A Microcomputer-based Control System for Electric Vehicles

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This paper describes a microcomputer-based algorithm used to control a dc separately excited motor for electric vehicle drive. The control programme consists essentially of two secondary programmes which perform respectively the command, and the output decision making tasks. The algorithm simulation on a Hewlett-Packard Model 64000 Logic Development System showed that it was possible to achieve an average execution time of 1 millisecond which is very short when compared to the mechanical time constant of the motor.

Introduction

Microprocessors have been finding increasing application in transistor-chopper dc motor drives, and their role may be either to replace the logic circuit which controls the conduction state of the chopper high-current transistors or, in some cases, to perform in addition the control law computations. Certain control techniques which must previously have been too expensive or too complicated to use are now made possible by means of a microprocessor, and this paper examines a digital system which uses an Intel 8085 microcomputer to control the torque of a dc motor.

The microcomputer control system of a dc separately excited motor for electric vehicle drive which is shown in Fig. 1 operates on the armature and field through the armature choppers and the field amplifier, after processing actual armature and field signals along with the signals generated by the vehicle driver. Armature signals generated by the microcomputer are braking or accelerating commands, whereas the field is regulated by the field current command. The motor speed is reversed by the reversing speed command operating on a field contactor.

Basically the control system is a torque-controlled system where armature and field currents are closed-loop controlled by the microcomputer. Motor armature current and, hence torque can be controlled by the field current once the motor has reached or exceeded base speed. Below base speed the field control limits and regulates the armature current. Therefore, in this current-limit controlled scheme, the armature current is controlled between certain maximum and minimum values.

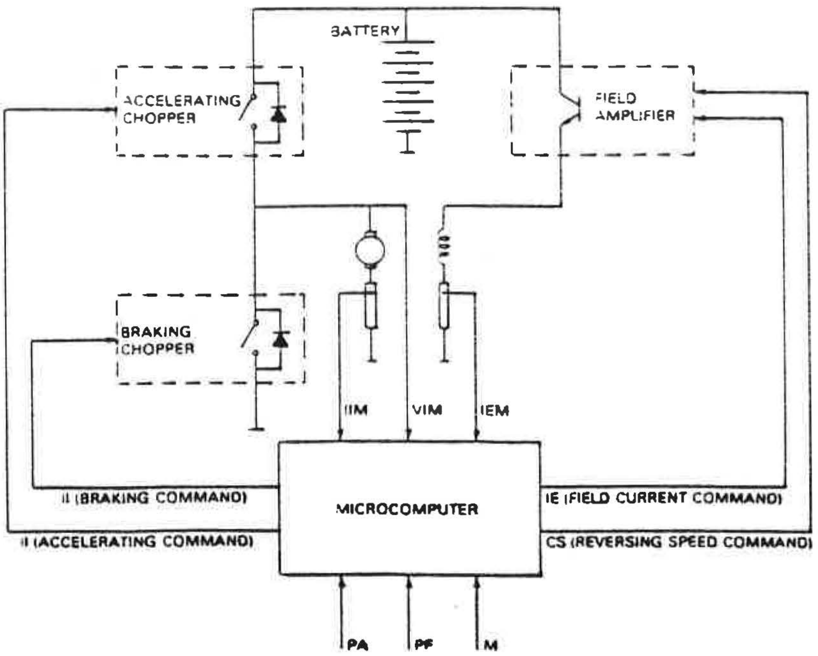

Fig. 1 Functional block diagram of the microcomputer control system

DESCRIPTION OF CONTROL ALGORITHM

Input/output variables

Microcomputer input variables contain information relative to the following:

Armature current	(IIM)
Armature voltage	(VIM)
Field current	(IEM)
Accelerator position	(PA)
Brake position	(PF)
Motion sense	(M)

The ouput variables are related to armature and field. In the first case we find the braking and accelerating commands I_I, while the variables relative to the field are the field current command (I_F) and the reversing speed command (CS).

Programme organisation

The control programme is separated into two routines, as shown in Fig. 2.

The microcomputer executes the first routine to obtain the information which the second routine needs. That intermediate information is the result of the following tasks:

1. Reading of accelerator and brake positions.
2. Simulation of accelerator retention (tendency of accelerator signal position to increase or decrease).
3. Elaboration of a reference accelerating/braking signal (F).
4. Change of performance mode (from braking to accelerating or vice-versa).
5. Elaboration of reference armature current (IIS).
6. Elaboration of maximum field armature (IEMA).
7. Elaboration of speed sense change command.

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8. **Reading of actual armature and field currents (IIM, IEM).**

Once this routine is done, the microcomputer performs the "Actions routine" acting on the armature choppers and field amplifier. Its corresponding tasks are:

1. Comparison of IIS to IIM.
2. Change of control mode (from armature control to field control or vice-versa).
3. Elaboration of accelerating/braking and field current commands.

The delay time may be determined to be:

$$TD = t_1 + (t_2 + t_3 + t_4) N + t_5,$$

where the times $t_1, t_2 \ldots$ are based on the clock frequency of the microprocessor. It can be easily seen that the one-loop execution time can be controlled by modifying N.

Initiation and State Vehicle Routine

Figure 3 shows the flow chart of the initiation and state vehicle routine. To initiate, armature control mode is used because a high starting torque is required.

The "state vehicle routine" begins by calling TTY and storing in memory data concerning accelerator and brake positions, speed sense and one-loop execution time, after which the microcomputer allows external interrupts containing any kind of information data from the rest of the vehicle.

Accelerator retention then takes place comparing the accelerator positions corresponding to the present and previous iterations. If the difference signal is a non-negative value, the choice of braking may be offered. Otherwise, we make $F_s = 0$ to indicate that the vehicle driver wants to accelerate. On the other hand, the braking option can appear when the intermediate variable PF(I) is greater than a reference value K. In that case we make $F_s = 1$, meaning that the vehicle driver is decreasing acceleration and increasing the braking signal.

After reading the data from the current and voltage external transducers, the next programme step stores them in memory. The test "$F_s = F$?" allows the microprocessor to know if it is intended to work in the same performance mode (acceleration or braking) as the former iteration. If the answer is negative, the microprocessor will search whether the present variable F_s corresponds to an accelerating or to a braking decision. The latter being the case, the next step will be to check from a non-positive actual armature current. If I_M is non-positive, the programme equals F and F_s. In case of an acceleration decision, the microcomputer asks for a non-negative I_{IM}. In that case, F equals F_s as well.

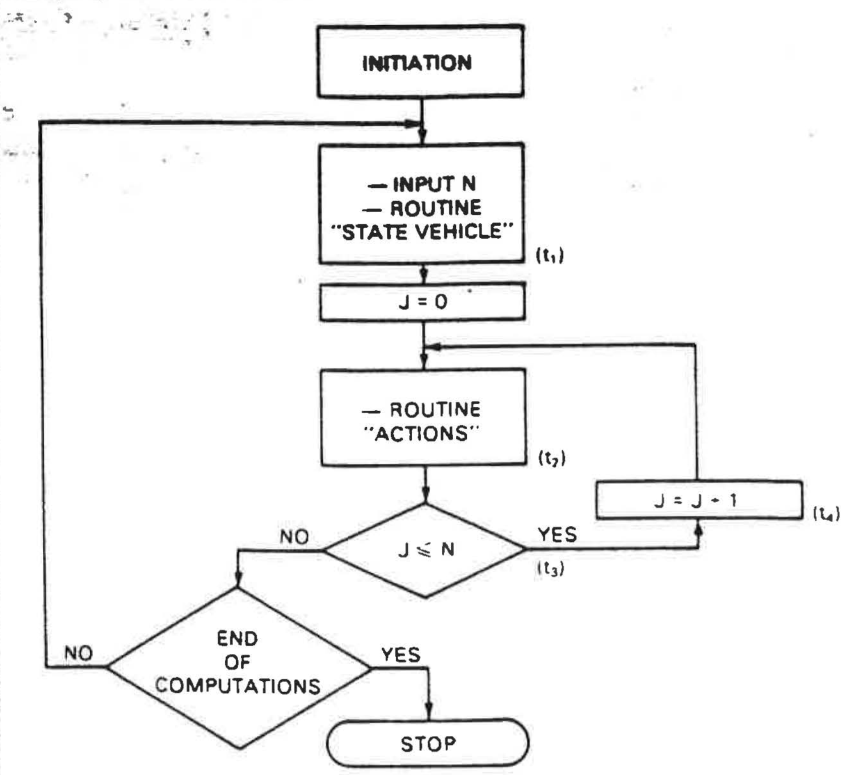

Fig. 2 Flow chart of the control algorithm

Depending on the driver's decision (accelerating or braking), the programme will equal the reference armature current either to PF(I) or to PA(I).

Elaborating the maximum field current becomes the next programme step and to do that, the microprocessor makes the "stopped car" test. In other words, it checks that the actual armature current and voltage are simultaneously zero. If the car is acknowledged to have stopped, the maximum allowed field current will be zero, otherwise, I_{EMAS} will be allowed to take two values, depending on the performance mode. In case of braking, I_{EMAS} will be I_{MAX}, the maximum field current which the field characteristics allow. If I_{EMAS} is equal to I_{MAX}, the motor counter electromotive force reaches its maximum value at that particular speed, this having as a consequence that the regenerative braking system takes advantage of this optimization. A high required acceleration, namely, $F_s = 1$ and a high value of PA(I) ($PA(I) > REC/2$, where REC indicates the whole course of the accelerator potentiometer, so that $0 < PA(I) < REC$) will imply that I_{EMAS} be limited to I_{MIN} – the minimum field rated current.

After reading information about the speed sense, the microprocessor checks whether there is a coincidence between the present sense and the previous one. If the answer is affirmative, it will not need to change the sense and the programme will jump to execute the actions routine. If there is no coincidence between M(I) and M(I-1), a change of sense order will happen, but only in case of I_{EMAS} and I_{EM} being zero; which means that, the microprocessor has acknowledged that the car is at stop and the actual field current is zero, it being already possible to reverse its sense. In that case the microcomputer generates the reversing speed command in order to reverse the field contactor.

Actions Routine

Figure 4 shows the actions routine flow chart. This routine brings to zero the counter which controls its execution time. The next step is the generation of an armature current signal and, after that, depending on the performance mode (accelerating or braking), it will be possible to change the control mode.

Braking

Once there is an acknowledgement of braking, a comparison is made between the error signal and a reference error value. If the actual error ϵ_i is larger than the set point ϵ, the motor must be field-controlled. When this happens, the motor behaves as a generator and, the field current must therefore be decreased in order to make ϵ_i smaller.

On the other hand, if the actual error ϵ_i is smaller than the set point ϵ, the microprocessor will inquire whether ϵ_i is smaller than $-\epsilon$ or not. If the answer is no, there will be no change of control mode because the error signal ϵ_i is placed inside the set point error range, i.e., $|\epsilon_i| < \epsilon$. If the answer is yes, we must change to armature control and, the armature

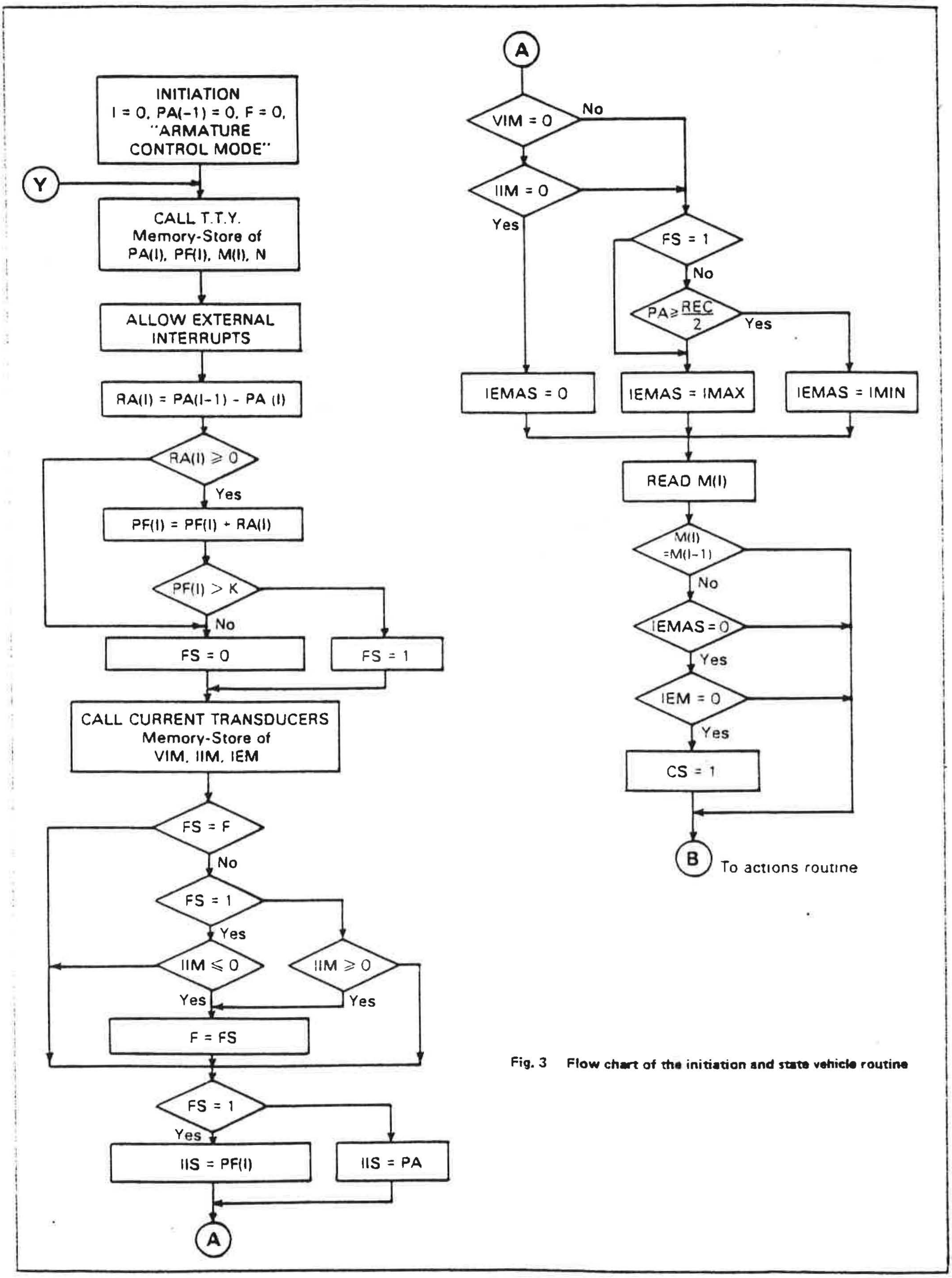

Fig. 3 Flow chart of the initiation and state vehicle routine

current must be increased so that ϵ_i can be enlarged.

Accelerating

If there is an accelerating decision, ϵ_i then ϵ will also be compared. In the case of ϵ_i being larger than ϵ, armature control must be used, decreasing armature current to make ϵ_i smaller. If ϵ_i is smaller than the reference error, ϵ, it is compared to $-\epsilon$. If ϵ_i is smaller, the motor must be field-controlled and the field current decreased to make ϵ_i larger.

Control Modes

As has just been explained, the armature current is controlled in such a manner that two operating modes are obtained: Armature Control and Field Control.

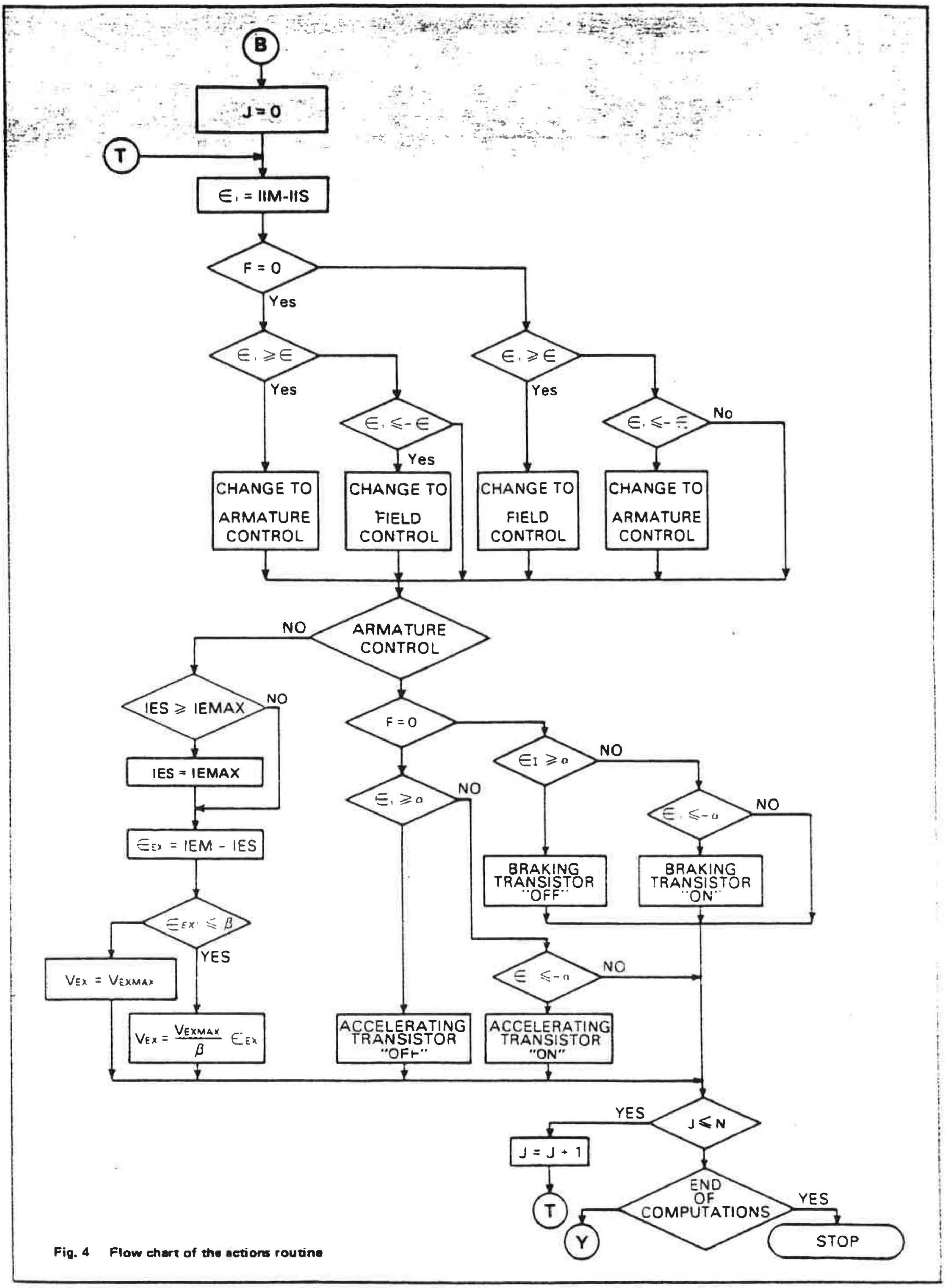

Fig. 4 Flow chart of the actions routine

Field Control

The next step is a comparison between I_{ES} and the maximum field current I_{EMAX} obtained by the first routine. The field current is limited to I_{EMAX} in case of I_{ES} being larger than I_{EMAX}. In the opposite case, the microprocessor obtains the field current error by substracting I_{EM} and I_{ES} and determines the field voltage control law, as shown on Figure 5.

Armature Control

Once the armature control is acknowledged by the microprocessor,

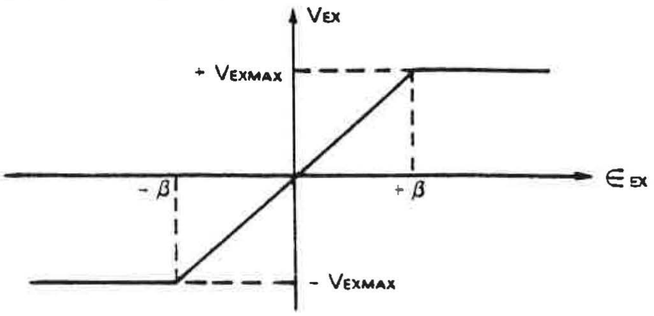

Fig. 5 Field voltage control law

a comparison is made between ϵ_i and a reference value α. In case of braking and ϵ_i being larger than α, the braking transistor must be off to make the armature current decrease. Braking and ϵ_i smaller than α imply a comparison between ϵ_i and $-\alpha_i$. If ϵ_i is smaller than $-\alpha$, the braking transistor must be on to increase the armature current. Accelerating and ϵ_i larger than α will make the microprocessor open the accelerating transistor. On the other hand, if ϵ_i is smaller than $-\alpha$, the accelerating transistor will be on.

Conclusions

A microcomputer-based algorithm to control a dc separately excited motor for electric drive vehicle has been investigated.

Microprocessor programming provides two modes of control as well as two ways of performance (accelerating and braking) and the armature current is controlled between maximum and minimum limit values.

Simulation shows an average execution time of 1 millisecond which allows a classical wired logic circuit to be replaced in the control functions by any microprocessor showing an average instruction time about 2 microseconds. 8-bit N-MOS microprocessors such as INTEL 8080/8085 or MOTOROLA 6800 can meet the above requirement. Since the motor response of a standard electric vehicle is much slower than that of the controller, a significant quantity of time is left to the rest of the elements (I/O ports, transducers, choppers and field amplifier).

References

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2 CENDAGORTA-GALARTA, M. and PRATS, J: 'Vehiculo electrico con alimentacion solar'. Proyecto Fin de Carrera. E.T.S.I.T. de Barcelona, 1980

3 LIN, A. G. and KOEPSEL, W. W: 'A microprocessor speed control system', IEEE Trans. Indust. Electron. Contr. Instrum., vol. IECI-24, no 3, Aug 1977

Electric Vehicle Events

9-13 August 1982, Annual Transportation Convention, Pretoria, Republic of South Africa. Conference theme is 'Intermodal Co-ordination' and will include a full day on electric transportation. Details from Organising Secretary, Annual Transportation Convention, NITRR, P.O. Box 395, Pretoria, Republic of South Africa, 0001. Telex. SA 3-630.

6-8 September 1982, International Conference on Electrical Machines, Budapest, Hungary. Organized by the Chair for Electrical Machines of the Technical University of Budapest, BME. Details from S. Berzensenyi, Kossuth Lajos tér 6-8. H-1055 Budapest, Hungary. Telephone (361) 112-027 or 318-926.

13-17 September 1982, International Symposium on Automotive Technology and Automation (ISATA), Wolfsburg, W. Germany, Volkswagenwerk.

21-23 September 1982, 'Transportation is the Keystone of Civilisation' The Annual Conference of the Confederation of British Road Transport (CPT) at Bowness-on-Windermere, Cumbria, England. Details from D. B. Rossiter, Director-Administration, The CPT, Sardinia House, 52 Lincoln's Inn Fields, London WC2A 3LZ.

27-30 September 1982, 13th International Power Sources Symposium at the Hotel Metropole, Brighton, covering research, development or use of non-mechanical power sources. Details from International Power Sources Symposium Committee, PO Box 17, Leatherhead, Surrey KT22 9QB, England.

25-29 October 1982, Drive Electric Amsterdam 82, to be held at Amsterdam, Netherlands, organised by ASNE, the Netherlands Section of the European Electric Road Vehicle Association (AVERE). Details from: Conference Secretariat, Drive Electric Amsterdam 82, c/o Organisatie Bureau Amsterdam BV, Europaplein, 1078 GZ Amsterdam, The Netherlands.

8-12 November 1982, 'Energy and Mobility' The XIX International Fisita Congress, Melbourne, Australia. Details from Society of Automotive Engineers, National Science Centre, 191 Royal Parade, Parkville, Victoria 3052, Australia.

20-22 April 1983, 4th IFAC/IFIP/IFORS international conference on 'Control in transportation systems' to be held at Baden-Baden, West Germany. Details from VDI/VDE-Gesellschaft Mess- und Regelungstechnik (GMR), PO Box 1139, D-4000 Dusseldorf 1, Federal Republic of Germany.

26-29 April 1983, World Conference on Transportation Research (WCTR) to be held in Hamburg, Federal Republic of Germany. Details from SNV-Congress Division, Postfach 2908, D-2000 Hamburg 20, Fed. Rep. of Germany.

9-11 May 1983, 'Electrical Drives for Ground Transportation', Positano, Italy. Sponsored by the Italian Research Council (CNR), Details from Prof E. Pagano, Institute of Electrotechnology, University of Naples, Via Claudio 21, Italy.

The Editor will be pleased to consider items submitted for inclusion in *Electric Vehicle Events.*