overnight.

**[0007]** In the prior art, it is known to provide for an isolating relay connected in series between the electrical system and the positive terminal. The relay is closed when the load is operative and drawing power but can be opened to prevent quiescent current flowing from the supply to the load when the vehicle is left unattended.

**[0008]** The applicant has realised that the use of a relay is undesirable in a modern automotive system. Relays are costly and quite bulky devices and sometimes unreliable. Also, the "on" resistance of the device - its

resistance across the contacts when closed-can be significant when it is conducting high currents of the order of 60amps. The consequent loss of power across the relay reduces the amount of power available for the remainder of the electrical load.

**[0009]** Apart from requiring additional drive and protection circuitry, relays are prone to damage when closing the contacts in the presence of the high charging currents associated with the high value smoothing capacitors required. High charging currents also reduce the reliability of large electrolytic capacitors.

**[0010]** In accordance with the present invention there is provided an electronic circuit for connection to a voltage source comprising:

- an electrical load, such as a motor;
- a first connection provided between an input node of the load and the voltage source,
- a second connection provided between an output node of the load and a ground rail,
- at least one smoothing capacitor connected in parallel with the load between the input node and the ground rail,
- a switching device connected in series between the at least one smoothing capacitor and the ground rail, the switching device being normally closed during operation of the load, and
- a control circuit which is operative to open the switching device to isolate the at least one capacitor from the ground when the load is inoperative.

**[0011]** Providing a switch between the smoothing capacitor and the ground rail provides a considerable advantage over the prior art. The applicant has appreciated that the largest source of unwanted quiescent current for a load, for a well designed system, is often the current leakage from the smoothing capacitor. By isolating the capacitor from the ground this source of quiescent current is eliminated. The remainder of the electrical load can then remain connected to the battery supply at all times if desired.

**[0012]** Furthermore, since the switch is not in series with the power supply an increase in efficiency is gained as there is no power loss associated with the "on" resistance of the switch. A still further benefit is that the switch no longer has to carry the full current drawn by the load and is not subject to the high voltages present in the 42 volt bus, and so can be of a lower power and voltage rating. This reduces the package size of the device and its associated heat sink.

**[0013]** An additional advantage of such a switching element is that the charging current can be controlled to be a 'soft' start by switching the element ON in a pulse width modulation PWM mode of operation. Thus, the switching device may be modulated using a PWM mode in which the duty cycle is gradually increased when closing the switch from open to allow a gradual increase in the current allowed to charge the capacitor. This pro-

vides a slow charge feature which protects the capacitor. Consequently, the switch may be modulated using a PWM in with the duty cycle is decreased when moving from closed to open.

**[0014]** The electrical circuit may comprise part of an automotive system. In this case the supply may comprise a battery. The supply may comprise a 42 volt supply, which may be stepped up from a lower battery voltage. The supply may remain connected to the load at all times, even when the ignition is switched off.

**[0015]** The switching device provided between the capacitor and OV may be driven from a lower voltage than the supply voltage.

**[0016]** The electronic circuit may be self-contained, with the electric load, the capacitor and the switching device being housed within a common housing. The control circuit may also be located within the housing, or may be located remote from the housing.

**[0017]** The electrical load may include a switch which is operable to control the average current drawn by the load when it is operating. The load may comprise a motor, for example, connected in series with a switch which may be pulse width modulated. The switch may receive signals generated by a processing unit. The processing unit may further be arranged to provide the control signal for the isolating switch.

**[0018]** In one arrangement the load may therefore comprise an electric motor. The motor may form a part of an active suspension system for a vehicle. The motor may be used to drive a pump.

**[0019]** Preferably, the switching device comprises a semiconductor device such as field effect transistor (FET) or MOSFET. Other solid state switching devices may be employed.

**[0020]** The switching device may be opened when the ignition of the vehicle is switched off. Alternatively, it may be opened at some other convenient time when the load that is associated with is inoperative.

**[0021]** The switching device may comprise two switches arranged in parallel. The first one of the switches may be opened to allow only a limited flow of current through the capacitor, the second being opened to permit unlimited flow of current through the capacitor only once it has changed to a predetermined level. The first and second switches may be operated by respective control signals, with the first switch defining a part of a trickle charge circuit. A resistance may be provided in series with the first switch to limit the rate of charging of the capacitor.

**[0022]** There will now be described, by way of example only, one embodiment of the present invention with reference to the accompanying drawing.

**[0023]** Figure 1 illustrates schematically an electronic circuit for a vehicle automotive system. The circuit includes a load comprising an electric motor 1 which drives a pump (not shown). The motor 1 is represented by a resistance R1 in series with an inductance L1. The motor 1 is connected in series with a switching device

3 between voltage source 6 comprising a 42 volt supply and a ground rail. The switch 3 is driven by a control signal  $V_{LOAD}$  from a controller (not shown) to vary the speed of the motor when it is operational. The motor is rated to draw a maximum load current of 60 amps from the supply. Of course it will be appreciated that in a practical circuit a number of such switches may be provided to control each phase of a multi-phase motor.

**[0024]** In parallel with the load is an array of smoothing capacitor. This is represented in the figure as a single 4500uFarad capacitor 4 and its associated leakage path resistance. A series resistance R2 representing the series resistance of the capacitor 4 is also shown.

**[0025]** In series with the capacitor 4, between the capacitor 4 and the ground rail is an isolating semiconductor switch 5. This switching device is normally closed to present a low impedance path between the capacitor 4 and the ground rail when the electrical load circuit is operational. By this, we mean that the vehicle is running or at least that the ignition is switched on.

**[0026]** In the event that the circuit is inoperative - for example when the vehicle ignition is switched off - the second switch is opened to isolate the capacitor from the ground rail. The isolation of the switch prevents unwanted quiescent currents flowing from the battery through the capacitor 4 to the ground rail.

**[0027]** The isolating switch is driven by a charge pump circuit applied to its gate which ensures that the switch is fully enhanced and independent of the 42 volt supply rail. A pulse applied to the  $V_{IN}$  terminal turns the switch on or off.

**[0028]** The applicant has appreciated that the quiescent currents arising from leakage from the capacitor are the main source of quiescent current in many electrical loads and power circuits to be connected to battery supplies. By isolating the capacitors from the ground rail rather than isolating the entire load from the supply a relatively low rating switch can be employed as the switch only has to carry the transient currents rather than the full load current of the load.

**[0029]** Figure 2 illustrates schematically an alternative electronic circuit similar to that shown in Figure 1 but including additional circuitry arranged to avoid rapid charging of the capacitor thereby increasing its reliability. For clarity, features which are common to features in Figure 1 have been provided with the same reference numerals.

**[0030]** The additional circuitry comprises a trickle charge circuit which limits the rate at which current can be drawn through the capacitor when the isolating switch 5 is closed. The circuit includes a secondary isolating switch connected in parallel with switch J. When a voltage at the node marked A/D is above a pre-set threshold the isolating switch is prevented from closing yet a current can flow through the capacitor 4 and the trickle charge circuit. When the voltage at the node A/D drops below a predetermined value as the capacitor is charged up, a control signal is sent to the isolating switch

to tell it to open. In effect, the trickle charge circuit provides for a two-stage opening of the connection from the smoothing capacitor to the ground rail to prevent a sudden increase in charging. This feature improves the reliability of the capacitor.

## Claims

1. An electronic circuit for connection to a voltage source comprising:
  - an electrical load (1), such as a motor;
  - a first connection provided between an input node of the load (1) and the voltage source (6),
  - a second connection provided between an output node of the load (1) and a ground rail,
  - at least one smoothing capacitor (4) connected in parallel with the load (1) between the input node and the ground rail,
  - a switching device (3) connected in series between the at least one smoothing capacitor and the ground rail, the switching device being normally closed during operation of the load, and
  - a control circuit (5) which is operative to open the switching device to isolate the at least one capacitor from the ground when the load is inoperative.
2. An electrical circuit according to claim 1 which comprises part of an automotive system.
3. An electrical circuit according to claim 1 or claim 2 in which the supply (6) comprises a battery.
4. An electrical circuit according to any preceding claim in which the switching device (3) provided between the capacitor (4) and the ground rail is driven from a lower voltage than the supply voltage.
5. An electrical circuit according to any preceding claim in which the electric load (1), the capacitor (4) and the switching device (3) are housed within a common housing.
6. An electrical circuit according to any preceding claim in which the electrical load (1) includes a switch which is operable to control the average current drawn by the load (1) when it is operating.
7. An electrical circuit according to any preceding claim in which the load comprises a motor connected in series with a switch which is pulse width modulated.
8. An electrical circuit according to claim 7 in which the switch receives signals generated by a processing unit.

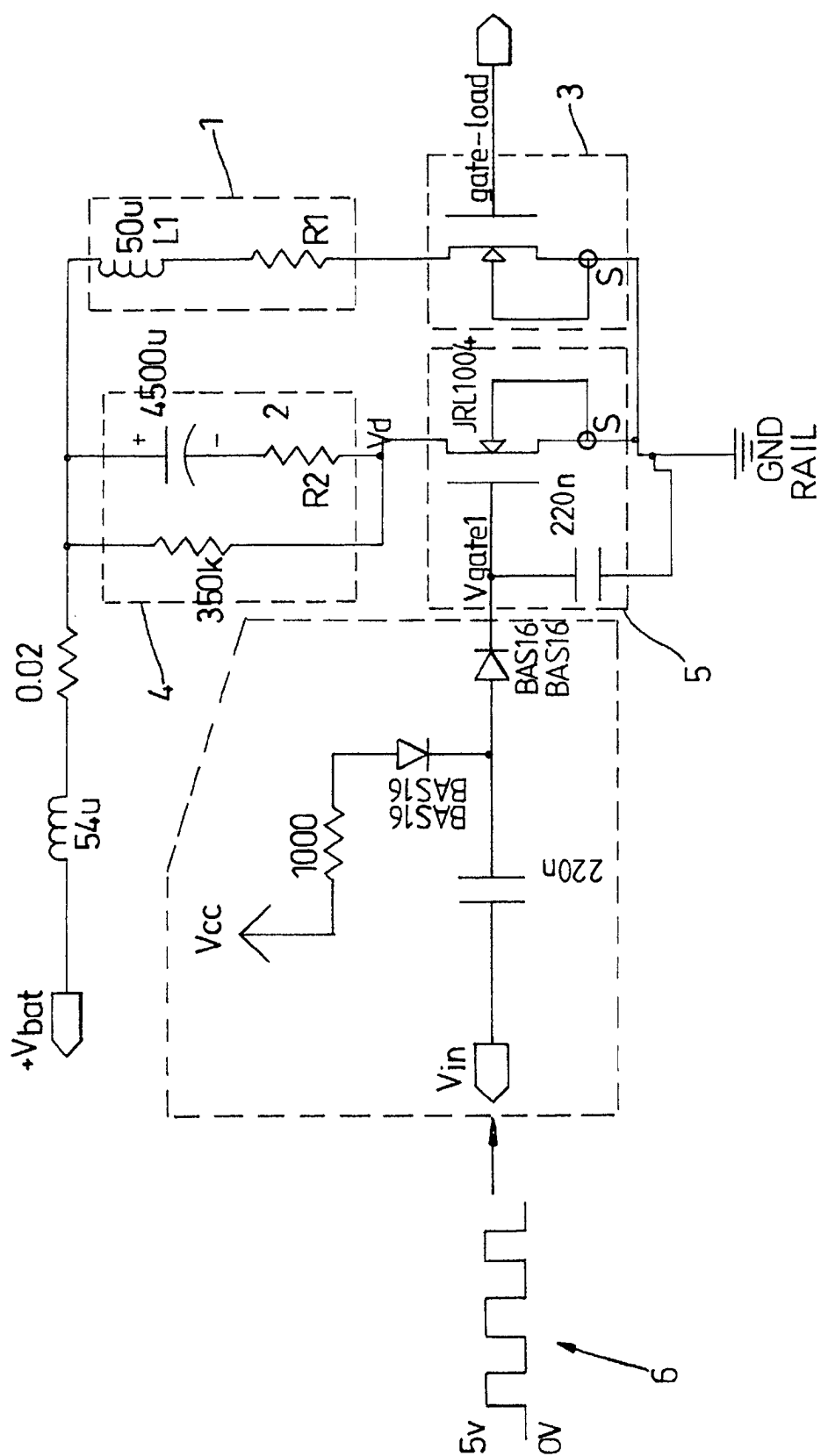
9. An electrical circuit according to claim 8 in which the switching device comprises a semiconductor device such as effect transistor (FET) or MOSFET.

10. An electrical circuit according to any preceding claim when dependent from claim 2 in which the automotive system includes a vehicle ignition switch and in which the switching device may be opened when the ignition of the vehicle is switched off.

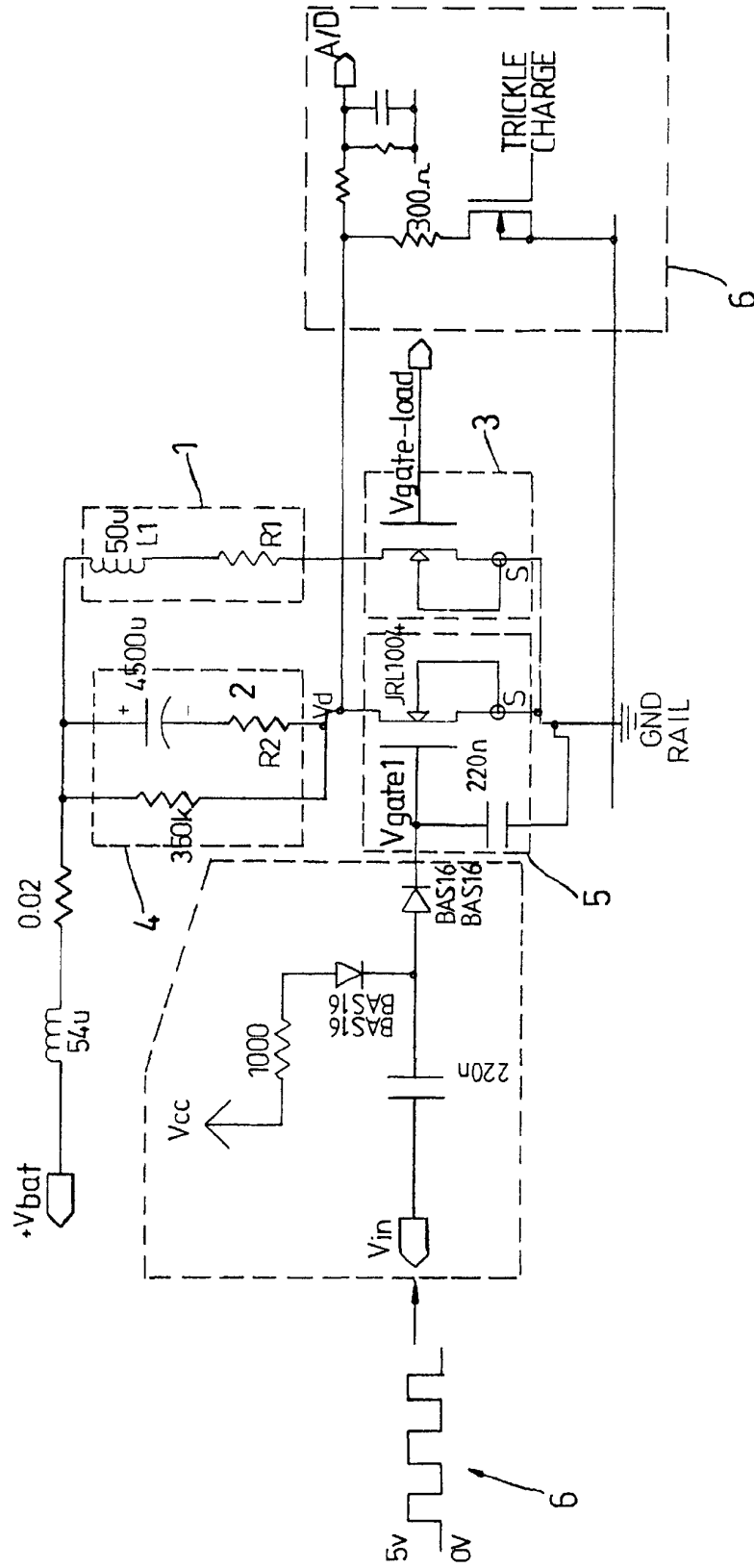
11. An electrical circuit according to any preceding claim in which the switching device (3) comprises two switches arranged in parallel, in which a first one of the switches is opened to allow only a limited flow of current through the capacitor (4) and a second of the switches is opened to permit unlimited flow of current through the capacitor (4), the second one once the load current has changed to a predetermined level.

12. An electrical circuit according to claim 11 in which the first and second switches are operated by respective control signals and the first switch defines a part of a trickle charge circuit.

13. An electrical circuit according to claim 11 or claim 12 in which a resistance is provided in series with the first switch to limit the rate of charging of the capacitor.



**Fig. 1**



**Fig. 2**



European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number  
EP 02 25 1515

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                   |                                                        |                                                                         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|-------------------------------------------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Citation of document with indication, where appropriate, of relevant passages                                                                                     | Relevant to claim                                      | CLASSIFICATION OF THE APPLICATION (Int.Cl.7)                            |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | EP 0 823 775 A (DELCO ELECTRONICS CORP)<br>11 February 1998 (1998-02-11)<br>* column 3, line 7; figures 3,4 *<br>* column 5, line 1,53 *<br>* column 1, line 41 * | 1                                                      | G08B3/10<br>F02P3/055<br>H02P7/29                                       |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | * column 1, line 12; figure 3 *                                                                                                                                   | 2,3                                                    |                                                                         |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | * column 3, line 51-58 *                                                                                                                                          | 4                                                      |                                                                         |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | * column 5, line 53; figure 3 *                                                                                                                                   | 5                                                      |                                                                         |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | * column 4, line 33-36; figure 3 *                                                                                                                                | 6                                                      |                                                                         |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | * column 5, line 2; figure 2 *                                                                                                                                    | 7                                                      |                                                                         |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | * column 5, line 9 *                                                                                                                                              | 8                                                      |                                                                         |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | * column 3, line 21 *                                                                                                                                             | 9                                                      |                                                                         |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | * column 1, line 12 *                                                                                                                                             | 10                                                     |                                                                         |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | * figures 3,4 *<br>----                                                                                                                                           | 11-13                                                  |                                                                         |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | US 4 088 106 A (BORST WOLFGANG ET AL)<br>9 May 1978 (1978-05-09)<br>* column 1, line 36-38; figure 1 *                                                            | 1-9                                                    |                                                                         |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | * column 4, line 43; figure 1 *<br>----                                                                                                                           | 10                                                     |                                                                         |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | US 4 954 805 A (BUYAK WILLIAM P)<br>4 September 1990 (1990-09-04)<br>* column 4, line 49-53; figure 2 *<br>* column 6, line 27-36 *<br>-----                      | 11-13                                                  | <b>TECHNICAL FIELDS SEARCHED (Int.Cl.7)</b><br><br>G08B<br>F02P<br>H02P |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                   |                                                        |                                                                         |
| Place of search<br><b>MUNICH</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                   | Date of completion of the search<br><b>14 May 2002</b> | Examiner<br><b>Kanelis, K</b>                                           |
| <b>CATEGORY OF CITED DOCUMENTS</b><br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                                                   |                                                        |                                                                         |

EPO FORM 1503 03/02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 02 25 1515

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

14-05-2002

| Patent document<br>cited in search report |   | Publication<br>date | Patent family<br>member(s) |               | Publication<br>date |
|-------------------------------------------|---|---------------------|----------------------------|---------------|---------------------|
| EP 0823775                                | A | 11-02-1998          | US                         | 5742142 A     | 21-04-1998          |
|                                           |   |                     | EP                         | 0823775 A2    | 11-02-1998          |
| US 4088106                                | A | 09-05-1978          | DE                         | 2541594 A1    | 24-03-1977          |
|                                           |   |                     | FR                         | 2324894 A1    | 15-04-1977          |
|                                           |   |                     | GB                         | 1560689 A     | 06-02-1980          |
|                                           |   |                     | IT                         | 1071693 B     | 10-04-1985          |
| US 4954805                                | A | 04-09-1990          | CA                         | 2035537 C     | 16-05-1995          |
|                                           |   |                     | GB                         | 2241816 A , B | 11-09-1991          |