Microcomputer Based Fibre Analyser

PROJECT REPORT

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IN PARTIAL FULFILMENT OF THE REQUIREMENTS
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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Kumaraguru College of Technology

COIMBATORE-641 006.

Elcot Trident Automations Limited

(Joint Venture Project of Tamilnadu Govt Undertaking)

Textile Division

CERTIFICATE

This is to certify that the final year students of ECE Department of Kumaraguru College of Technology, Coimbatore, namely:

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3. Sumy Koshy
4. V.Shanmuga Priya

have developed Software and Hardware design aspects of "MICROCOMPUTER BASED FIBRE ANALYSER"

They have exhibited keen aptitude in the design of the above modules and their overall performance is good. We wish them success in all their future endeavours.

For ELCOT TRIDENT AUTOMATIONS LTD.

R. Raghavan

MANAGING DIRECTOR

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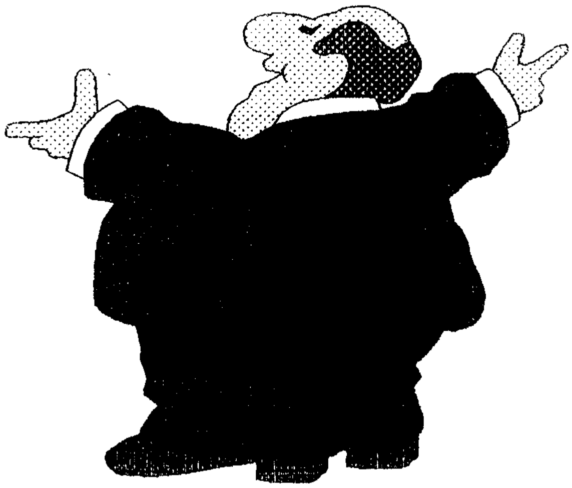

ACKNOWLEDGEMENT

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It is with deep sense of gratitude that we wish to thank the management of our college and The Principal,**Dr.S.SUBRAMANIAN B.E., M.Sc.,(Engg.),Ph.D.**,for having provided us an opportunity.

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We express our sincere & heartful thanks to **Mr.RAGHAVAN**,Managing director and staff, **Elcot trident automations limited,** Coimbatore for their help in the completion of the project.

We would also like to thank all the teaching & non teaching staff for guiding us throughout, without which our project would not have been a success.

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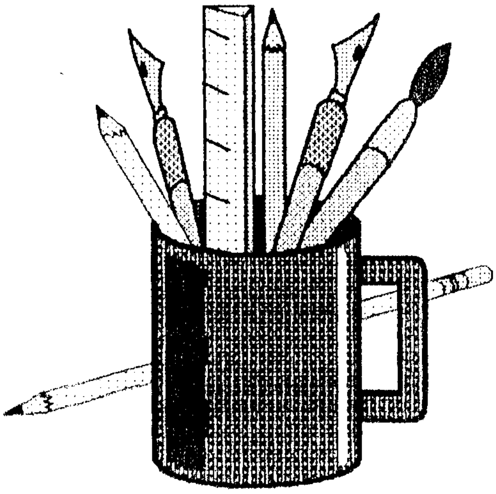

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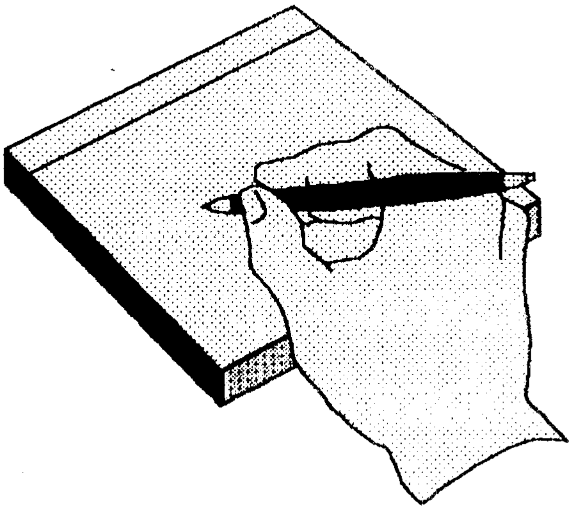
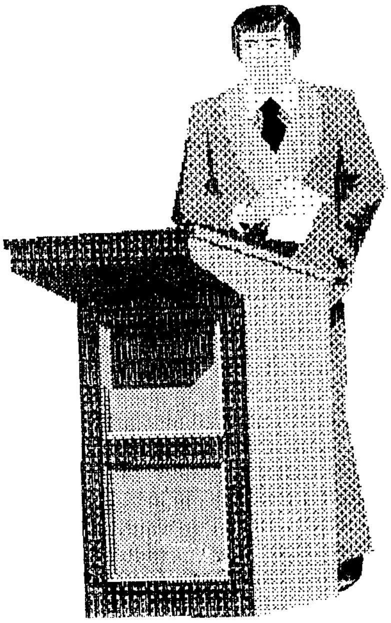


SYNOPSIS

SYNOPSIS

Microcomputerised fibre analyser gives an accurate assessment of standard span lengths, short fibre content and traditional Baer sorter diagrams to help in perfect setting of the processing machines adopting the well known technique of optical scanning.

The system features includes measuring sensor based on optical transmission method, automated linear motion system with a resolution of 0.20 mm movements using stepper motor controller, computerised data acquisition system and self calculation features along with data storage facility for large number of samples tested with statistics database management built in.



INTRODUCTION

1.INTRODUCTION TO TEXTILE INDUSTRY

Cotton, the raw material used by the textile industry is most variable in nature influenced by soil&climatic conditions.

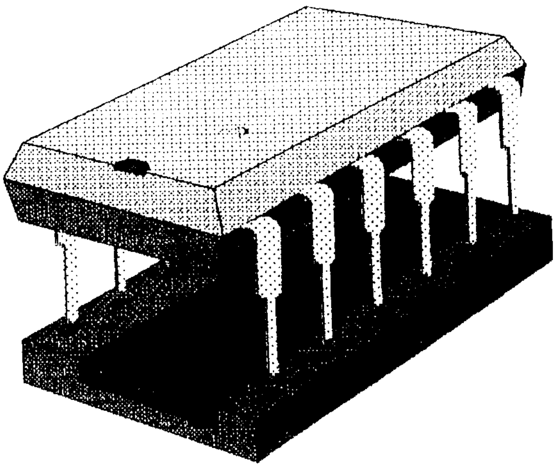
The development of series of instruments to specific properties of the same has been made long back and is being perfected by integrating latest innovations in electronic and measurement technologies today.

Of the important characteristics, staple length and grade takes prime position followed by maturity, strength, fineness, moisture and trash contents. The whole idea of developing such instruments and testing the same is to help the industry (mills) in selecting ideal ones for their end products and to **arrive** at **blend** proportions from a range of cottons having similar characteristics using linear technique.

With the availablity of fibre properties it will be easy to predict the expected quality, of the product namely yarns and fabrics using various techniques developed by research institutes.

As mentioned earlier, if all the fibre characteristics, fibre length or staple is the prime property which influences the decision on its end used namely spinnable content expected strength and helps to determine the price that can be offered for the same.

It must be borne in mind that cotton as raw materials contributes 60% of the selling cost in normal times and 70% in certain occasions. This in turn decides the profitability and healthiness of the textile sector as a whole. In other the words the assesment of properties of cotton fibre **especially** price **realisation** and profits there on.



HARDWARE DESCRIPTIONS

2. HARDWARE DESCRIPTION

2.1 FIBRE LENGTH ANALYSER SETUP

Staple length is one of the most important properties of cotton, greatly affecting the price and suitability of the raw material of the spinner. If other factors are equal, finer yarns can be produced from longer cottons, and in a given count increased strength is associated with increased staple length.

The general practice of the brokers and spinners in to estimate length by "Pulling" the cotton, but the disadvantage different results on the same sample. The most widely adopted semi-mechanical method is that in which a comb sorter is used, and the fibres from a small sample of cotton are arrayed in order of length along a velvet pad. This method eliminates the personal problem and gives unbiased estimates of tuft lengths. The image of filament of a lamp is projected on to the tuft of parallel fibres, lying on a black velvet pad and appears as a setup of light across the width of the tuft. The pad resets on a stage which may be moved along a screw parallel to the directionof the fibres in the tuft. Light is reflected from the fibres an angle of about 45° to the vertical and then falls on the surface of a photo-electric cell which is connected to a sensitive galvanometer.

The position of lines most sharply defining the ends of a tuft are where the rate of change of visual density is a maximum. The position of these two lines may be determined from the reading of the galvanometer and occur where the differences between successive galvanometer readings reach a maximum. The distance apart of these two positions corresponds to the most frequent or "Modal" length of the fibres as they lie in tuft. The distance is termed the "Photo electric modal staple". Which is abbreviated to PEM staple to distinguish it from other measures of the sample length. In practice the free tuft are prepared for each sample of cotton to be tested. The tufts are placed side byside on the movable stage and illuminated by seperate lamps. The light reflected from the fibres in each tuft is focused on to one of three photo-cells which are connected parallel to the galvanometer. Variations in the current registered by the galvonometer corresponds to variations in the combed densities of the tufts and the necessity for three seperate sets of determinations is avoided. (FIG 2·1·1)

The galvanometer current varies directly as the visual density at the illuminated portion of the tuft. By moving the stage along the screw, determinations of visual density may be made at equal intervals along the length of the unit.

This movement is achieved by using the stepper motor controller circuit along with additional circuitry to improve torque and clock generation.

The received light after passing through the fibre are collected and converted into electrical signals with the help of photo sensors. Further details are included in the later chapters.

2.2.BASICS OF STEPPER MOTOR

There are two basic types of stepper motor in common use: permanent magnet and variable reluctance. Permanent magnet motor are divided into bipolar and unipolar types.

Here bipolar motor is used for moving mechanism.

BIPOLAR MOTOR

Simplified to the bare essentials, a bipolar permanent magnet motor consists of a rotating permanent magnet surrounded by stator poles carrying the windings. Bidirectional drive current is used and the motor is stepped by switching the windings in sequence.

For a motor of this type there are three possible drive sequences.

The first is to energize the windings in the sequence AB/CD/BA/DC(BA means that the winding AB is energized but the opposite sense). This sequence is known as "One phase on" full step or wave drive mode. Only one phase is energized at any given moment (figure 4a).

The second possibility is to energize both phases together, so that the rotor always alighns itself between two pole positions. Called "two phase-on" full step, this mode is the normal drive sequence for a bipolar motor and gives the highest torque (figure 4b).

The third option is to energize one phase, the two, then one,etc., So that the motor moves in half step increments. This sequence, known as half step mode,halves the effective step angle of the motor but gives a less regular torque (figure 4c).

For rotation in the opposite direction (counter-clock-wise) the same three sequences are used,except of course that the order is reserved.

For further details refer the appendix.

2.3 STEPPER MOTOR CONTROLLER

The L297 integrates all the control circuitry required to control bipolar and unipolar stepper motors. Used with a dual bridge driver such as the L298 N forms a complete microprocessor to bipolar stepper motor interface. Unipolar stepper motor can be driven with an L297 plus a quad darlington array.

The L297 stepper Motor controller is primarily intended for use with an L298 N or L293E bridge driver in stepper motor driving applications.

It receives control signals from the systems, controller usually a micro computer chip, and provides all the necessary drive signals for the power stage. Additionally it includes two PWM chopper circuits to regulate the current in the motor windings. (FIG 2.3.a)

ADVANTAGES :

The L297 + driver combination has many advantages. Very few components are required (so assembly costs are low, reliability high and little space required), software development is simplified and the burden on the micro in reduced. The L297 can be used with any power stage, including discrete power devices. Higher currents are obtained with power transistors or darlingtons.

APPLICATIONS :

Applications of the L297 can be found almost every where-printers (Carriage position, daisy position, paper feed, ribbon feed), typewriters, plotters, numerically controlled machines, rotors, floppy disk drives, electronic sewing machines, cash registers, photocopiers, photographic equipment, paper tape readers, optical character recogniser, electric valves and so on.

2.3.b CIRCUIT OPERATION

The L297(A) is intended for use with a dual bridge drives, quad darlington array or discrete power devices in step motor driving applications. It receives step clock, direction and mode signals from the systems controller and generates control signals for the power stage.

The principle functions are a translator, which generates the motor phase sequences, and a dual PW/M. Chopper circuit which regulates the current in the motor windings. The translator generates three different sequences, selected by the half/full input. These are normal (two phases energised), wave drive (one phase energised) and half-step (alternatively one phase energised/two phases energised). Two inhibit signals one also generated by the L297 in half step and wave drive modes. These signals, which connect directly to the L298's enable inputs are intended to speed current decay when a winding is deenergised. when the L297 is used to drive a unipolar motor the chopper acts on these lines.

An input called control determines whether the chopper will act on the phase lines ABCD or the inhabit lines 1NH1 and INH2. When the phase lines are chopped the non-active phase lines of each pair (AB or CD) in activated (rather than interrupting the line then active). In L297 + L298 configurations this technique reduces dissipation in the load current sense resistors.

A common on-chip oscillator drives the dual chopper. It supplies pulses at the chopper rate which set the two flip-flops. **FF1** and **FF2** When the current in a **Winding** reaches the proogrammed peak value the voltage across the sense resistors equals Vref & the corresponding comparator resets its flip-flop, interrupting the drive current until the next oscillator pulse arrives. The peak current for both winding is programmable by voltage divider on the **Vref** input.

Ground noise problems in multiple configurations can be avoided by synchronising the chopper oscillators. This is done by connecting all the **sync** pins together, mounting the oscillator RC network on one device only and grounding the osc pin on all other devices.

The L297A includes a pulse doubler on the step clock line which in intended to simplify the implementation of multiple stepping. A ghost pulse in generated automatically after each input pulse, delayed by the time 0.75 RsCd.

The network should be dimensioned to place the ghost pulse roughly halfway between clock pulses. If pin (doubler) in grounded the doubler function is disabled.

DRIVE SIGNALS FOR THE MICRO ELECTRONIC

A direct current motor runs by itself if a voltage is supplied, whereas the stepping motor needs the commutation siganl in for of several seperated but linkable commands.

In its simplest form, a full-step control needs only two rectangular signals in quadrature. According to which phase is leading the motor axis rotates clockwise or counter clockwise, whereby the rotation speed is proportional to the clock frequency.

In the half-step system the situation becomes more complicated. The minimal two control signals becomes four control signals. In some conditions as many as six signals are needed. If the tri-state-command for the phase ranges without current, necessary for high motor speeds, may not be obtained from the 4 control signals. The figure shows the relationship between the phase current diagram and the control signal for full and half step. (FIG 2.3.b (1) & (2)).

A typical control circuit that meets all there requirements is the L297 unit.

Four signals control the motor is all operations:

1. Clock : The clock signal, giving the stepping command
2. Reset : Puts the final level signals in a defined start position
3. Direction : Determines the sense of rotation of the motor axis
4. Half/Full : Decides whether to operate in full or in half step.

Another inhibit input allows the device to switch the motor output into the tristate-mode in order to prevent undesired movements during undefined operation conditions,

SWITCH - MODE CURRENT REGULATION :

The primary function of the current regulation circuit is to supply enough current to the phase windings of the motor, even at high step rates.

The functional blocks required for a switchmode current control are the same blocks required in switching power supplies; flip-flops, comparators; and an oscillator are required. These blocks can be easily included in the same IC that generates the phase control signals. Let us consider the implementation of chopper current control in th L297.

The oscillator on pin 16 of the L297 resets the two flip-flops at the start of each oscillator period. The flip-flop outputs are then combined with the outputs of the translator circuit to form the 6 control signal supplied to the power bridge (L298).

When activated, by the oscillator, the current in the winding will raise, following th L/R time constant curve, until the voltage across the sense resistor (pin 1,15 od L298) is equal to the reference voltage input (pin 15, L297) the comparator then sets the flip-flop, causing the output of the L297 to the change to an equiphase condition, thus effectively putting a short circuit across the phase winding. The bridge is activated into a diagonally conductive state when the oscillator resets the flip-flop at the start of the next cycle.

Using a common oscillator to control both current regulators maintains the same chopping frequency for both, thus avoiding interference between the two.

An important characteristics of this circuit implementation is that, during the reset time, the flip-flops are kept reset. The reset time can be selected by selecting the independance of the R/C network or pin 16. In this way, the current spike and noise across the sense resistors that may occur during switching will not cause a premature seting of the flip-flop. Thus the recovery current spike of the protection diodes can be ignored and the filter in the sense line is avoided.

THE RIGHT PHASE CURRENT FOR EVERY OPERATING CONDITIONS :

The chopper principle of the controller unit reveals that the phase current in the motor windings is controlled by two data; the reference voltage at pin 15 of the controller and the value of the sense resistance at pins 1 and 15 of the L298, that is I = Vref/RS. By changing Vref it is very easy to vary the current within large limits.

More phase current means more torque, but also higher energy consumption.

An analysis of the torque consumption for different periods and load position changes shows that there is no need for different energies.

There is a high energy need during the acceleration or break phases, whereas during continous operation or neutral or stop position less energy has to be supplied. A motor with its phase current continuously oriented at the load moment limit, even with the load moment lacking, consumed needlessly energy that is completely transformed into heat.

MOTOR DRIVING PHASE SEQUENCES :

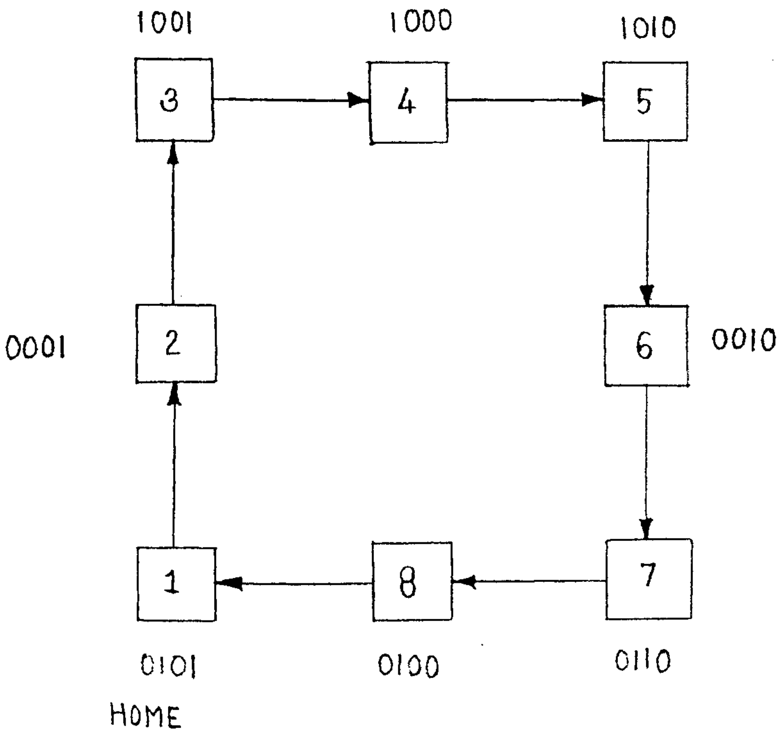
The L297's translator generates phase sequences for normal drive, wave drive and half step modes. The state sequences and output waveforms for these three modes are shown below. In all cases the translator advances on the low to high transistion of CLOCK.

Clockwise rotation is indicated : for anticlockwise rotation the sequences are simply reversed RESET restores the translatro to state 1. where ABCD = 0101.

Any of the three modes can be implemented. The mode used in the stepper motor controller part of the fibre analyser is the half step mode.

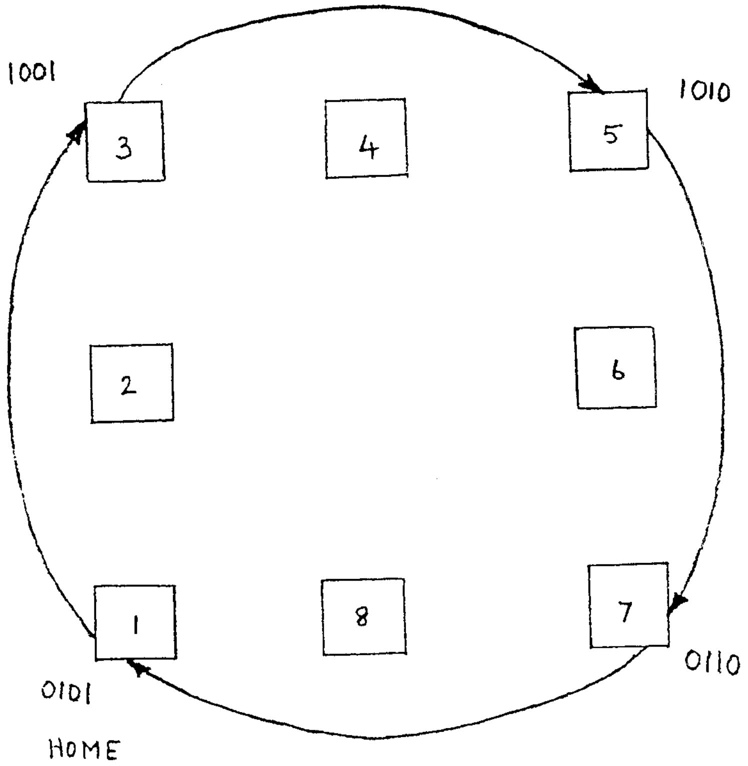
HALF STEP MODE

Half step mode is selected by a high level on the HALF FULL input. (FIG 2·3·b (3)).



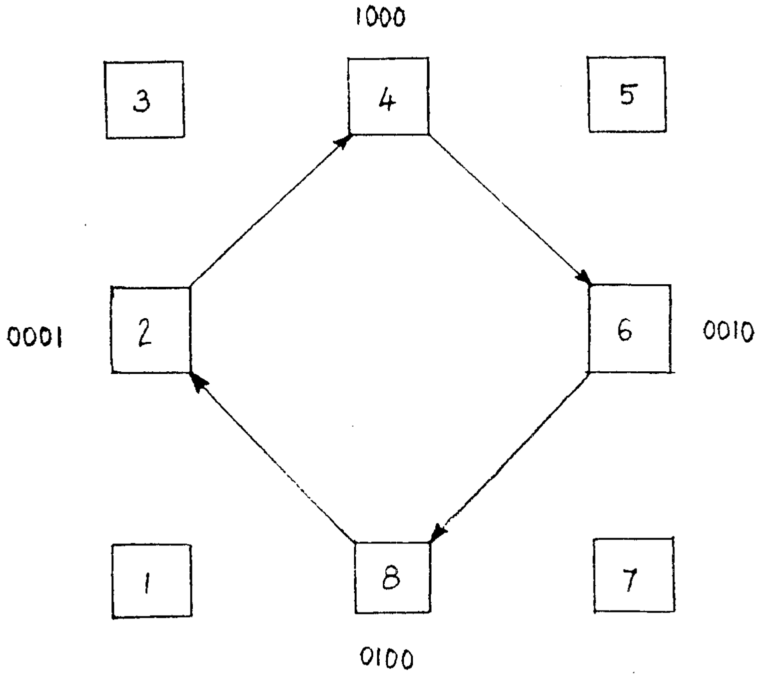
NORMAL DRIVE MODE

Normal drive mode (also called "two-phase-on"drive) is selected by a low level on the HALF/FULL input when the translator is at an odd numbered state (1,3,5 or 7). In this mode the INH1 and INH2 outputs remain high throughout. (FIG 2·3·b (4)) ·



WAVE DRIVE MODE

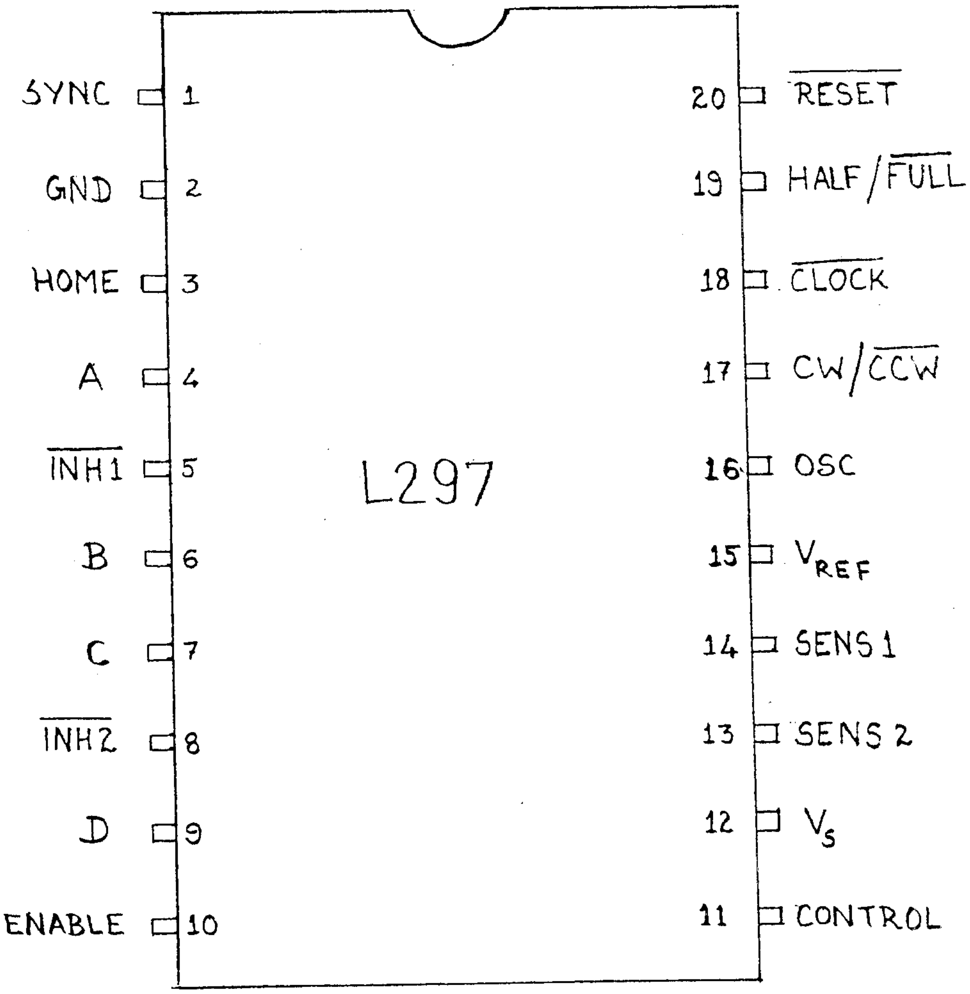
Wave drive mode (also called "One-phase-on"drive) is selected by a low level on the HALF/FULL input when the translator is at an even numbered state (2,4,6 or 8). (FIG 2·3·6 (5)).



2.3.c IC DETAILS

2.3.C1 STEPPER MOTOR CONTROLLER (L 297)

PIN CONNECTION OF L297



PIN FUNCTIONS OF L297

1- sync : Output of the on-chip chopperoscillator

2- GND : Ground connection

3- home : open collector O/P that indication athen the L297 in is its intial state (ABCD = 0101)
The transistor in open when this signal is active.

4- A : Motor phase A drive signal for power stage

5- INHI : Active low inhibit control for stages of A & B phase

6- B : Motor phase B drive signal for power stage

7- C : Motor phase C drive signal for power stage

8- INH2 : Active low inhibit control for drive stages of C & D phases

9- D : Motor phase D drive signal for power stage

10-Enable : chip enable input. when low (inactive) INH1,INH2, A, B,C and D are brought low.

11-control : control i/p that defines action of chopper

12-Vs : 5 v supply input

13 sens2 : Input for load current sense voltage from power stages of phases C & D

14- sens1 : Input for load current sense voltage from power stages of phases A & B

15- Vref :Reference voltage for chopper circuit

16- Osc : An RC network connected to this terminal determine the chopper rate

17. CW/CCW : Clock wise/counter clockwise direction control i/p

18- Clock : Step clock

19- half/full : when high selects half step operation & when low selects the full step operation.

20 - Reset : Reset i/p. An active low pulse on this i/p restores the translator to the home position.

2.3 c2 POWER BRIDGE (L 298 N)

The L298N and L293E contain two bridge driver stages, each controlled by two TTL-level logic inputs and a TTL-level enable input. In addtion, the emither connections of the lower transistors all brought out to external terminals to allow the connectionof current sensing registors.

For the L298 SGS innovative con-implanted high voltage current technology is used, allowing it to handle effective powers upto 200W. (46 supply, 2.5 A per bridge). A seperate 5V logic supply input in provided to reduce dissipation and to allow direct connection to L297 a other control logic.

2.4 ADDITIONAL CIRCUIT TO IMPROVE TORQUE IN HALF STEP POSITION.

With the help of the inhibit signals at the o/p5 and 8 of the controller, which are alternatively active only when the half step control in programmed, the reference voltage is increased by the factor 1.41 with a very simply additional wiring as soon as one of the two inhibits- signals switches low. This increases the current in the active motor phase proportionally to the reference voltage and compensates the torque loss. The motor works with poor resonance and a double position resolution at a torque, that is almost the same as that of the full step. (FIG 2.4.a).

2.5 CIRCUIT FOR CLOCK GENARATION AND FOR CONTROLLING THE OPERATION OF STEPPER MOTOR

Let the voltage at pin no.1 of 324 be slightly positive at the instant of switching the circuit on. It will cause a voltage at the non inverting input of the operation amplifier given by

$$V = (R/(R+R))V_o$$

$$= 1/2\ V_o$$

This positive voltage at non inverting terminal will drive the output voltage towards the saturation value Vs. Thus the voltage at non inverting terminal reaches almost immediately to the value given by

$$V = (R/(R+R))\ V_s$$

$$= 1/2\ V_s$$

The positive voltage Vs at pin no.1 charges the capacitor through the feedback resistor R. This causes the voltage at the inverting terminal of the operation amplifier. to rise towards +Vs with the time constant T. given by

$$T = (R.R/(R+R))C$$

$$= RC/2$$

Here a clock of frequency 1 KHz is generated with the value of resistor of 100 K & Capacitor of 0.02 F. (FIG 2.5.a).

FUNCTIONS OF INH1 AND INH2

In half step and one-phase on full step modes two other signals are generated : INH1 and INH2. These are inhibit signals which are coupled to the L298 N's enable inputs and serve to speed the current decay when a winding is switched off.

Since both windings are energized continuously in two phase-on full step mode no winding is ever switched off and these signals are not generated.

To see what these signals do lets look at one half of the L298N connected to the first phase of a two phase bipolar motor (fig:(i)). Remember that the L298N's A and B inputs determine which transistor in each push pull pair will be on. INH1, on the other hand, turns off all four transistors.

Assume that A is high, B low and current flowing through Q1, Q4 and the motor winding. If A is now brought low the current would recirculate through D2,Q4,Rs, given a slow decay and increased dissipation in Rs. If, on a other hand, A is brought low and INH1 is activated, all four transistors are turned off. The current recirculates in their case from ground to Vs Via D2 & D3, giving a faster decay, thus allowing faster operation of the motor. Also since the reciruclation current does not flow through Rs, a less expensive resistor can be used.

Exactly the same thing happens with the second winding, the other half of the L298 & the signals C, D and INH2. The INH1, and INH2 signals are generated by OR functions.

$$A + B = INH1$$

$$C + D = INH2$$

However, the output logic is more complex because inhibit lines are also used by the chopper.

2.6 PCL - 818 HG CARD DETAILS

The PCL-818HG is a high gain, high performance multifunction data acquisition card for IBM PC/XT/HT or compatible computers. It offers the five most desired measurement and control function : 12 bit A/D conversion, D/A conversion, digital input digital output and timer/counter.

A programmable - gain instrument amplifier (X 0.5, 1,5,10,50,100,500,1000) lets you acquire very low level input signals without external conditioning. An on-board 1K word FIFO buffer provides high speed data transfer and predictable performance under windows.

Automatic channel scanning circuitry and on-board RAM let you perform multiple - channel A/D Conversion with DMA and individual gains for each channel.

The PCL - 818HG uses a custom 160 pin ASIC chip designed in-house by dynalog's engineers. This single chip integrates most of the card's function, giving you maximum accuracy and reliability, along with minimum cost, size and power consumption.

The PCL-818HG package includes a special wiring board with a DB-37 Connector and CJC circuit. Together they let you measure low-level thermocouple signals without an external signal conditioning board.

The PCL-818 HG is hardware and software compatible with its popular predecessor the PCL 818. This puts rich software support and a wide variety of external signal conditioning boards at your disposal.

FEATURES

- 16 Single - ended or eight differential analog inputs, switch selectable.
- 12 bit A/D, up to 100 KHZ sampling rate with DMA transfer and different gain for each channel
- software - selectable gain X 0.5,1,5,10,50,100,500 or 1000
- On board 1K word FIFO buffer with software selectable interrupt
- software selectable analog input ranges (Vdc)

Bipolar : ± 0.005, ± 0.01,± 0.05 ± 0.1, ±0.5 ±1,±5, ±10

- 16 digital inputs and 16 digital outputs TTL/DTL compatible.
- one 12 bit analog output channel
- Flexible triggering options : software programmable pacer and external pulse.
- Data tranfer by program control, interupt handler routine or DMA.
- New technology 160 pin 1.0 m-CMOS ASIC Chip.

For further details of the card refer to the appendix.

2.7 OPTICS

CONVEX LENSES

Convex lenses are typically used for focussing an image magnification. The plano-convex (PCX) lens is the most common focussing element. The PCX is sufficient in systems requiring a f/#>10 for a minimum spot size when focussing collimated light. This lens is equallly suitable for collimating diverging beams **parallel to optical axis .** Double convex (DCX) lenses are used for focussing with lower f/#'s than the PCX. However, DCX lenses are ideal for single element one to one imaging (0 = 1=2f)

DETERMINE LIGHT TRANSMISSION

Knowing where the light will go is only the first step in designing a light projection systems; it is just as important to know how much light is transmitted. Typically the light-gathering capablility of a lens is quantified as follows:

f/# (f-number)=f(focal length of lens) / D (diameter of lens)

NA (numerical aperture) 0.5/f/#

DOUBLE CONVEX LENSES (DCX)

Double convex lenses are lenses which have two outward curving faces. This faces may be symmetric (or) they may have one curve sharper than the outer. Double convex lenses have positive focal length and will act as a magnifying or condensing lens.

The type of lens used in our setup is A32,426 which has a diameter of 127 mm and the focal length of which is 141 mm.

2.8 SENSOR

SILLICON DETECTORS:

Basic Principle:

Through the photovoltic effects, detectors provide a means of transforming light energy to an electrical current. The roof of the theory behind this phenomeneon is a small energy gap between the valance and conduction bands of the detector.

OPTICAL DIFFUSING GLASS:

It is similar to ground glam (Ground glass in the glass finely ground on one side to give good light diffusion. It is ideal rear projection screen). But one surface is flashed with a milky white "Opal" covering to diffuse light evenly. Opal coating is approximately 1 mm thick.

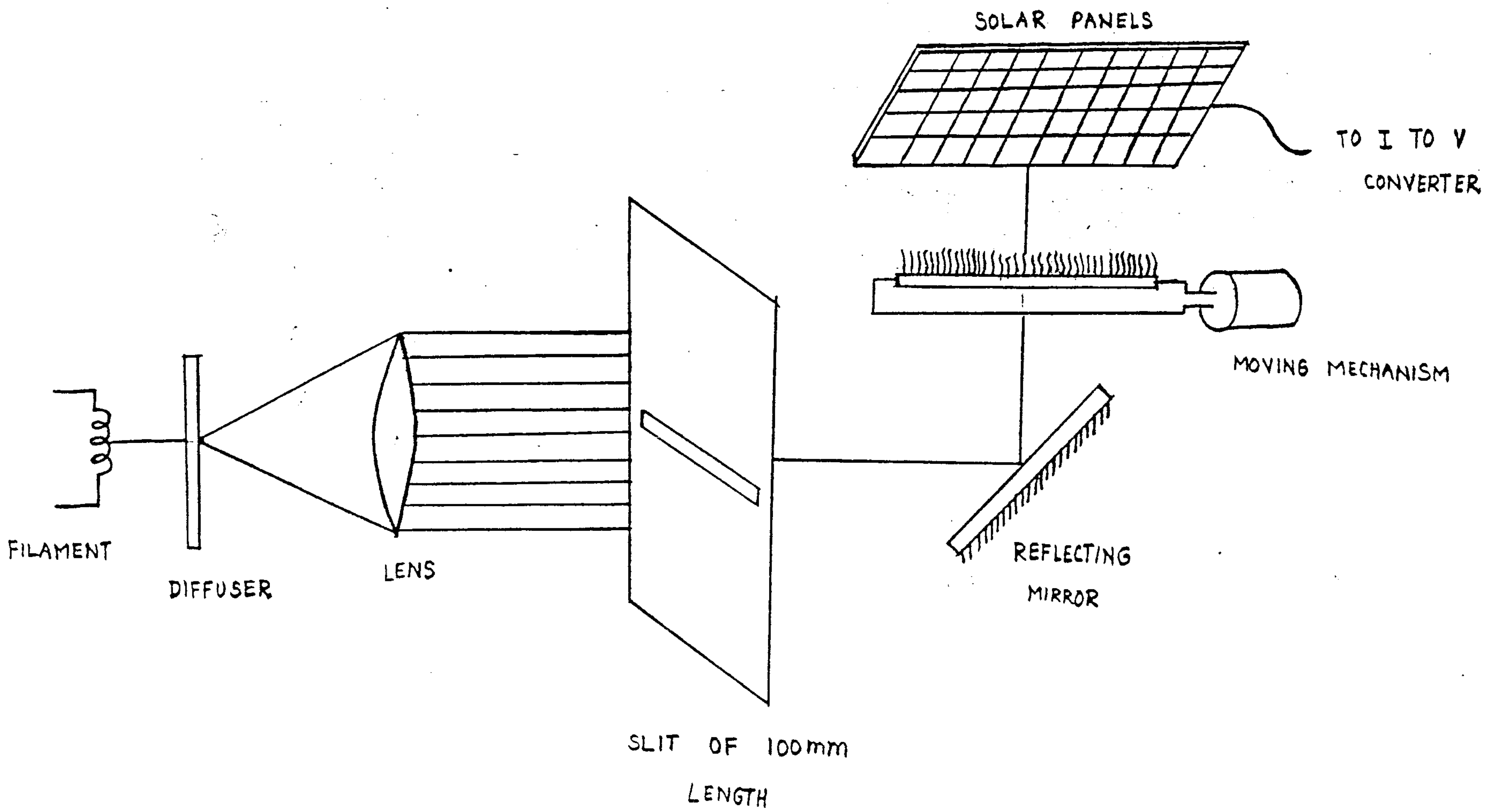
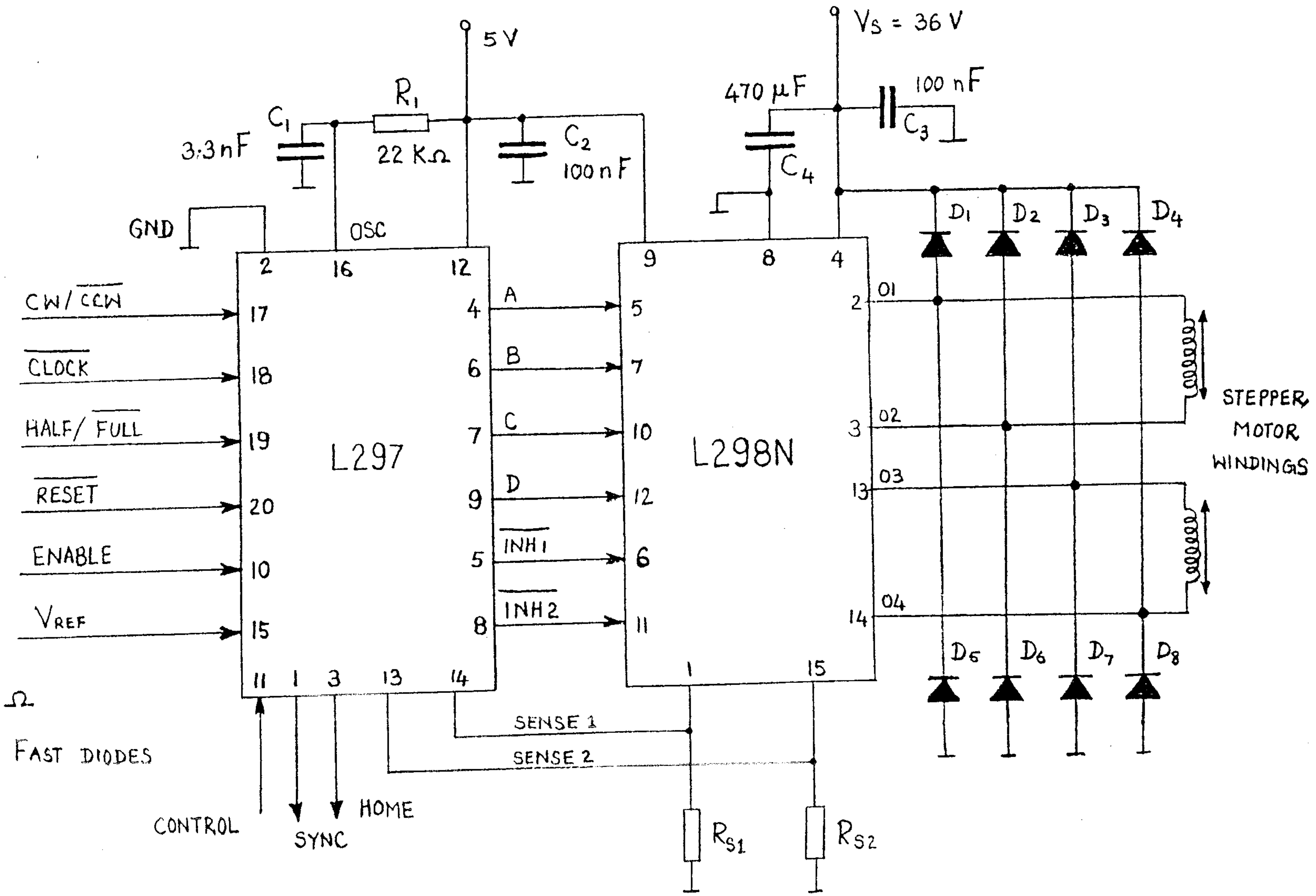


FIG 2·1·1

FIBRE LENGTH ANALYSER SETUP



$R_{S1} = R_{S2} = 0.5\,\Omega$

D_1 to D_8 = 2A FAST DIODES

FIG 2.3.a. TWO PHASE BIPOLAR STEPPER MOTOR CIRCUIT

FULL STEP: TWO SIGNALS FOR FULL STEP

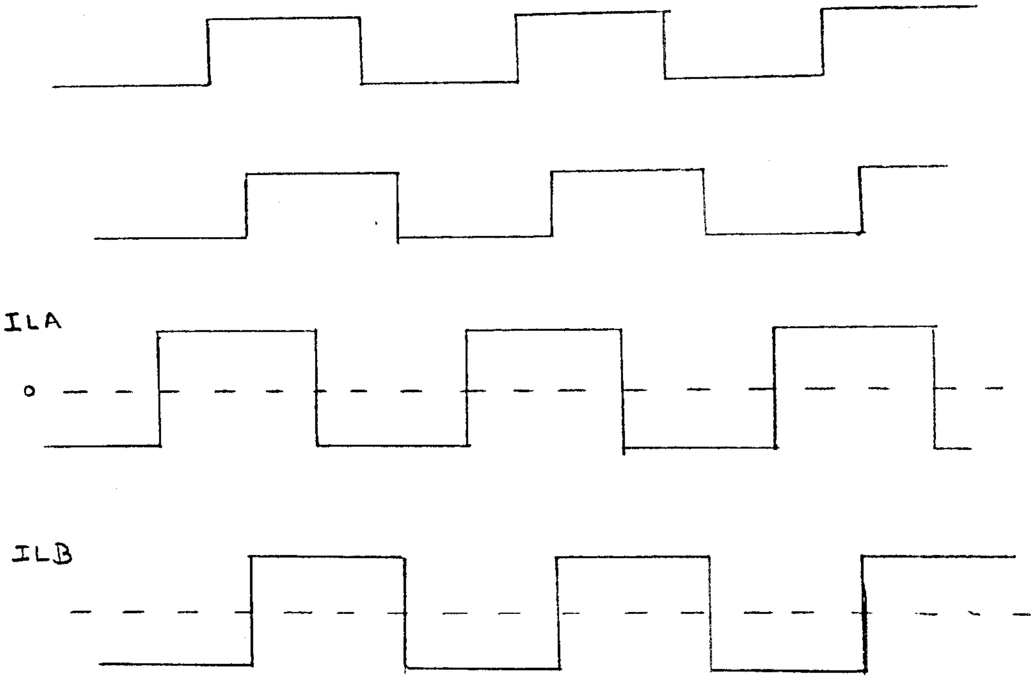


Fig 2.3.b(1)

HALF STEP : SIX SIGNALS FOR HALF STEP

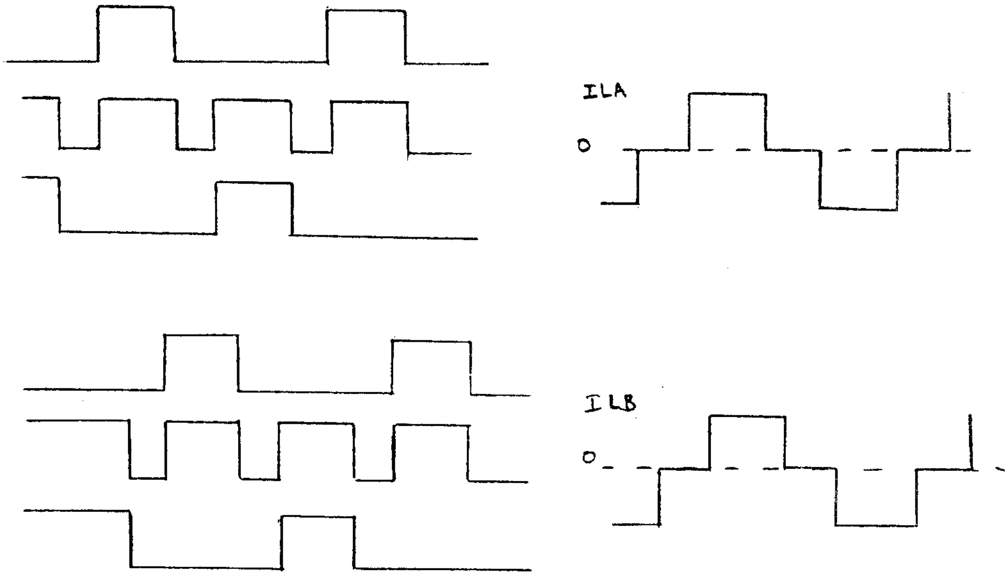
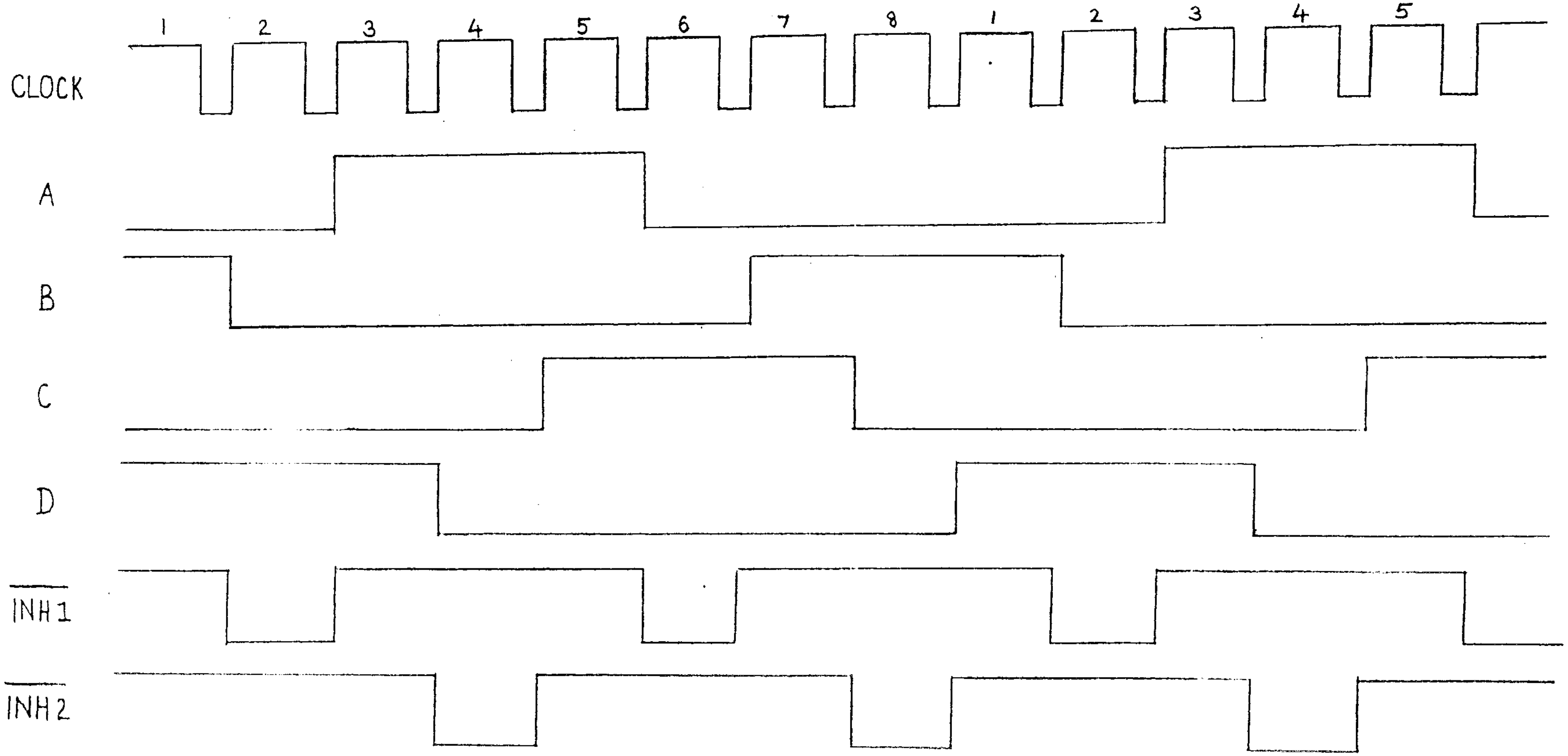
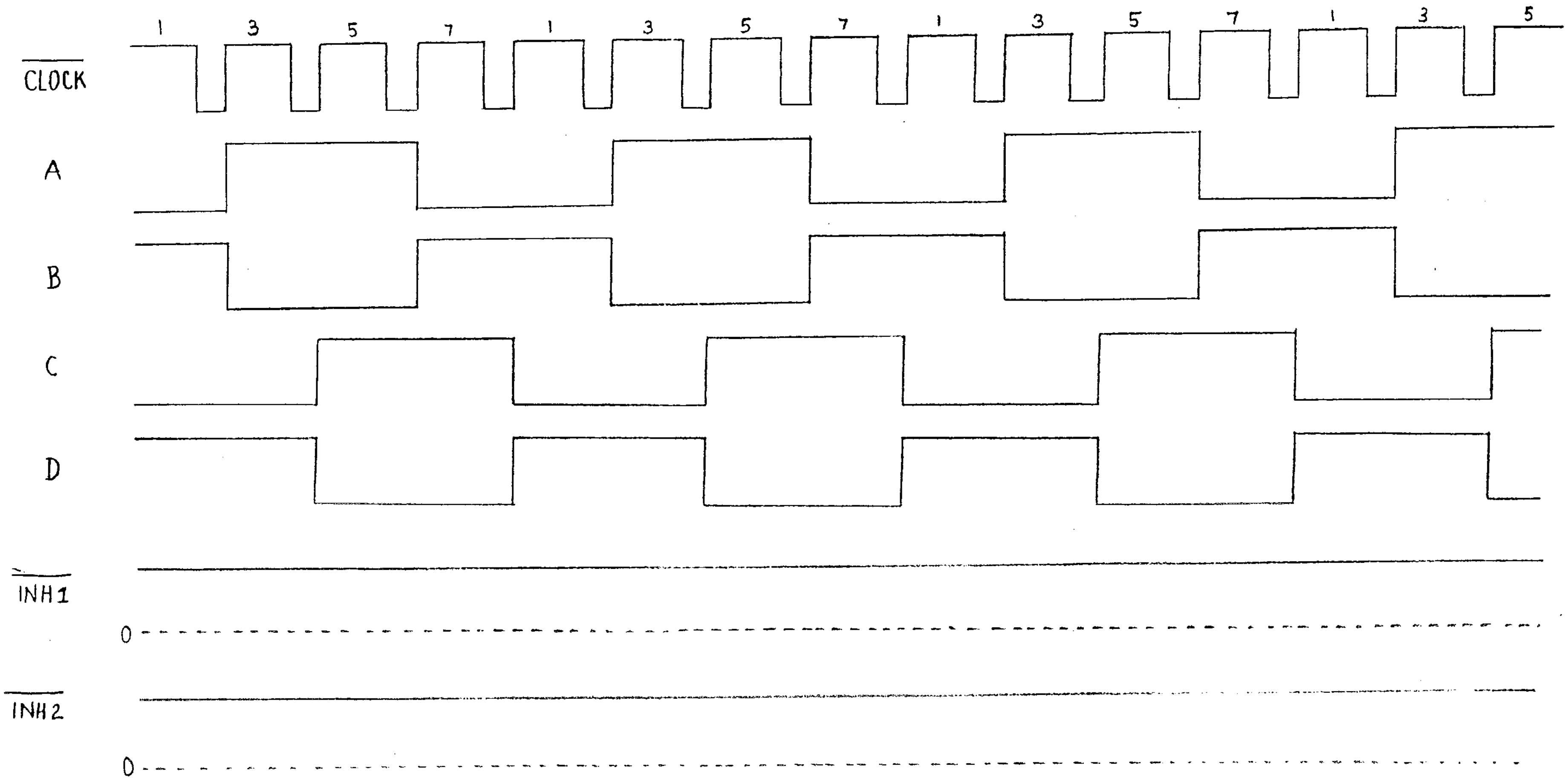


Fig 2.3.b(2)



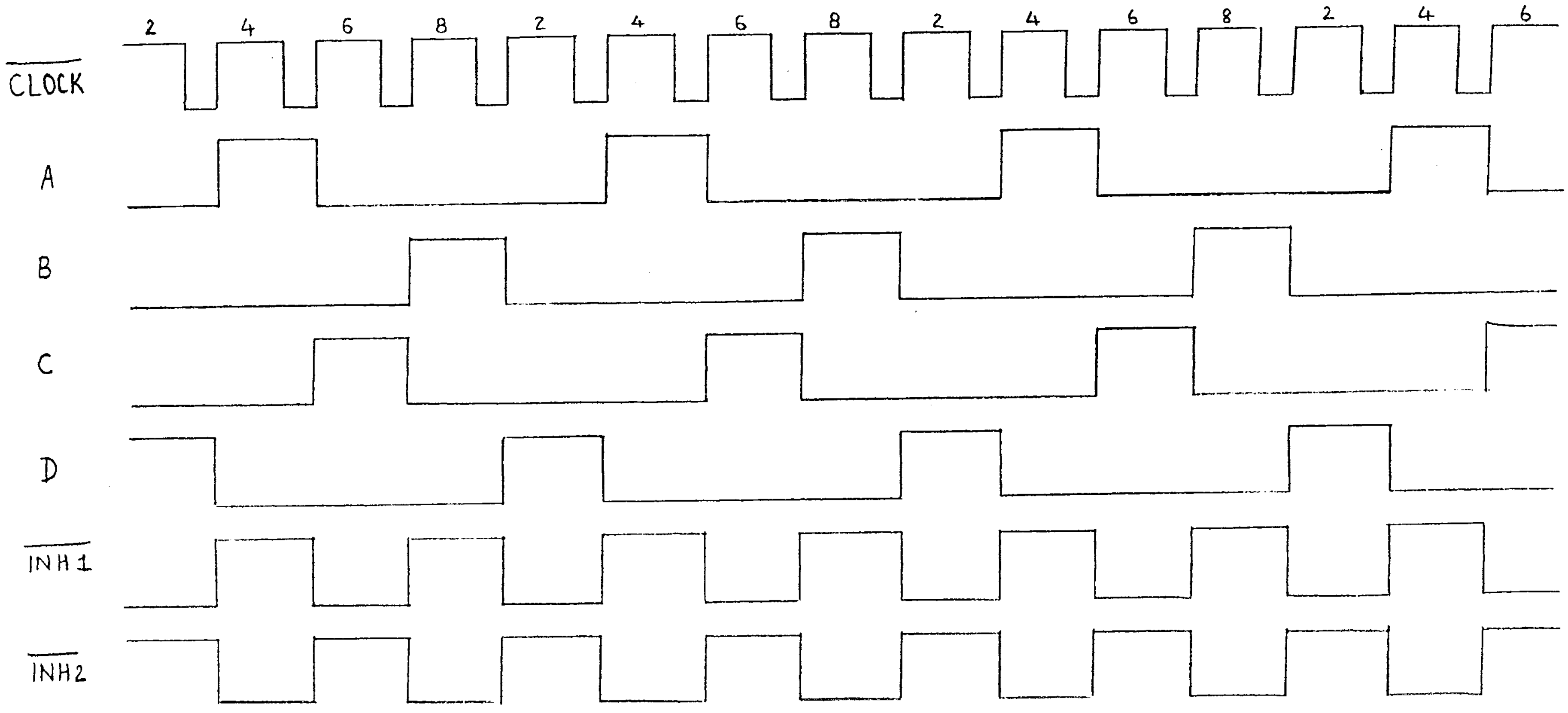
HALF STEP MODE

FIG 2·3·b (3)



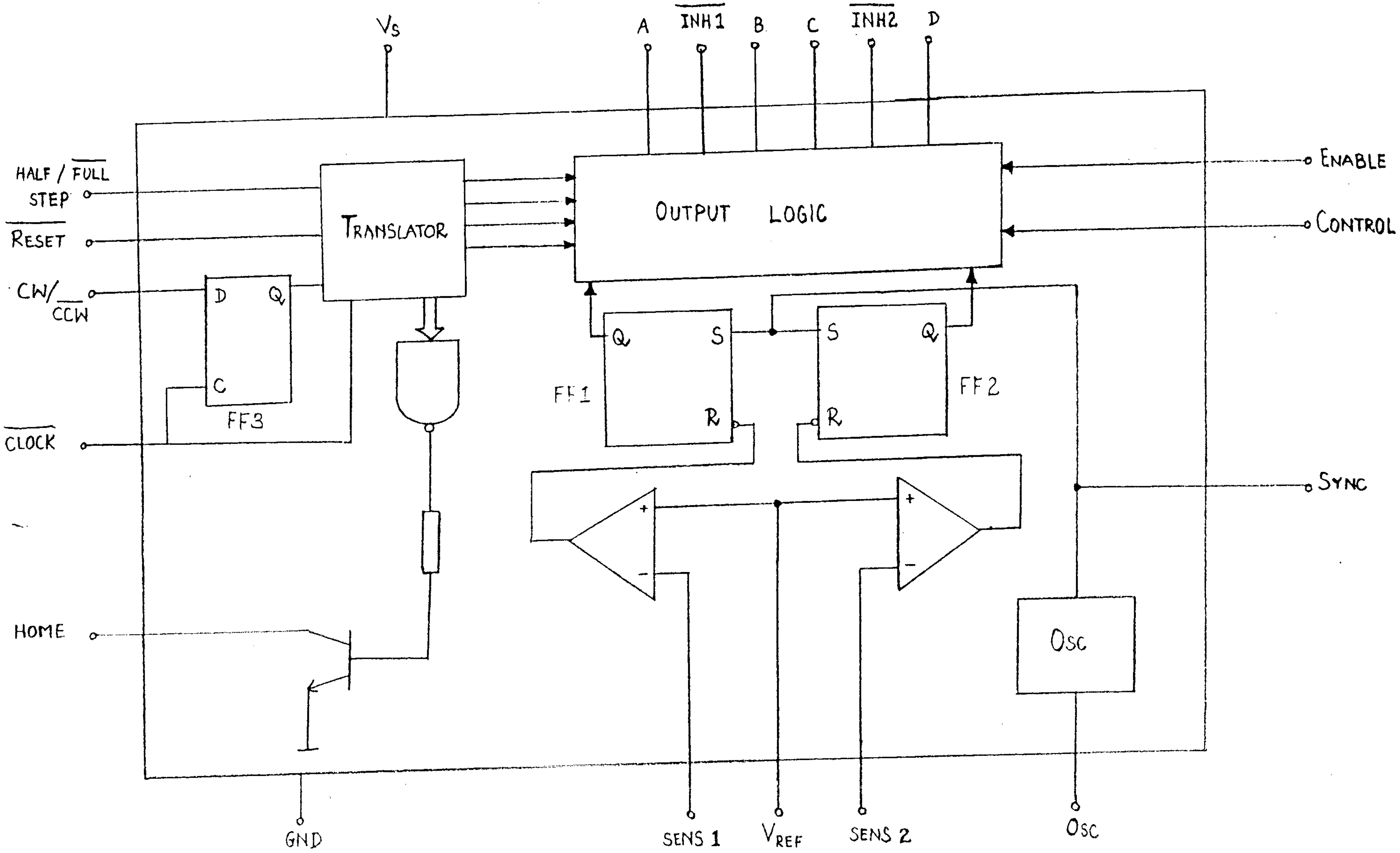
NORMAL DRIVE MODE

FIG 2.3.b (4)



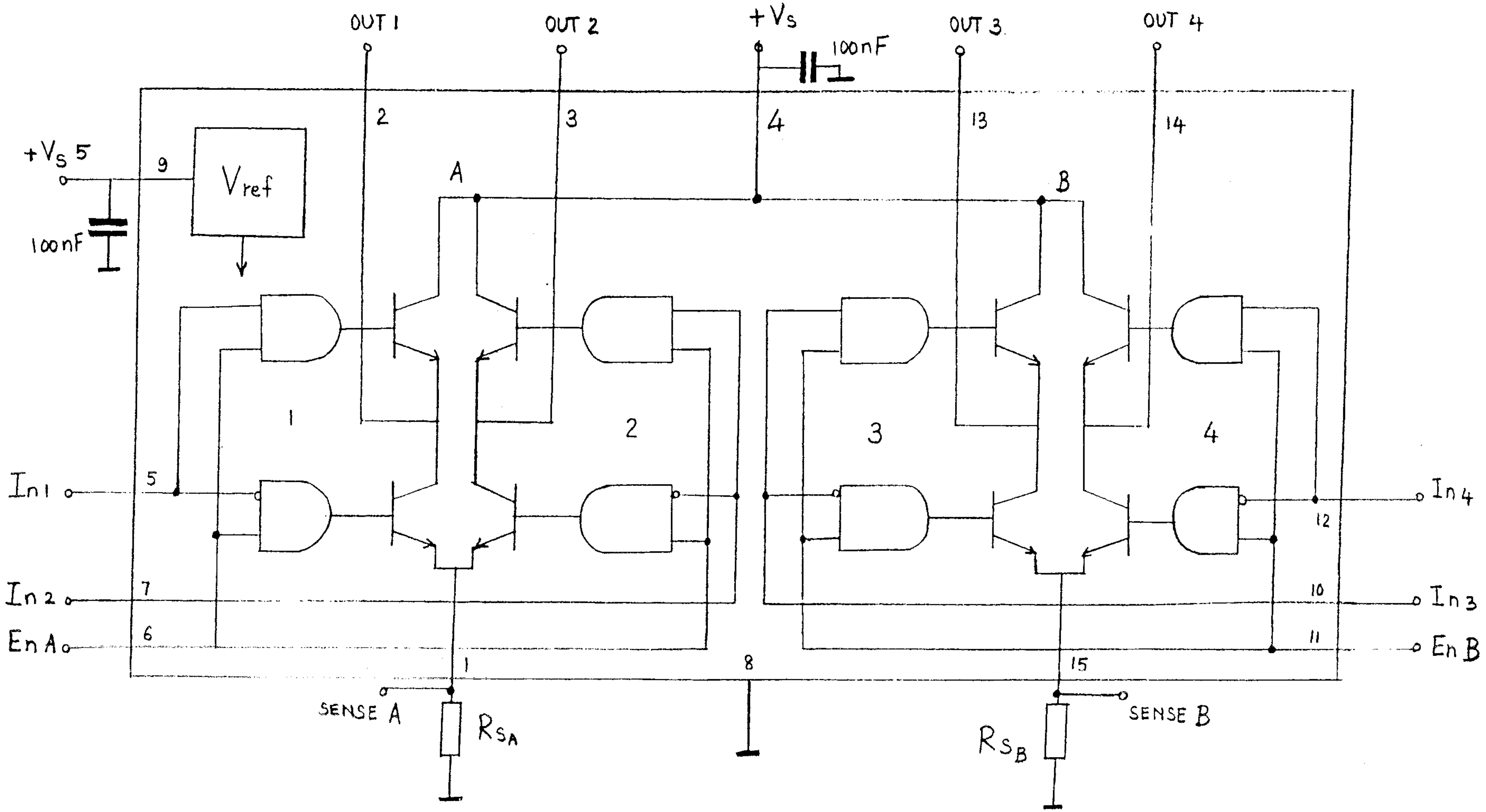
WAVE DRIVE MODE

FIG 2.3.b (5)



INTERNAL BLOCK DIAGRAM OF L297

FIG 2.3.C1



BLOCK DIAGRAM OF L298N

FIG 2.3.C2

CIRCUIT TO OBTAIN HALF-STEP WITH SHAPING OPERATION AND THEREFORE MORE TORQUE

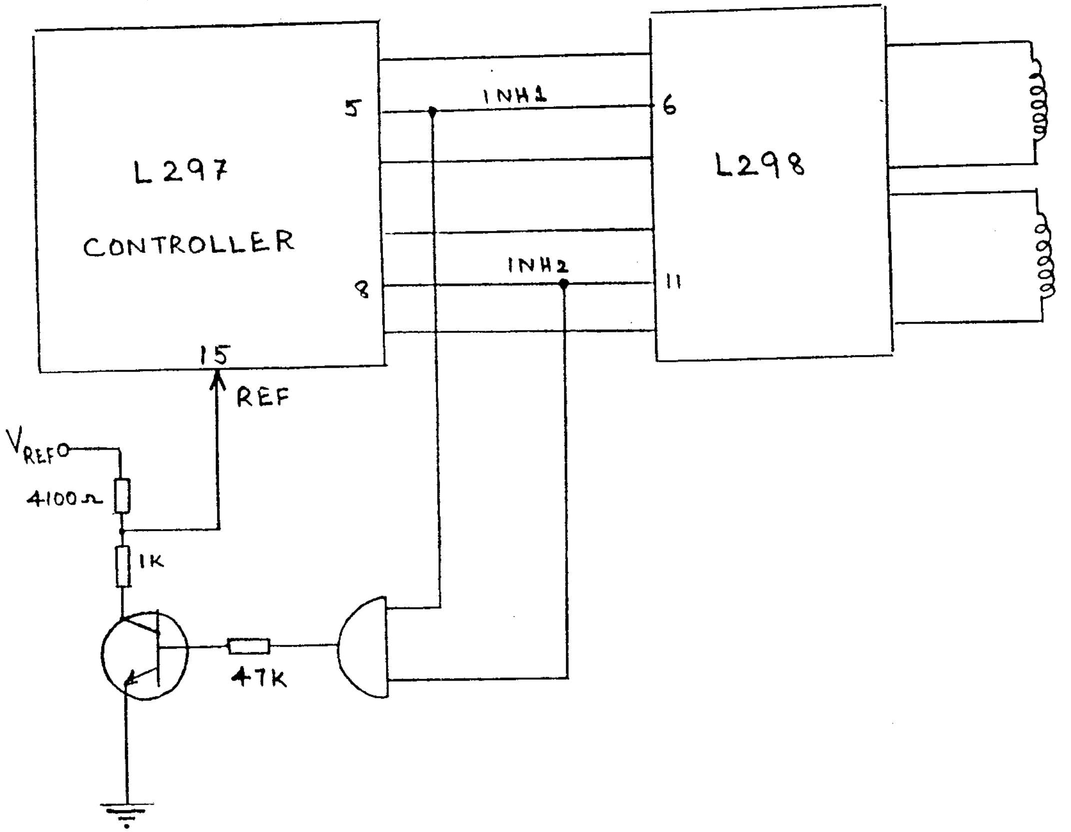
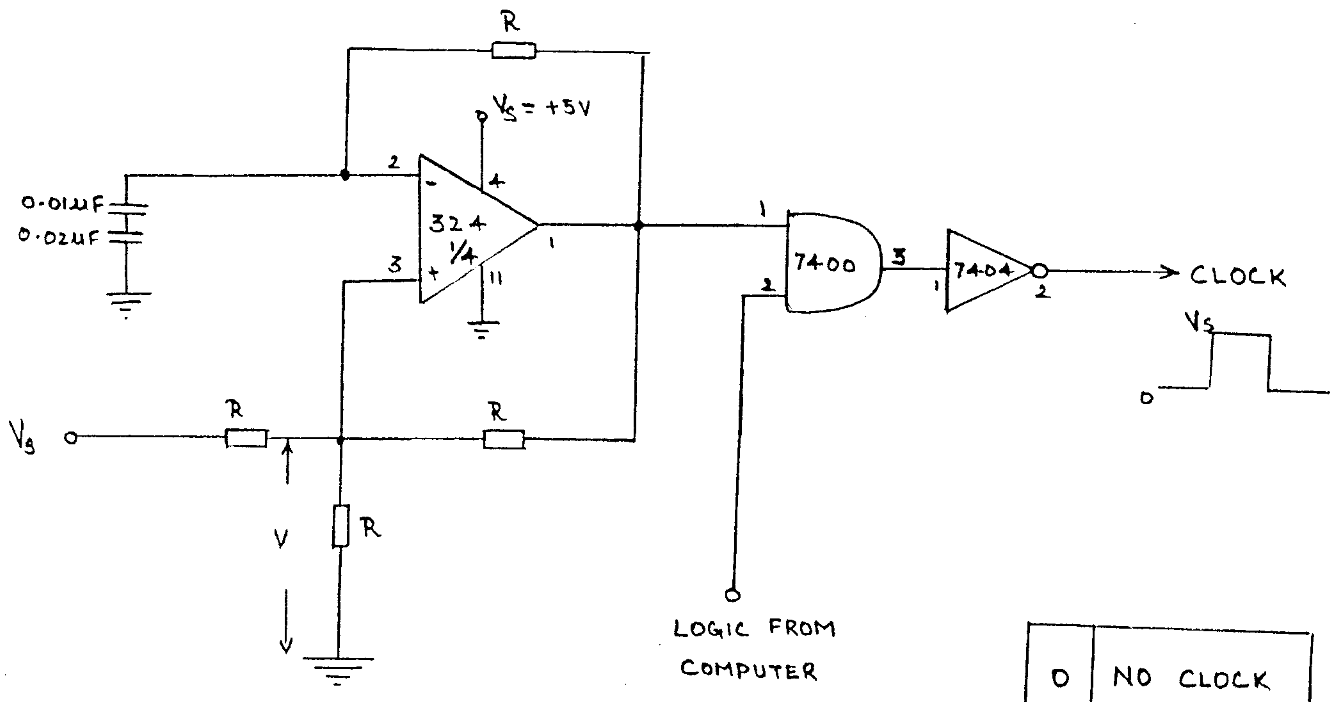


FIG. 2·4·a

CLOCK GENERATION CIRCUIT



R = 100kΩ

0	NO CLOCK
1	CLOCK

FIG. 2·5·a

CIRCUIT TO ACTIVATE INHIBIT INPUT TO SPEED CURRENT DECAY

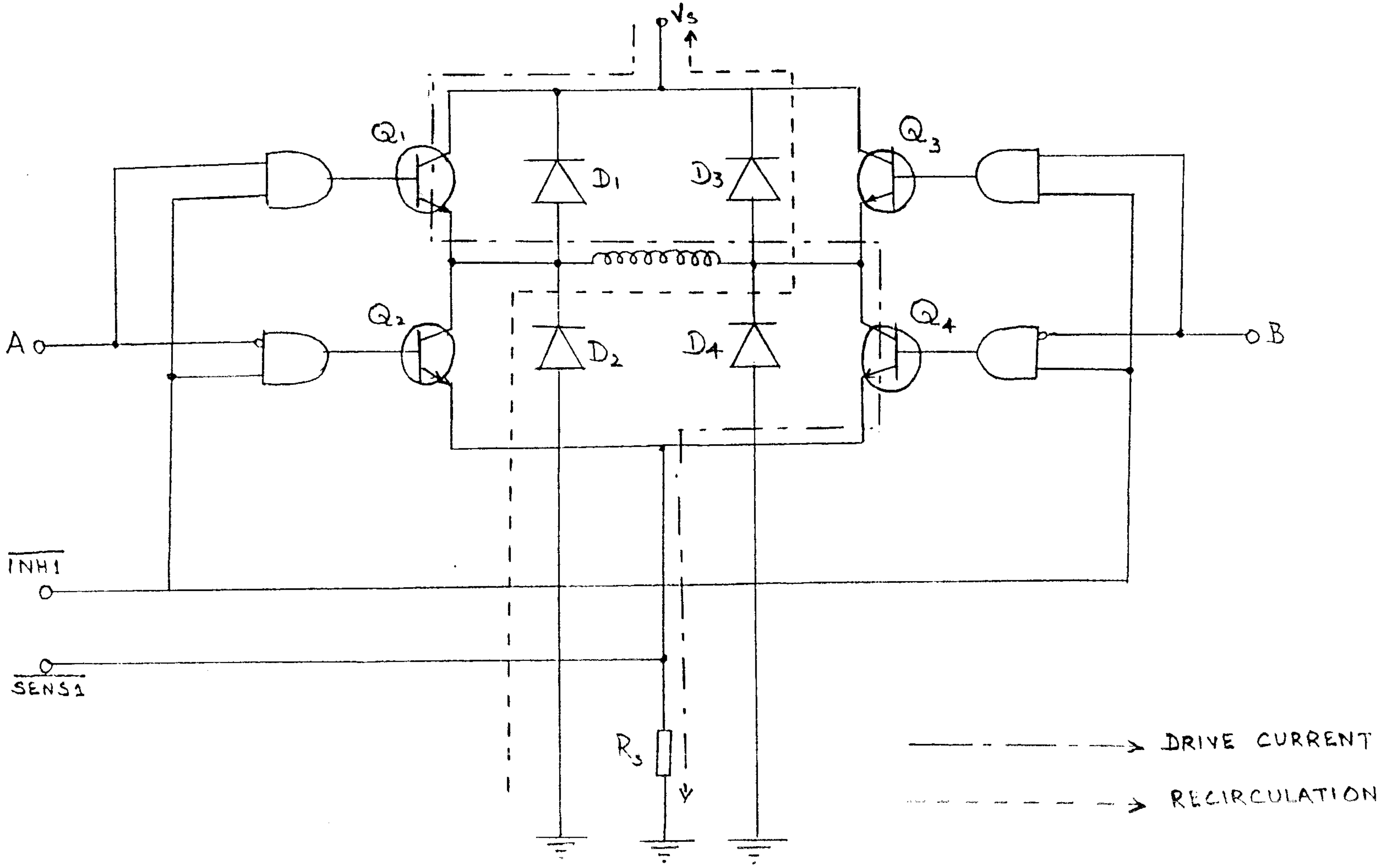
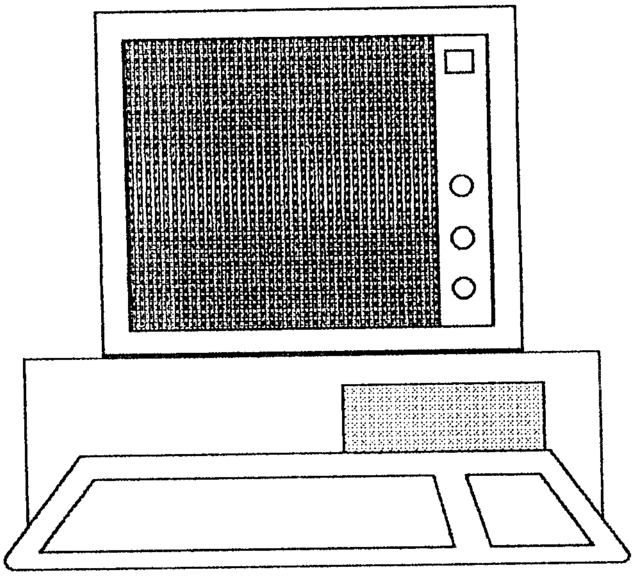


Fig. (i)



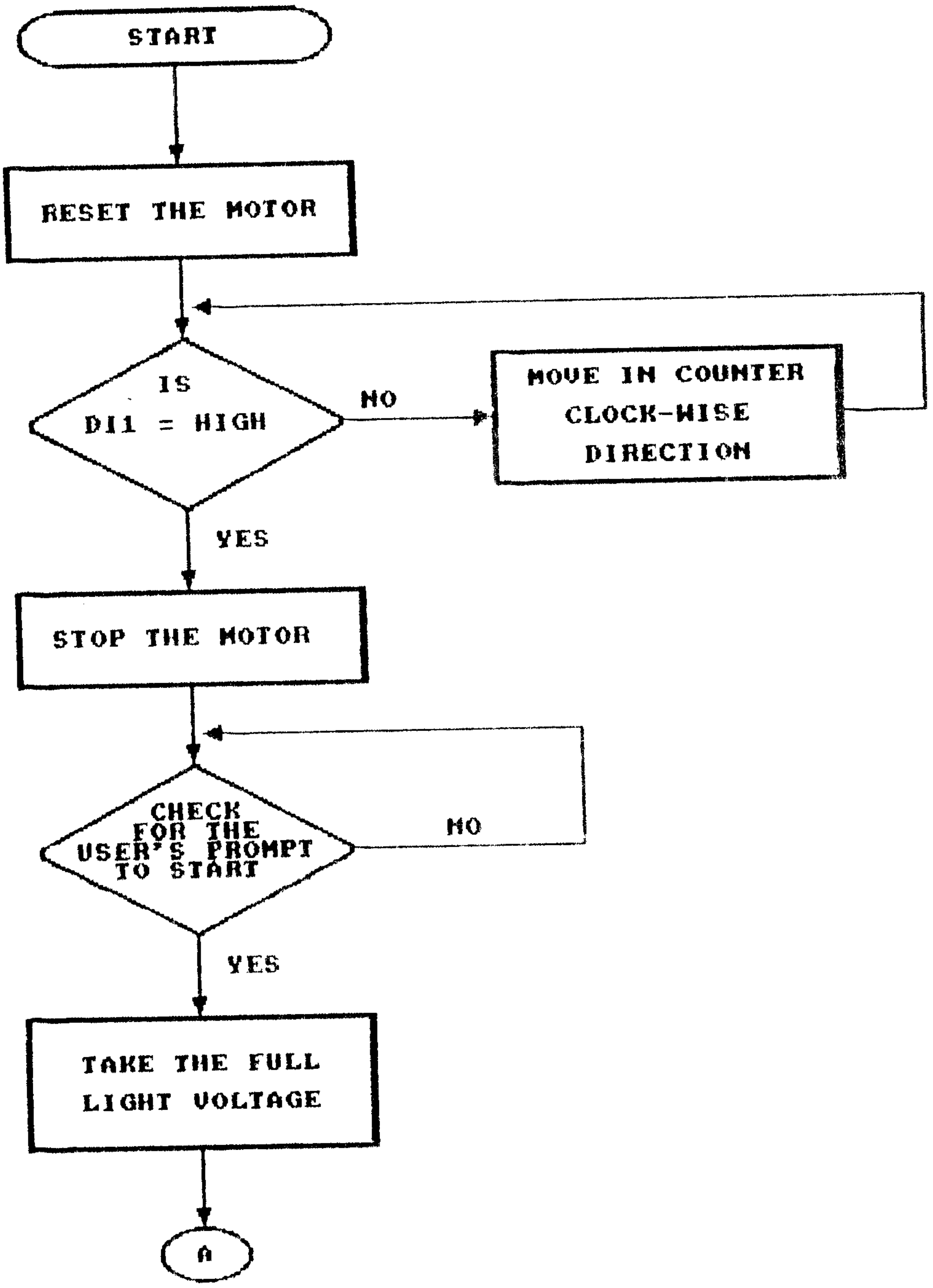
SOFTWARE

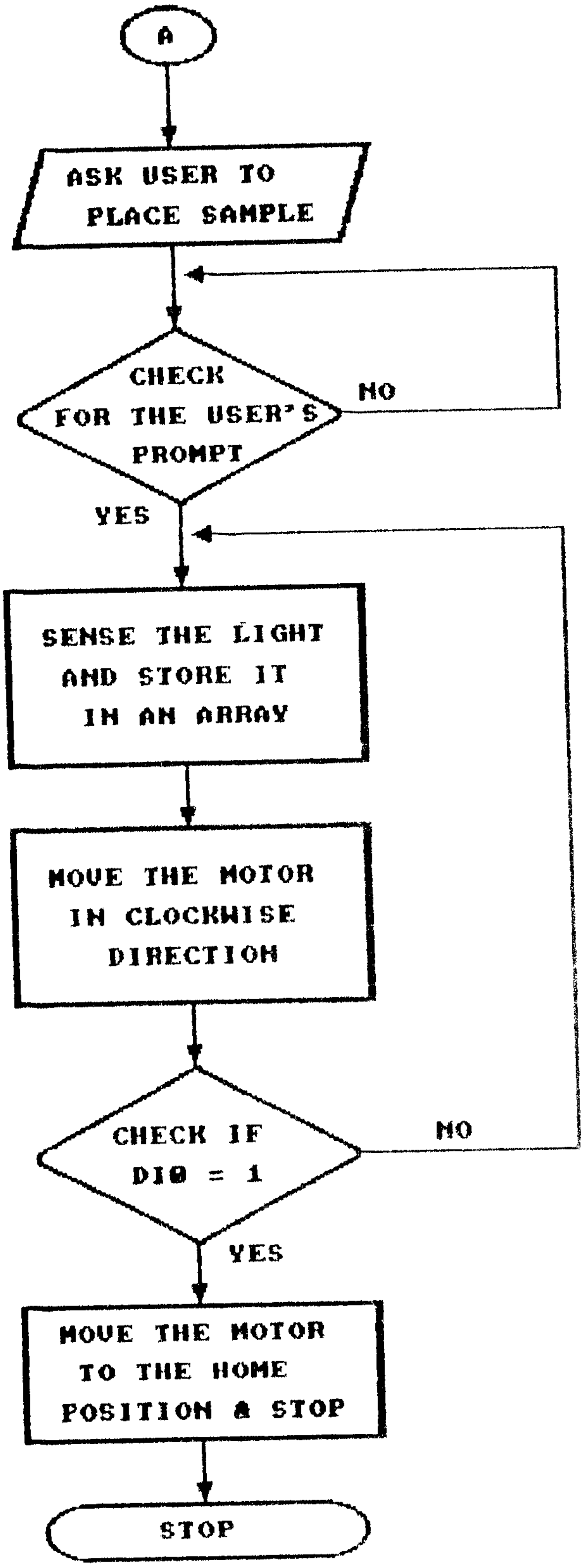
Part of the work done in Software

(i) Stepper motor control

(ii) Simulation of the fibre diagram.

STEPPER MOTOR CONTROLLER




A
ASK USER TO PLACE SAMPLE
CHECK FOR THE USER'S PROMPT
NO
YES
SENSE THE LIGHT AND STORE IT IN AN ARRAY
MOVE THE MOTOR IN CLOCKWISE DIRECTION
CHECK IF DI0 = 1
NO
YES
MOVE THE MOTOR TO THE HOME POSITION & STOP
STOP

3.1 STEPPER MOTOR CONTROL

ALGORITHM

1. Reset the motor

   Send 0003

   0002

   0003

2. Check if

   D/I1 is low are move to home position by running the motor in counter clockwise direction.

   If D/I is high the platform is in the home position.

3. Stop the motor. Send 0003

4. Read the full light voltage from A/Dso in the connector CN3 and store it in an array.

5. Ask the user to place the sample that is to be tested.

6. When the user wants the test to be started, start key is pressed. ASCII value of that key is read.

7. Motor is started (ie to move in clockwise direction)

   send 000F

   Read the analog voltage from A/Dso and store in an array.

8. Check is D/I 0 is high if not go to 7

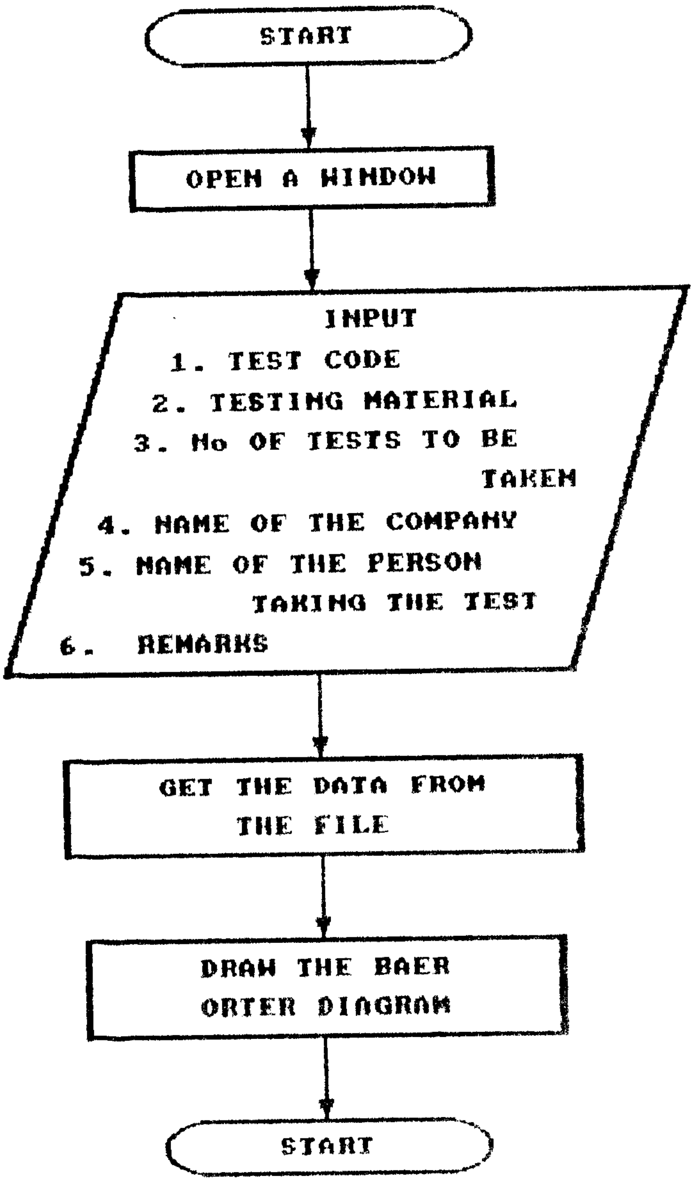
9. Move to home position and stop the motor

moving to home position

1) send 000B

2) If D/I1 is low go to 1 and carryon. Else stop the motor by sending 0003.

SIMULATION OF FIBRE DIAGRAM



3.2 SIMULATION OF FIBRE DIAGRAM

ALGORITHM

1. Loading the card driver PCL 818HG
2. Declaration of the required functions (some of the function like A/D Initialization & D/A Initialization)
3. Setting the parameters in the required form
4. Drawing the window and making the required markings in the x and y axis.
5. Get the input from the signal conditioning system and make the required manipulations.
6. Plot these data in the window. This is the Baer sorter diagram.
7. Print the 50% and 2.5% span length on the screen.
8. With the mouse cursor arrangement we can read the required point in the graph.
9. Print the corresponding percentage and the corresponding fibre length on the screen.
10. If the number of tests to be taken is more continue from step 5.

INPUT

1. Open a window as required

2. Get the following data from the user.

   a) test code or filemane

   b) Testing material

   c) No of tests to be taken

   d) Name of the company

   e) Name of the person who is taking the test.

   f) Remarks if any

3. Store all these datas in the specified file and proceed to testing.

RESULT :

Three types of cotton were tested using the MFA equipment and the results obtained by us were as follows:

CLASS	2.5% SPAN LENGTH VALUES MIN	MAX
Extra long staple	34.5 mm	35.50 mm
Long staple	30.5 mm	31.00 mm
Medium staple	26.0 mm	26.50 mm

SPAN LENGTH

Span length parameters are based on the length of fibre measured from any random point on the fibre. Only partial lenfth of the fibre is considered while computing span length.

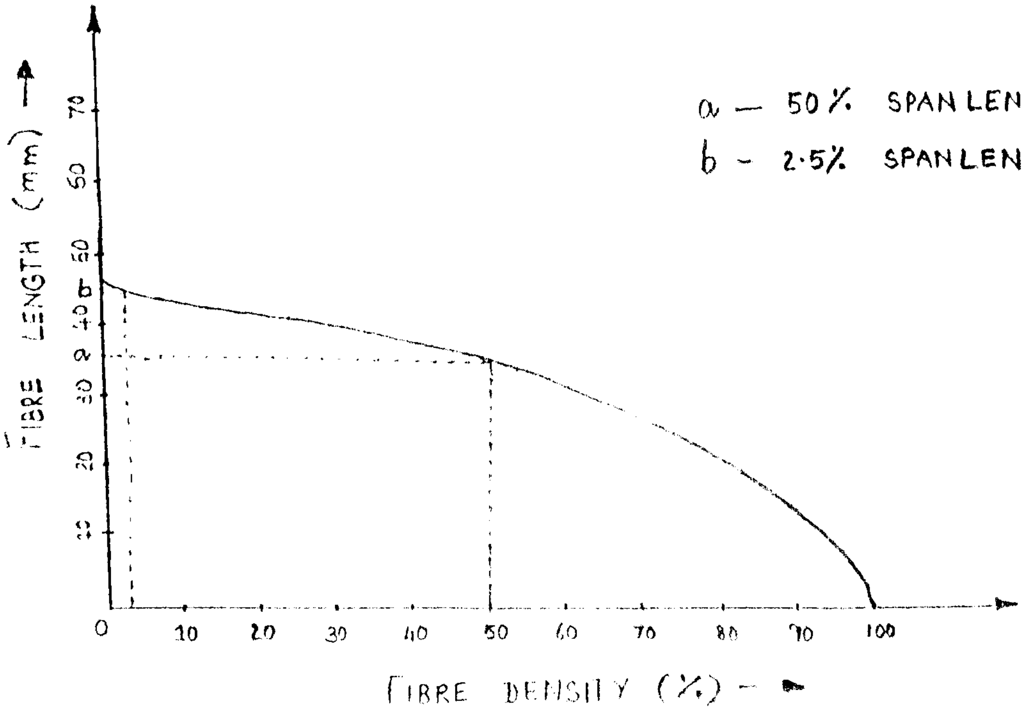
2.5% SPAN LENGTH

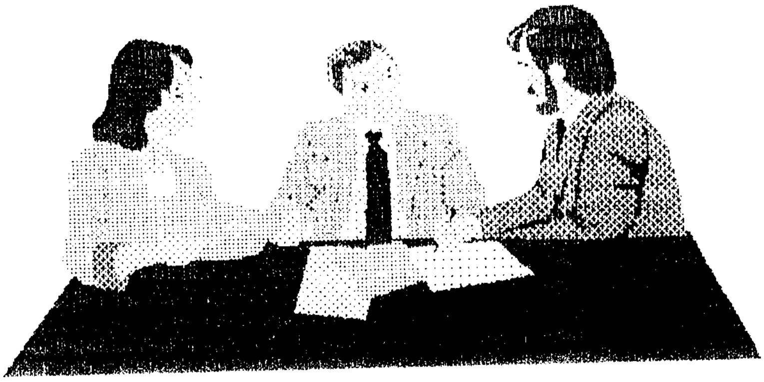
2.5% Span length is defined as the distance 2.5% of the fibres extend from the clamp where they are caught at random along their length. This length is numerically nearer to the staple length as determined by the American classers.

THE BAER SORTER DIAGRAM

The Baer sorter diagram of textile fibres is of considerable interest and helps in judging the length of the fibre. This diagram is obtained by plotting the values of fibre density (%) and fibre length (mm) along the x and y axis. The 50% span length and 2.5% span length of the cotton fibre are obtained from the Baer sorter diagram.

BAER SORTER DIAGRAM





CONCLUSION

4. CONCLUSION

To conclude, our project would be the most accurate and economic method for measuring the span length of cotton fibre. It also facilitates for application of statistical techniques for analysis, comparison, interpretation and storage of data over a period of 3-6 months. The sample outputs are upper half mean length, Effective length, Short fibre content, maximum length, 50% span length, 2.5% span length, short fibre index, user defined span length and the Baer sorter diagram.

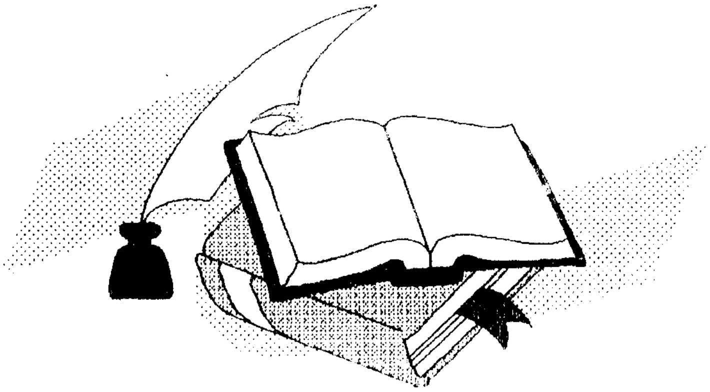
For the user industry it helps in solving the basic problem in the manufacture of a standard product from an essentially non-standard and highly variable raw material namely cotton, optinizing mixing cost, choosing the right quality of cotton and for the mills to blend varieties on the basis of fibre properties.

Our product will have a good market beacuse of its comparitively low cost available in the textile industry.

FUTURE ADVANCEMENTS

The other features that could be included are:

- strength
- Maturity and
- Elongation
- Trash content



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5.BIBLIOGRAPHY

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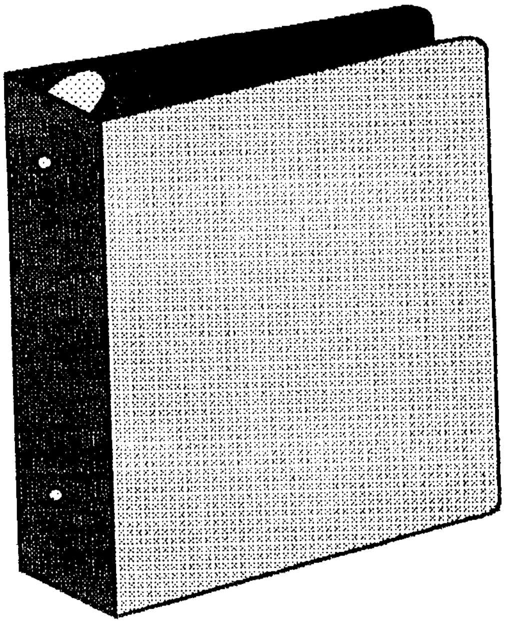
DATA MANUAL

2. SGS - THOMSON MICROELECTRONICS
APPLICATION MANUAL

3. PCL - 818 HG USERS MANUAL

4. THE JOURNAL OF THE TEXTILE INSTITUTE.



APPENDIX

Figure 5 : Sink Current Delay Times vs. Input 0 V Enable Switching.

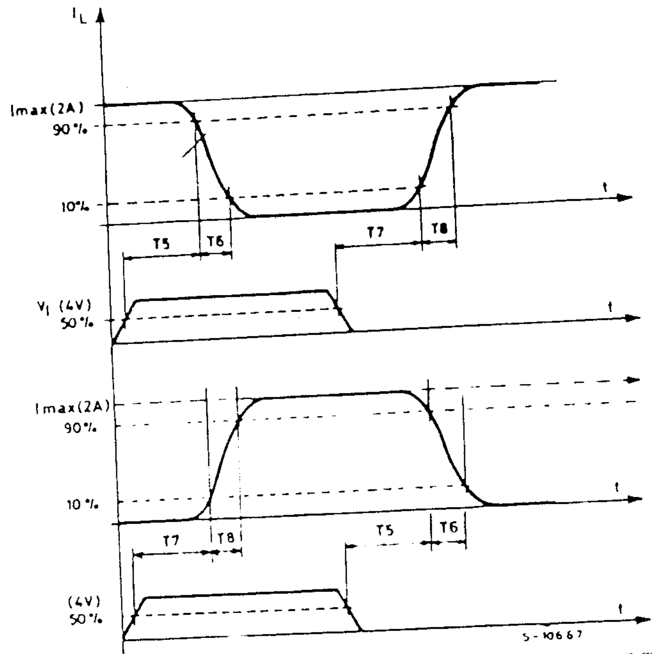
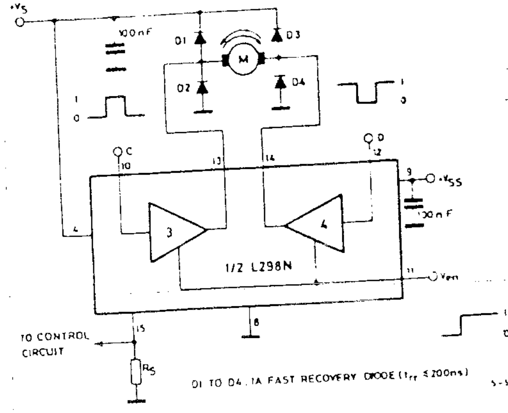


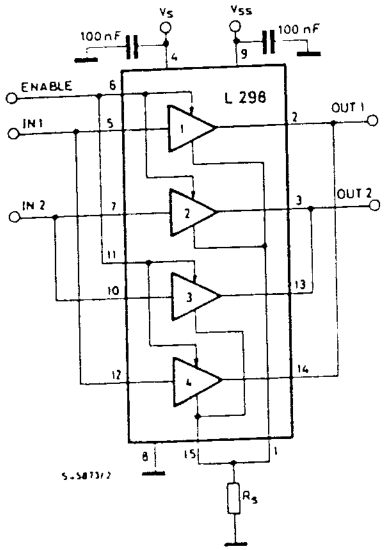
Figure 6 : Bidirectional DC Motor Control.



Inputs		Function
V_{en} = H	C = H ; D = L	Turn Right
	C = L ; D = H	Turn Left
	C = D	Fast Motor Stop
V_{en} = L	C = X ; D = C	Free Running Motor Stop

L = Low H = High X = Don't care

Figure 7 : For higher currents, outputs can be paralleled. Take care to parallel channel 1 with channel 4 and channel 2 with channel 3.



APPLICATION INFORMATION (Refer to the block diagram)

1.1. POWER OUTPUT STAGE

The L298N integrates two power output stages (A ; B). The power output stage is a bridge configuration and its outputs can drive an inductive load in common or differenzial mode, depending on the state of the inputs. The current that flows through the load comes out from the bridge at the sense output : an external resistor (R_{SA} ; R_{SB}.) allows to detect the intensity of this current.

1.2. INPUT STAGE

Each bridge is driven by means of four gates the input of which are In1 ; In2 ; EnA and In3 ; In4 ; EnB. The In inputs set the bridge state when The En input is high ; a low state of the En input inhibits the bridge. All the inputs are TTL compatible.

2. SUGGESTIONS

A non inductive capacitor, usually of 100 nF, must be foreseen between both Vs and Vss, to ground, as near as possible to pin 8 (GND). When the large capacitor of the power supply is too far from the IC, a second smaller one must be foreseen near the L298N.

The sense resistor, not of a wire wound type, must be grounded near the negative pole of Vs that must be near the GND pin of the I.C.

Each input must be connected to the source of the driving signals by means of a very short path.

Turn-On and Turn-Off : Before to Turn-ON the Supply Voltage and before to Turn it OFF, the Enable input must be driven to the Low state.

3. APPLICATIONS

Fig 6 shows a bidirectional DC motor control Schematic Diagram for which only one bridge is needed. The external bridge of diodes D1 to D4 is made by four fast recovery elements (trr ≤ 200 nsec) that must be chosen of a VF as low as possible at the worst case of the load current.

The sense output voltage can be used to control the current amplitude by chopping the inputs, or to provide overcurrent protection by switching low the enable input.

The brake function (Fast motor stop) requires that the Absolute Maximum Rating of 2 Amps must never be overcome.

When the repetitive peak current needed from the load is higher than 2 Amps, a paralleled configuration can be chosen (See Fig.7).

An external bridge of diodes are required when inductive loads are driven and when the inputs of the

ELECTRICAL CHARACTERISTICS (continued)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
$V_{CE\,sat(L)}$	Sink Saturation Voltage	I_L = 1 A (5)		1.2	1.6	V
		I_L = 2 A (5)		1.7	2.3	
$V_{CE\,sat}$	Total Drop	I_L = 1 A (5)			3.2	V
		I_L = 2 A (5)			4.9	
V_{sens}	Sensing Voltage (pins 1, 15)		– 1		2	V
T_1 (V_i)	Source Current Turn-off Delay	0.5 V_i to 0.9 I_L (2) ; (4)		1.5		µs
T_2 (V_i)	Source Current Fall Time	0.9 I_L to 0.1 I_L (2) ; (4)		0.2		µs
T_3 (V_i)	Source Current Turn-on Delay	0.5 V_i to 0.1 I_L (2) ; (4)		2		µs
T_4 (V_i)	Source Current Rise Time	0.1 I_L to 0.9 I_L (2) ; (4)		0.7		µs
T_5 (V_i)	Sink Current Turn-off Delay	0.5 V_i to 0.9 I_L (3) ; (4)		0.7		µs
T_6 (V_i)	Sink Current Fall Time	0.9 I_L to 0.1 I_L (3) ; (4)		0.25		µs
T_7 (V_i)	Sink Current Turn-on Delay	0.5 V_i to 0.9 I_L (3) ; (4)		1.6		µs
T_8 (V_i)	Sink Current Rise Time	0.1 I_L to 0.9 I_L (3) ; (4)		0.2		µs
f_c (V_i)	Commutation Frequency	I_L = 2 A		25	40	KHz
T_1 (V_{en})	Source Current Turn-off Delay	0.5 V_{en} to 0.9 I_L (2) ; (4)		3		µs
T_2 (V_{en})	Source Current Fall Time	0.9 I_L to 0.1 I_L (2) ; (4)		1		µs
T_3 (V_{en})	Source Current Turn-on Delay	0.5 V_{en} to 0.1 I_L (2) ; (4)		0.3		µs
T_4 (V_{en})	Source Current Rise Time	0.1 I_L to 0.9 I_L (2) ; (4)		0.4		µs
T_5 (V_{en})	Sink Current Turn-off Delay	0.5 V_{en} to 0.9 I_L (3) ; (4)		2.2		µs
T_6 (V_{en})	Sink Current Fall Time	0.9 I_L to 0.1 I_L (3) ; (4)		0.35		µs
T_7 (V_{en})	Sink Current Turn-on Delay	0.5 V_{en} to 0.1 I_L (3) ; (4)		0.25		µs
T_8 (V_{en})	Sink Current Rise Time	0.1 I_L to 0.9 I_L (3) ; (4)		0.1		µs
f_c (V_{en})	Commutation Frequency	I_L = 2 A		1		KHz

1) Sensing voltage can be –1 V for t ≤ 50 µsec; in steady state V_{sens} min ≥ – 0.5 V
2) See fig. 2.
3) See fig. 4
4) The load must be a pure resistor
5) PIN 1 and PIN 15 connected to GND

Figure 1 : Typical Saturation Voltage vs. Output Current.

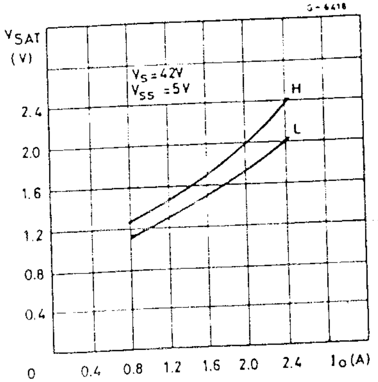
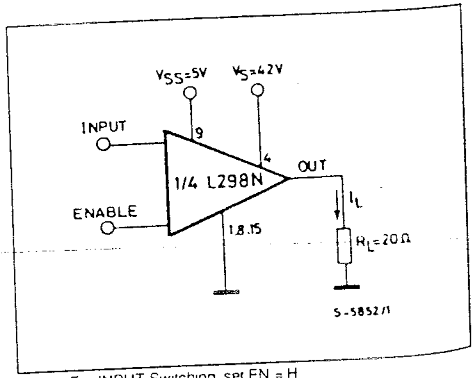


Figure 2 : Switching Times Test Circuits.



Note : For INPUT Switching, set EN = H
For ENABLE Switching, set IN = H

Figure 3 : Source Current Delay Times vs. Input or Enable Switching.

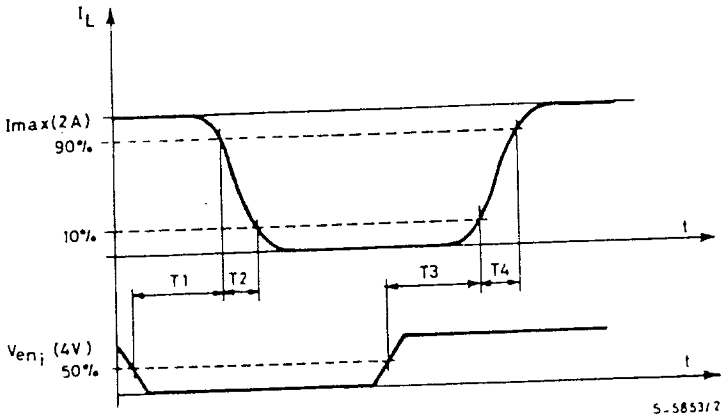
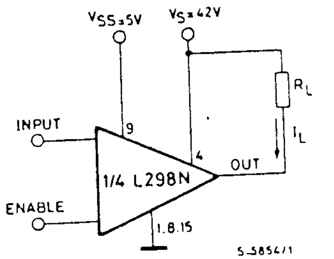


Figure 4 : Switching Times Test Circuits.

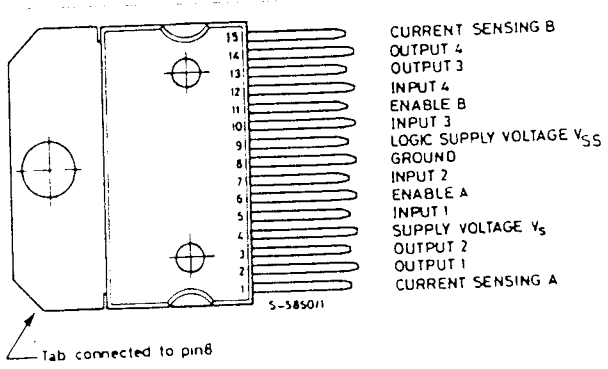


Note : For INPUT Switching, set EN = H
For ENABLE Switching, set IN = L

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Test Conditions	Unit
V_S	Power Supply	50	V
V_{SS}	Logic Supply Voltage	7	V
V_I, V_{en}	Input and Enable Voltage	– 0.3 to 7	V
I_O	Peak Output Current (each channel) · Non Repetitive (t = 100 µs) · Repetitive (80 % on – 20 % off ; t_{on} = 10 ms) · DC Operation	 3 2.5 2	 A A A
V_{sens}	Sensing Voltage	– 1 to 2.3	V
P_{tot}	Total Power Dissipation (T_{case} = 75 °C)	25	W
T_{stg}, T_j	Storage and Junction Temperature	– 40 to 150	°C

PIN CONNECTION (top view)



THERMAL DATA

$R_{th\,j\text{-}case}$	Thermal Resistance Junction-case	Max	3	°C/W
$R_{th\,j\text{-}amb}$	Thermal Resistance Junction-ambient	Max	35	°C/W

PIN FUNCTIONS (refer to the block diagram)

N°	Name	Function
1 ; 15	Sense A ; Sense B	Between this pin and ground is connected the sense resistor to control the current of the load.
2 ; 3	Out 1 ; Out 2	Outputs of the Bridge A ; the current that flows through the load connected between these two pins is monitored at pin 1.
4	V_S	Supply Voltage for the Power Output Stages. A non-inductive 100 nF capacitor must be connected between this pin and ground.
5 ; 7	Input 1 ; Input 2	TTL Compatible Inputs of the Bridge A.
6 ; 11	Enable A ; Enable B	TTL Compatible Enable Input : the L state disables the bridge A (enable A) and/or the bridge B (enable B).
8	GND	Ground.
9	V_{SS}	Supply Voltage for the Logic Bloks. A 100 nF capacitor must be connected between this pin and ground.
10 ; 12	Input 3 ; Input 4	TTL Compatible Inputs of the Bridge B.
13 ; 14	Out 3 ; Out 4	Outputs of the Bridge B. The current that flows through the load connected between these two pins is monitored at pin 15.

ELECTRICAL CHARACTERISTICS (V_S = 42 V ; V_{SS} = 5 V, T_j = 25 °C ; unless otherwise specified)

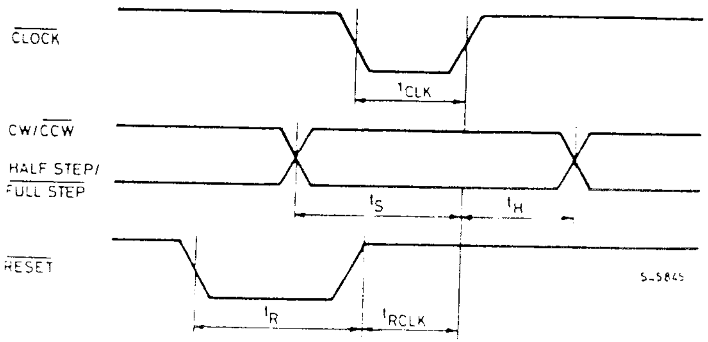
Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
V_S	Supply Voltage (pin 4)	Operative Condition		V_{IH} + 2.5		46	V
V_{SS}	Logic Supply Voltage (pin 9)			4.5	5	7	V
I_S	Quiescent Supply Current (pin 4)	V_{en} = H I_L = 0	V_i = L		13	22	mA
			V_i = H		50	70	
		V_{en} = L	V_i = x			4	
I_{SS}	Quiescent Current from V_{SS} (pin 9)	V_{en} = H I_L = 0	V_i = L		24	36	mA
			V_i = H		7	12	
		V_{en} = L	V_i = x			6	
V_{iL}	Input Low Voltage (pins 5.7.10.12)			– 0.3		1.5	V
V_{iH}	Input High Voltage (pins 5.7.10.12)			2.3		V_{SS}	
I_{iL}	Low Voltage Input Current (pins 5.7.10.12)	V_i = L				– 10	µA
I_{iH}	High Voltage Input Current (pins 5.7.10.12)	V_i = H ≤ V_{SS} – 0.6 V			30	100	
V_{en} = L	Enable Low Voltage (pins 6.11)			– 0.3		1.5	V
V_{en} = H	Enable High Voltage (pins 6.11)			2.3		V_{SS}	
I_{en} = L	Low Voltage Enable Current (pins 6.11)	V_{en} = L				– 10	µA
I_{en} = H	High Voltage Enable Current (pins 6.11)	V_{en} = H ≤ V_{SS} – 0.6 V			30	100	
$V_{CE\,sat\,(H)}$	Source Saturation Voltage	I_L = 1 A			1.35	1.7	V
		I_L = 2 A			2	2.7	

ELECTRICAL CHARACTERISTICS (continued)

	Parameter	Test conditions	Min.	Typ.	Max.
I_{leak}	Leakage current (pin 3, 11*)	$V_{CE} = 7$ V			1
V_{sat}	Saturation voltage (pins 3, 11*)	I = 5 mA			0.4
V_{off}	Comparators offset voltage (pins 13, 14, 15)	$V_{ref} = 1$ V			5
I_b	Comparator bias current (pins 13, 14, 15)		− 100		10
V_{ref}	Input reference voltage (pin 15)		0		3
t_{CLK}	Clock time		0.5		
t_S	Set up time		1		
t_H	Hold time		4		
t_R	Reset time		1		
t_{RCLK}	Reset to clock delay		1		

* L297A only

Figure 1.

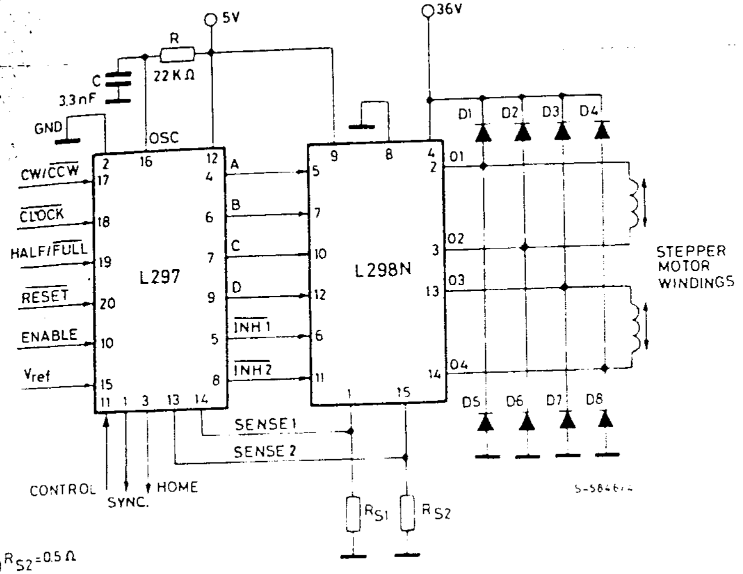


APPLICATION INFORMATION

TWO PHASE BIPOLAR STEPPER MOTOR CONTROL CIRCUIT

This circuit drives bipolar stepper motors with winding currents up to 2A. The diodes are fast 2A types.

Figure 2.



$R_{S1}R_{S2} = 0.5\ \Omega$
D1 to D8 = 2A FAST DIODES

Figure 3 : Synchronising L297s

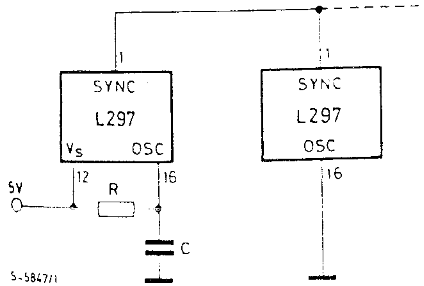
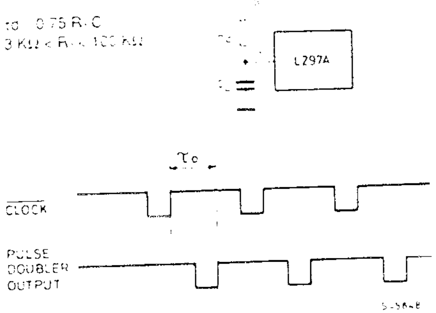


Figure 4 : Pulse doubler (L297A)



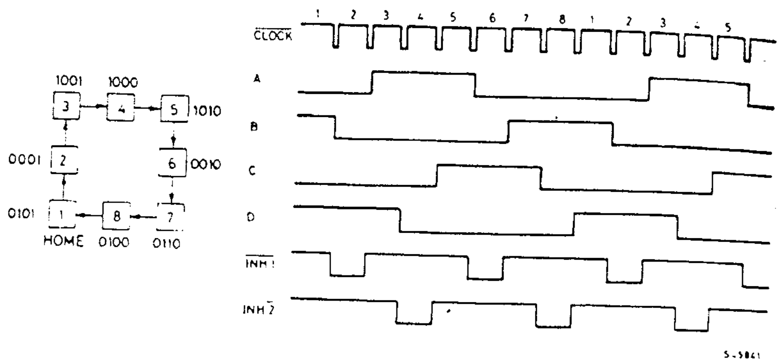
MOTOR DRIVING PHASE SEQUENCES

The L297's translator generates phase sequences for normal drive, wave drive and half step modes. The state sequences and output waveforms for these three modes are shown below. In all cases the translator advances on the low to high transition of $\overline{CLOCK}$.

Clockwise rotation is indicated ; for anticlockwise rotation the sequences are simply reversed. $\overline{SET}$ restores the translator to state 1, where ABCD = 0101.

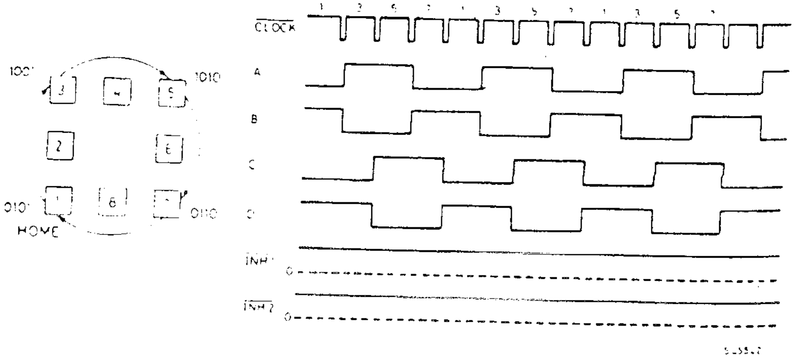
HALF STEP MODE

Half step mode is selected by a high level on the HALF/$\overline{FULL}$ input.



NORMAL DRIVE MODE

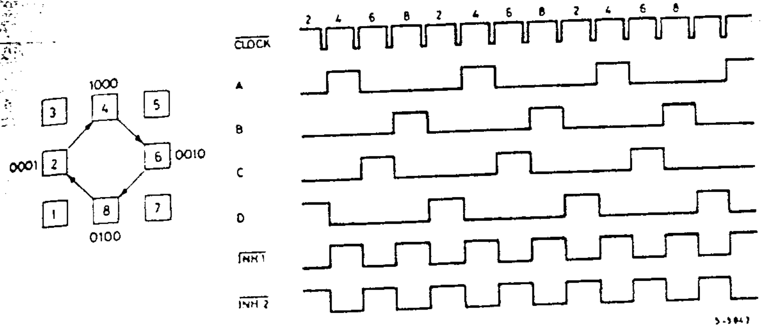
Normal drive mode (also called "two-phase-on" drive) is selected by a low level on the HALF/$\overline{FULL}$ input when the translator is at an odd numbered state (1, 3, 5 or 7). In this mode the INH1 and $\overline{INH2}$ outputs remain high throughout.



MOTOR DRIVING PHASE SEQUENCES (continued)

WAVE DRIVE MODE

Wave drive mode (also called "one-phase-on" drive) is selected by a low level on the HALF/$\overline{FULL}$ input when the translator is at an even numbered state (2, 4, 6 or 8).



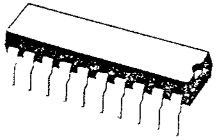
ELECTRICAL CHARACTERISTICS (Refer to the block diagram T_{amb} = 25 C, V_S = 5V unless otherwise specified)

	Parameter	Test conditions		Min.	Typ.	Max.	Unit
V_s	Supply voltage (pin 12)			4.75		7	V
I_s	Quiescent supply current (pin 12)	Outputs floating			50	80	mA
V_i	Input voltage (pin 11, 17, 18, 19, 20)		Low			0.8	V
			High	2		V_s	V
I_i	Input current (pin 11, 17, 18, 19, 20)		V_i = L			– 100	µA
			V_i = H			10	µA
V_{en}	Enable input voltage (pin 10)		Low			1.5	V
			High	2		V_s	V
I_{en}	Enable input current (pin 10)		V_{en} = L			– 100	µA
			V_{en} = H			10	µA
V_o	Phase output voltage (pins 4, 6, 7, 9)	I_o = 10mA	V_{OL}			0.4	V
		I_o = 5mA	V_{OH}	3.9			V
V_{inh}	Inhibit output voltage (pins 5, 8)	I_o = 10mA	$V_{inh L}$			0.4	V
		I_o = 5mA	$V_{inh H}$	3.9			V

STEPPER MOTOR CONTROLLERS

- NORMAL/WAWE DRIVE
- HALF/FULL STEP MODES
- CLOCKWISE/ANTICLOCKWISE DIRECTION
- SWITCHMODE LOAD CURRENT REGULATION
- PROGRAMMABLE LOAD CURRENT
- FEW EXTERNAL COMPONENTS
- RESET INPUT & HOME OUTPUT
- ENABLE INPUT
- STEP MULSE SOUBLER (l297a only)

The L297 Stepper Motor Controller IC generates four phase drive signals for two phase bipolar and four phase unipolar step motors in microcomputer-controlled applications. The motor can be driven in half step, normal and wawe drive modes and on-chip PWM chopper circuits permit switch-mode control of the current in the windings. A feature of this device is that it requires only clock, direction and mode input signals. Since the phase are generated internally the burden on the microprocessor, and the programmer, is greatly reduced. Mounted in a 20-pin plastic package, the L297 can be used with monolithic bridge drives such as the L298N or L293E, or with discrete transistors and darlingtons. The L297A also includes a clock pulse doubler.



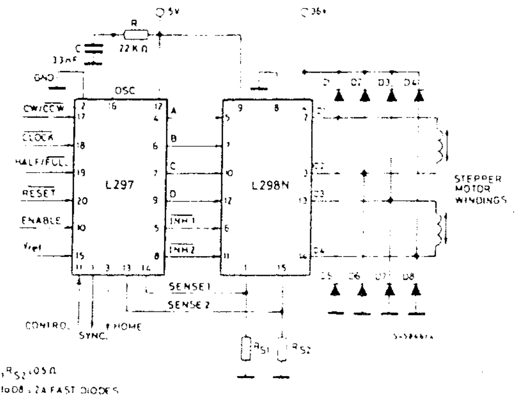
DIP-20 Plastic
(0.25)

ORDER CODES : L297 – L297A

ABSOLUTE MAXIMUM RATINGS

V_s	Supply voltage	10	V
V_i	Input signals	7	V
P_{tot}	Total power dissipation (T_{amb} = 70 C)	1	W
T_{stg}, T_j	Storage and junction temperature	– 40 to + 150	C

TWO PHASE BIPOLAR STEPPER MOTOR CONTROL CIRCUIT



HIGH MOTOR CLOCK RESETS IN THE HALF-STEP SYSTEM

In the half-step position one of the motor phases has to be without current. If the motor moves from a full-step position into a half-step position, this means that one motor winding has to be completely discharged. From the logic diagram this means for the high level bridge an equivalent status of the input signals A/B, for example in the HIGH-status. For the coil this means short circuit (fig. 17 up) and consequently a low reduction of the current. In case of high half-step speeds the short circuit discharge time constant of the phase winding is not sufficient to discharge the current during the short half-step phases. The current diagram is not neat, the half step is not carried out correctly (fig. 17 center).

For this reason the L297 controller-unit generates an inhibit-command for each phase bridge, that switches the specific bridge output in the half-step position into Tri-state. In this way the coil can start swinging freely over the external recovery diodes and discharge quickly. The current decrease rate of change corresponds more or less to the increase rate of change (fig. 17 below).

In case of full-step operation both inhibit-outputs of the controller (pin 5 and 8) remain in the HIGH-status.

Figure 17 : The Inhibit Signal Turns Off Immediately the Output Stages Allowing thus a Faster Current Decay (mandatory with half-step operation).

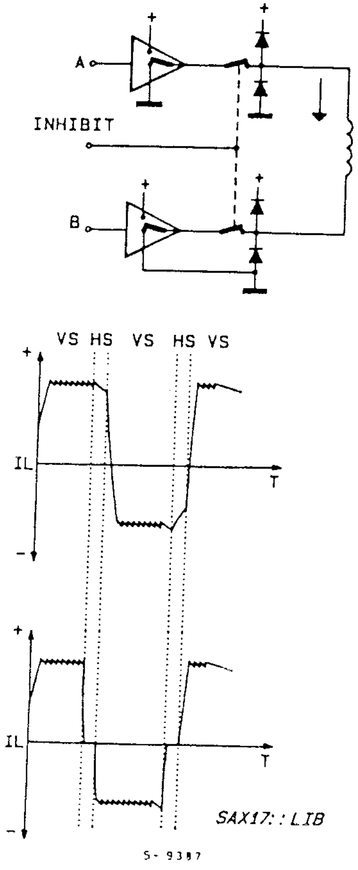
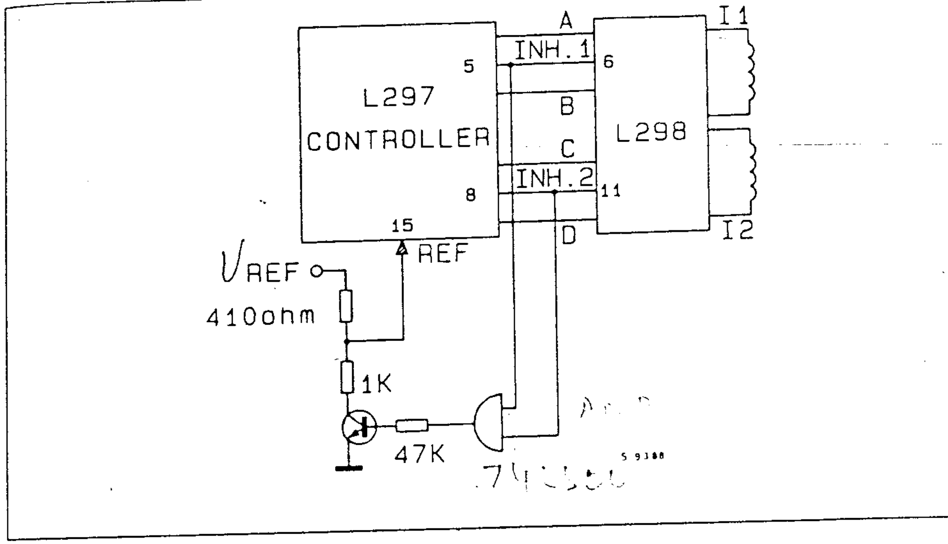


Figure 18 : With This Configuration it is Possible to Obtain Half-step with Shaping Operation and Th fore More Torque.



MORE TORQUE IN THE HALF-STEP POSITION

A topic that has already been discussed in detail. So we will limit our considerations on how it is carried out, in fact quite simply because of the reference voltage controlled phase current regulation.

With the help of the inhibit-signals at outputs 5 and 8 of the controller, which are alternatively active only when the half-step control is programmed, the reference voltage is increased by the factor 1.41 with a very simple additional wiring (fig. 18), as soon as one of the two inhibit-signals switches LOW. This increases the current in the active motorphase proportionally to the reference voltage and compensates the torque loss in this position. Fig. 19 shows clearly that the diagram of the phase current is almost sinusoidal, in principle the ideal form of the current graph.

To sum up we may say that this half-step version offers most advantages. The motor works with poor resonance and a double position resolution at a torque, that is almost the same as that of the full-step.

BETTER GLIDING THAN STEPPING

If a stepper motor is supposed to work almost gliding and not step by step, the form of the phase current diagram has to be sinusoidal.

The advantages are very important :
- no more phenomena of resonance
- drastic noise reduction
- connected gearings and loads are tre with care
- the position resolution may be increased ther.

However, the use of the L297 controller-uni scribed until now is no longer possible of the semplicated form of the phase current diagran Controller may become simpler in its functions

Fig. 20 shows us an example with the L6505 This IC contains nothing more than the clo phase current regulation which works accordi the same principle as L297. The four control si emitting continuously a full-step program are generated directly by the microprocessor. In to obtain a sinusoidal phase current course th erence voltage inputs of the Controller are m lated with sinusoidal half-waves.

The microprocessor that controls the direction current phase with the control signals also g ates the two analog signals.

For many applications a microprocessor with cated digital to analog converters can be ch Eliminating the need for separate D A circuits

About 5 bit have proved to be the most suitable division of the current within one full-step. A h

Figure 14 : Two ICs and very Few External Components Provide Complete Microprocessor to Bipolar Stepper Motor Interface.

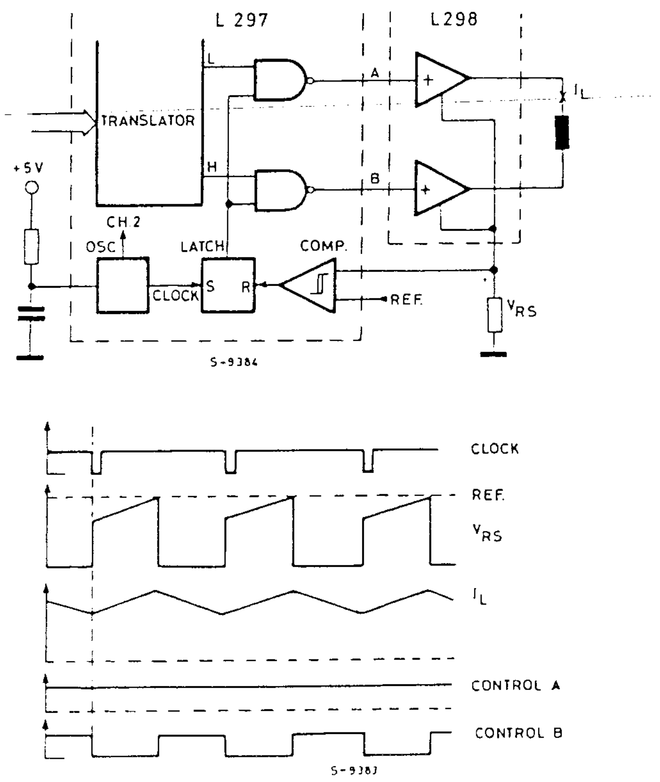


Figure 15 : Because of the Set-dominant Latch Inside the L297 it is Possible to Hide Current Spikes and Noise Across the Sense Resistors thus Avoiding External Filters.

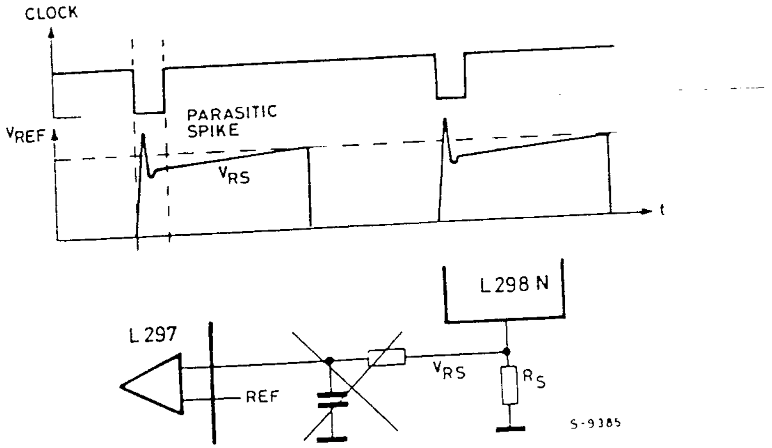
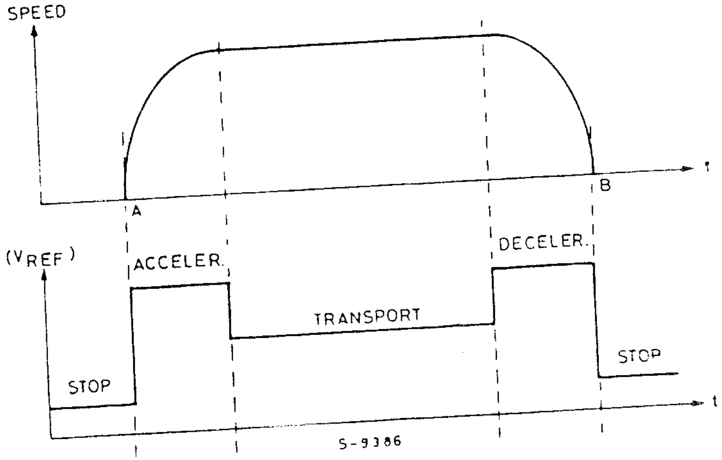


Figure 16 : More Energy is needed During The Acceleration and break Phases Compared the Continuous Operation. Neutral or Stop Position.



HALF-STEP OPERATION

It's clear that, especially in limit situations, the torque loss in half-step is a disadvantage. If one has to choose the next larger motor or one with a double resolution operating in full-step because of some insufficient torque percentages, it will greatly influence the costs of the whole system.

In this case, there is an alternative solution that does not increase the coats for the bipolar chopping stabilized current drive circuit.

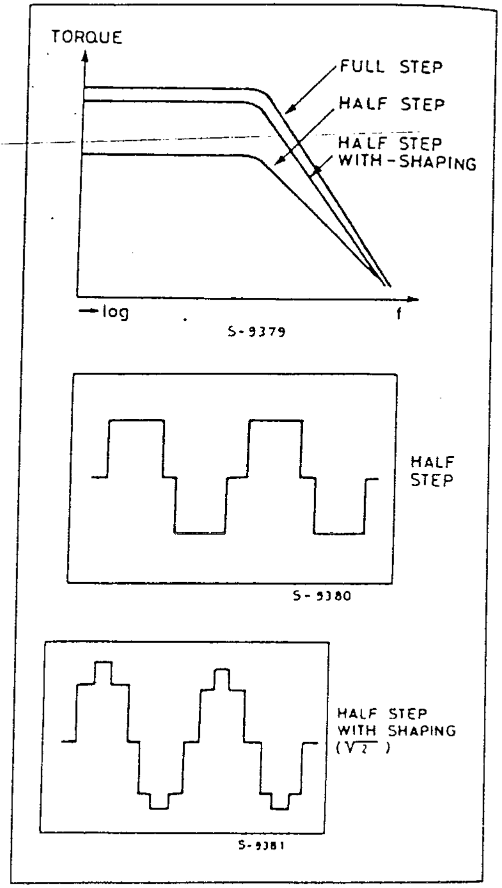
The torque loss in the half-step position may be compensated for by increasing the winding current by the factor √2 in the phase winding that remains active. This is also permissible if, according to the motor data sheet, the current limit has been reached, because this limit refers always to the contemporary supply with current in both windings in the full-step position. The factor √2 increase in current doubles the stray power of the active phase. The toal dissipated power is like that of the full-step because the non-active phase does not dissipate power.

The resulting torque in the half-step position amounts to about 90 % of that of the full-step, that means dynamically more than 95 % torque compared to the pure full-step ; a neglectable factor.

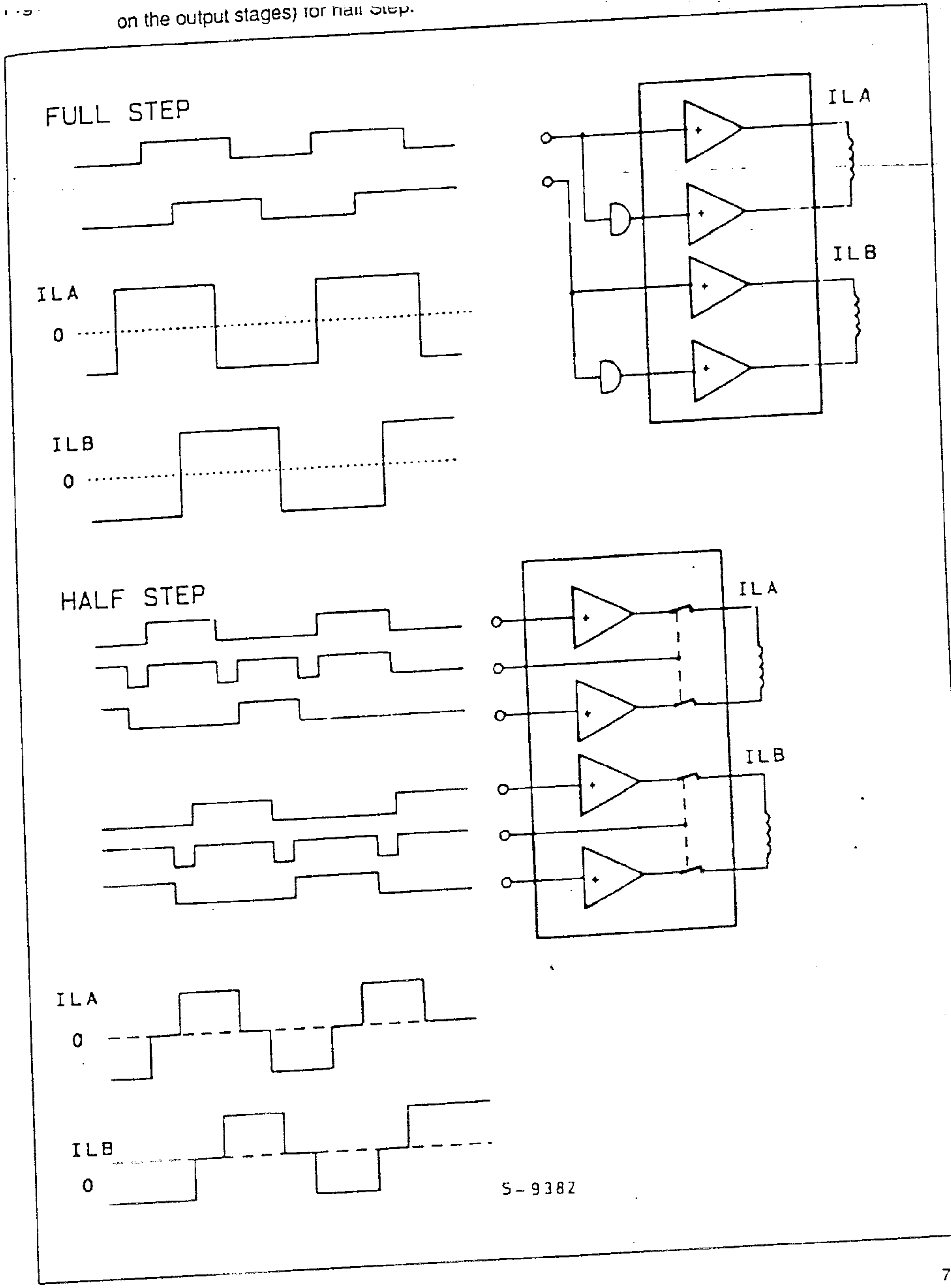
The only thing to avoid is stopping the motor at limit current conditions in a half-step position because it would be like a winding thermal phase overload concentrated in one.

The best switch-technique for the half-step phase current increase will be explained in detail later on Fig. 11 shows the phase current of a stepping motor in half-step control with an without phase current increase and the pertinent curves of stap frequency and torque.

to Increase the Motor's Torque to about 95 % of that of the Full Step.



on the output stages) for half step.



TORQUE LOSS COMPENSATION IN THE HALF-STEP OPERATION

It's clear that, especially in limit situations, the torque loss in half-step is a disadvantage. If one has to choose the next larger motor or one with a double resolution operating in full-step because of some insufficient torque percentages, it will greatly influence the costs of the whole system.

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Figure 11 : Half Step Driving with Shaping Allows to Increase the Motor's Torque to about 95 % of that of the Full Step.

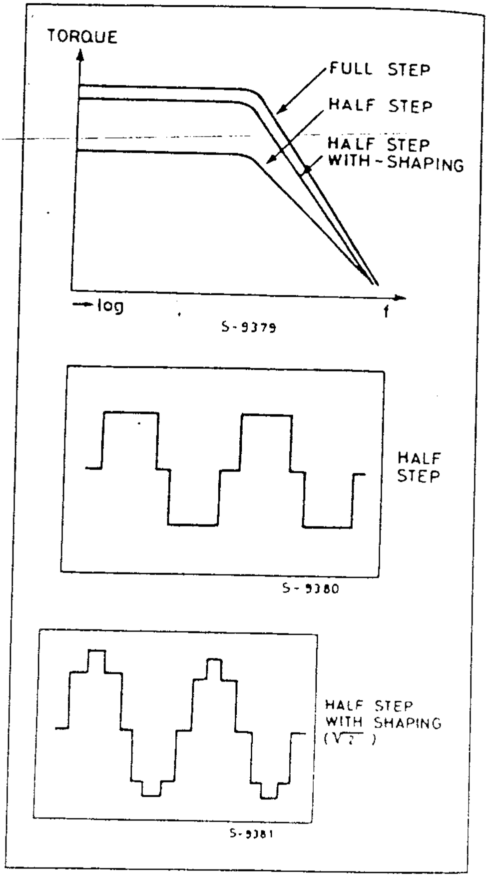
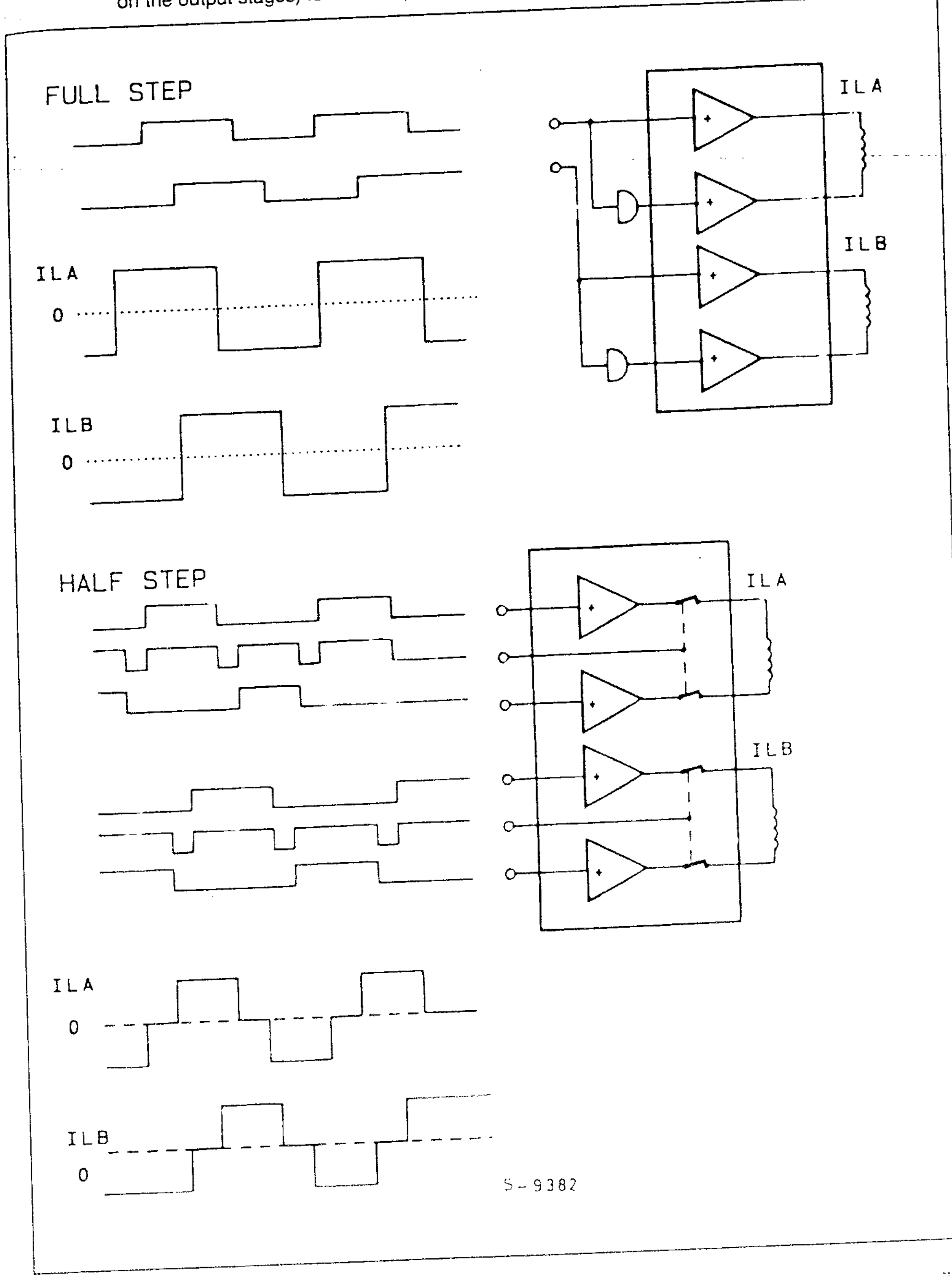


Figure 12 : Only Two Signals for Full Step Driving are Necessary while Four (six if three-state is needed on the output stages) for half Step.



Since the only losses in this technique are the saturation loss of the switch and that of the coil resistance, the total efficiency is very high.

The average current that flows from the power supply line is less than the winding current due to the concept of circuit inversion. In this way also the power unit is discharged. This king of phase current control that has to be done separately for each motor phase leads to the best ratio between the supplied electrical and delivered mechanical energy.

POSSIBLE IMPROVEMENTS OF THE UNIPOLAR CIRCUIT

It would make no sense to apply the same principle to a stabilized current controlled unipolar circuit, as two more switches per phase would be necessary for the shortening out of the windings during the free phase and thus the number of components would be the same as for the bipolar circuit ; and moreover, there would be the well known torque disadvantage.

From the economic point of view a reasonable and justifiable improvement is the "Bi-Level-Drive" (fig. 9). This circuit concept works with two supply voltages ; with every new step of the motor both windings are connected for a short time to a high supply voltage. This considerably increases the current rate of change and its behaviour corresponds more or less to the stabilized power principle. After a predetermined the switch opens, a no a lower supply voltage is connected to the winding thru a diode.

This kind of circuit by no means reaches the performance of the clocked stabilized power control as per fig. 8, as the factors : distribution voltage oscillation, B.e.m.f., thermal winding resistance, as well as the separate coil current regulation are not considered, but it is this circuit that makes the simple unipolar R/L-control suitable for many fields of application.

Figure 8 : With Switch Mode Current Regulation Efficiency is Increased.

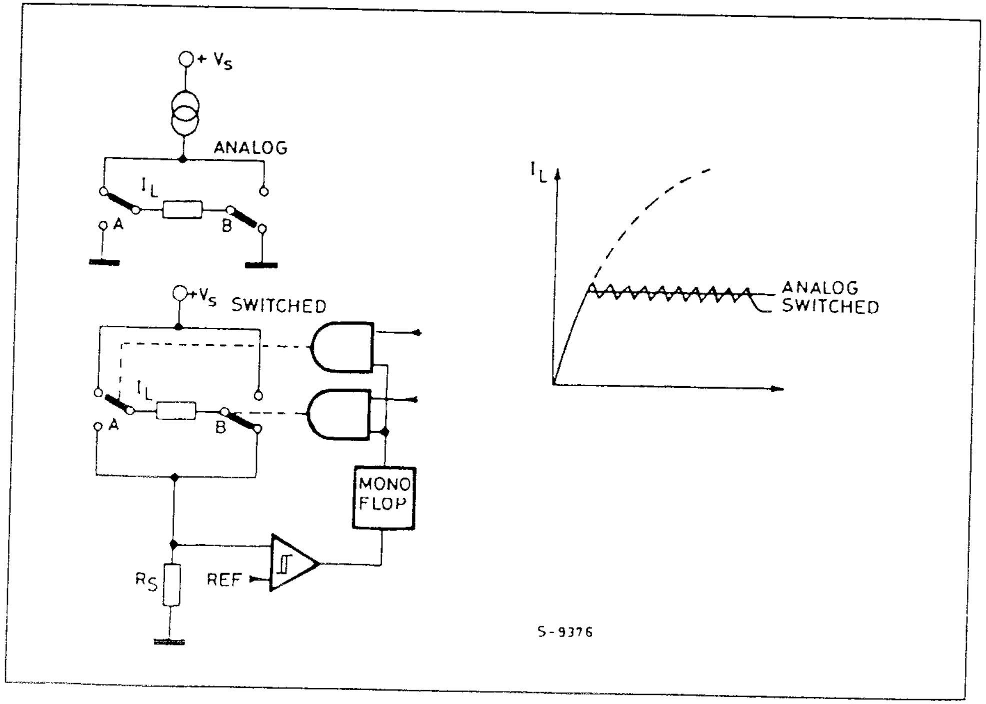
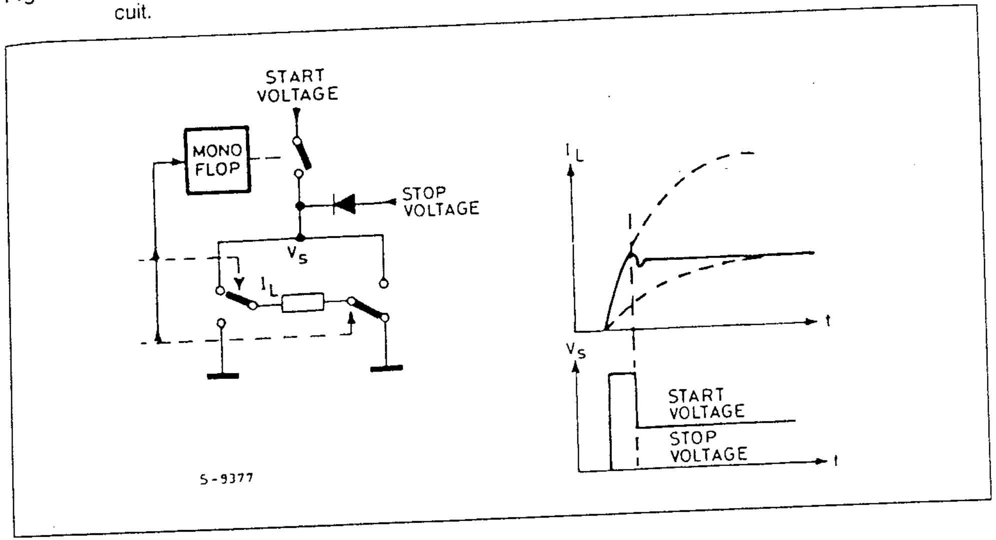


Figure 9 : At Every New Step of the Motor, it is Possible to Increase the Current Rate with a Bilevel Circuit.



ADVANTAGES AND DISADVANTAGES OF THE HALF-STEP

An essential advantage of a stepper motor operating at half-step conditions is its position resolution increased by the factor 2. From a 3.6 degree motor you achieve 1.8 degrees, which means 200 steps per revolution.

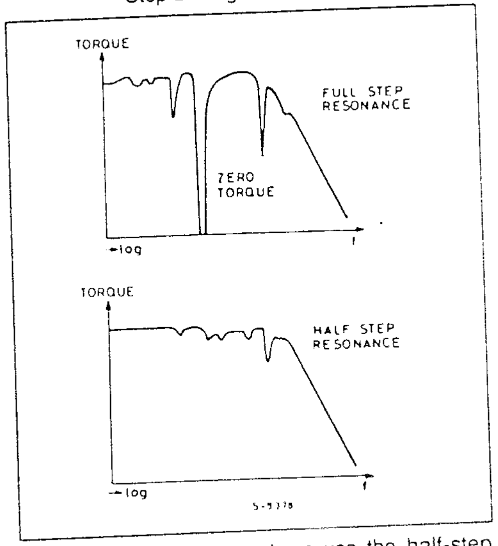
This is not always the only reason. Often you are forced to operate at half-step conditions in order to avoid that operations are disturbed by the motor resonance. These may be so strong that the motor has no more torque in certain step frequency ranges and looses completely its position (fig. 10). This is due to the fact that the rotor of the motor, and the changing magnetic field of the stator forms a spring-mass-system that may be stimulated to vibrate. In practice, the load might deaden this system, but only if there is sufficient frictional force.

In most cases half-step operation helps, as the course covered by the rotor is only half as long and the system is less stimulated.

The fact that the half-step operation is not the dominating or general solution, depends on certain disadvantages :

- the half-step system needs twice as many clock-pulses as the full-step system ; the clock-frequency is twice as high as with the full-step.
- in the half-step position the motor has only about half of the torque of the full-step.

Figure 10 : The Motor has no More Torque in Certain Step Frequency Ranges with Full Step Driving.



For this reason many systems use the half-step operation only if the clock-frequency of the motor is within the resonance risk area.

The dynamic loss is higher the nearer the load moment comes to the limit torque of the motor. This effect decreases at higher numbers of revolutions.

The advantage of the bipolar circuit is that there is only one winding, with a good bulk factor (low winding resistance). The main disapuantages are the two changeover switches because in this case more semiconductors are needed.

The unipolar circuit needs only one changeover switch. Its enormous disadvantage is, however, that a double bifilar winding is required. This means that at a specific bulk factor the wire is thinner and the resistance is much higher. We will discuss later the problems involved.

Unipolar motors are still popular today because the drive circuit appears to be simpler when implemented with discrete devices. However with the integrated circuits available today bipolar motors can be driver with no more components than the unipolar motors. Figure 2 compares integrated unipolar and bipolar devices.

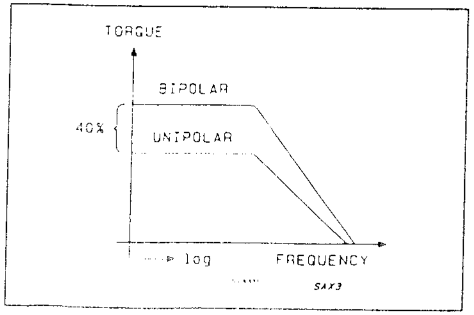
BIPOLAR PRODUCES MORE TORQUE

The torque of the stepper motor is proportional to the magnetic field intensity of the stator windings. It may be increased only by adding more windings or by increasing the current.

A natural limit against any current increase is the danger of saturating the iron core. Though this is of minimal importance. Much more important is the maximum temperature rise of the motor, due to the power loss in the stator windings. This shows one advantage of the bipolar circuit, which, compared to unipolar systems, has only half of the copper resistance because of the double cross section of the wire. The winding current may be increased by the factor $\sqrt{2}$ and this produces a direct proportional affect on the torque. At their power loss limit bipolar motors thus deliver about 40 % more torque (fig. 3) than unipolar motors built on the same frame.

If a higher torque is not required, one may either reduce the motor size or the power loss.

Figure 3 : Bipolar Motors Driver Deliver More Torque than Unipolars.



CONSTANT CURRENT DRIVING

In order to keep the motor's power loss within a reasonable limit, the current in the windings must be controlled.

A simple and popular solution is to give only as much voltage as needed, utilizing the resistance (R_L) of the winding to limit the current (fig. 4a). A more complicated but also more efficient and precise solution is the inclusion of a current generator (fig. 4b), to achieve independence from the winding resistance. The supply voltage in Fig. 4b has to be higher than the one in Fig. 4a. A comparison between both circuits in the dynamic load/working order shows visible differences.

Figure 4 : Resistance Current Limiter (a) and Current Generator Limiting.

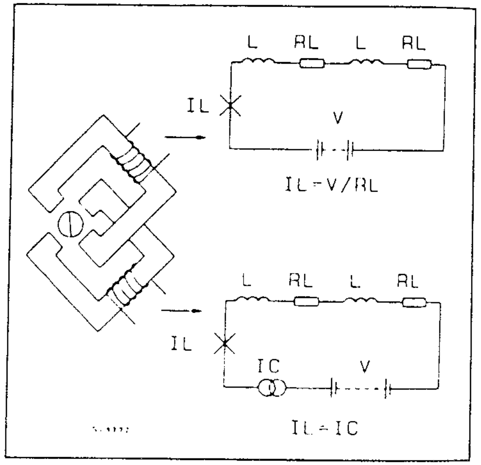
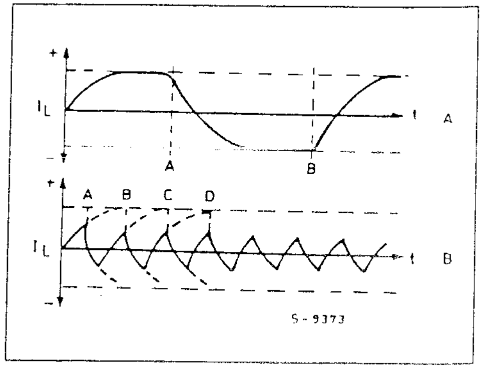


Figure 5 : At High Step Frequencies the Winding Current cannot Reach its Setting Value because of the Continuous Direction Change.



It has already been mentioned that this power of the motor is, among others, proportional to the winding current.

In the dynamic working order a stepper motor changes poles of the winding current in the same stator winding after two steps. The speed with which the current changes its direction in the form of an exponential function depends on the specified inductance, the coil resistance and on the voltage. Fig. 5a shows that at a low step rate the winding current I_L reaches its nominal value V_L/R_L before the direction is changed. However, if the poles of the stator windings are changed more often, which corresponds to a high step frequency, the current no longer reaches its saturating value because of the limited change time ; the power and also the torque diminish clearly at increasing number of revolutions (fig. 5).

MORE TORQUE AT A HIGHER NUMBER OF REVOLUTIONS

Higher torque at faster speeds are possible if a current generator as shown in Fig. 4b is used. In this application the supply voltage is chosen as high possible to increase the current's rate of change. The current generator itself limits only the phase current and becomes active only the moment in which the coil current has reached its set nominal value. Up to this value the current generator is in saturation and the supply voltage is applied directly to the winding.

Fig. 6. shows that the rate of the current increase is now much higher than in Figure 5. Consequently at higher step rates the desired current can be maintained in the winding for a longer time. The torque decrease starts only at much higher speeds.

Fig. 7 shows the relation between torque and speed in the normal graphic scheme, typical for the stepper motor. It is obvious that the power increases in the upper torque range where it is normally needed, as the load to be driven draws most energy from the motor in this range.

EFFICIENCY - THE DECISIVE FACTOR

The current generator combined with the high supply voltage guarantees that the rate of change of the current in the coil is sufficiently high.

At the static condition or at low numbers of revolutions, however, this means that the power loss in the current generator dramatically increases, although the motor does not deliver any more energy in this range ; the efficiency factor is extremely bad.

Help comes from a switched current regulation using the switch-transformer principle, as shown in fig. 8. The phase winding is switched to the supply voltage until the current, detected across Rs, reaches the desired nominal value. At that moment the switch, formerly connected to + Vs, changes position and shorts out the winding. In this way the current is stored, but it decays slowly because of inner winding losses. The discharge time of the current is determined during this phase by a monostable or pulse oscillator. After this time one of the pole changing switches changes back to + Vs, starting an induction recharge and the clock-regulation-cycle starts again.

Figure 6 : With a Step Current Slew, it is not a Problem to Obtain, even at High Step frequencies Sufficient Current in Windings.

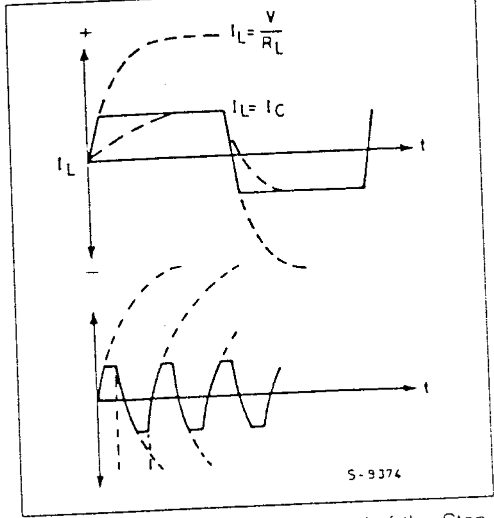


Figure 7 : Constant Current Control of the Stepper Motor Means more Torque at High Frequency.

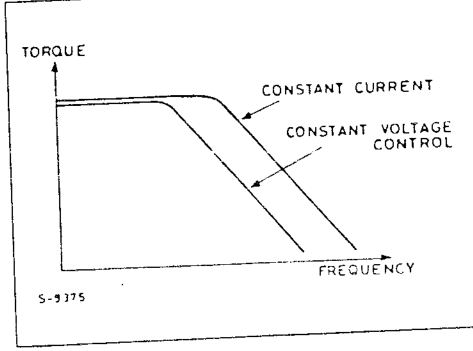


Figure 9.

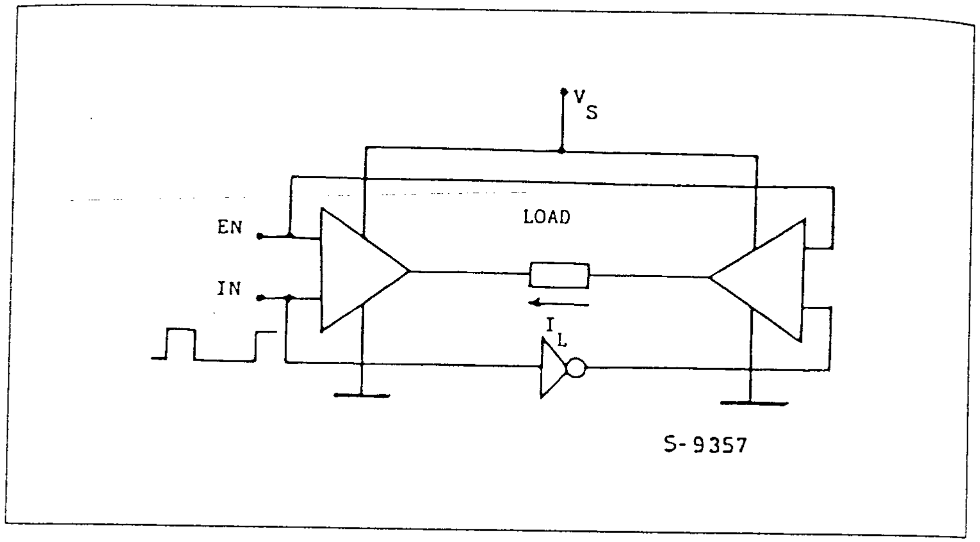
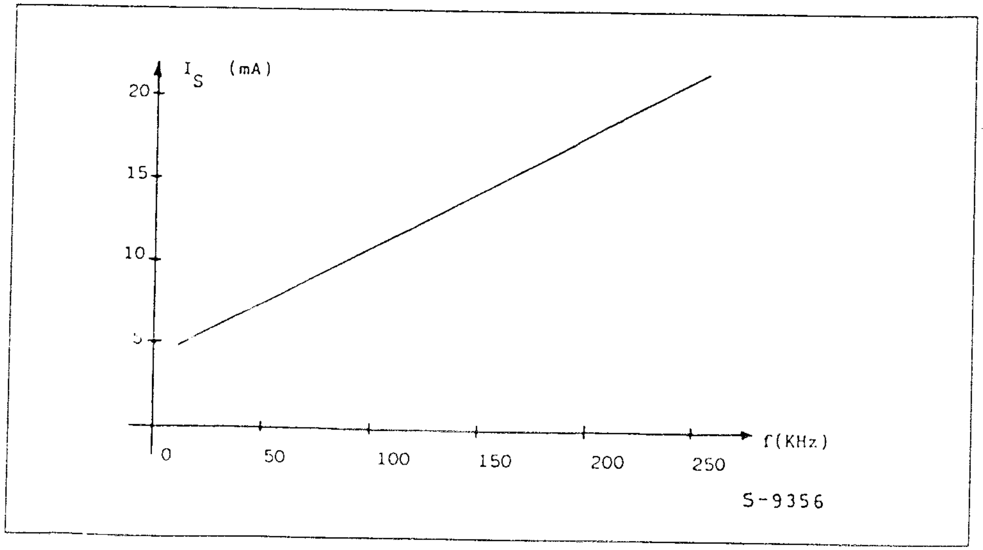


Table 2 : Main Features of L6202/6203.

• V_S (maximum supply voltage)		= 60 V	
• I_L (maximum output current)		= 1.5 A DIP.16	
		= 5 A MULTIWATT Package	
• Efficiency	η	= 90 %	I_L = 1.5 A $f_{chopper}$ = 50 KHz V_S = 54 V
• Power Dissipation	P_d	= 1.5 W	
• t_d (turn-on, turn-off propagation delay)		= 100 ns	

Figure 10.



SGS-THOMSON
MICROELECTRONICS

APPLICATION NOTE

STEPPER MOTOR DRIVING

By H. SAX

Dedicated integrated circuits have dramatically simplified stepper motor driving. To apply these ICs designers need little specific knowledge of motor driving techniques, but an under-standing of the basics will help in finding the best solution. This note explains the basics of stepper motor driving and describes the drive techniques used today.

From a circuit designer's point of view stepper motors can be divided into two basic types : unipolar and bipolar.

A stepper motor moves one step when the direction of current flow in the field coil(s) changes, reversing the magnetic field of the stator poles. The difference between unipolar and bipolar motors lies in the may that this reversal is achieved (figure 1) :

Figure 1a :BIPOLAR - with One Field Coil and Two Chargeover Switches That are Switched in the Opposite Direction.

Figure 1b :UNIPOLAR - with Two Separate Field Coils and are Chargeover Switch.

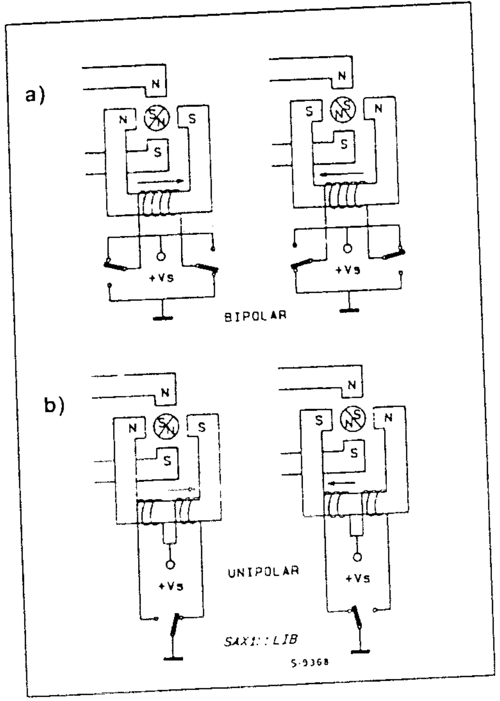
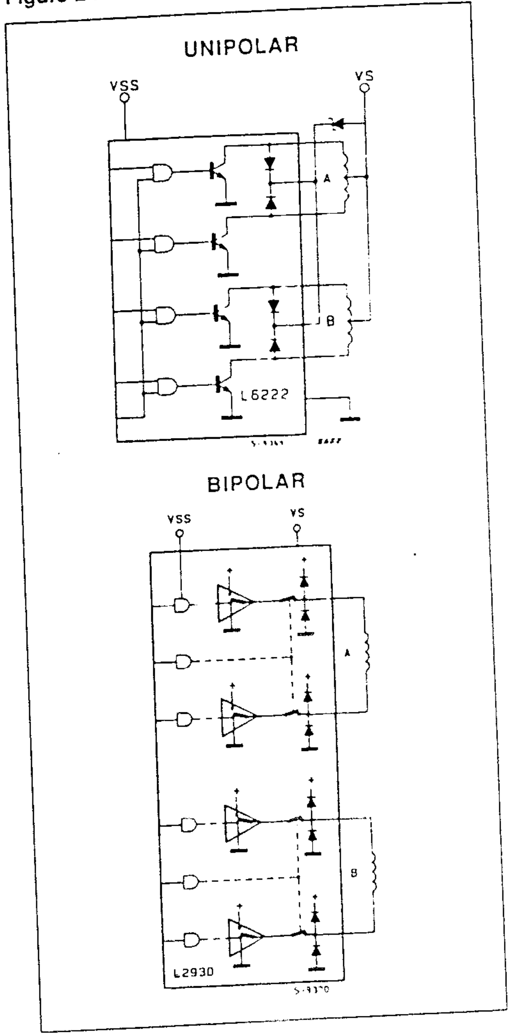


Figure 2 : ICs for Unipolar and Bipolar Driving.



In this case when the voltage accross Rs reaches V_{REF} the chopper flip flop is reset and INH1 activated (brought low). INH1, remember, turns off all four transistors therefore the current recirculates from ground, through D2, the winding and D3 to V_S. Discharged across the supply, which can be up to 46V, the current decays very rapidly (figure 18).

The usefulness of this second faster decay option is fairly obvious ; it allows fast operation with bipolar motors and it is the only choice for unipolar motors. But why do we offer the slower alternative, phase chopping ?

The answer is that we might be obliged to use a low chopper rate with a motor that does not store much energy in the windings. If the decay is very fast the average motor current may be too low to give an useful torque. Low chopper rates may, for example, be imposed if there is a larger motor in the same system. To avoid switching noise on the ground plane all drivers should be synchronized and the chopper rate is therefore determined by the largest motor in the system.

Multiple L297s are synchronized easily using the SYNC pin. This pin is the squarewave output of the on-chip oscillator and the clock input for the choppers. The first L297 is fitted with the oscillator components and outputs a sqarewave signal on this pin (figure 19). Subsequent L297s do not need the oscillator components and use SYNC as a clock input. An external clock may also be injected at this terminal if an L297 must be synchronized to other system components.

Figure 18 : Inhibit Chopper Waveforms. Winding AB is energized and CONTROL is low.

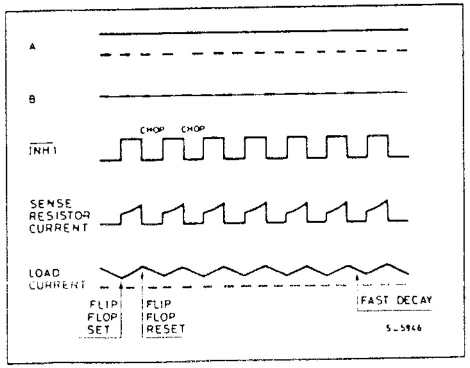
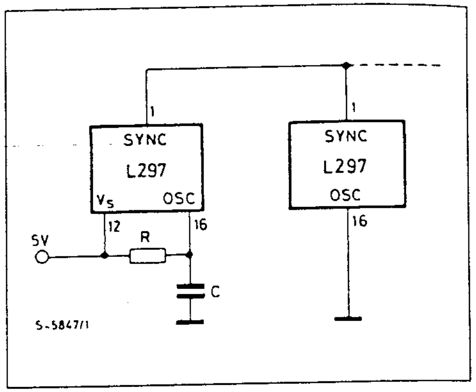


Figure 19 : The Chopper Oscillator of Multiple L297s are synchronized by connecting the SYNC Inputs together.



THE L297A

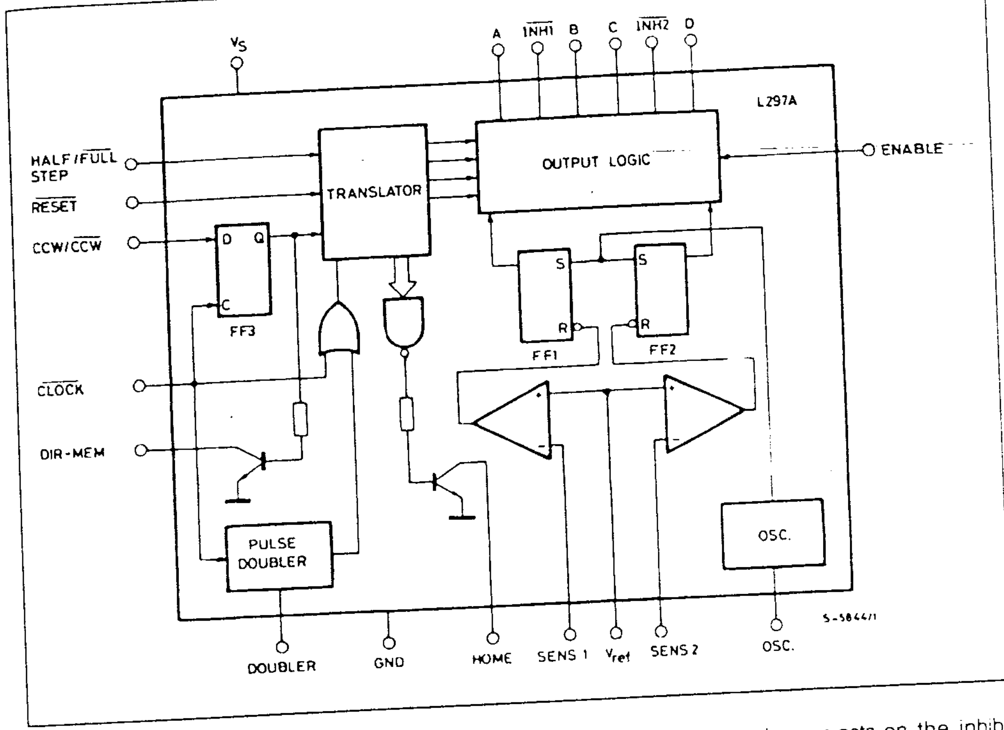
The L297A is a special version of the L297 developed originally for head positioning in floppy disk drives. It can, however, be used in other applications.

Compared to the standard L297 the difference are the addition of a pulse doubler on the step clock input and the availability of the output of the direction flip flop (block diagram, figure 20). To add these functions while keeping the low-cost 20-pin package the CONTROL and SYNC pins are not available on this version (they are note needed anyway). The chopper acts on the ABCD phase lines.

The pulse doubler generates a ghost pulse internally for each input clock pulse. Consequently the translator moves two steps for each input pulse. An external RC network sets the delay time between the input pulse and ghost pulse and should be chosen so that the ghost pulses fall roughly halfway between input pulses, allowing time for the motor to step.

This feature is used to improve positioning accuracy. Since the angular position error of a stepper motor is noncumulative (it cancels out to zero every four steps in a four step sequence motor) accuracy is improved by stepping two of four steps at a time.

Figure 20 : The L297A, includes a Clock Pulse Doubler (DIR – MEM).



APPLICATION HINTS

Bipolar motors can be driven with an L297, an L298N or L293E bridge driver and very few external components (figure 21). Together these two chips form a complete microprocessor-to-stepper motor interface. With an L298N this configuration drives motors with winding currents up to 2.5A ; for motors up to 1A per winding and L293E is used. If the PWM choppers are not required an L293 could also be used (it doesn't have the external emitter connections for sensing resistors) but the L297 is underutilized. If very high powers are required the bridge driver is replaced by an equivalent circuit made with discrete transistors. For currents to 3.5A two L298N's with paralleled outputs may be used.

For unipolar motors the best choice is a quad darlington array. The L702 can be used if the choppers are not required but an L7150 or L7180 is preferred. These quad darlingtons have external emitter connections which are connected to sensing resistors (figure 22). Since the chopper acts on the inhib lines, four AND gates must be added in this appl cation.

Also shown in the schematic is a zener diode series with the suppression diodes. This serves increase the voltage across which energy stored the winding is discharged and therefore speed tr current decay.

In all applications where the choppers are not use it is important to remember that the sense inpu must be grounded and V_{REF} connected either to or any potential between Vs and ground.

The chopper oscillator frequency is determined the RC network on pin 16. The frequency is roug ly 1/0.7 RC and R must be more than 10 KΩ. Wh the L297A's pulse doubler is used, the delay time determined by the network R_d C_d and is appro mately 0.75 R_d C_d . R_d should be in the range 3 – 100 kΩ (figure 23).

PHASE CHOPPING AND INHIBIT CHOPPING

The chopper can act on either the phase lines (ABCD) or on the inhibit lines INH1 and INH2. An input named CONTROL decides which. Inhibit chopping is used for unipolar motors but you can choose between phase chopping and inhibit chopping for bipolar motors. The reasons for this choice are best explained with another example.

First let's examine the situation when the phase lines are chopped.

As before, we are driving a two phase bipolar motor and A is high, B low (figure 15). Current therefore flows through Q1, winding, Q4 and R_s. When the voltage across R_s reaches V_{ref} the chopper brings B high to switch off the winding.

The energy stored in the winding is dissipated by current recirculating through Q1 and D3. Current decay through this path is rather slow because the voltage on the winding is low ($V_{CEsat\,Q1} + V_{D3}$) (figure 16).

Why is B pulled high, why push A low ? The reason is to avoid the current decaying through R_s. Since the current recirculates in the upper half of the bridge, current only flows in the sensing resistor when the winding is driven. Less power is therefore dissipated in R_s and we can get away with a cheaper resistor.

This explain why phase chopping is not suitable for unipolar motors : when the A winding is driven the chopper acts on the B winding. Clearly, this is no use at all for a variable reluctance motor and would be slow and inefficient for a bifilar wound permanent magnet motor.

The alternative is to tie the CONTROL input to ground so that the chopper acts on INH1 and INH2. Looking at the same example, A is high and B low. Q1 and Q4 are therefore conducting and current flows through Q1, the winding, Q4 and R_s, (figure 17).

Figure 15 : Phase Chopping. In this Example the Current X is interrupted by activating B, giving the Recirculation path Y. The Alternative, de-activating A, would give the Recirculation path Z, increasing Dissipation in R_s.

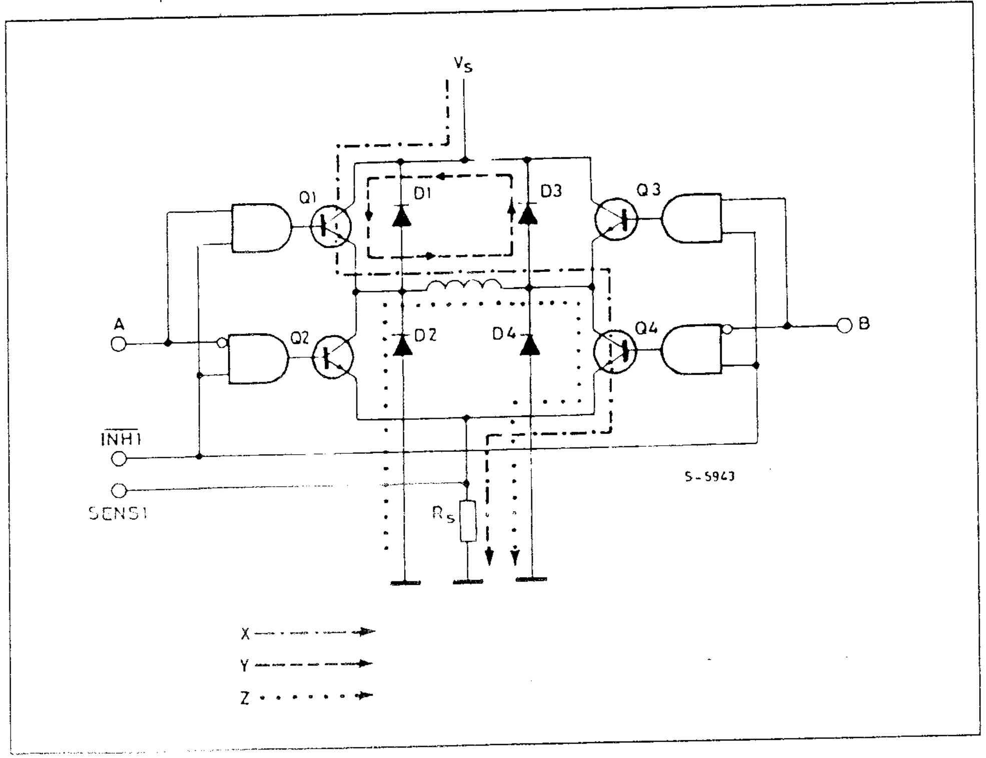


Figure 16 : Phase Chopping Waveforms. The Example shows AB winding energized with A positive with Respect to B. Control is high.

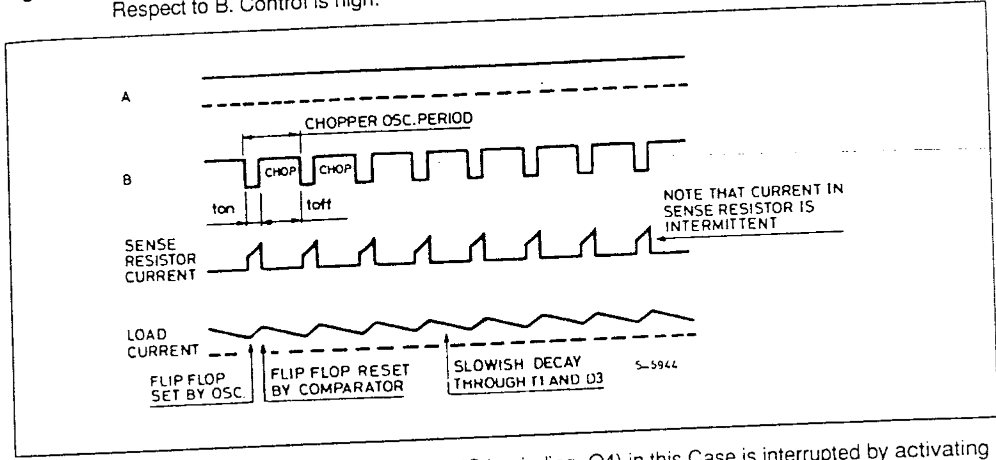


Figure 17 : Inhibit Chopping. The Drive Current (Q1, winding, Q4) in this Case is interrupted by activating INH1. The Decay Path through D2 and D3 is faster than the Path Y of Figure 15.

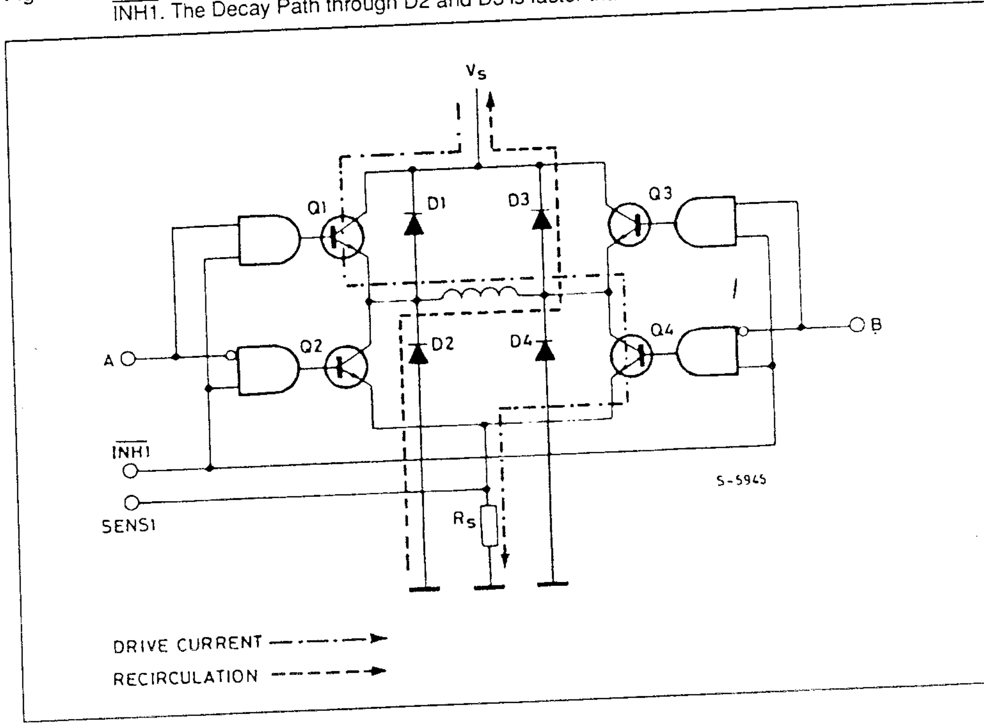


Figure 4 : The three drive sequences for a two phase bipolar stepper motor. Clockwise rotation is shown.

Figure 4a : Wave drive (one phase on).

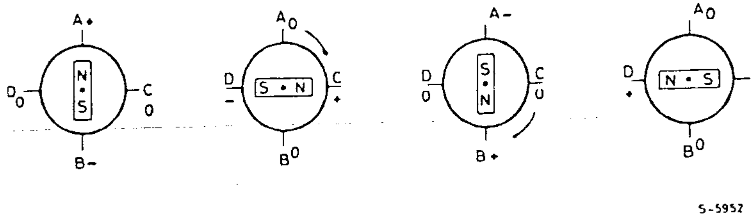


Figure 4b : Two phase on drive.

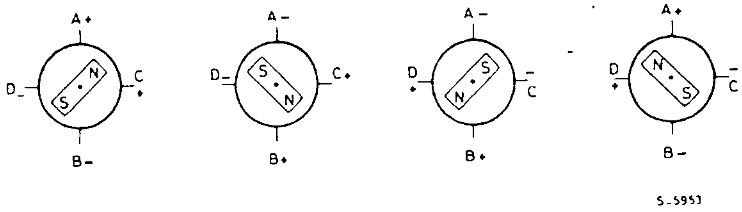


Figure 4c : Half step drive.

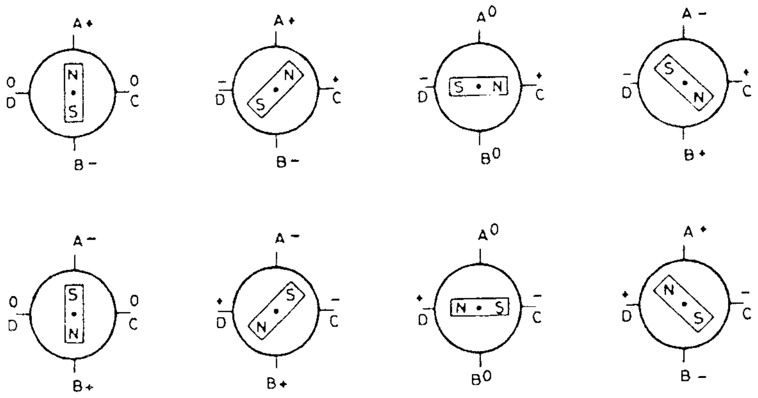


Figure 5 : A real motor. Multiple poles are normally employed to reduce the step angle to a practical value. The principle of operation and drive sequences remain the same.

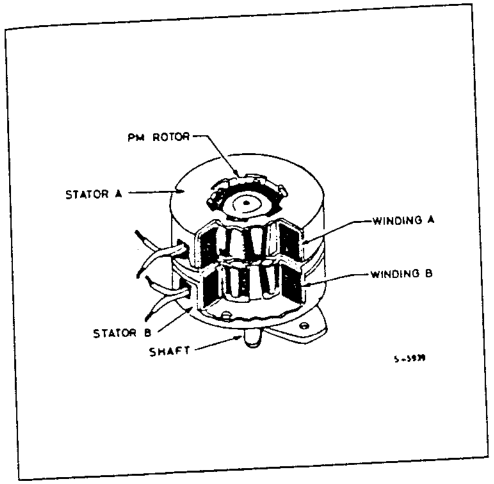
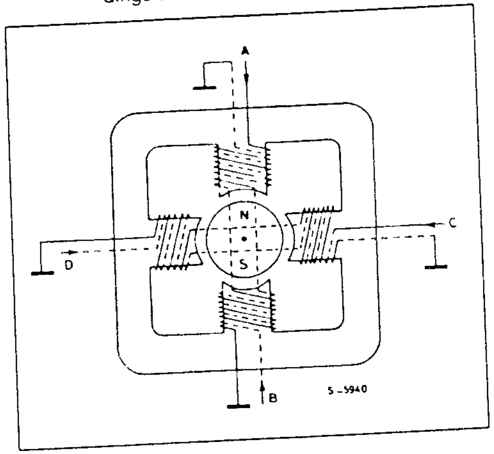


Figure 6 : A unipolar PM motor uses bifilar windings to reverse the flux in each phase.



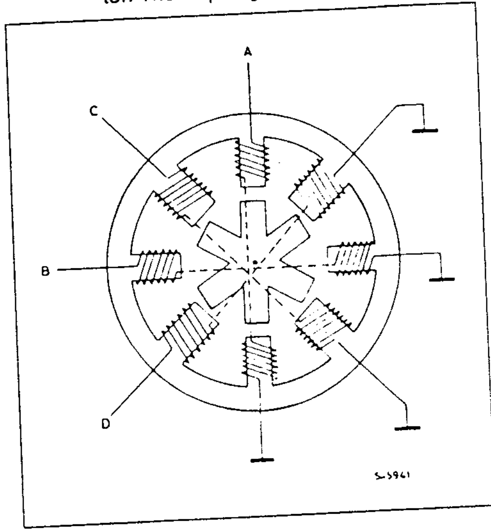
VARIABLE RELUCTANCE MOTORS

A variable reluctance motor has a non-magnetized soft iron rotor with fewer poles than the stator (figure 7). Unipolar drive is used and the motor is stepped by energizing stator pole pairs to align the rotor with the pole pieces of the energized winding.

Once again three different phase sequences can be used. The wave drive sequence is A/C/B/D ; two-phase-on is AC/CB/BD/DA and the half step sequence is A/AC/C/BC/B/BD/D/DA. Note that the step angle for the motor shown above is 15 °C, not 45 °.

As before, pratical motors normally employ multiple poles to give a much smaller step angle. This does not, however, affect the principle of operation of the drive sequences.

Figure 7 : A variable reluctance motor has a soft iron rotor with fewer poles than the stator. The step angle is 15 ° for this motor.

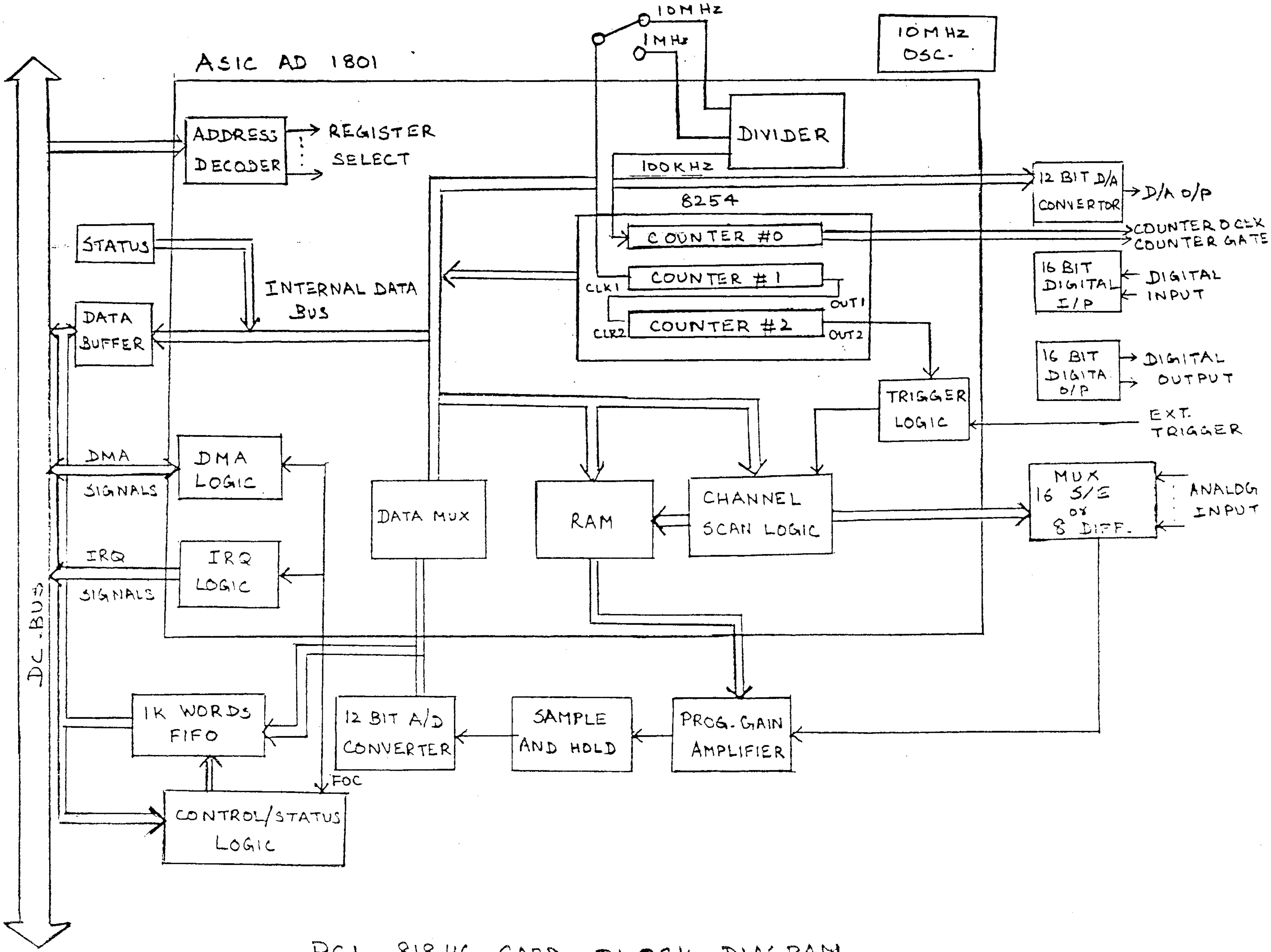


GENERATING THE PHASE SEQUENCES

The heart of the L297 block diagram. figure 8. is a block called the translator which generates suitabl phase sequences for half step. one-phase-on fu step and two-phase-on full step operation. Thi block is controlled by two mode inputs – directio (CW/ $\overline{\text{CCW}}$) and HALF/ $\overline{\text{FULL}}$ – and a step cloc which advances the translator from one step to th next.

Four outputs are provided by the translator for sul sequent processing by the output logic block whic implements the inhibit and chopper functions.

Internally the translator consists of a 3-bit count plus some combinational logic which generates basic eight-step gray code sequence as shown figure 9. All three drive sequences can be generat easily from this master sequence. This state s quence corresponds directly to half step mode. s lected by a high level on the HALF/ $\overline{\text{FULL}}$ input.



PCL-818HG CARD BLOCK DIAGRAM

identical with the diameter of fibres conditioned to 65 per cent. R.H. at 70° F. It is important that the fibres should be conditioned to 65 per cent. relative humidity because plug measurements are very sensitive to the regain of the fibres. It affects plug measurements through two factors: the diameter of the fibres varies with regain, and their density also varies with regain; the r.h.s. of equation (8) is sensitive to changes in density, and values of d obtained from this equation will be in error, quite apart from an actual change in diameter, unless the fibres are carefully conditioned. Table IV gives the variation with regain of the time of flow through the plug of a given volume of air; the results show very clearly the need for conditioning the wool and making the measurements under controlled conditions.

Table IV
Time of Air Flow and Regain

	Regain increasing					Regain decreasing			
Regain (%)	4·75	10·6	13·1	17·5	17·9	17·0	15·0	9·65	5·6
Time of flow (sec.) ...	35·0	39·7	43·0	50·0	52·0	49·0	46·0	41·0	37·5

It is worth noting that data such as those of Table IV may be used to determine changes of both the diameter and density of fibres with regain, and it is hoped to report such determinations in Part II.

SUMMARY AND CONCLUSIONS

The plug method gives a simple and useful means of measuring the mean diameter of wool fibres provided these are free from kemp.

The calculations required have been simplified as far as possible and a value is given for the shape factor which is applicable to plugs with parallel pores and a porosity around 35 per cent. The density of wool must be taken as 1·35 gm./c.c. if the plug measurements are to give consistent values of diameter for different porosities.

The thickness of any oil film on the fibres is included in the diameter deduced from plug measurements, and it is recommended that oil should be removed from the fibres before measurements are made.

Plug measurements are sensitive to regain of the fibres, and it is essential that the wool should be conditioned and that the measurements should be made at constant temperature and relative humidity.

ACKNOWLEDGMENTS

I am greatly indebted to Mr. F. Morris, who has carried out the experimental work of this paper.

My thanks are due to Mr. B. H. Wilsdon, Director of Research, for continued encouragement, and to Mr. Daniels and Mr. Semple for samples of their standard tops and helpful discussions on the two methods of fibre diameter measurement. My thanks are also due to the Council of the Wool Industries Research Association for permission to publish this account.

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Suny Koshy

12—THE STAPLE LENGTH OF COTTON

By Edmund Lord, B.Sc.

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CONTENTS

INTRODUCTION AND SUMMARY

Of all the characteristics of raw cotton, staple length has probably the most value to the spinner. Other things being equal, finer yarns can generally be produced from the longer cottons, and in any one count the longer cottons lead to greater strength than shorter cottons. Since length is so important the question arises: "How is the staple length of cotton to be determined?" Until the advent of the so-called "sorters," length was always estimated by "pulling" the cotton. Even at the present time, brokers and spinners rely on the length obtained from the "pull" because they have neither the apparatus nor the time to make sorter measurements on every sample of cotton that passes through their hands.

It is common knowledge that those who determine staple length by pulling obtain different results on the same sample of cotton, and efforts have been made from time to time to standardise the stapling of raw cotton. For instance, the United States Department of Agriculture has set up official standards for staple length. These standards may be used either for the purpose of direct comparison with a given sample of raw cotton, or for reference, and so enable staplers to adjust and maintain their own particular standards to a common basis. Cotton brokers in this country are familiar with these standards but, in general, spinners prefer to retain and rely upon their own personal judgements.

The result obtained in hand stapling is dependent upon the personal skill of the classer in the preparation of the tufts of cotton, upon his choice of the criterion used for assigning the length and also upon the reliability of his judgement. Primarily for these reasons, the Shirley Institute has [illegible] policy of determining staple length in such a manner that personal judgement is eliminated as much as possible. The method adopted after trials of various devices is that in which a comb sorter is used and the fibres from a small sample of cotton are arrayed in order of length along a velvet pad. From the sorter diagram various measures of length can be obtained; the mean, or average, length is one of the most obvious. This quantity is greatly affected by the amount of short fibre in the sample and experience has shown that it is an unsuitable measure for many purposes, in particular for determining roller settings. A more stable measure is that called the "Effective Length," which, within limits, has been found to be fairly typical of a given variety of cotton. Other measures may be chosen such as the modal length (the length of fibres occurring with greatest frequency), or the median length (on either side of which there is an equal number of fibres). The purpose of the work described in this paper is to investigate the relationship between the lengths of staple measured by the American Standards, by practical spinners in this country and by the sorter diagram method used in the laboratory.

The first part of the paper is devoted to a study of 24 samples of cotton, 20 of American Upland type and 4 of American-Egyptian. These form a complete set of the official standards issued by the United States Department of Agriculture and cover the whole range of length of American cottons. Stapling tests were made on the comb sorter and the nominal lengths of the Standards were compared with the lengths obtained from the sorter diagrams.

In the second part of the paper the results of hand stapling tests made by brokers and spinners are compared with those obtained from the sorter diagram.

It is shown that the *Effective Length* is closely related to the nominal staple length of the American Standards. The relationship is not linear, and for all American types the effective length is the larger quantity. Near the extreme end of the scale, that is for the long American-Egyptian types, the two quantities approach equality. A table is provided so that the effective length can be translated into the corresponding staple length of the Standard. In cases where the highest accuracy is not required, the subtraction of $\frac{3}{32}$ in. from the effective length gives the American staple. The consistent error which may arise by the use of this simple rule will not exceed $\frac{1}{32}$ in. within the range of staples encountered in American Upland cotton.

The *Modal Length* would not be expected to agree exactly with the staple length because of the rejection of short fibre that occurs during hand stapling. By suitable transformation of the fibre distribution, chosen to reduce the effect of short fibre, a modified measure of modal tendency has been calculated from the results of the sorter diagrams. This quantity, termed the *Doubly Weighted Mode*, is closely related to the American Staple. For the American Upland types it is always the longer quantity, the excess being about $\frac{1}{32}$ in. for $\frac{3}{4}$ in. staple, increasing to $\frac{3}{32}$ in. for $1\frac{1}{4}$ in. staple.

By a construction similar to that used in the determination of effective length, a quantity has been calculated to give a median measure of fibre length in a sorter diagram. This *Modified Median* does not correspond to the actual median length of fibres in the diagram—it is designed to eliminate the effect of short fibre—but it is found to be closely related to the staple length. It is about $\frac{1}{16}$ in. longer than the American Standards for cottons up to a length of about $1\frac{5}{16}$ in.

Other length characteristics of sorter diagrams have been investigated but these provide less accurate estimates of staple length than those already given. A poor relationship with American staple is obtained if the length characteristic is unduly affected by the presence of a small percentage of excessively long fibre, or by short fibre, quantities that have no appreciable effect on staple length obtained by hand stapling methods. The *Mean Length* is such a characteristic.

The hand stapling experiment described in the second part of the paper was made possible by the co-operation of two brokers and 90 spinning concerns. Over 1,000 samples of cotton were stapled, the different varieties ranging from short Bengals to the longest Sea Island and covering nearly all the main types in general use. In both instances the brokers' results average a little higher than the American Standards, although the difference is small, three-quarters of $\frac{1}{32}$ in. for Broker A and half of $\frac{1}{32}$ in. for Broker B. For convenience of reference a summary of the average levels of stapling in the three sections of the trade (American, Egyptian and General) is given in tabular form below.

Section of Trade	Relation between Mill Staple and	
	AMERICAN STAPLE LENGTH	EFFECTIVE LENGTH
American	Below $\frac{7}{8}$ in., mills staple $\frac{1}{32}$ in. shorter Above $\frac{7}{8}$ in. mills staple on same basis.	Mills staple $\frac{3\frac{1}{4}}{32}$ in. shorter.
General	Between $\frac{13}{16}$ in. and $1\frac{1}{16}$ in., mills staple $\frac{1\frac{1}{2}}{32}$ in. longer. Outside above limits mill staple approaches equality with American staple.	Mills staple $\frac{1}{16}$ in. shorter, up to $1\frac{1}{8}$ in.
Egyptian	Mill staple $\frac{1}{8}$ in longer	Mill staple of Uppers type cotton same as effective length. All other Egyptian types mill staple $\frac{1}{16}$ in. longer.

The above table only gives the general tendency. As pointed out later, the average level of stapling by an individual firm may consistently deviate by as much as $\frac{1}{8}$ in. from the corresponding level of the section of the trade to which it belongs.

In the trade it is recognised that the so-called Liverpool Standards represent staple lengths of $\frac{1}{8}$ in. longer than the corresponding classification based on the American Standards. It follows from the results given above, that the average level of classification in the American section of the industry is $\frac{1}{8}$ in. below the Liverpool Standards, that the General section of the trade staple on an intermediate level, and that the Egyptian section tend to staple on the same basis as the Liverpool Standards.

PART I. RELATIONS BETWEEN OFFICIAL STAPLE STANDARDS AND CHARACTERISTICS OF FIBRE LENGTH DISTRIBUTIONS

(a) The Physical Conception of Staple Length

Before making comparisons between various length measurements derived from sorter diagrams and corresponding hand staple determinations based on accepted standards, it is appropriate to make a few observations on the general practice of hand stapling. Few persons staple cotton in [illegible] but whether the technique followed is based

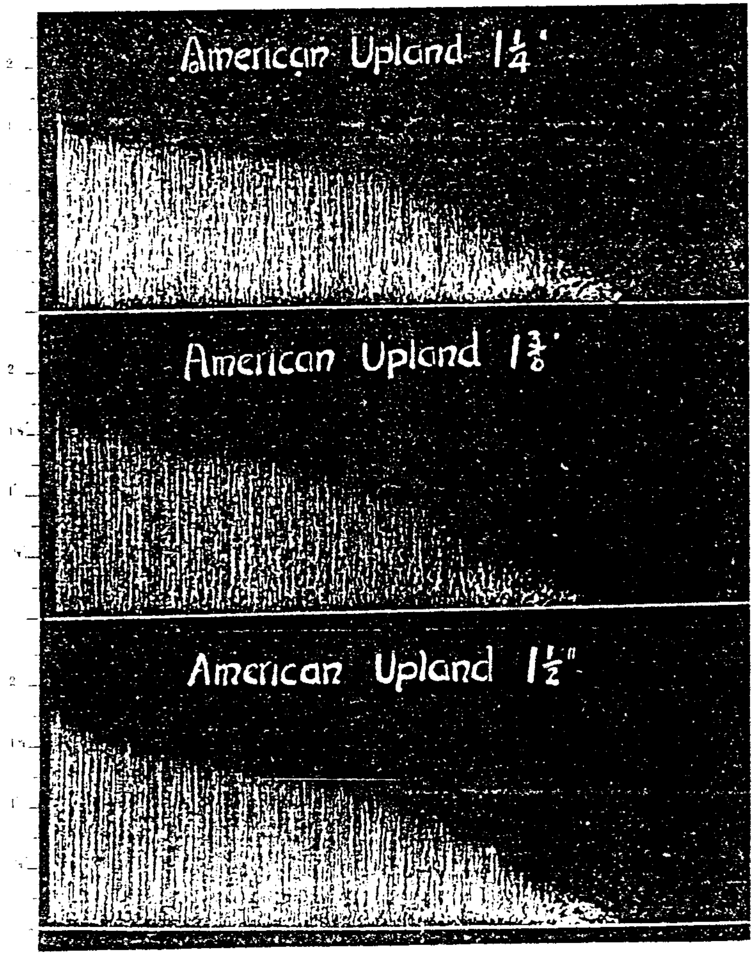

Plate I (b)

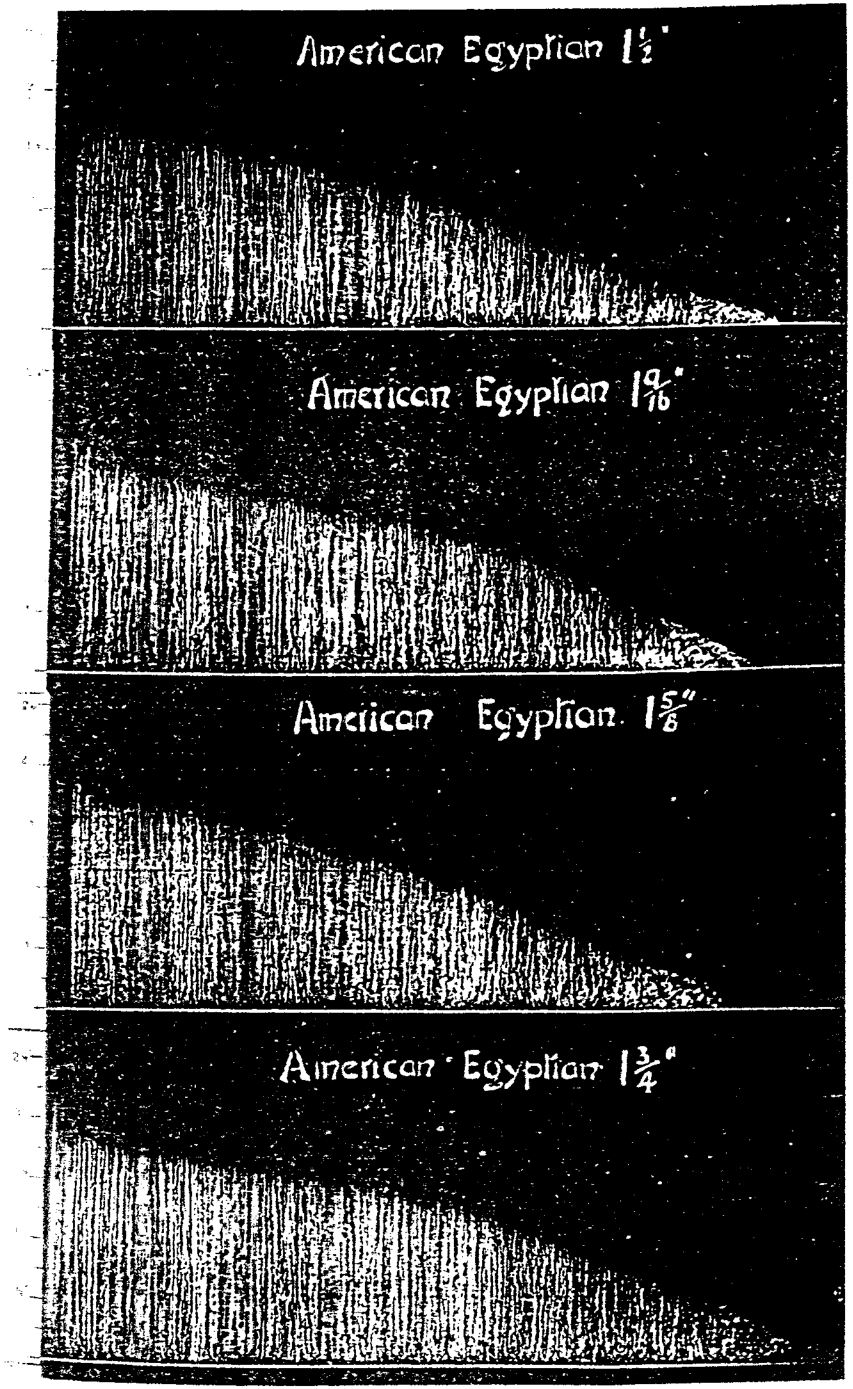

Plate I ([illegible])

For lower percentiles such as the upper quartile and the median, the values of such measures become increasingly affected by the amount of short fibre present, a quantity which has been shown to be ignored in determining the staple length.

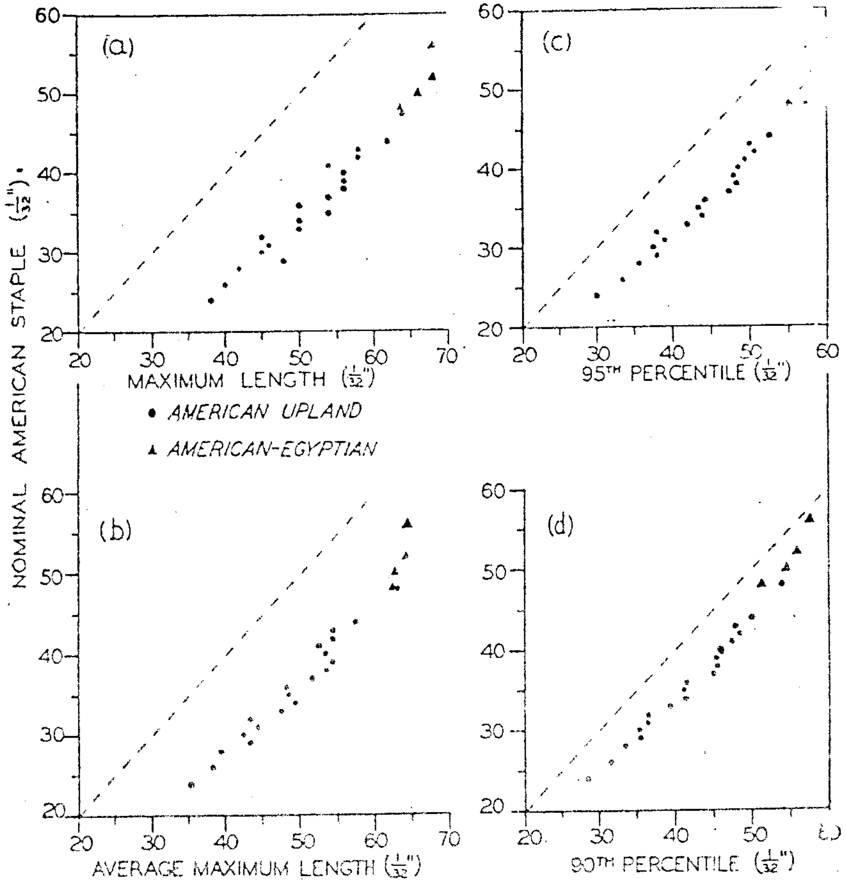

Fig. 5

A Modified Measure of the Median.

It is suggested above that one of the possible criteria for use in determining the position of the lines defining the effective edges of a tuft of fibres prepared by hand pulling may be such that the lines are assigned to positions where the density is considered to be equal to half of the density at the centre. The distance apart of lines judged by such a criterion would then correspond to the median length of fibres in the tuft. Furthermore it was pointed out that, because of the discarding of short fibre in the process of hand stapling, such a measure would not be expected to bear a close relationship with the median determined from sorter diagrams. This assertion may be easily verified by plotting the median measures given in Table II against the corresponding values of nominal staple and noting the large degree of variation.

It will now be shown that it is possible to compute a measure of a median length, which is closely related to the staple length, by the use of a construction which greatly reduces the effect of the amount of short fibre in [illegible] "modified median" quantity may be defined as corresponding to the median of the distribution obtained by rejecting all fibres shorter than **r times this modified median**, r being a pre-assigned fraction less than 1. By suitable choice of the fraction r, it has been found possible to obtain a measure which is little affected by the amount of short fibre, or of excessively long fibre, in a given sample. The general method for determining this measure for any value of r is described below.

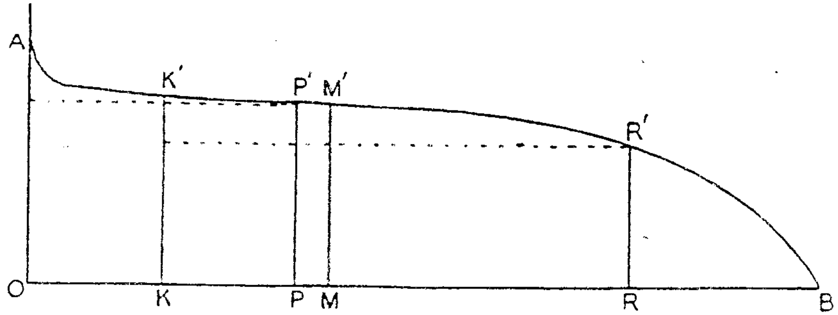

Fig. 6

Fig. 6 represents the trace of a sorter diagram curve of a cotton. Determine the maximum length AO and choose the point P such that $PP' = r.AO$ where r is the given fraction. Mark off KK' such that $OK = KP$. The construction is then repeated, letting $RR' = r.KK'$ and choosing M such that $OM = MR$. Providing that r is not too close to unity these two constructions are sufficient, and the value of MM' is taken to be the modified median.

The most suitable value of r was found to be equal to $\frac{3}{4}$. For values of r smaller than $\frac{3}{4}$ the effect of short fibre on this measure is still appreciable; for greater values of r the effect of short fibre is negligible but the measure is unduly affected by the presence of a few excessively long fibres in a sample.

Using the value of $r = \frac{3}{4}$, measures of the modified median have been determined for all diagrams of the standard types. The average values of the sets of eight results from the same standard type are given in Table II, and the relationship between these quantities and the corresponding staple lengths is diagrammatically illustrated in Fig. 7.

The results have been statistically analysed by the same methods used for effective length and doubly-weighted mode. A polynomial of the third degree has been fitted to the data and the equation to the curve found to be

$$L''_e = -41{\cdot}28 + 4{\cdot}731\ X - 0{\cdot}11445\ X^2 + 0{\cdot}0011418\ X^3 \quad \ldots\ldots\ldots\ldots(3)$$

where L''_e is the estimate of staple length predicted from X, the corresponding average value of the modified median. A range of values of staple length predicted from corresponding figures for the modified median is given in Table III. Reference to this Table or to Fig. 7 indicates that the modified median is approximately $\frac{1}{16}$ in. longer than the nominal staple for all standard types between [illegible] in. and [illegible] in.