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DIGIPLAN

1073 Stepper Motor Drive

INSTRUCTION MANUAL

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DIGIPLAN 1073 STEPPER MOTOR DRIVE
INSTRUCTION MANUAL

PREFACE

The 1073 Digidrive is a high-power, high-performance drive produced in three versions for driving stepper motors up to 2000 watts shaft power. The various options available cater for a wide range of applications and control systems.

This manual gives descriptions of the various system components together with information on installation, setting up and fault location. An introduction to stepper motors is included for those who may not be familiar with their characteristics.

For further advice on the use of the drive, and assistance with any stepping motor application, please contact **Digiplan Limited**.

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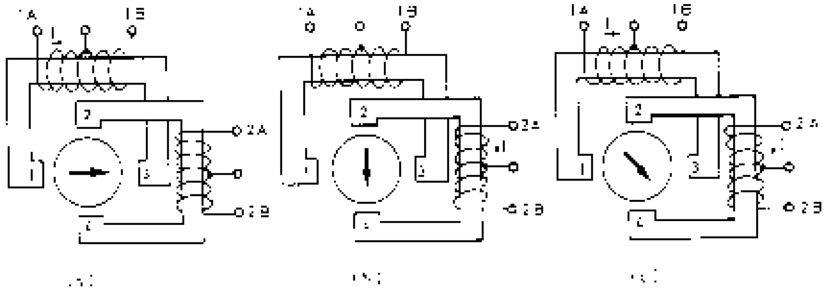
2. AN INTRODUCTION TO STEPPER MOTORS

2.1 Basic Principles

A stepper motor may be described as a rotating machine in which the rotor moves through discrete angular steps in response to voltage pulses applied to the motor windings. The size of each angular step depends primarily on the construction of the motor, therefore it is possible to use the device in a position control system without a feedback loop since the movement obtained from a given electrical input is well defined. Such a control system gives high accuracy and fast response without the complexity and stabilisation problems associated with feedback control systems, and the incremental nature of the motion is ideally suited to control by a digital logic system. Nevertheless there are certain limitations which must be taken into account if the full potential performance of a stepper motor system is to be realised.

Stepper motors may be divided into three main groups — variable reluctance, permanent magnet and hybrid. The hybrid motor has emerged as the most suitable type for the majority of applications since it combines the desirable features of the other two types, so further discussion will be confined to this type of motor.

The theory of operation is most easily understood by considering the simple 4-phase, 4 step/rev. motor shown diagrammatically in Fig. 1.



SIMPLE 4 STEP/REV. MOTOR FIG 1

The motor consists of a permanently magnetised rotor and two pairs of stator poles, each pair carrying two windings or 'phases'. In the absence of any stator current the rotor tries to assume a position of minimum magnetic reluctance, which means it attempts to align itself with one or other of the pairs of stator poles. This gives rise to a 'detent torque' which produces the 'notchy' feel of a de-energised motor.

When a current is made to flow in one of the phases as shown in Fig.1(a), the rotor will align itself with the field produced by the stator. Hence if current flows in phase 1A the rotor aligns itself with poles 1 and 3 as indicated. The torque which would now be required to pull the rotor out of alignment is very much greater than the detent torque and is called the 'holding torque'.

Suppose now that current is made to flow in phase 2A instead of phase 1A, as indicated in Fig. 1(b). The rotor will align itself with the new stator field and will therefore rotate through 90 degrees to line up with poles 2 and 4 as shown. Similarly, subsequent energisation of phases 1B and 2B will produce further rotation of the rotor in 90-degree increments (the fields produced by 1B and 2B are in opposite directions from those generated by 1A and 2A). Hence by sequentially energising the four phases the rotor may be made to turn continuously but always in discrete, defined steps. By reversing the sequence in which the phases are energised the rotor may be made to turn in the opposite direction.

If two phases are energised simultaneously, the resultant magnetic field will be the vectorial sum of the individual fields. Thus by energising phases 1A and 2A together the rotor becomes aligned as shown in Fig.1(c). It is seen that this new position is displaced 45 degrees from the previous adjacent positions, in other words a half step has been produced. By alternately energising the phases singly and in pairs it is therefore possible to produce eight half-steps per rev. instead of four full steps, and in fact there are advantages in using the smaller step size, as will be explained later.

Of course a motor with such a large basic step angle would be of limited practical value, but it is a simple matter to reduce the step size by making a multi-toothed stator which has many pole faces equally distributed around the rotor. During a complete energising sequence the field from such a stator appears to rotate only through the angle between one stator tooth and the next, hence the rotor steps are correspondingly reduced in size. It is important to realise that now the energisation of one particular phase no longer determines uniquely the position of the rotor; it will be stable in as many angular positions as there are teeth on the stator. If sufficient load torque is applied to the rotor to deflect it by more than half a stator tooth pitch, it will jump to the next stable point and a permanent positional error will have been introduced. This is an important aspect of stepper motor behaviour from which it is clear that the motor must always be able to develop sufficient torque to overcome the frictional and inertial loads imposed upon it.

2.2. Terminology

At this point it is appropriate to define some of the terms used in connection with stepper motors and their operation. Some of the terms have been used already and others will be introduced in the next section. The list has been confined to those terms which are necessary for a basic understanding of stepper motor systems.

Detent Torque — the maximum torque which may be applied to the shaft of an unexcited permanent-magnet or hybrid motor without causing continuous rotation. There is no detent torque with a variable-reluctance motor.

Holding Torque — the maximum torque which may be applied to the shaft of an energised motor without causing continuous rotation. This torque is very much greater than the detent torque.

Step Angle — the angle through which the rotor moves in response to a single electrical step from the drive. It depends partly on the motor construction and partly on the drive system being used. It is possible to subdivide the basic motor step in order to produce smaller step angles.

Resolution — another way of expressing the step angle, but given in terms of the number of steps for one complete revolution of the motor shaft.

Angular Velocity — the mean rate of shaft rotation when the motor is being stepped continuously. It is equal to the product of step angle and stepping rate and may be expressed in revolutions per minute.

Stepping Rate — the number of steps per second performed by the motor.

Loss of Synchronism — the condition in which the number of steps performed by the motor differs from the number of electrical steps delivered by the drive. This may be caused in many ways but it is usually the result of the instantaneous stepping rate being too high or an excessive load on the motor. The error produced is always a multiple of 4 steps on a 200 step/rev. motor.

Start-Stop Range — the range of stepping rates within which the motor may be started or stopped instantaneously without loss of synchronism with a given load.

Slew Range — the range of stepping rates above the start/stop range which the motor will follow without loss of synchronism provided that ramping is used. The motor cannot be started or stopped instantaneously within the slew range.

Ramping — the technique of progressively increasing or decreasing the stepping rate so that the motor accelerates or decelerates without losing steps.

Phase — one of the motor windings across which the drive voltage is applied. The 1073 Drive was designed for 4-phase motors which have four windings arranged as two pairs. When used with a bipolar drive the two windings in each pair are connected together and treated as a single winding. The motor then has effectively only two windings which are referred to as Phase 1 and Phase 2.

2.3 Performance Characteristics

1. Single-step response

In order to understand the behaviour characteristics of a stepper motor it is necessary to appreciate the nature of the torque developed by the rotor. There is clearly no torque produced when the rotor is in its stable position, i.e. aligned with the stator field. If the rotor is forcibly displaced to the next stable point there will again be no torque produced in this new position. Half-way between these two stable points there is another zero-torque position, but this is an unstable point since a slight deflection will cause the rotor to jump forward or back to the nearest stable point. In between the stable and unstable points the torque rises and falls in an approximately sinusoidal fashion as shown in Fig. 2. In the case of the simple 4 step/rev. motor of Fig. 1 the maximum torque will be produced when the rotor is displaced 90° from the stable position, i.e. one full step.

Consider now what happens when the phase currents are switched so as to advance the rotor one step, as in going from 1(a) to 1(b). When the current is established in the new winding the rotor now finds itself at a position of maximum torque, i.e. it is displaced 90° from what will be the new step position. It therefore begins to accelerate towards the new position, during which time the torque falls until it becomes zero at the stable point. By the time the rotor reaches the stable point,

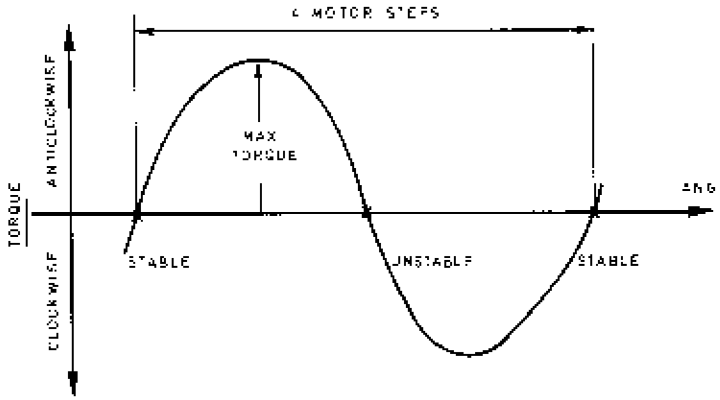
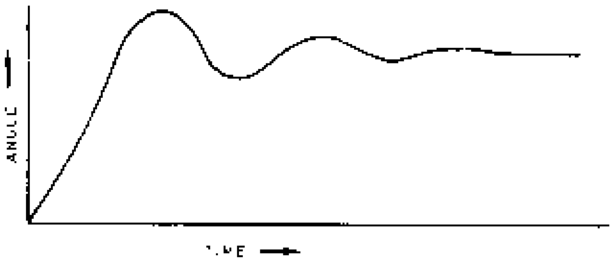


FIG. 2. TORQUE DISPLACEMENT CHARACTERISTIC

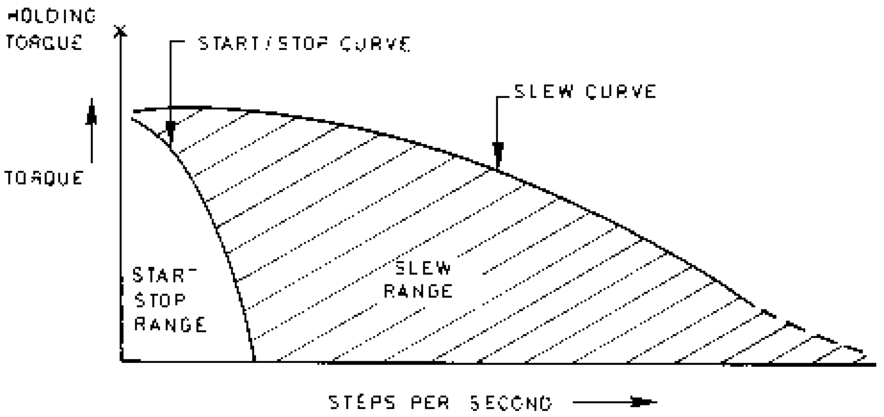


SINGLE – STEP RESPONSE FIG. 3

however, it has acquired momentum by virtue of its inertia and it therefore overshoots, causing a reverse torque to be produced which tends to return it to the stable position. This is clearly an oscillatory condition and in fact the nature of the single step response is typically as shown in Fig. 3. Frictional loading on the shaft acts as a damping force, and an increase in the frictional load causes the oscillations to die away more quickly.

2. Multiple-Step Response

The behaviour of a motor when performing multiple steps is usually described by means of a torque-speed curve. This curve indicates how the available torque varies with the stepping rate; the torque output decreases as stepping rate is increased, partly due to a reduction in input current caused by the winding inductance and partly as a result of an increase in eddy currents and hysteresis losses which reduce the efficiency of the motor. There are two basic curves which describe the performance of the motor – a start/stop curve and a slew curve, illustrated in Fig. 4. The start/stop curve shows the maximum torque load against which the motor can start in synchronism at a particular stepping rate, with a specified inertial load; the area under this curve is called the start/stop range. The slew curve shows the maximum torque available when the motor is gradually run up to speed, and the area between the two curves is called the slew range or slew region. The motor must always be started within the start/stop range and then be gradually accelerated into the slew range, as it cannot be started instantaneously within the slew range. Similarly a motor operating in the slew range must be decelerated into the start/stop range before it is brought to rest, otherwise it will overshoot on stopping. The start/stop and slew curves are sometimes referred to as the pull-in and pull-out torque curves respectively.



START/STOP & SLEW CURVES FIG 4

It should be noted that the performance of a motor is largely dependent on the drive system used and on any external load, therefore a torque-speed curve is meaningless unless this information is included.

3. Resonance

Referring back to Fig. 3, it is seen that the rotor oscillates about the final step position before coming to rest. At certain stepping frequencies these oscillations can seriously affect the behaviour of the motor by producing resonance effects or even causing the motor to stall. The amplitude, frequency and decay rate of the oscillations depend very much on load and drive conditions. An inertial load carries with it the risk of increased resonance trouble, a frictional load acts as a damping force and tends to reduce the problem. A step-division drive system,

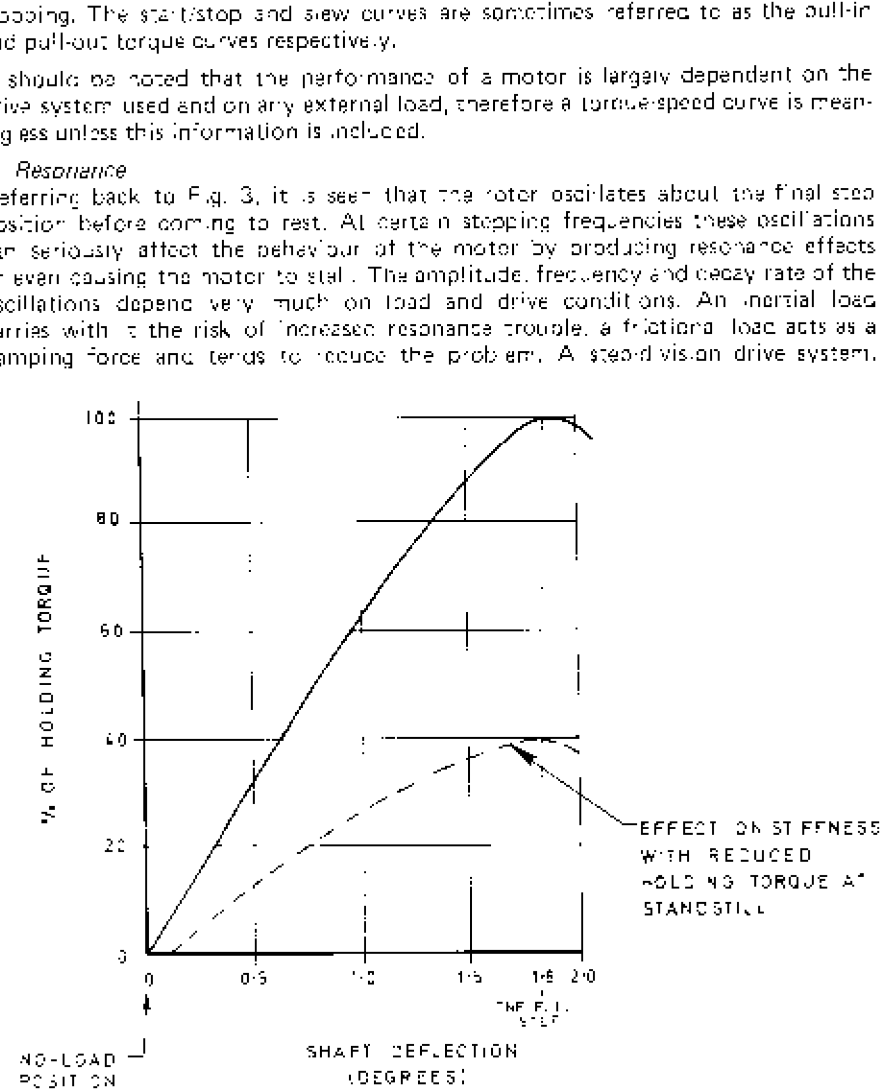


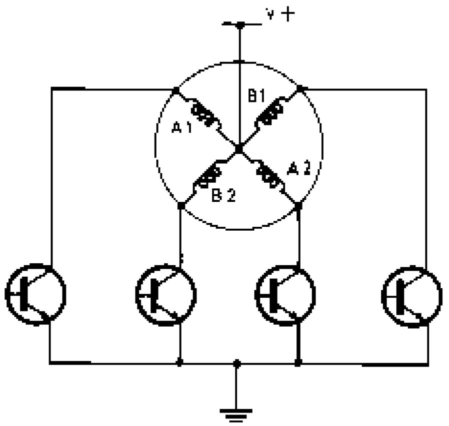
FIG 5. TYPICAL STATIC TORQUE / DEFLECTION CURVE

together with active current regulation as used in the 1073 Drive both result in a significant reduction in motor resonance phenomena.

4. Static Accuracy
With an unloaded motor the angular accuracy of any particular step depends mainly on the quality of construction and is typically ± 3 minutes of arc for a 200 step/rev. motor. It is important to realise that this error is non-cumulative, in other words the error after rotation through any number of steps will still be ± 3 minutes. In practice it is difficult to achieve this accuracy in systems which have any frictional load, and this is particularly true in a sub-step mode. When a torque load is applied to the motor the shaft will deflect from its no-load position until sufficient torque is generated to equal the load. Fig. 5 shows a typical torque/deflection curve for a 200 step/rev. motor. The holding torque depends on the motor current at standstill, and Digiplan high performance Drives are designed to allow adjustment of the standby current according to the application. In most cases a standby current of 30–40% of full motor current is sufficient and this ensures that the motor and drive remain cool during standby periods.

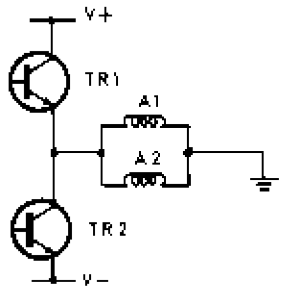
2.4 Drive Systems

In the simplest type of stepping motor drive, four transistor switches are used to energise the motor phases as shown in Fig. 6. In a full-step arrangement the phases are usually energised in pairs in the sequence A1+B1, B1+A2, A2+B2, B2+A1. In a half-step drive the phases are energised alternately singly and in pairs as explained in Section 2.1. In this case it is necessary to reduce the current when two phases are energised simultaneously so that the torque produced on alternate steps is the same, otherwise the steps will be alternately strong and weak.



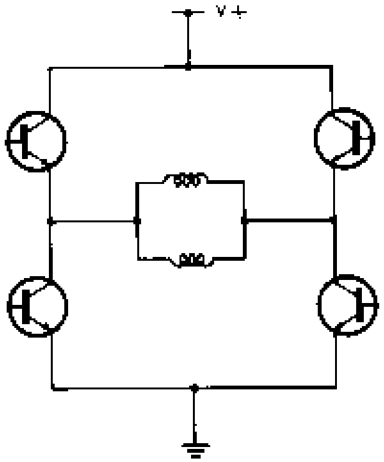
SIMPLE STEPPING-MOTOR DRIVE FIG.6.

It is found that the low-speed motor efficiency in terms of torque per watt is usually some 20% higher when two phases are energised instead of one, and a further improvement may be achieved by energising all four windings simultaneously. However, with the simple drive system, energising coils A1 and A2 together will produce magnetic fields which tend to cancel each other out. Hence it is necessary to employ a different driving arrangement which can feed current through the windings in either direction, and then the pairs of coils can be interconnected so that their magnetic fields are additive. Such a system is called a bipolar drive and is shown in its basic form in Fig. 7. Current is made to flow in either direction through the windings by switching on either TR1 or TR2, and it is found in practice that a further improvement of 25–30% in torque per watt is achievable using this technique. This improvement in efficiency will not normally apply at high speeds when the bulk of the losses are due to eddy currents and hysteresis.



BASIC BIPOLAR DRIVE (ONE PHASE ONLY) FIG.7

The drive system used in the 1073 is an extension of the basic bipolar arrangement and is known as a bipolar bridge, shown in simplified form in Fig. 8. This system uses an extra pair of switches but has two important advantages — only one power supply is required, and the peak-to-peak voltage applied across the windings is twice the supply voltage. This is important at high stepping rates as will shortly become clear.



BIPOLAR BRIDGE DRIVE FIG 8.

The drive systems so far considered operate very well at low stepping rates, but as speed is increased the inductance of the motor windings starts to become a problem. By its very nature an inductance opposes a rapid build-up of current and at high speeds the current may only have time to rise to a fraction of its steady state value, with a corresponding reduction in torque.

The rate at which current builds up in an inductance depends on the voltage applied to it, so in order to obtain a rapid rise of current in the coils a large voltage must be applied. Once the current has risen to the required value the high voltage must somehow be reduced, otherwise the current will continue to rise until it becomes limited only by the winding resistance. A common method of achieving this is to feed the coils via a series resistor which will limit the current to the required value, but this arrangement is very wasteful and at low speeds the drive may be dissipating considerably more power than is actually being delivered to the motor.

The method adopted in the 1073 Drive is to use the upper pair of bridge transistors as 'choppers'. The coil current is allowed to rise about 10% above the required value, at which point the upper transistor which was previously conducting is turned off. An alternative current path is provided by a free-wheeling diode so that current can continue to flow in the inductive winding, but due to resistive losses it will steadily fall. When it has dropped to 10% below the required value the transistor is turned back on. In this way the mean current is maintained at the required value with minimal dissipation within the drive.

Fig. 9 shows a simplified version of the chopper-stabilised bridge together with the associated current waveforms. The current path during each phase of the regulation cycle is indicated by a heavy line. It will be seen that the motor current always flows through a small sense resistor R to provide a feedback voltage proportional to current — this feedback voltage is used to control the motor current by modulating the conducting top switches.

During phase (a), switches S1 and S4 are turned on and the current rises in an approximately linear fashion as shown. When the upper threshold is reached, S1 is turned off and the current recirculates through S4, D1 and the sense resistor R as shown at (b). This continues until the current falls to the lower threshold when S1 is turned on again as at (a) and the cycle repeats.

When current is required to flow in the opposite direction in the coil, S2 and S3 are turned on as shown in (c). Again the current is allowed to rise to the upper threshold before S2 is turned off and the current recirculates via S3, D2 and R as shown in (d).

It will be seen that current always flows in the same direction through the sensing resistor regardless of which switches are on or which way it flows through the coil. Therefore the feedback voltage is always in the same sense and the same threshold levels apply.

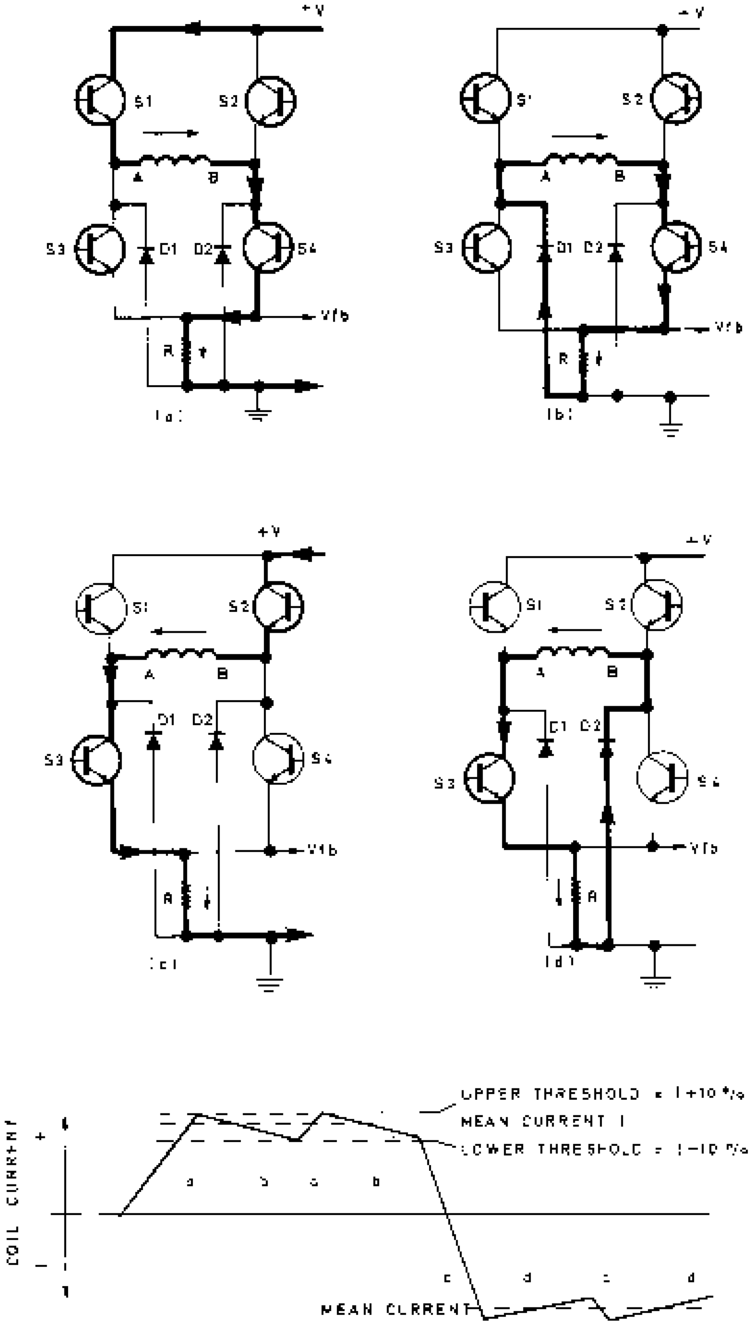


FIG 9 BIPOLAR, CHOPPER-STABILISED BRIDGE

3. DESCRIPTION OF THE 1073 DRIVE

3.1 Specification

Drive circuit:	bipolar, chopper regulated.
Max. Power output:	3000 watts (CA) 1500 watts (CB) 800 watts (CC)
Motor supply voltage:	240V DC (CA, CB) 120V DC (CC)
Max. motor current:	CA: 14A/phase (two phases on); 20A (one phase on). CB, CC: 7A/phase (two phases on); 10A (one phase on).
Max. stepping rate:	20,000 steps/second @ 400 steps/rev. 50,000 steps/second @ 1000 steps/rev.
Auxiliary power output:	+ 24vDC ± 20%, 400mA max. (CA) 500 mA max. (CB, CC)
Supply voltage:	172v RMS (CA, CB) 86v RMS (CC). Single or three-phase. Supply must be via isolating transformer.
Supply voltage tolerance:	+ 10% – 15%
Dimensions:	8" (203mm) wide, 8¼" (209mm) high, 15 ⅞ " (403mm) long (CA), 13½" (343mm) long (CB,CC) including handle.
Weight:	17lbs (7.8kg.)
Operating temperature range:	0°C to 40°C local ambient (CA version incorporates forced air cooling).

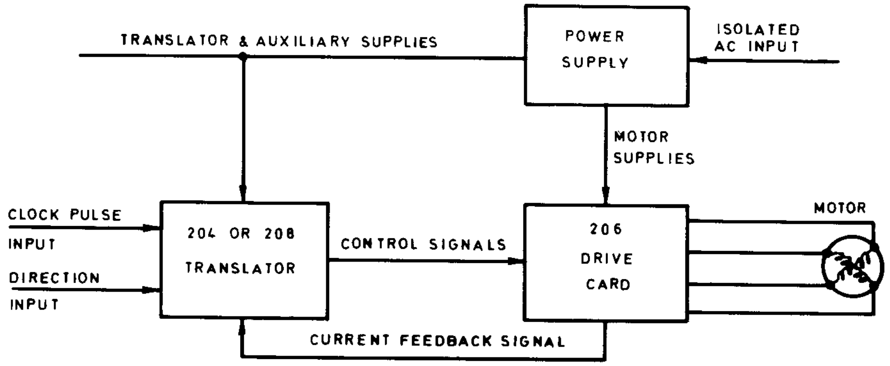
3.2 General Description

The 1073 is available in three versions as follows:

1073 CA	maximum output power	3000 watts
1073 CB	maximum output power	1500 watts
1073 CC	maximum output power	800 watts

The DC supply voltage is 240 volts for the CA and CB versions, and 120 volts for the CC version. The maximum output current from the drive is 20 amps for the CA and 10 amps for the CB and CC. The three types are physically identical apart from the extended length of the CA which incorporates a cooling fan.

Fig. 10 shows the main components of the 1073 system – the translator, drive



1073 DRIVE SYSTEM FIG. 10.

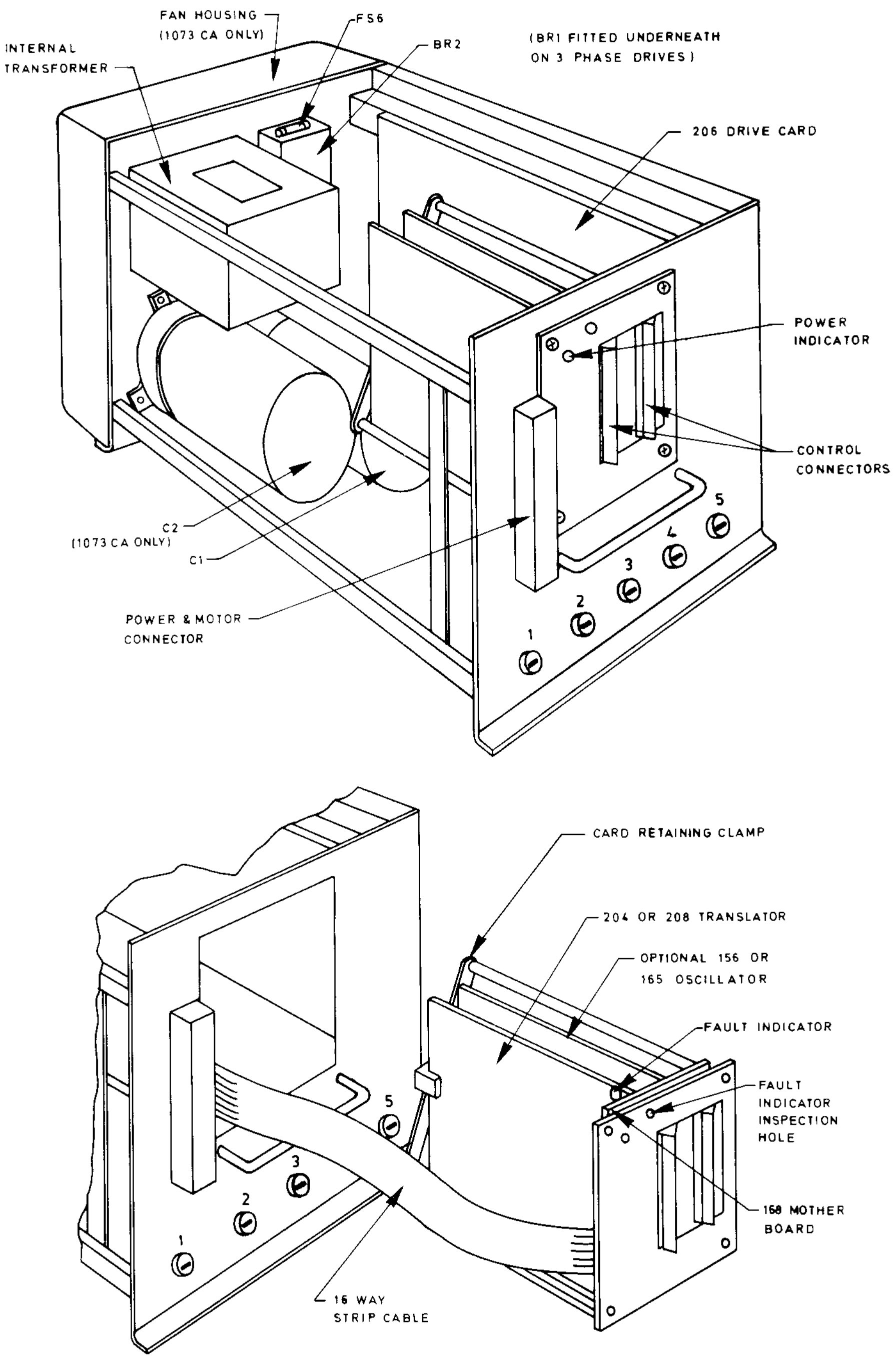


FIG.11 MAIN DRIVE COMPONENTS

card and power supply. An optional oscillator card may be included and this will be considered later.

Fig. 11 shows the physical layout of the drive and the location of the main components. The 206 drive card has an integral heat sink and forms the right-hand side of the drive assembly. The translator and optional oscillator cards plug into the 168 mother board which is carried on a removable sub-assembly. The 168 board incorporates a 24 volt power supply, and the main power supply makes up the remainder of the package. All terminations are brought to the front of the drive for ease of installation.

The basic input signal required by the system is a series of ramped or uniform clock pulses, the number of pulses corresponding to the number of steps the motor is required to perform. From this pulse sequence must be generated a set of controlled drive waveforms which, when applied to the stepping motor, will cause it to execute the required number of steps.

The first part of the process is carried out by the translator. It generates a series of low-level signals which will be fed to the drive card to control both the timing and direction of the currents flowing in the motor windings. In generating these signals the translator must take account of the required direction of rotation, as specified by the 'Motor Direction' input. Two alternative translators may be supplied with the 1073, the standard 204 translator giving 200 or 400 steps/rev. and the 208 multistep translator giving 600, 800 or 1000 steps/rev.

The drive card is essentially an amplifier which delivers the necessary power to the motor in response to the control signals from the translator. It incorporates the bipolar, chopper-regulated switching circuitry mentioned in Section 2.4.

A second function of the translator is to control the magnitude of the motor currents, both during the stepping sequence and whilst the motor is stationary. It achieves this by measuring the motor current using a sensing resistor and then using this information to control the signals fed to the drive card.

The system components will now be considered individually in greater detail.

3.3 The Translator and Drive Card

The translator and drive card are closely inter-related and are therefore best considered as a single unit. Fig. 12 is a block diagram of the complete system, and for the sake of clarity the components which are duplicated for phase 2 have been omitted. The system with a standard 204 translator will be considered first and the 208 multistep translator will be discussed later.

The incoming Clock and Direction signals are fed to an 8-state counting circuit which will produce 400 steps/rev. with the usual 200 step/rev. motor. The translator generates the timing waveforms shown in Fig. 13 and it will be seen that the phases are energised alternately singly and in pairs, this being a half-step sequence giving 400 steps/rev. A link may be inserted on the board to convert the system to 200 steps/rev. This is achieved by generating an auxiliary clock pulse 40μS after each incoming clock pulse which causes the translator to pass quickly through the intermediate state. It should be noted that 400 steps/rev. is the preferred mode of operation as motor resonance effects are much reduced and the behaviour is smoother, particularly at low speeds. The maximum angular velocity (or RPM) attainable from the motor is unaffected by the stepping mode, equivalent to

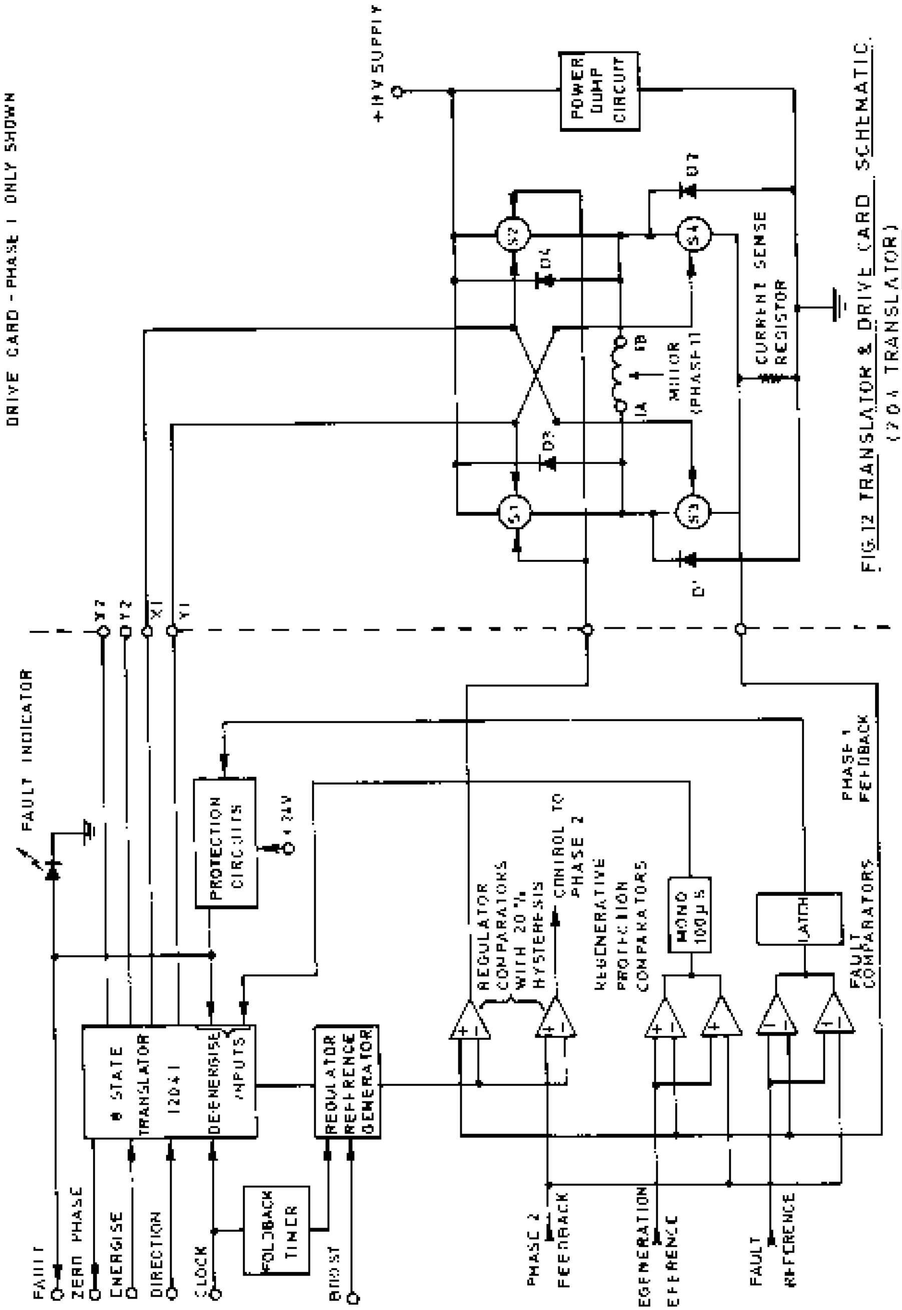


FIG.12 TRANSLATOR & DRIVE CARD SCHEMATIC (204 TRANSLATOR)

20,000 steps/second in the 400 steps/rev. mode or 10,000 steps/second in the 200 steps/rev. mode.

A 'zero phase' signal is available from the translator which indicates that it is in the first of its eight states; this signal will occur 50 times per rev. In addition, the translator is always preset to the zero phase state when the drive is switched on. This signal is therefore useful in establishing a mechanical reference datum.

The X and Y timing waveforms from the translator determine the timing and direction of the current in each motor winding. Associated with each winding are four power switches S1 to S4, interconnected in pairs as shown. The upper switches S1 and S2 have an additional control input to which is applied the chopping signal for current regulation.

When X1 goes high, switches S2 and S3 are turned on. Current starts to flow through the motor winding from 1A to 1B and it is monitored by the regulator comparator using the voltage feedback signal VFBI. When the upper threshold is reached the comparator switches over and turns off S2 so that the current then recirculates via D2. The current slowly falls and reaches the lower threshold, causing the comparator to switch back and turn S2 on again. The frequency at which this "chopping" occurs depends primarily on motor inductance and it is typically around 2kHz.

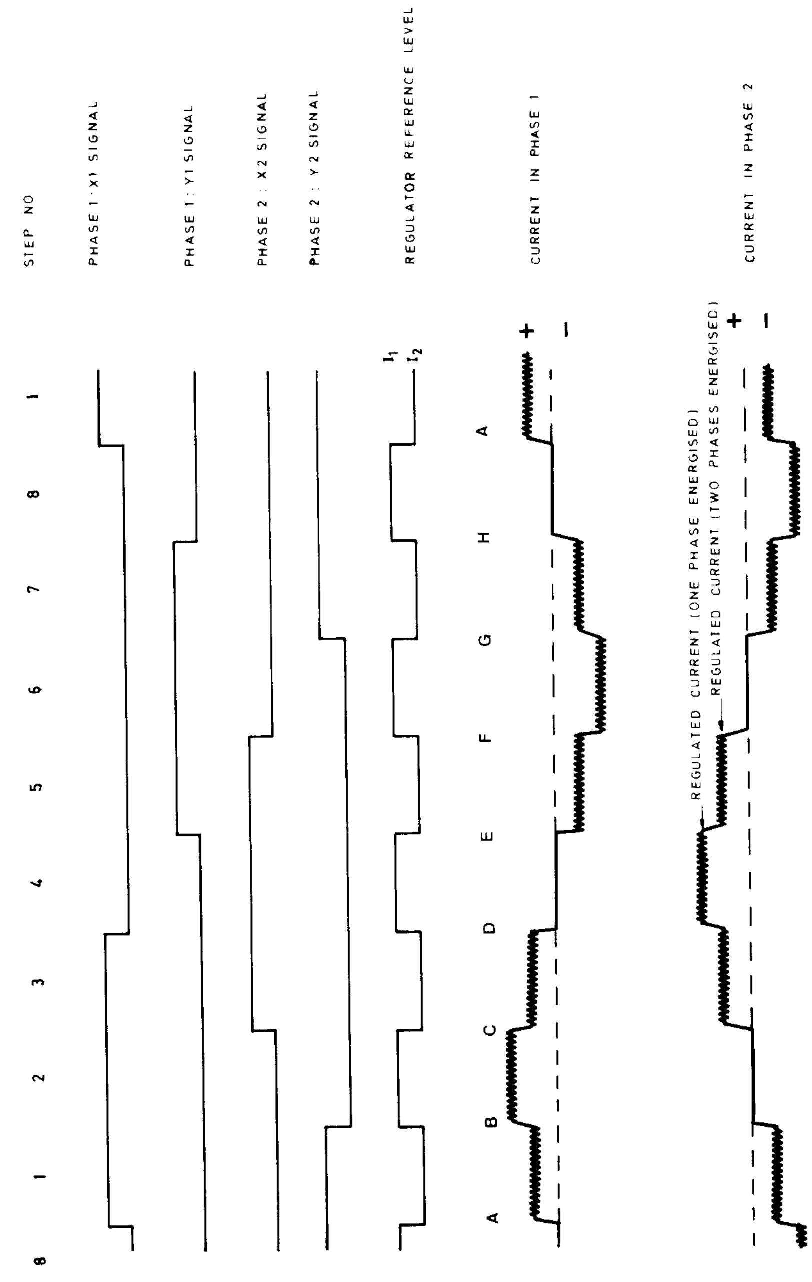
Similarly when Y1 goes high, switches S1 and S4 are turned on and the same cycle of events continues but with current flowing in the opposte direction through the winding. To de-energise the motor all X and Y signals are forced low, preventing any current flow through the windings. It will be seen from the timing diagram that a larger current flows when only one phase is energised in order to help maintain the torque on intermediate steps. The reference generator therefore has an input from the translator which causes the reference level to be raised when only one phase is energised (points B, D, F and H on the diagram).

The regulator reference level may also be modified by means of the boost input, which enables the current levels to be increased at strategic times when extra torque is required. Conversely the facility may be used to reduce the current when the torque demand is lower.

A circuit is included which will automatically reduce the current at standstill. In most applications the torque required at standstill is less than when the motor is running, and by reducing the current at this time the dissipation in both the motor and drive may be minimised. A delay circuit, triggered by the incoming clock pulses, reduces the regulator reference level if no clock pulses have been received for 80mS. The reference level is restored immediately another clock pulse arrives.

All the operating currents (i.e. regulated, boost and standby) are programmable by means of resistors on the translator board. Tables 3 and 4 give values of the programming resistors for a range of operating currents.

The translator board also incorporates circuitry to protect the switching components from damage caused by excessive motor current during deceleration. When the motor is running at high speed there is energy stored in the rotor and load which must be dissipated during deceleration. During this period the motor therefore behaves as a generator and pumps power back into the drive, and this can cause excessive current to flow in the power switches. A comparator monitors motor current against a fixed reference, and if this limit is exceeded it causes all power switches to be turned off for a period of 100μS. The regenerated current now flows into the power supply capacitor which presents a significant load to the



TIMING WAVEFORMS FIG.13

motor and aids deceleration (see Fig. 14). Further protection is given by the power dump circuit which senses a rise in the high voltage rail and connects a load resistor across the supply to dissipate the surplus power. The resistor is switched out of circuit as soon as the rail voltage returns to normal.

Should an even larger current flow in the motor due to a fault condition, this is detected by a further comparator which totally de-energises the drive.

An L.E.D. on the translator board gives a visual indication of this condition and is visible through a hole in the front panel. There is also a 'Fault' signal available for use by the control system. The protection circuit can only be reset by disconnecting the mains supply, and power should not be re-applied until the cause of the fault has been established. The circuit also monitors the −24V. supply, since a failure in this supply could result in damage to the switching transistors. In the event of a power supply failure the protection circuit operates in the same way as for an overcurrent fault.

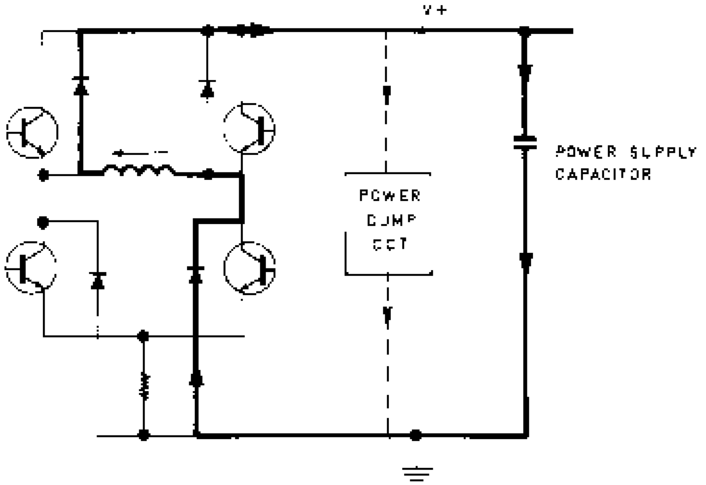


FIG 14 CURRENT FLOW DURING REGENERATION WITH ALL SWITCHES OFF

3.4 208 Multistep Translator Option

In certain applications it may be desirable to use a smaller step size to improve the low-speed smoothness of the system and to minimise the effects of resonance. The 208 Multistep translator is available to meet this requirement and may be specified with a resolution up to 1000 steps/rev.

In the standard translator operating at 400 steps/rev., the intermediate or half-steps are produced by energising one phase only using extra current. This causes the rotor to align itself half way between the full step positions. Further subdivision of the basic step is possible by varying the proportion of the currents flowing in the two phases, causing the rotor to assume an intermediate position related to the ratio between the currents. This is the technique used in the 208 translator.

Fig. 15 shows in schematic form the step division circuitry in the 208 card. Incoming clock pulses pass through a divider circuit with a variable modulus, and

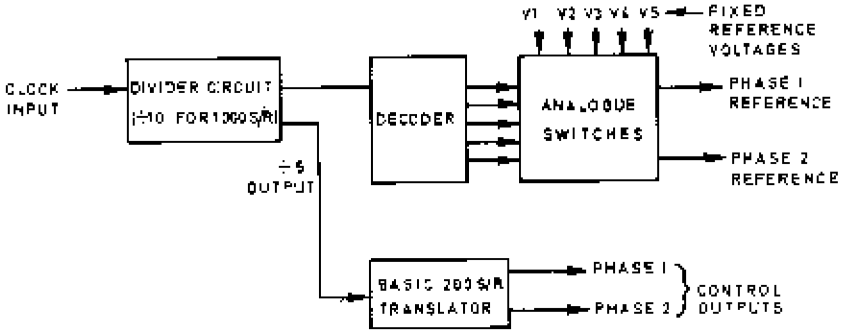


FIG.15 STEP DIVIDE CIRCUITRY

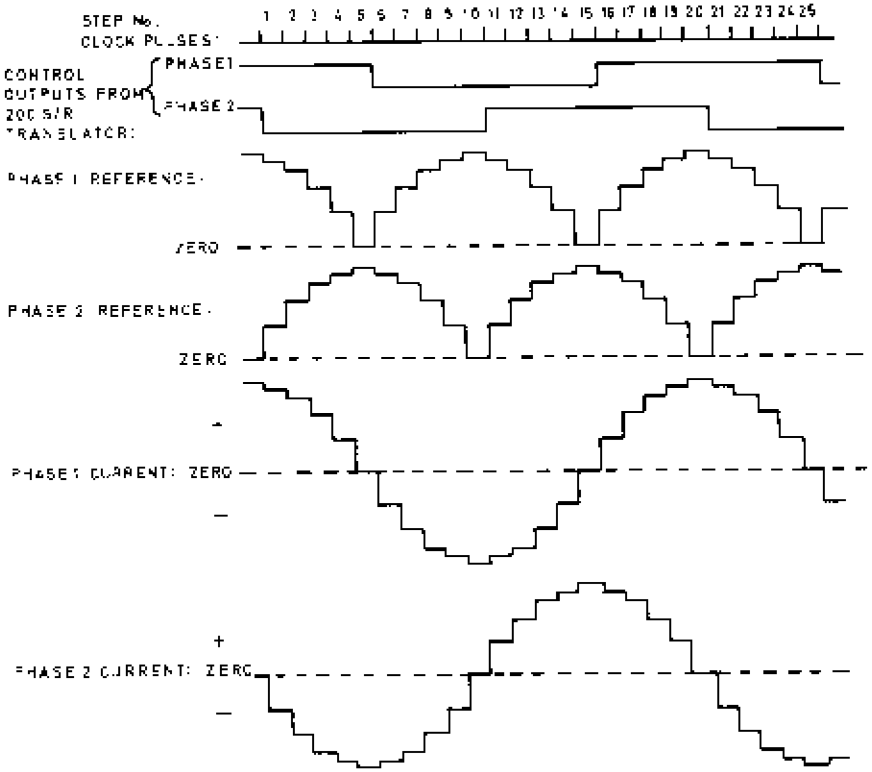


FIG 16 MULTISTEP TRANSLATOR WAVEFORMS (1000 STEP/REV.)

in the case of a 1000 step/rev. translator this modulus will be set at 10. The outputs from the divider are decoded and arranged to control a series of analogue switches which are fed from various reference voltages; these voltages correspond to the different current levels required during the stepping sequence, as shown in Fig. 16. In this way a composite reference voltage is generated for each phase and this is fed to a current regulator as in the standard translator.

Every fifth clock pulse is routed to a basic 200 step/rev. translator which generates the control waveforms shown in Fig. 16. These signals are fed to the power switches and thereby control the direction of current flow in the motor windings.

It should be emphasised that the relationship between rotor position and relative phase currents is not linear and varies from one type of motor to another. Therefore it is necessary for this translator to be set up during manufacture according to the type of motor to be driven.

3.5 The Power Supply

The circuit of the power supply is shown in Fig. 17. A separate isolating transformer must be provided and this may be either single or three phase. The required supply voltage is 172 volts for CA and CB versions, and 86 volts for the CC version. The incoming AC is rectified and smoothed to provide the high-voltage rail for the drive card, and the low-voltage supplies are derived from a separate internal transformer running from the 86V or 172V input. A 19.5-volt winding on this transformer feeds the 168 Mother Board which incorporates a rectifier and smoothing capacitor for the +24v supply (see Fig. 18). The translator and optional oscillator cards plug into 168 and each card has its own 12V zener stabiliser which is fed from the +24V supply. The 12V rail derived on each card powers both the CMOS logic and the analogue circuitry. Spare capacity is included in the +24V supply which permits up to 500mA to be drawn from the auxiliary power outlet (400 mA CA version).

The internal transformer also supplies 3 volts for a negative rail used in the drive card, and an extension to the primary winding is used for the cooling fan when fitted.

3.6 Oscillator Options

Digiplan currently manufacture two types of oscillator card which may be plugged directly into the 1073 drive. They simplify the problem of generating clock pulse sequences which will run the motor up to its maximum speed without loss of synchronism.

The 156 Ramped Clock is a wide-range voltage controlled oscillator which may be controlled by DC inputs or switches. Acceleration circuits are included which allow the motor to be accelerated and decelerated between speeds as well as from rest. This type of oscillator is equally suitable for digital control or for positioning systems which are controlled by an operator.

The 165 Buffered Clock is intended mainly for use with computer-based and similar control systems which generate output commands in the form of a pulse train at the required rate, the number of pulses corresponding to the required number of motor steps. The buffered clock will cause the motor to run at the required speed, storing pulses to permit acceleration and deceleration as necessary.

When either of these oscillator cards is specified, the appropriate instruction manual will be supplied.

	CA	CB	CC
C1	1500µF 350V	1500µF 350V	1500µF 350V
C2	1500µF 350V	—	—

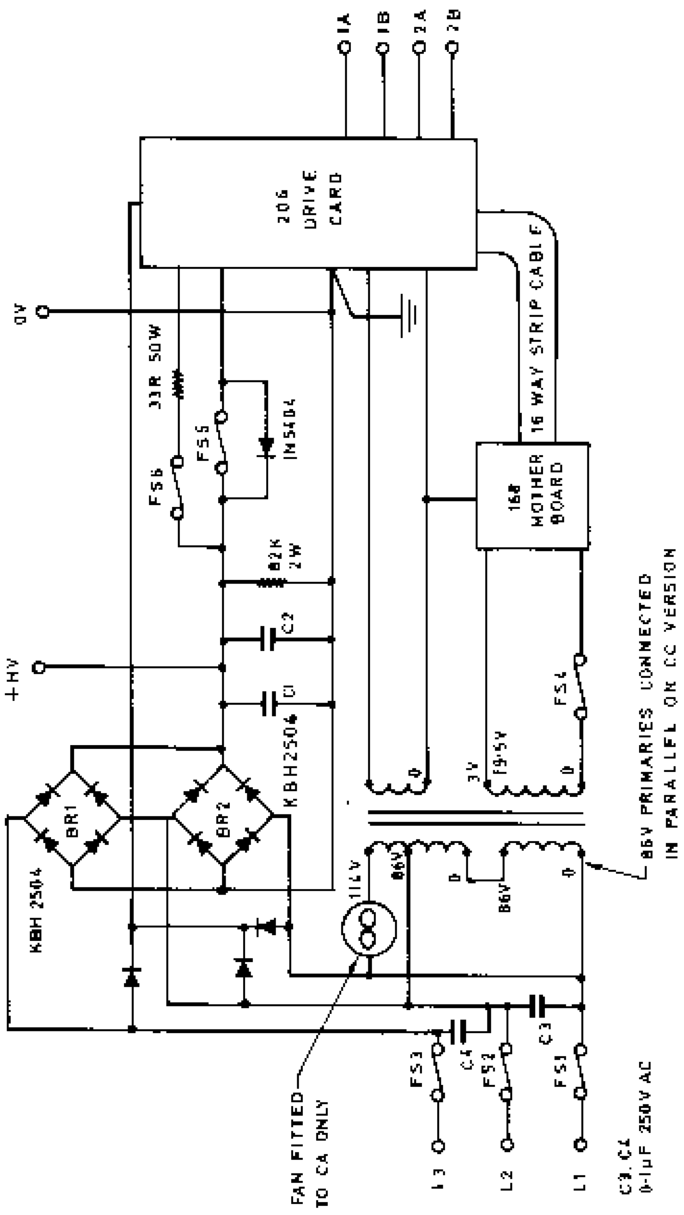


FIG 17 POWER SUPPLY CIRCUIT

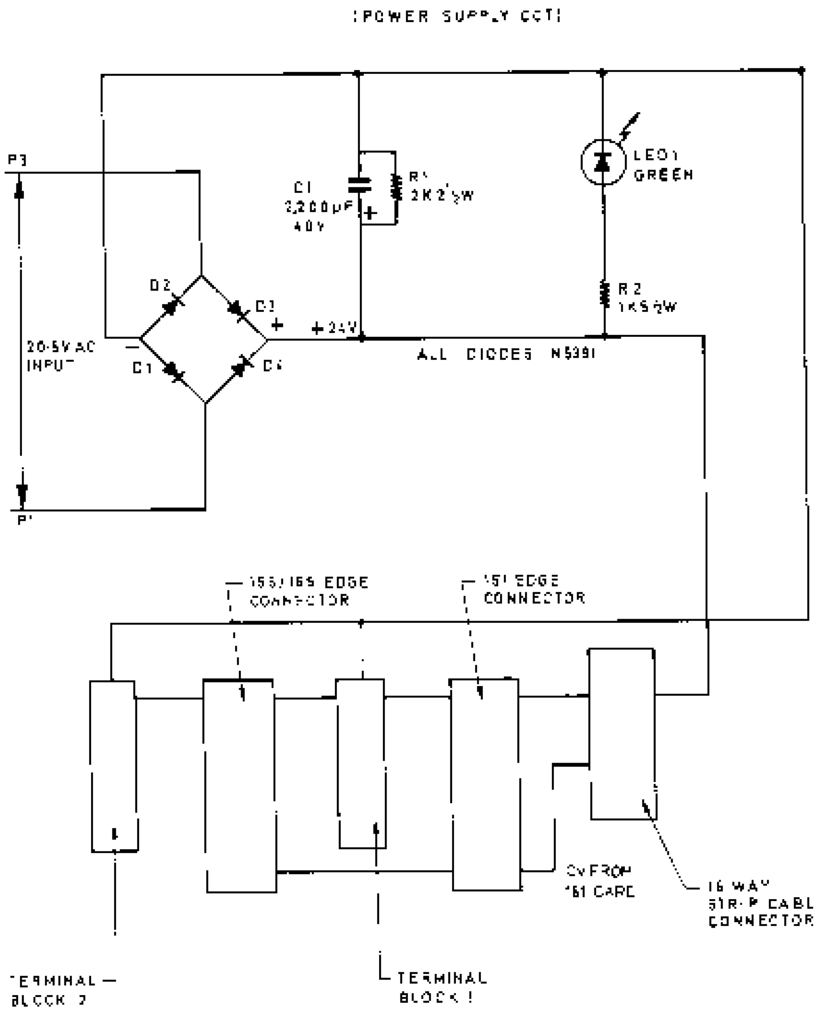


FIG 18 158 MOTHER BOARD SCHEMATIC

4. INSTALLATION

NOTE:

Before commencing installation remove the cover and check that all components are secure and undamaged.

4.1 Physical Location and Mounting

When deciding on the location and mounting of the drive, there are a number of factors to be borne in mind.

a) Adequate provision must be made for cooling. The power dissipated in the drive depends almost entirely on the application and can vary between wide limits; it is related to such factors as motor current, stepping rate, duty cycle, duration of boost periods etc. and it is therefore almost impossible to give any meaningful dissipation figures. In situations where the available space or volume of cooling air is restricted, it is recommended that preliminary tests are carried out under normal operating conditions with the drive in free air. By measurement of the mean heatsink temperature it is then possible to estimate the dissipation from the formula

$$W = 2T + 20$$

where W is the dissipated power in watts and T is the difference between the heatsink and ambient temperatures in degrees Centigrade.

When performing this test on a 1073CA, first disconnect the cooling fan by removing the four screws securing the fan cover, withdrawing the cover and removing the push-on fan connectors. The equipment is designed for a maximum operating heatsink temperature of 80°, but it should be borne in mind that for maximum reliability the power semiconductors should be kept as cool as possible. If an enclosed cubicle is to be used it is essential that suitable ventilation is provided, and Fig. 19 gives information regarding mounting enclosures. It is preferable for the drive to be mounted on open rails to allow the maximum unobstructed air flow. When more than one drive is installed and cooling is by natural convection, allow for a minimum horizontal spacing of 3" (75mm) between units.

The drive is fitted with mounting flanges front and rear as shown in Fig. 20, and these are provided with open-ended slots to simplify installation and removal. The drive may be mounted in any position but it is advisable to keep the heatsink in a vertical plane, i.e. it should not form the top or bottom surface of the drive when mounted.

In the case of the 1073CA, this version is fitted with a cooling fan as standard and the air entry port must not be obstructed in any way. This drive may be supplied without a fan for use in systems which already incorporate a means of forced-air cooling, and where possible the supply of cooling air should be aimed directly at the heatsink side of the drive.

b) Where there is considerable distance between the control system and the motor, the drive should generally be located as close to the control system as possible. Very long motor leads are unlikely to present a problem as long as they have a low resistance, but low-level control signals may become prone to pickup or crosstalk problems over long distances. In any event the total amount of wiring will generally be minimised with the drive close to the control system.

c) For setting up and servicing purposes it is desirable to have easy access to the front of the drive. Where this is not possible with the drive in its normal position, ensure that the wiring and fixing method allow the unit to be withdrawn for setting up and servicing.

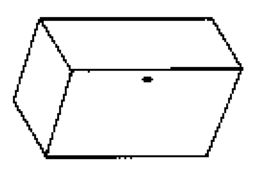
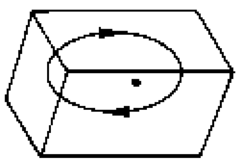
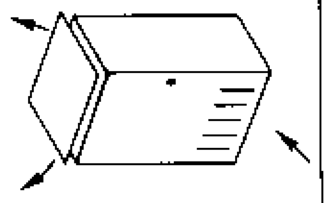
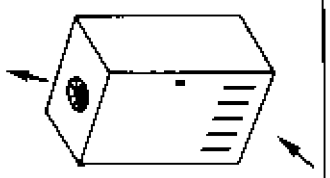
ENCLOSED		VENTILATED	
NO INTERNAL FAN	FORCED CIRCULATION BY INTERNAL FAN	THROUGH VENTILATION BY NATURAL CONVECTION	THROUGH VENTILATION BY FAN
			
UP TO APPROX 175 W LOCALISED HEATING MAY BE HIGH AT TOP OF CUBICLE	UP TO APPROX 350 W FORCED CIRCULATION MINIMISES LOCAL HEATING	UP TO APPROX 500 W WITH AIR SLOTS TOTALLING 0·3m² AREA	UP TO APPROX 2000 W ACCORDING TO TYPE OF FAN AND FILTER USED

FIG.19 HEAT DISSIPATION FIGURES FOR A TYPICAL FREE-STANDING ENCLOSURE 600 X 600 X 1500 mm. MAX. TEMP. RISE 25°C

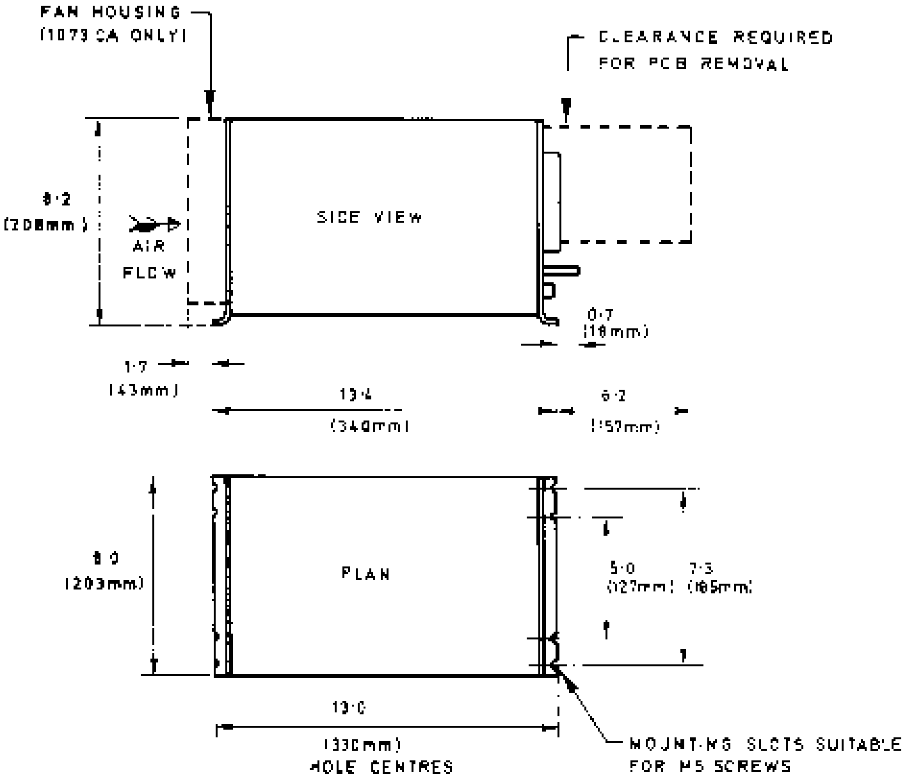


FIG. 20 DIMENSIONS & LOCATION OF MOUNTING POINTS

4.2 AC Supply Transformer

The drive must be fed from an isolated AC supply of either 86 volts or 172 volts as shown in Table 1. A suitable transformer may be supplied with the drive or it may be provided by the customer. Since there is no AC isolation within the drive it is essential that a double-wound transformer is used. Note that the transformer secondary voltage should be specified on open-circuit.

The current ratings shown in Table 1 correspond to the maximum power which the drive will deliver. In many applications the maximum power may not be needed or the duty cycle is such that the average power is very much lower. When assessing the transformer requirements, take account of such things as duty cycle in order to avoid specifying an unnecessarily large transformer.

In multi-axis systems it is permissible to run two or more drives from the same transformer. In general it is preferable to use a separate secondary winding for each drive. Here again the average power demand may be less than the total drive capability if for instance all axes are never called upon simultaneously. Keep in mind that an unused axis will still be drawing the standby current. In all cases, ensure that the regulation of the supply from zero to full load meets the supply voltage tolerance of + 10% to − 15%. Ideally the transformer regulation should be such that under full load the DC supply does not fall by more than 10% as this can represent a proportionate loss of torque and also reduce the permissible mains voltage fluctuation.

4.3 Supply connections.

For single-phase operation, connect the transformer secondary winding to terminals L1 and L2. For three-phase operation, use L1, L2 and L3. Use 50/0.25 for the supply connections to a CA drive, and 32/0.2 for CB or CC drive. Ensure that there is a sound earth connection and that any metalwork to which the drive is attached is separately earthed.

Table 1. Power requirements and fuse ratings

	TYPE OF DRIVE			FUSE TYPE
	CA	CB	CC	
RMS AC SUPPLY VOLTAGE	172	172	86	
MAXIMUM CURRENT, A	20	10	10	
FUSE RATINGS: FS1	15A	8A	8A	ANTI-SURGE
FS2	15A	8A	8A	ANTI-SURGE
FS3	15A	8A	8A	ANTI-SURGE
FS4	2A	2A	2A	QUICK BLOW
FS5	16A	8A	8A	QUICK BLOW
FS6	2A	2A	1A	ANTI-SURGE (INTERNAL FUSE)

Suitable anti-surge fuses Bussmann Type MDA.

4.4 Motor Connections

Four connections are required between the motor and the plug in connector on the drive. Section 6 shows the connection data for various motors. It will be seen that the windings may be connected either in series or in parallel, unless the motor has only six leads in which case the choice is between using one or both halves of each winding. The preferred connection mode depends on the application since the performance characteristics are different in each case.

Series connection increases the inductance per phase to four times the inductance of one coil only. There is a significant increase in low speed torque, but the torque begins to drop off rapidly at higher speeds.

Parallel connection results in less torque at low speeds, but the torque will be maintained up to high stepping rates and in fact the maximum power obtainable from the motor is greater in this mode.

Wire used for the interconnections between motor and drive should generally be not smaller than 50/0.25 for the CA and 32/0.2 for the CB or CC. The length of the cable will not normally present a problem, but in situations where radio-frequency interference must be minimised it may be preferable to use cable with a collective screen. The screen should be earthed at one end only, and the body of the motor should also be earthed.

The importance of correct motor connections cannot be over-emphasised. For instance, if a pair of windings became connected in series-opposition the effective inductance becomes zero and the impedance seen by the drive is virtually a short-circuit.

It is also important that any unused motor leads are individually insulated, and under no circumstances should they be joined together unless this is specified in the motor connection data. Do not attempt to use a 5-lead motor with this drive.

4.5 Control Signal Connections

The main part of this section lists the low-level signals appropriate to the basic drive with translator; those which relate to the optional clock cards are shown in the relevant manual. Fig. 21 shows the interface circuits used on the drive and these should provide sufficient information for the signal requirements to be established. Since the voltage and current levels are low there is virtually no restriction on the size of wire used for these connections, particularly where the drive and control system are in the same housing. Stranded wire such as 16/0.2 will generally be suitable. Where the drive and control systems are housed separately, it will normally be necessary to use some kind of multicore cable for the interconnection and here a cable with a single collective screen is recommended. The screen should be earthed at the control system end only to avoid the creation of earth loops.

Logic Convention. The voltage levels corresponding to logic 1 (high) and logic 0 (low) are shown on the interface circuit diagrams (Fig. 21). Most of the terminal functions are complementary, shown by a bar above the function name, and the logic level is low when the signal or condition is present. For example, an input such as Motor Clock in will respond to low-going transition, i.e. a change from logic 1 to logic 0, which in this case will cause the motor to advance one step. In the case of a true function (no bar above the function name) the logic level is high when the signal is present.

List of Terminal Functions. The number preceding each function denotes the terminal strip number and this information is summarised in Table 2. Refer to Fig. 21 for the interface circuit details.

1. Logic Ov. This is the common point for both the logic signals and the −24V auxiliary supply, and it should be connected to the common point of the control system. This point is also connected to mains earth. In systems using several drives it is preferable for them to be housed in the same enclosure and wired back to the same mains earth point. If this is not possible and the drives are widely separated, it may be advisable to use optically coupled isolators to interface with the control system.

2. Boost. Taking this input low (i.e. short-circuiting it to Ov) increases the regulated and standby currents. The amount by which these currents are increased is programmable by means of resistor R11 on the 204 translator board; refer to the Table 3 for information on the programming resistor values. The percentage boost is fixed in the case of the 208 Multistep translator. *Boost should not be used for more than 25% of the time or for longer than 5 seconds at a time. The boost facility cannot be used if the motor inductance is less than 1.2mH (CA, CC) or 2mH (CB).*

3. $\overline{\text{Energise}}$. During normal operation this input should be at logic 0 and the motor will be energised. Taking the input to logic 1 turns off all the power switches and de-energises the motor. This facility enables the motor to be turned by hand or overriden by other mechanical means, BUT IT SHOULD NOT BE DRIVEN AT HIGH SPEED BY EXTERNAL MEANS WITH THE $\overline{\text{ENERGISE}}$ INPUT HIGH as this pumps power back into the supply and may overload the power dump circuit. Similarly the drive should NOT be de-energised whilst the motor is running. A Link is normally inserted on the translator board to hold this input permanently low and it must be removed if the de-energise facility is required. For information on these links, refer to Fig. 22 for the standard 204 translator or Fig. 23 for the 208 multistep translator.

4. Zero Phase. This is an output signal which is low during the first of the translator states; it occurs 50 times per rev. with a 200 step/rev. motor. At switch-on the translator is always reset to the zero phase state. This signal may be used when establishing a mechanical reference since the datum position may be made to correspond with a specific motor step.

5. +24V. This auxiliary power output may be used to drive a simple control system or other low-power external modules. The current drawn from this output should not exceed 500mA (400 mA for 1073CA). To preserve the full supply voltage tolerance, this output should be decoupled by a 2200μF 40V capacitor if more than 150mA is drawn.

6. Motor Direction. Changing the logic level at this input will reverse the direction of motor rotation. If the motor runs in the wrong direction in relation to the logic level, reverse the connections to one phase (eg. interchange the connections to terminals 1A and 1B). The motor direction input should only be changed whilst the motor is stationary or running within its start/stop speed range. Note that if one of the optional oscillator cards is fitted, this connection becomes an output indicating the motor direction. This is not necessarily the same as the requested direction at a time when the motor is being reversed.

7. Motor Clock In. A low-going transition on this input causes the motor to advance one step. With the standard 204 translator, the input should remain at logic 0 for not less than 5μS and not more than 30μS and another low-going pulse should not occur within 50μS (equivalent to a maximum frequency of 20kHz). Should the clock input be held at logic 0 the drive will not revert to the standby condition and the motor will run hot whilst stationary.

With the 208 multistep translator, the input should remain low for at least 5μS and at the maximum running frequency it should stay high for at least 10μS between clock pulses. The maximum frequency for the 208 translator is 50kHz at 1000 steps/rev. and pro rata at lower resolutions (equivalent to 3000 rpm). Note that the clock frequency must be ramped if speeds within the motor slew range are required.

13. Fault. Operation of the overload cut-out circuit or a power supply failure is indicated by this output going high, and the control system must be alert to this condition since no further commands will be obeyed until the fault is cleared. The drive must be switched off to reset the overload circuit. Should the fault condition reappear immediately on switch-on and there are no external wiring faults, it is probable that the drive has been damaged.

4.6 Preliminary Checks prior to switching on the Drive

NOTE: It is important that the following checklist is followed before power is applied to the drive. Faulty connections, and short circuits in particular, will invariably result in permanent damage.

1) Check that the AC supply voltage is correct. Where the isolating transformer has tappings or multiple windings for operation from different supply voltages, check the connections to these particularly carefully.

2) Check that there are no short circuits between any of the motor connections. With low-impedance motor windings this may be difficult, and if there is any doubt the wiring between motor and drive should be checked by temporarily disconnecting the motor.

3) Check that the motor phases are isolated from each other. With some types of drive it is usual for the centre-tap connections of 6-lead motors to be joined together, but with the 1073 they must be kept separate. Note that 5-lead motors are not suitable for use with this drive.

4) Check that the motor has been wired exactly in accordance with the published data and that any unused leads are individually insulated and anchored mechanically.

5) Check that there are no short-circuits to earth from any of the motor leads.

6) Confirm that the drive is being used with the same type of motor for which it was supplied. If this is not the case the drive settings may need to be altered, see section 4.7.

7) Finally check that all external connections are sound and tight, and that the fuses are securely fitted. Switch on the AC supply. With the drive energised it

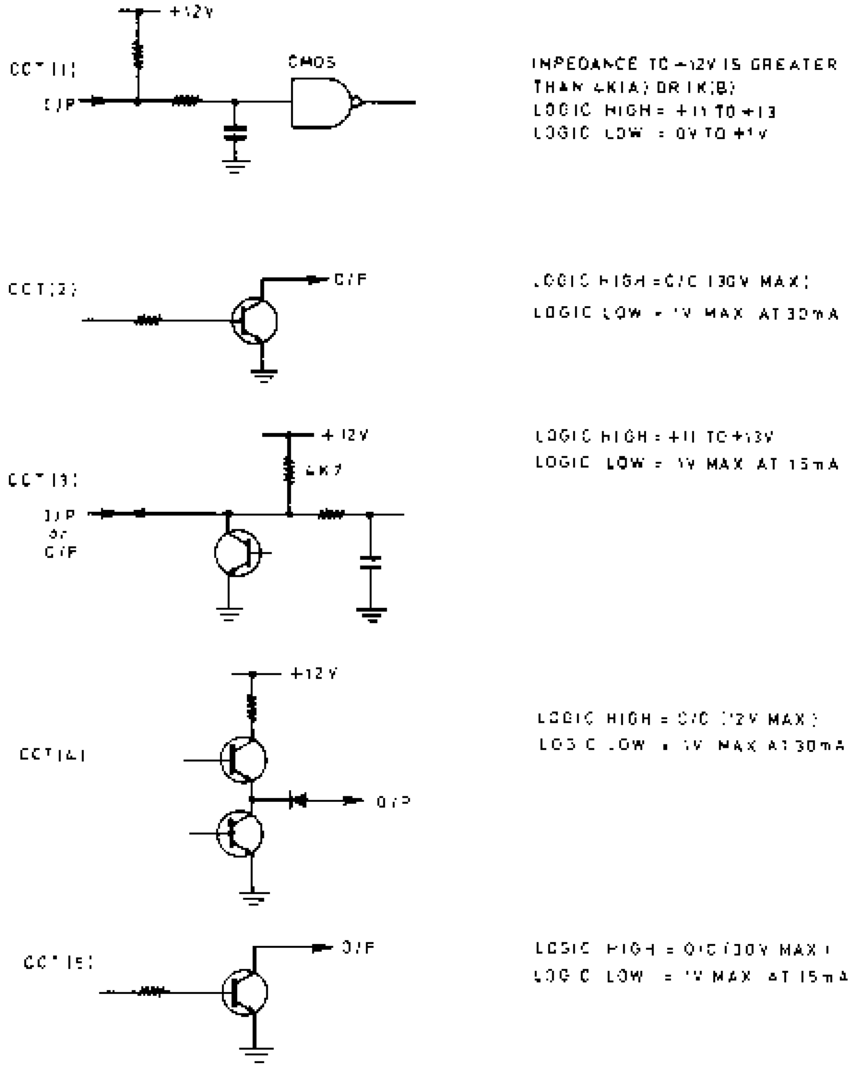


FIG. 21 INTERFACE CIRCUITS USED INTERNALLY ON DIGIPLAN DRIVES

should be possible to detect the chopper switching noise coming from the motor. The unit is now ready to be set up as required.

Table 2. Connections for basic drive with translator

FUNCTION	TERMINAL STRIP NUMBER	INTERFACE CIRCUIT (See Fig. 21)
Ov	1	–
$\overline{\text{Boost}}$	2	1A
$\overline{\text{Energise}}$	3	1A
$\overline{\text{Zero Phase}}$	4	2
+24V	5	–
Motor Dirn	6	1A
$\overline{\text{Motor Clock In}}$	7	1A
Fault	13	5

4.7 Setting up

1073 drives are normally supplied for use with a specified motor and in most cases no further adjustment will be necessary apart from setting up the oscillator. Where an oscillator is included with the drive, setting-up instructions will be found in the relevant supplement to this manual. However, should there be resonance problems or the motor runs excessively hot, the situation may well be improved by alteration of the drive settings. In this connection it should be noted that stepping motors are designed to permit operation at relatively high temperatures and a loaded motor running continuously may well become too hot to touch. In most cases a motor body temperature of up to 80°C need not cause concern, but above this temperature consideration should be given to minimising the dissipation by reducing the motor currents. If the motor will not provide the necessary torque without running excessively hot it is likely that the motor is unsuitable for the application.

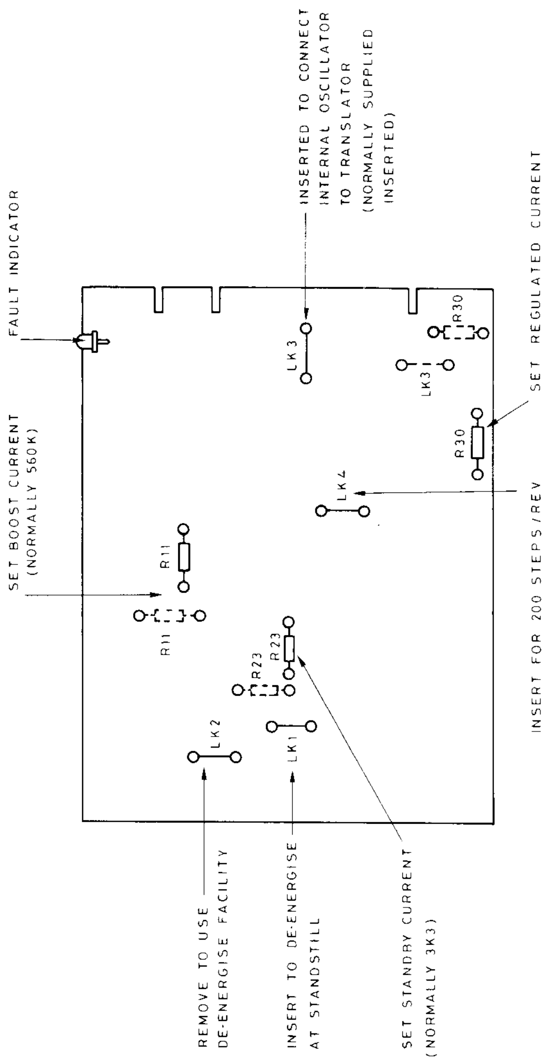
4.7.1 Setting up the standard 204 translator

1. *Motor resolution*

This translator normally operates in a half-step sequence giving 400 steps/rev. with a 200 step/rev. motor, and this is the preferred mode of operation. Should the 200 step/rev. mode be required, insert Link 4 on the 204 translator board (see Fig. 22). Note that the maximum obtainable RPM is unaffected by the stepping mode, so at 200 steps/rev. the maximum stepping rate is halved.

2. *Regulated Motor Current.* This is determined by resistor R30 on the 204 translator card (see Fig. 22) and Table 3 gives approximate resistor values for a range of motor currents. The manufacturer's current rating may be used as a guide to the maximum regulated current, but it is usually based on resistive power loss in the motor and only applies at low stepping rates. At high speeds other losses predominate and motor current may have to be limited by motor temperature considerations (see section 4.7).

Unless otherwise stated the rated current per phase normally refers to unipolar operation with two phases energised. With a bipolar drive the maximum current ratings may have to be modified according to the operating configuration. For 6 or 8-lead motors with the windings connected in series, the permissible current is 70%



NOTE

DOTTED COMPONENT POSITIONS RELATE TO BOARDS FROM ISSUE 'F' ONWARDS

FIG. 22 LINKS AND PRESET RESISTORS ON 204 TRANSLATOR

of the uni-polar rating. For 8-lead motors with the windings in parallel the rated current per phase may be increased by 40%. 6-lead motors cannot be operated in parallel, but when one winding is used per phase the maximum current will be the same as the rated value. Whenever the full motor torque is not required it will generally be advantageous to reduce the motor current. This will reduce the dissipation in both motor and drive and will also help to reduce resonance effects. Note that the boost facility may be used if full torque is only required occasionally.
3. *Boost current.* By using the boost facility the regulated current may be increased when extra torque is required, for instance during acceleration. The increased current during boost is limited to the peak output of the drive, therefore the maximum percentage increase in current depends on the regulated current. Resistor R11 on the 204 translator board determines the boosted current, and Table 3 shows the minimum value of R11 for given regulated currents.

If the boost facility is to be used frequently, consideration should be given to the resulting increase in motor dissipation; this may already be offset by standby periods (see Part 4), alternatively it may be possible to reduce the regulated current.
4. *Standby Current.* In most applications the torque required at standstill is much lower than when the motor is running, and the translator takes advantage of this by automatically reducing the motor current at standstill. The standby current is determined by R23 on the translator card (see Fig. 22) and the drive is normally supplied with R23 set to 3K3 which gives a standby current of about 25% of the regulated current. The value of R23 for a given standby current depends on the regulated current, and it is best determined experimentally using a current meter in series with one of the motor leads. Do not use a standby current greater than 50% of the regulated current. In certain applications it may be desirable to de-energise completely at standstill, provided that a possible loss of position is acceptable. This may be achieved by inserting Link 1 on the 204 translator board (see Fig. 22).

Table 3. Resistor values for regulated and boost currents – 204 translator.

VALUE OF R30	REGULATED CURRENT (ONE PHASE ON)		MINIMUM VALUE OF R11	MAX. % BOOST
	CA	CB, CC		
10K	8.3A	4.1A	82K	140%
15K	10A	5A	100K	100%
22K	11.4A	5.7A	150K	70%
47K	13.6A	6.8A	220K	50%
180K	15.1A	7.5A	390K	33%
Open Circuit	16.6A	8.3A	560K	20%

Note that the two-phase-on current (equivalent to the unipolar rating of the motor) is 70% of the value shown above.

The table shows the minimum permitted value of R11, and the corresponding percentage boost, for a given regulated current. For smaller percentage boosts, use the value of R11 shown opposite the required boost value.

Table 4. Resistor values for regulated current – 208 translator.

VALUE OF R82 and R83	REGULATED CURRENT (ONE PHASE ON)	
	CA	CB, CC
2K2	8.8A	4.4A
3K3	10.6A	5.3A
4K7	12.2A	6.1A
5K6	13.6A	6.8A
10K	15.2A	7.6A
15K	16.3A	8.1A

(see note under Table 3)

4.7.2 Additional information on setting up the 208 Multistep Translator. (To be read in conjunction with 4.7.1.)

1. *Motor resolution.* The 208 Translator may be specified with resolutions of either 400, 600, 800 or 1000 steps/rev. The adjustment of the step-division circuitry is not a task which can be readily undertaken by the customer, and should a change in resolution be required it is recommended that the board be returned to the manufacturer.
2. *Regulated Motor Current.* This is determined by R82 and R83 on the 208 board (see Fig. 23). Table 4 gives approximate resistor values for a range of motor currents. Note that both resistors must be of the same value.
3. *Boost current.* When boost is applied, the motor current increases to 20A (CA) or 10A (CB, CC).
4. *Standby current.* R5 and R6 on the 208 board determine the standby current (see Fig. 23). These resistors are normally set to 2K2 which typically reduces the motor current by about 50% at standstill. However, as in the case of the 204 translator, the resistance value for a given reduction depends also on the regulated current. Do not use a standby current greater than 50% of the regulated current. Insert Link 10 to completely de-energise the motor at standstill.

5. FAULT LOCATION

In the event of a fault occurring, first switch off the drive and carry out a visual inspection to ensure that all external connections are sound and tight. If all is in order, study the following list of fault symptoms and then follow the appropriate checking sequence. The possible causes marked * relate to systems with a built-in oscillator.

Table 5. Power Supply voltages

TEST POINT	NOMINAL VOLTAGE	
	CA, CB	CC
L1 – L2 Terminals *	172 AC	86 AC
+ HV Terminal	240 DC	120 DC
Control signal connector, terminal 5	+24 DC	+24 DC

DC voltages are with respect to 0v.

*On drives with 3-phase input, this voltage will also be measured across L2 – L3 and L1 – L3.

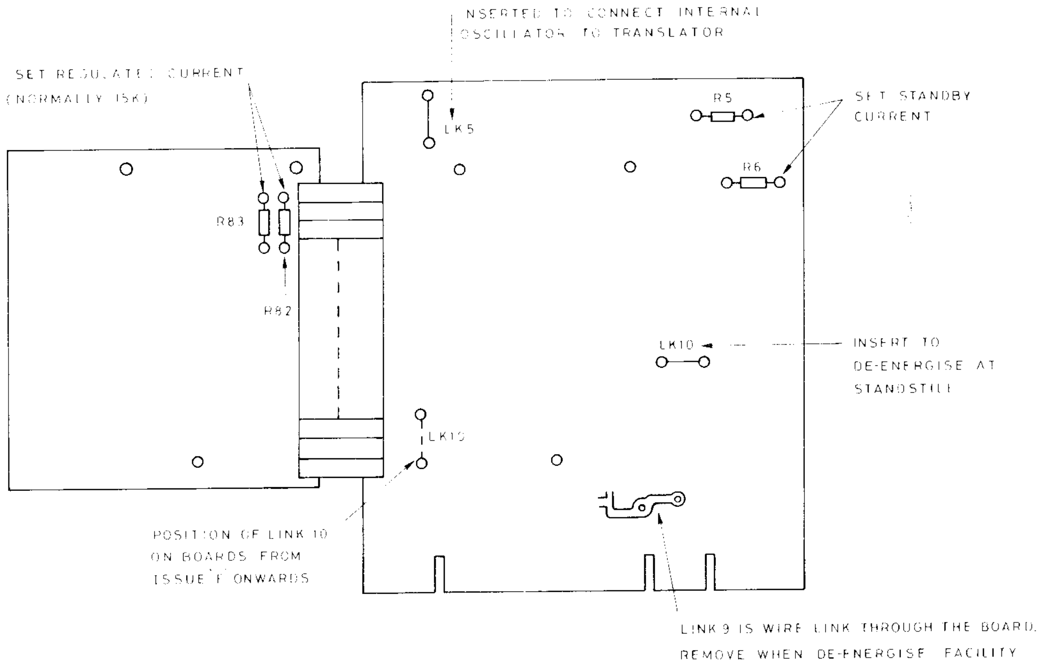


FIG 23 LINKS AND PRESET RESISTORS ON 208 TRANSLATOR

SYMPTOM	POSSIBLE CAUSE	ACTION
Motor fails to rotate but can be turned by hand. Green light not on.	AC supply failure.	Check incoming AC supply, mains fuses FS1, FS2 and FS3 (Where used).
	Power supply fault.	Check voltages at test points in Table 5. If incorrect, check fuses, bridge rectifiers and capacitors.
Motor fails to rotate but can be turned by hand. Green light on.	Energise input high or open-circuit.	Check (terminal 3).
	Motor windings or leads open circuit.	Check for continuity at the drive end (terminals 1A, 1B, 2A and 2B).
	Overload tripped (shown by LED on translator).	Switch off, disconnect motor, switch on. If LED stays off, check motor and wiring for shorts. If LED comes on again, drive is damaged.
	Drive card or translator fault.	Replace (see Note 1)
Motor fails to rotate and cannot be turned by hand.	Motor or load seized.	Switch off drive and check that motor shaft is free to rotate.
	No clock pulses.	Check for presence of clock pulses at terminal 7.
	Clock pulses inadequate.	Check that the clock pulse waveform is not more positive than +1V during the pulse and is at least +11 volts between pulses; check timing with information given on Page 26.
	* 'Limit' in operation, wrong direction request.	Check that the Direction Request Signal is correct to bring the system off limit.
	* Oscillator fault.	If there are no clock pulses at terminal 7, check that the input signals to the oscillator are correct. If so, oscillator is faulty.
	Drive card or translator fault.	Replace (see Note 1)
Motor buzzes but does not rotate.	One phase open-circuit.	Check for continuity between terminals 1A and 1B, and between 2A and 2B.
	Phase connections crossed.	Check as above.

SYMPTOM	POSSIBLE CAUSE	ACTION
Motor buzzes but does not rotate (contd.)	Excessive load	Switch off drive and check motor shaft free to rotate.
	Clock too fast.	Check that the initial clock rate is within the start/stop range (terminal 7).
	Acceleration rate too high.	Reduce acceleration rate (from control system or built-in oscillator) and re-check.
	Power supply fault.	Check voltages at test points in Table 5. If incorrect, check fuses, bridge rectifiers and capacitors.
	Control signal fault.	Check for abnormal input signals such as oscillating direction input.
	Resonance problem.	If possible, slightly raise or lower clock frequency and re-check.
	Boost input fault.	If the boost facility is being used, check that the Boost input goes low at the right time (terminal 2).
Motor runs wrong way.	Direction control incorrect.	Check at terminal 6 (or terminal 20 with built-in oscillator).
	Phase connections incorrect.	Interchange connections to one phase, eg. 1A and 1B.
Motor will only run at low speeds, stalls if speed increased.	Power supply fault.	Check power supplies as above.
	Boost input fault.	Check as above.
	Excessive load.	If system was previously operating correctly look for signs of increased loading, eg. bearings becoming tight.
	Acceleration rate too high.	Reduce acceleration rate and re-check.
	Drive card or translator fault.	Replace (see Note 1)
Motor runs up to high speed but then stalls.	Final clock rate too high.	Reduce maximum clock rate.
	Acceleration rate too high.	Reduce acceleration rate and re-check.
	Excessive load at high speed.	Check as above for tight bearings etc.
	Poor transformer regulation.	Check supply voltage on large terminal block when all axes loaded simultaneously.

SYMPTOM	POSSIBLE CAUSE	ACTION
Motor overshoots when coming to rest.	Deceleration rate too high.	Reduce deceleration rate and re-check.
Motor cannot be de-energised.	Energise input shorted to ground.	Check at terminal 3; check that appropriate link has not been inserted on translator.
Motor runs very hot.	Current levels too high for motor.	Consult motor manufacturer's data for motor current ratings and check that programming resistors are correct (see section 4.7)
	Unsuitable type of motor specified.	Refer to specifications (see section 3.1.).
	Boost permanently in operation.	Check that the Boost input (terminal 2) is not held low or shorted to ground.
	Standby circuit fault, or standby current too high.	If motor still hot after long period at standstill, connect current meter in series with one phase and check standby current. Check value of standby current resistors. (see 4.7.1. or 4.7.2)

Note: 1 The drive card and translator are interdependent and it is necessary to check both in the event of a failure. If no Switch and Translator Test Set is available, return the suspect units to Digiplan Ltd. or their local Agent.

6. MOTOR CONNECTION DATA

MAKE	SERIES				NOTES	PARALLEL				NOTES
	1A	1B	2A	2B	Isolate unused leads	1A	1B	2A	2B	Isolate unused leads
Evershed & Vignoles	Red	Grn	Blue	Yel	Brn & Blk N.C.	Red	Brn	Blue	Blk	Grn & Yel. N.C.
G.E.C.	1	2	3	4	5 & 6 Link 7 & 8 Link	1 & 6	5 & 2	3 & 8	4 & 7	
Sigma 6-Lead	Blk	Org	Red	Yel	Wht/Blk/Org Wht/Rd/Yel N.C.	Blk	Wh/Blk & Org	Red	Wh/Rd & Yel	Org & Yel. N.C.
8-Lead	Blk	Org	Red	Yel	Wh/Blk & Wh/Org Link Wh/Red & Wh/Yel Link	Blk & Wh/Org	Org & Wh/Blk	Red & Wh/Yel	Yel & Wh/Rd	
T-Box	1	3	2	4	5 & 6 Link 7 & 8 Link	1 & 5	3 & 6	4 & 8	2 & 7	
Slo-Syn Astrosyn Rapidsyn	Red 1	Red/Wh 3	Grn 4	Grn/Wh 5	Wh & Blk N.C. 2 & 6 N.C.	Red 1	Blk 6	Grn 4	Wh 2	Red/Wh Grn/Wh N.C. 3 & 5 N.C.
Step-Syn 6A	Blk	Grn	Red	Blue	(2 x Wh) N.C.	Blk	Wh	Red	Wh	Grn & Blue N.C. Use correct Wh common with relevant Blk or Red
6B	Gn/Wh 1	Grn 3	Red 4	Red/Wh 6	Wh. 2 & Blk 5 N.C.	Grn/Wh 1	Wht 2	Red 4	Blk 5	Grn & Red/Wh N.C. 3 6 N.C.
8A	Blk 1	Org 3	Red 2	Yel 4	Blk/Wh 6 & Org/Wh 5 Link Red/Wh 8 & Yel Wht 7 Link	Blk & Org/Wh 5 Link	Blk/Wh 6 & Org 3 Link	Red 2 & Yel/Wh 7 Link	Rd/Wh 8 & Yel 4 Link	
Zebotronics	1	4	5	8	2 & 3 Link, 6 & 7 Link	1 & 2	3 & 4	5 & 6	7 & 8	
Stebon	1	2	3	4	5 & 6 Link 7 & 8 Link	1 & 6	2 & 5	3 & 8	4 & 7	
M.A.E. 6-Lead	Gn/Wh	Grn	Red	Red/Wh	Wh & Blk N.C.	Grn/Wh	Wh	Red	Blk	Grn & Red/Wh N.C.
8-Lead	Blk	Org	Red	Yel	Wh/Blk & Wh/Org link Wh/Red & Wh/Yel link	Blk & Wh/Org	Org & Wh/Blk	Red & Wh/Yel	Yel & Wh/Red	
T-Box	6	5	8	7	1 & 3 link, 2 & 4 link	3 & 6	1 & 5	4 & 8	2 & 7	
Vactric Moore-Reed					Consult Manufacturers					

N.C. – Not Connected.

Note: If the wire colours on a particular motor do not agree with those shown above, consult the motor manufacturer's information.