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(71) Applicant *(for all designated States except US)*: LUCAS INDUSTRIES PLC [GB/GB]; 46 Park Street, London W1Y 4DJ (GB).

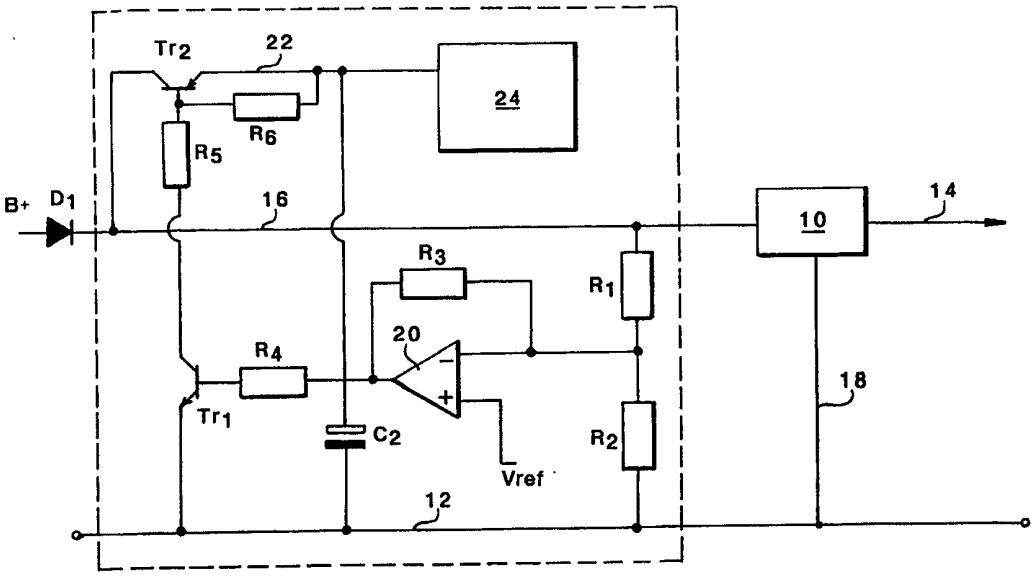
(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: DAVIES, Garry, Raymond [GB/GB]; 84 Constable Road, Hillmorton, Rugby CV21 4DA (GB).

(74) Agent: W.P. THOMPSON & CO.; Coopers Building, Church Street, Liverpool L1 3AB (GB).

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(57) Abstract

A voltage supply circuit for an ECU, of the type which uses a capacitor to hold charge for use in maintaining the supply during temporary supply interruptions, wherein a charge pump (24) is provided for increasing the voltage available for charging the capacitor to a level above that of the supply to enable the stored energy of the capacitor to be boosted.

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DESCRIPTION

POWER SUPPLIES FOR ECUs

The present invention relates to power supplies for microprocessors acting as electronic control units/controllers (ECUs) and is concerned in particular with the problem of maintenance of ECU operation in the event of unintentional power supply interruptions.

Microprocessors are used widely to control systems that are safety-critical, for example electronic servo braking systems in vehicles, vehicle anti-lock braking systems, vehicle engine management systems, vehicle active suspension systems, vehicle ignition system, and the like.

Since it is common for a controller in a vehicle to experience a very harsh power supply, it is important that such controllers be arranged to have a high immunity to electrical noise generated within, or transmitted to it, by its operational environment.

The supply voltage to an ECU controller is unpredictable, and may contain many glitches and spikes of high energy, fast transient or long duration disturbance. These disturbances constitute noise in the electrical supply system and, if the ECU power supply system is not adequate to cope with such noise, the ECU may give unpredictable results, and degrade system and vehicle performance.

The source of noise in the electrical system of a vehicle may be generated from a wide variety of sources, such as fans, relays, rapid changes in current through inductive loads (spikes), high current transients through the

battery source impedance (glitches), alternator and starter motor noise and ignition circuit noise. An ECU power supply must be designed to both tolerate and operate within these worst case (noise) conditions.

For example, in a practical situation, a controller may have a specification to work down to 7.000 volts continuous battery (from a normal 12 volt level), and operate during a condition where the supply to the ECU has a supply interruption where the voltage falls instantaneously to zero, remains at that level for some time, then rises up to 7.000 volts again. The controller needs to be fully functional during this disturbance and so requires a power supply with "hold-up" capabilities.

The traditional way to achieve hold-up operation for the controller supply is illustrated in Fig. 1 of the attached drawings which shows the input of a voltage regulator 10 coupled to a B^+ supply (say 12 volts) via a forward biassed blocking diode D_1. Coupled in parallel between the input of the low-drop voltage regulator 10 and the other power supply line 12 are a high power zener diode Z_1, and an electrolytic storage capacitor C_1. The B^+ line normally also includes a current limiting resistor (not shown). The voltage regulator output is on a line 14 and leads to the controller itself (not shown).

This circuit copes with supply interruptions by storing charge within the electrolytic capacitor C_1. The energy stored (E) is given by:

$$E = 0{\cdot}5.C.V^2$$

where E is in Joules

C is in Farads

V is in Volts

The equation can be expanded to give:

$$E = 0{\cdot}5.C.(V_1-V_2)^2, \text{ where}$$

V_1 = Capacitor start voltage before supply interruption

V_2 = Capacitor end voltage that causes the voltage regulator to be out of regulation.

In order for this circuit to be successful, therefore, the capacitor C_1 must be physically large enough to cope with supply interruptions from a low start voltage, eg. when cranking the engine. The rated voltage of the capacitor must be at least the clamp voltage of the zener Z_1. Furthermore, the rated capacity of the capacitor must be large as $V_1 - V_2$ is small. Thus, the capacitance value, and hence the physical size of the capacitor, must increase as supply voltage falls. For a constant value of the required energy, the

capacitance C must be $\frac{2E}{V^2}$.

This results in the requirement for a physically large capacitor.

An object of the present invention is to provide a circuit by which the physical size of the capacitor could be smaller for a given performance.

In accordance with the present invention, a means is provided for increasing the voltage available for charging the capacitor to enable the stored energy of the capacitor to be increased.

Preferably, the capacitor is arranged to be charged continuously to a level above the supply voltage.

The means for increasing the voltage is preferably a charge pump, for example an n^{th} voltage multiplier.

Preferably the charged capacitor is arranged to be selectively coupled to the input of the voltage regulator when the regulator input voltage falls to a predetermined level as a result of a supply interruption such as thereafter to maintain the regulator input voltage substantially and preferably constantly at that level until the supply interruption is over.

In one preferred embodiment, a voltage dependent on the input voltage to the regulator is input to a comparator whose output controls the conduction of a path connecting the charged capacitor to the regulator input.

The invention is described further hereinafter, by way of example only, with reference to the accompanying drawings, in which:-

Fig. 1 is a simplified circuit diagram of a conventional circuit used upstream of a voltage regulator to smooth unwanted supply disturbances;

Fig. 2 is a circuit diagram of one embodiment of an ECU supply voltage circuit in accordance with the present invention; and

Fig. 3 comprises a number of curves illustrating the operation of the circuit of Fig. 2.

Referring now to Fig. 2, the circuit again includes a conventional voltage regulator 10 connected to the B^+ battery supply voltage via a diode D_1 and an input line 16. The voltage regulator is connected to the other supply line 12 by a line 18. Resistors R_1 and R_2 connected between the supply lines 12, 16 form a voltage divider, the interconnection of these resistors being

connected to a first input (-) of an op-amp forming a comparator 20 whose second input (+) is connected to a reference voltage Vref. The output of the comparator 20 is coupled firstly back to its first input (-) and secondly to the base of a transistor Tr_1, via a resistor R_4. The emitter of the transistor Tr_1, is connected to the supply line 12 and its collector is connected via a resistor R_5 to the base of a further transistor Tr_2, whose collector is connected to the supply line 16 and whose emitter is connected by a line 22 to a charge pump in the form, in this example, of a n^{th} order voltage multiplier 24. The base and emitter of the transistor Tr_2 are coupled by a resistor R_6. This circuit operates as follows.

During normal operation with the voltage input to the regulator on line 16 being above its drop-out voltage, the transistor Tr_2 is non-conducting (off). The charge pump 24 operates continuously to charge the capacitor C_2 up to its normal rated working voltage, corresponding in the case of the use of an n^{th} order voltage multiplier to a voltage of n x B^+. The capacitor C_2 is therefore held at a voltage well above the B^+ level. The transistor Tr_2 is off at this time as the voltage on line 16 into the regulator 10 is above its threshold. However, in the event of an interruption to the B^+ supply, the voltage input to the op-amp 20, picked off between R_1 and R_2 controls the transistor Tr_2, via Tr_1, so that it opens sufficiently to maintain the voltage on the input to the regulator 10 (line 16) above its drop-out voltage level. Thus, the effect is to monitor the input supply voltage to the voltage regulator and, when the voltage approaches or falls below its threshold, to connect the charge in the capacitor

C_2 to the input to the regulator to maintain its operative condition. R_1, R_2 and R_3 control the threshold and gain of the op-amp 20. With the illustrated embodiment, the capacitor C_2 is effectively controlled by an active device, formed by the voltage divider R_1, R_2 of the op-amp 20 and transistors Tr_1, Tr_2, to hold the regulator input at a fixed voltage level, usually just above the worst-case "drop-out voltage" of the regulator for optimum circuit performance. However, in a simpler case (not shown), the capacitor C_2 could simply be connected via an instantaneous low impedance switching method so as to couple its stored charge to the regulator input.

With the illustrated embodiment, compared to the known circuit of Fig. 1, the present circuit can accommodate a longer lasting supply interruption for a given physical size of capacitor because it is being charged to a higher voltage, the stored energy available being dependent upon the square of the voltage, as evident from the energy equation:

$$E = 0{\cdot}5.C.V^2$$

Since the capacitor always stores charge and is working at or close to its maximum storage capacity, and since the operating voltage available to the regulator is closer to the working voltage of the capacitor, significant operational improvements are obtained.

Fig. 3 illustrates the operation of the circuit of Fig. 2 when the supply voltage B^+ is removed completely at time t_1. Initially, the input to the regulator on line 16 is at V_1, being less than B^+ by virtue of the voltage drop across D_1. The output of the regulator 10 is constant at Vr. When B^+

collapses to zero at time t_1, the circuit operates to hold the voltage on line 16 at V_2 above the drop-out voltage of the regulator, until time t_2 when no further charge is available and the input to the regulator, and hence its output fall to zero. By virtue of the action of this circuit, the time period t_2 to t_1 is increased significantly compared to the equivalent time period which would be available without the voltage boosting action of the circuit. In actual operation of course, the supply interruption would not be continuous but would be returned well before time t_2. No break in the output of the regulator 10 would then occur.

A number of advantages can be associated with the present circuit, as follows.

1) The physical size of the capacitor used in the ECU that would give equal performance to the old method discussed in connection with Fig. 1 is smaller, when the same construction of electrolytic capacitor is used.

2) The problems of ESR changes with temperature are minimised.

3) The cost of an ECU can be cheaper.

4) The system is more capable of dealing with supply interruptions when an electrolytic capacitor of the same type is used.

5) A large bulky capacitor can be difficult to house securely in an ECU; the present method is more robust.

6) The rated working voltage of the capacitor can be lower as it does not experience Zener diode clamp voltage.

7) The assembly time of an ECU is lower as smaller capacitors are

available in surface mount; the prior art method may require manual soldering of the capacitor.

8) The printed circuit board used to house the circuit can be entirely surface mount; plated through holes to secure the capacitor are not required.

9) The method allows non-electrolytic capacitors to be used, capacitors constructed from different materials can have significant advantages such as :- longer life, chemical resistance, temperature, higher charge densities.

10) The ECU can accommodate supply interruptions from a lower battery voltage.

11) Non-polarised capacitors can be used.

12) The capacitors operating voltage and rated working voltage can be equal utilising the maximum storage capability of the capacitor.

CLAIMS

1. A voltage supply circuit for an ECU, of the type which uses a capacitor to hold a charge for use in maintaining the supply during temporary supply interruptions, wherein a means is provided for increasing the voltage available for charging the capacitor to a level above that of the supply to enable the stored energy of the capacitor to be boosted.

2. A voltage supply circuit as claimed in claim 1, in which the capacitor is arranged to be charged continuously to said level above the supply voltage.

3. A voltage supply circuit as claimed in claim 1 or 2, in which the charged capacitor is arranged to be selectively coupled to the input of a voltage regulator when the regulator input voltage falls to a predetermined level as a result of a supply interruption, such as thereafter to maintain the regulator input voltage substantially at that level until the supply interruption is over.

4. A voltage supply circuit as claimed in claim 3, in which a voltage dependent on the input voltage of the regulator is input to a comparator whose output controls the conduction of a path connecting the charged capacitor to the regulator input.

5. A voltage supply circuit as claimed in claim 4, in which the path whose conduction can be controlled comprises a transistor coupled to the output of said comparator.

6. A voltage supply circuit as claimed in any of claims 1 to 5, wherein the means for increasing the voltage is a charge pump.

7. A voltage supply circuit as claimed in claim 6, wherein the means for increasing the voltage is an n^{th} voltage multiplier.

8. A voltage supply circuit for an ECU, substantially as hereinbefore described with reference to and as illustrated in Figs. 2 and 3 of the accompanying drawings.

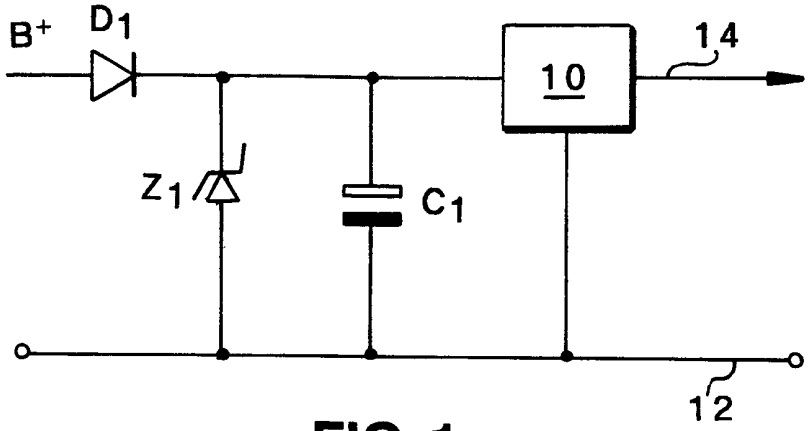


FIG. 1

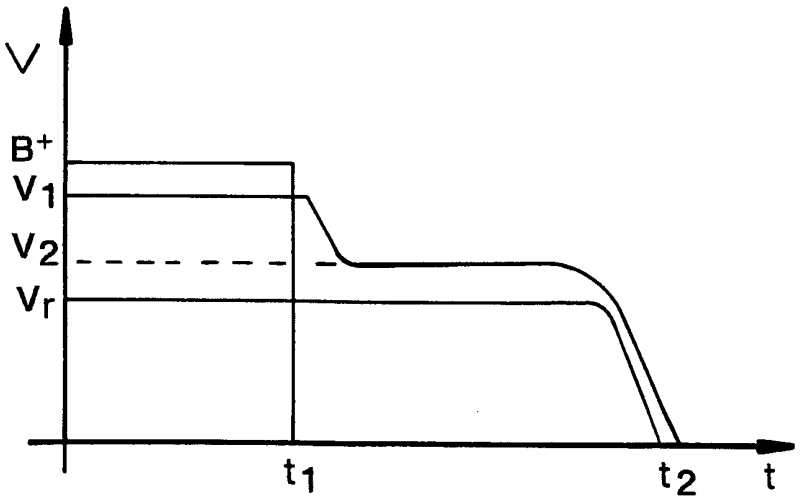


FIG. 3

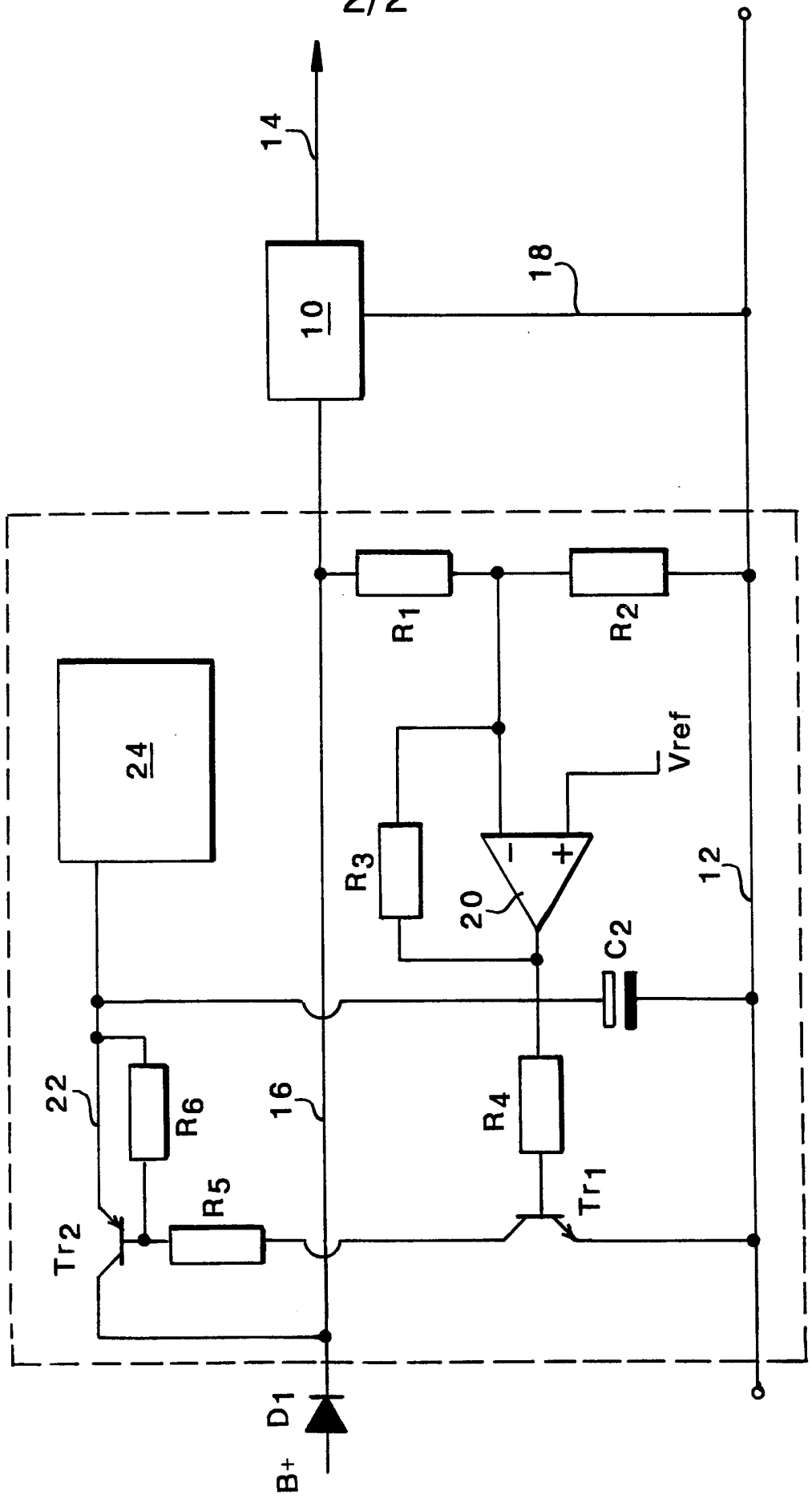


FIG. 2

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/GB 99/00319

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H02J9/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H02J B60R H02M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 262 003 A (MOTOROLA GMBH) 2 June 1993 see the whole document	1-3,6
Y		4
X	EP 0 183 597 A (THOMSON CSF) 4 June 1986 see the whole document	1-3
Y	PATENT ABSTRACTS OF JAPAN vol. 095, no. 004, 31 May 1995 & JP 07 015888 A (CANON INC), 17 January 1995 see abstract	4
A	US 4 533 986 A (JONES DWIGHT V) 6 August 1985 see abstract	1-7

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[X] Further documents are listed in the continuation of box C.

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12 May 1999	19/05/1999

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 506 775 A (TSURUSHIMA SHIN-ICHIRO ET AL) 9 April 1996 see claims 1-4; figures 11,13	4-7

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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