DIGIPLAN

1054 Stepper Motor Drive

INSTRUCTION MANUAL

DIGIPLAN 1054 STEPPER MOTOR DRIVE

INSTRUCTION MANUAL

PREFACE

The 1054 Stepping Motor Drive offers a versatile package suitable for driving the majority of 4-phase stepper motors up to 250 watts shaft power. The techniques employed give an outstanding motor performance with high drive efficiency, and the various options 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 Ltd.

CONTENTS

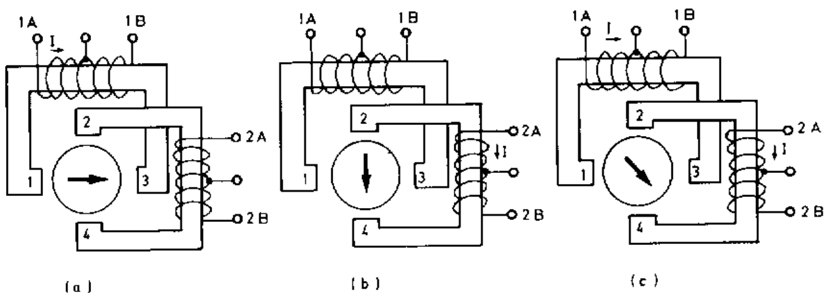
2. AN INTRODUCTION TO STEPPER MOTORS

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 1054 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,

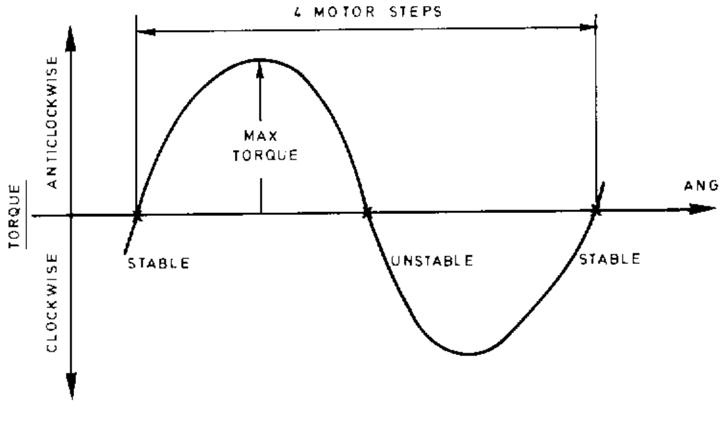
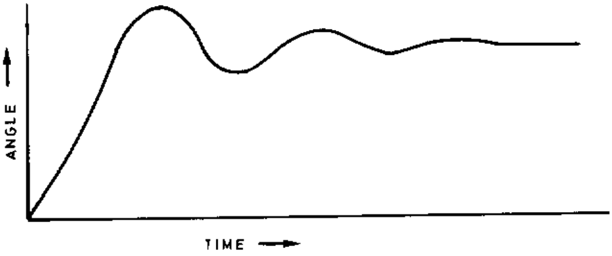


FIG. 2. TORQUE DISPLACEMENT CHARACTERISTIC

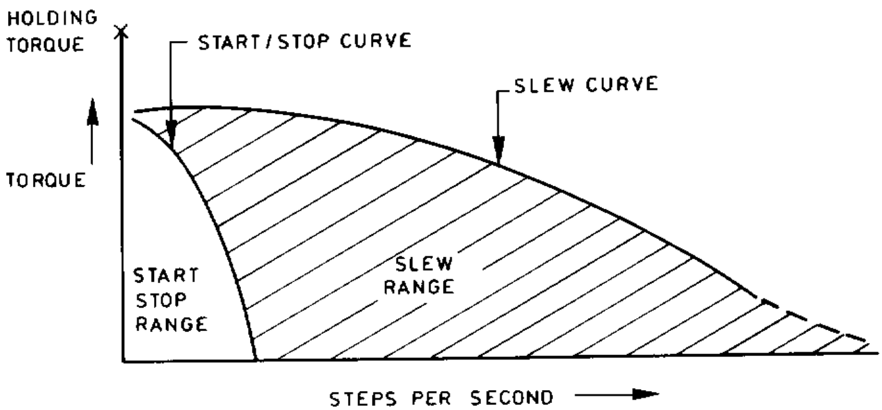


SINGLE – STEP RESPONSE FIG. 3.

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



START / STOP & SLEW CURVES FIG. 4

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.

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,

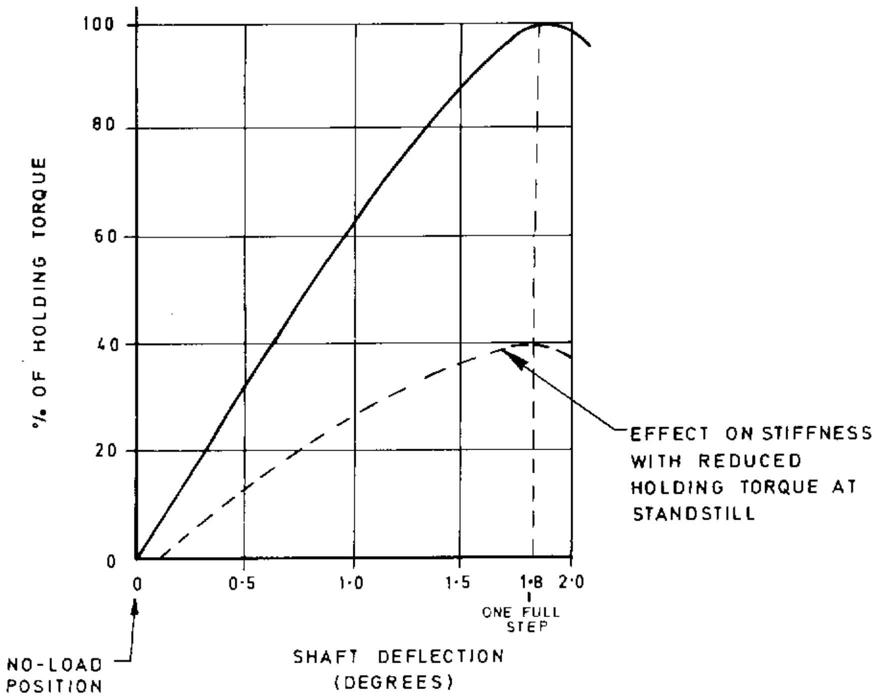


FIG. 5. TYPICAL STATIC TORQUE / DEFLECTION CURVE

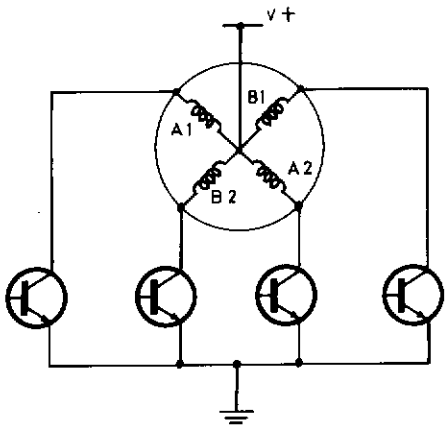
together with active current regulation as used in the 1054 Drive both result in a significant reduction in motor resonance phenomena.

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.

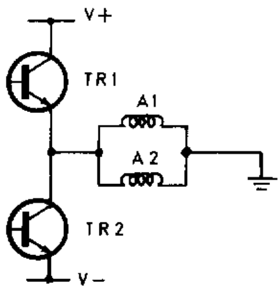
2.4 Drive Systems

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.



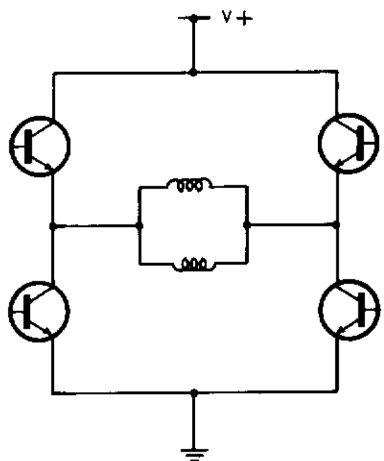
SIMPLE STEPPING-MOTOR DRIVE FIG.6.

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 1054 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.

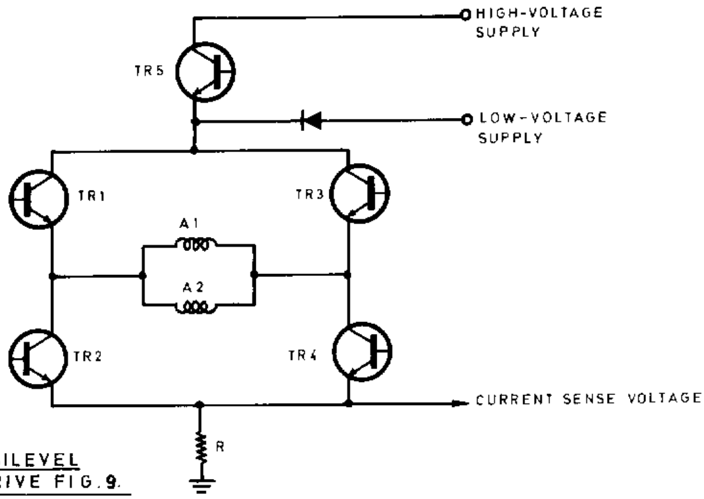


BIPOLAR BRIDGE DRIVE FIG.8.

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 bilevel drive system overcomes this problem by employing separate high and low voltage power supplies. When a coil is energised the high voltage is applied across the winding and this ensures a rapid build-up of current; when the current has reached a pre-determined level the high voltage supply is turned off and the coil current is maintained at the required value from the low voltage supply, enabling the dissipation within the drive to be kept to a minimum. The advantage of the full bridge configuration will now be apparent — for a given transistor collector voltage rating the windings may be driven at twice the voltage of the simpler bipolar arrangement with a corresponding improvement in high-speed performance.



BIPOLAR, BILEVEL BRIDGE DRIVE FIG.9.

Fig. 9 illustrates the extension of the bipolar bridge to bilevel operation. At the start of the step, transistor TR5 is turned on and this connects the bridge to the high-voltage supply. The voltage appearing across the sense resistor R gives a measure of the coil current, and when this has built up to the required value TR5 is turned off and the low-voltage supply takes over.

The combination of bipolar bridge with bilevel excitation results in a powerful system giving both high drive efficiency and excellent motor performance.

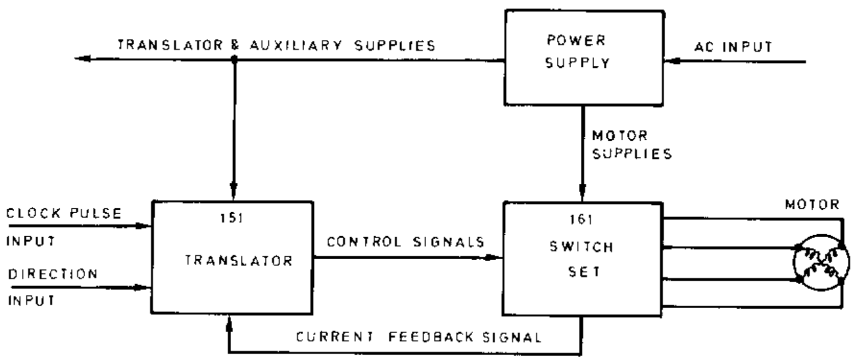
3. DESCRIPTION OF THE 1054 DRIVE

3.1 Specification

Drive Circuit:	Bipolar, bilevel bridge
Max. Power Output:	300 Watts.
Rated output current:	one phase on with boost 5.3A; two phases on with boost 4A/phase
Max. Motor Voltage:	10 volts (less than 5 volts recommended)
Max. Stepping Rate:	20,000 steps per second (400 steps/rev) 50,000 steps per second (1000 steps/rev)
Auxiliary Power Output:	+24V DC ± 20%, ½A maximum.
Supply Voltage:	100-125V or 200-250V, 40-60 Hz.
Supply Voltage Tolerance:	± 10%
Power Consumption:	350 VA fully loaded.
Dimensions:	12" (305mm) long x 6" (152mm) wide x 5¼" (133mm) high.
Weight:	16 lbs (7.25 Kg).
Operating Temperature Range:	0°C to 40°C local ambient.

3.2 General Description

Fig. 10 shows the main components of the 1054 system – the translator, switch set and power supply. An optional oscillator card may be included and this will be considered later.



1054 DRIVE SYSTEM FIG.10.

Figs. 11 and 12 show the physical layout of the drive and the location of the main components. The 161 switch set has an integral heat sink and forms the left-hand side of the drive assembly. The translator and optional oscillator cards plug into the 168 mother board which incorporates a 24-volt power supply. The main power supply and power dump circuits make 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 switch set 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.

The switch set 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, bilevel switching circuitry mentioned in Section 2.4.

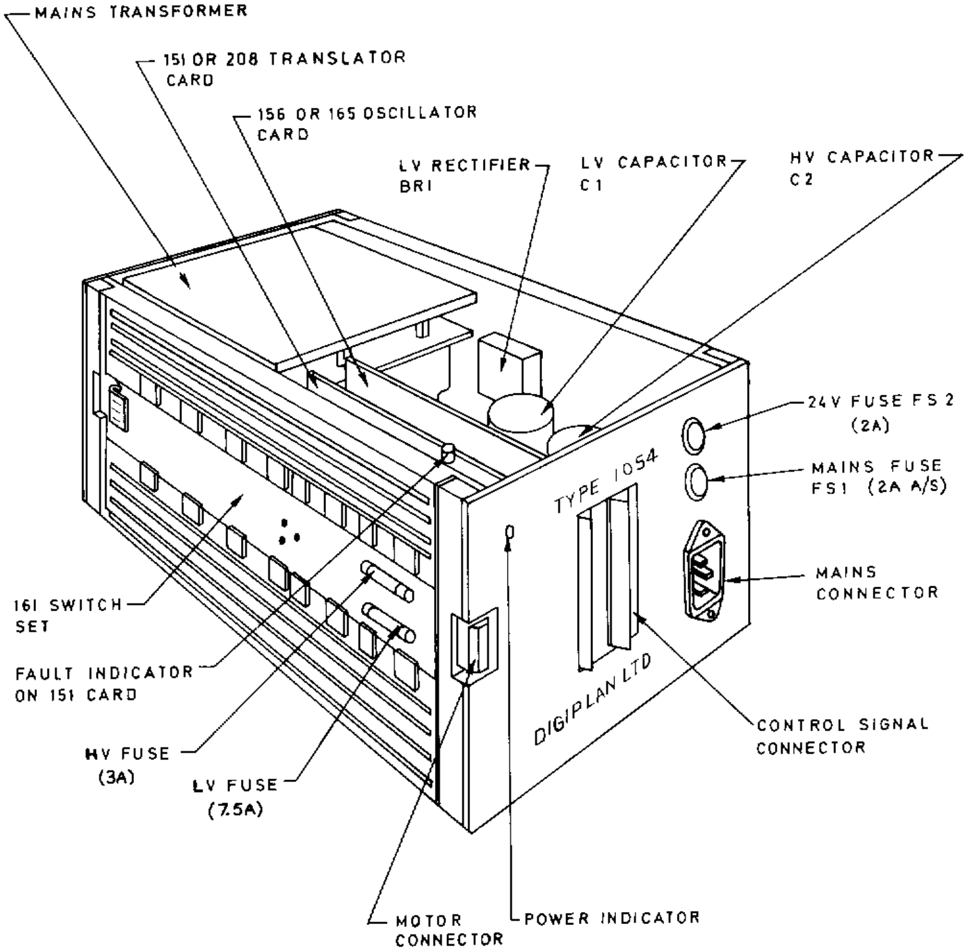


FIG.11. MAIN DRIVE COMPONENTS, L.H. SIDE

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 switch set.

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

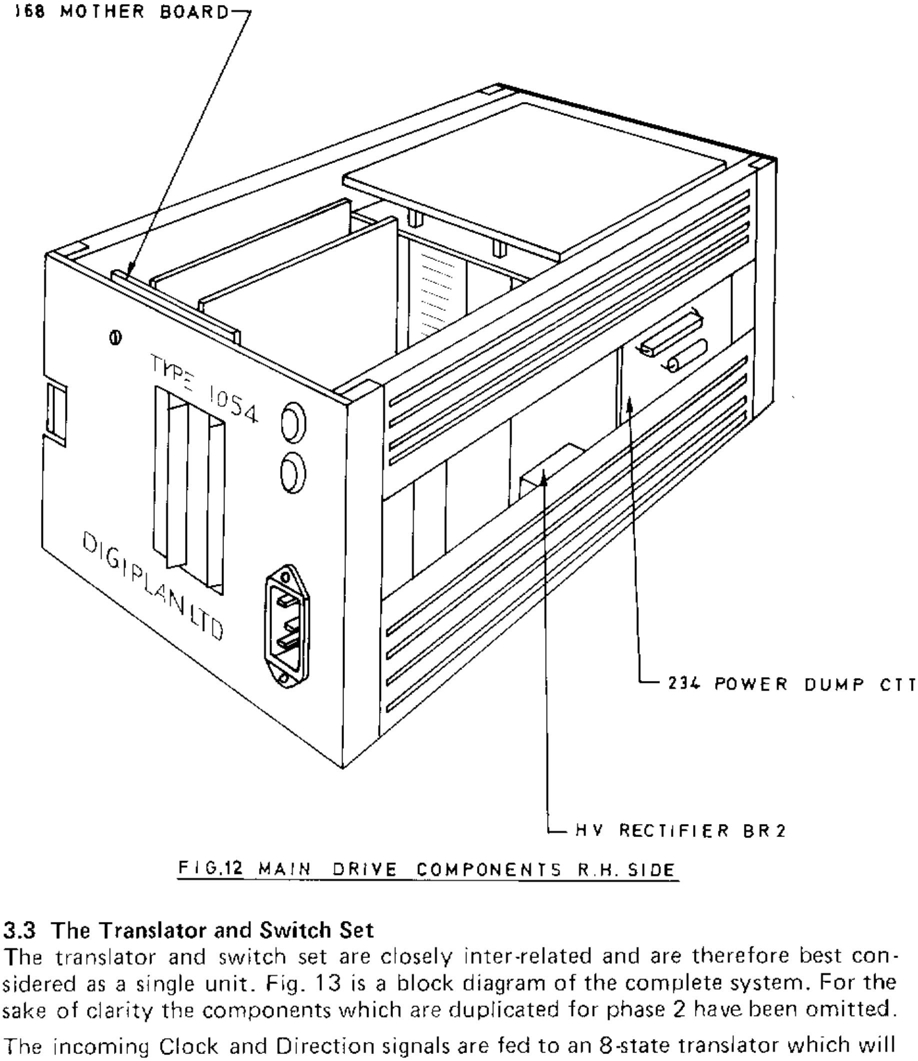
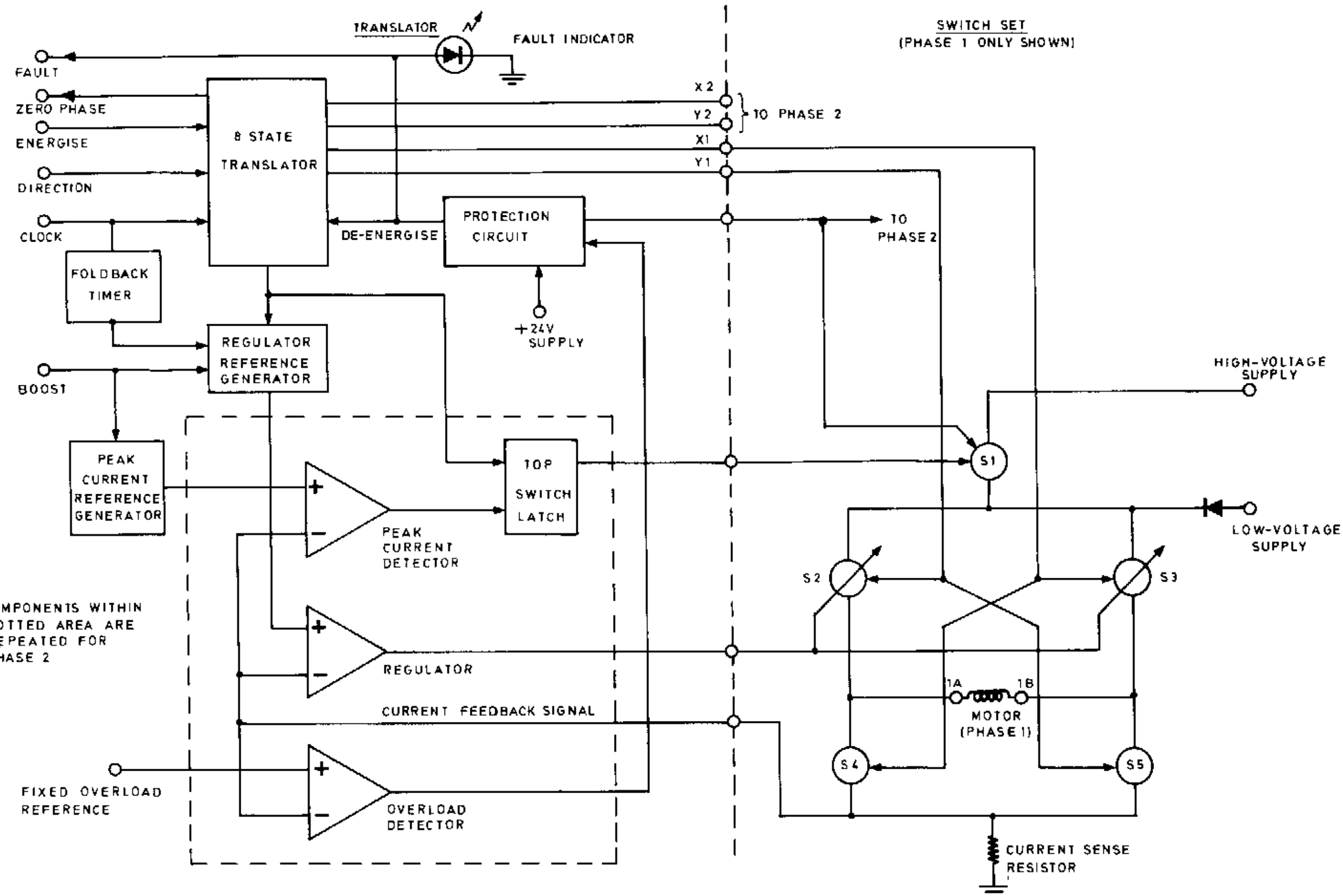


FIG.12 MAIN DRIVE COMPONENTS R.H. SIDE

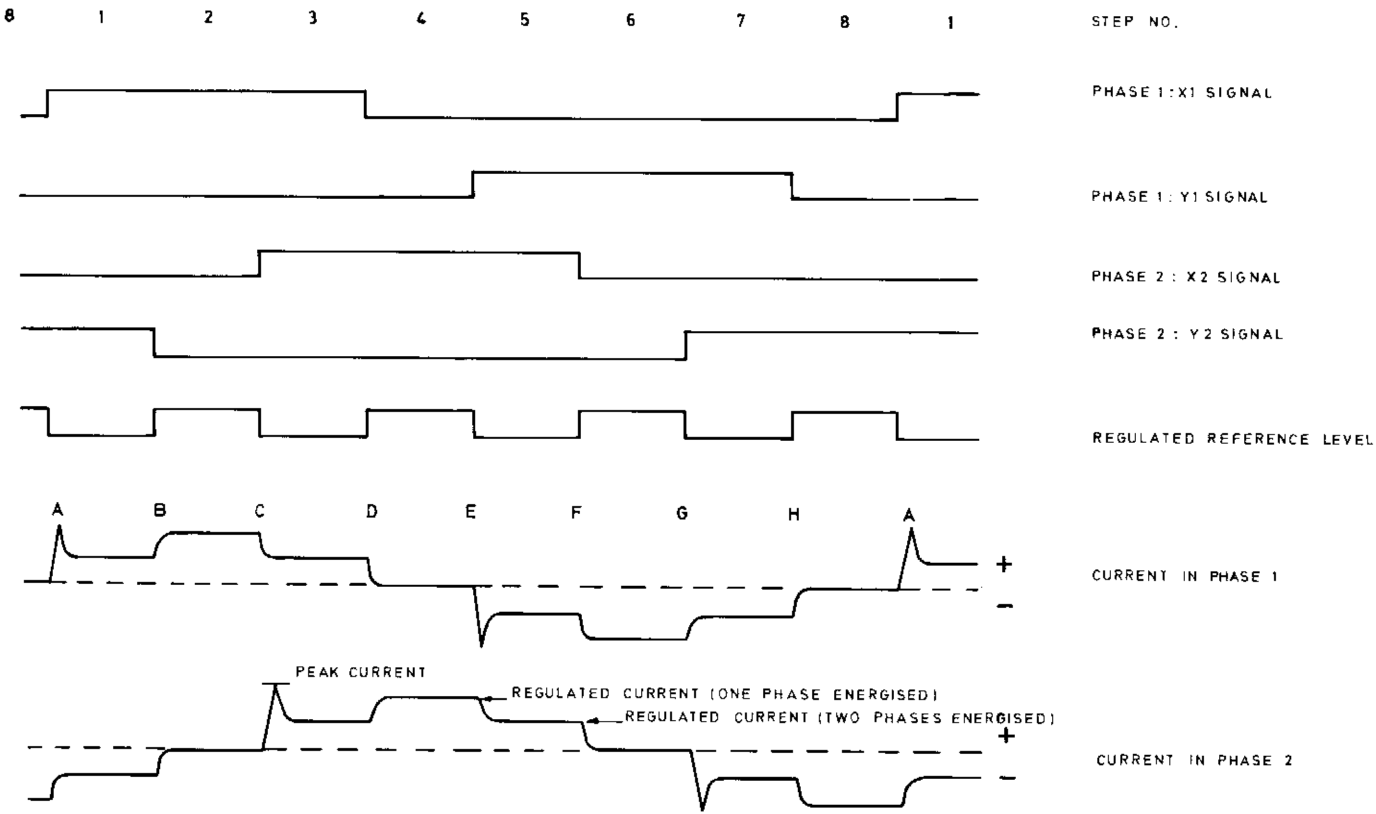
3.3 The Translator and Switch Set

The translator and switch set are closely inter-related and are therefore best considered as a single unit. Fig. 13 is a block diagram of the complete system. For the sake of clarity the components which are duplicated for phase 2 have been omitted.

The incoming Clock and Direction signals are fed to an 8-state translator which will produce 400 steps/rev. with the usual 200 step/rev. motor. The translator generates the timing waveforms shown in Fig. 14 and it will be seen that the phases are alternately energised 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



TRANSLATOR & SWITCH SET BLOCK SCHEMATIC FIG. 13.



TIMING WAVEFORMS FIG.14.

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 20,000 steps/second in the 400 steps/rev. mode or 10,000 steps/second in the 200 step/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 phase are five power switches S1 to S5 as shown in the diagram. All five switches may be operated as straightforward on-off devices, but in addition S2 and S3 function as linear control elements, in other words the device behaves like a variable impedance in order to regulate the phase current. The timing waveforms are taken to the four main power switches S2 – S5 which are interconnected in pairs as shown. When X1 is high, current will flow through S3, through the motor winding from 1B to 1A, then via S4 and the sense resistor to ground. Similarly when Y1 is high, current flows through S2, through the winding in the opposite direction from 1A to 1B, through S5 and the resistor to ground. When both X1 and Y1 are low there is no current in the winding. When the Energise input to the translator is taken high, all X and Y signals from the translator are forced low regardless of the state of the translator, thus no current flows in either of the windings and the motor is de-energised.

Whenever current must be established in a new direction in the winding, as at points A and E on the timing diagram, the bilevel switching system is brought into operation. A separate output from the translator sets the top switch latch at the appropriate points in the sequence, and this turns on the high-voltage switch S1. The high voltage supply will now appear across the winding and produce a rapid build-up of current which is monitored by the peak current detector. When the current has reached the required value, determined by the peak current reference generator, the top switch latch is reset and S1 is turned off. At this point the low-voltage supply takes over and the motor current comes under control of the regulator.

The regulator compares the current feedback voltage (developed across the sense resistor) with a voltage from the regulator reference generator. The resulting error signal is taken to the linear control inputs of S2 and S3 (of which only one will be conducting) and thereby regulates the current flowing in the windings. It will be seen from the timing diagram that a larger current flows when only one phase is energised in order to 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).

Both the regulator and peak current reference levels may be modified by means of the boost input. This enables either or both of the current levels to be increased at strategic times when extra torque is required, or 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

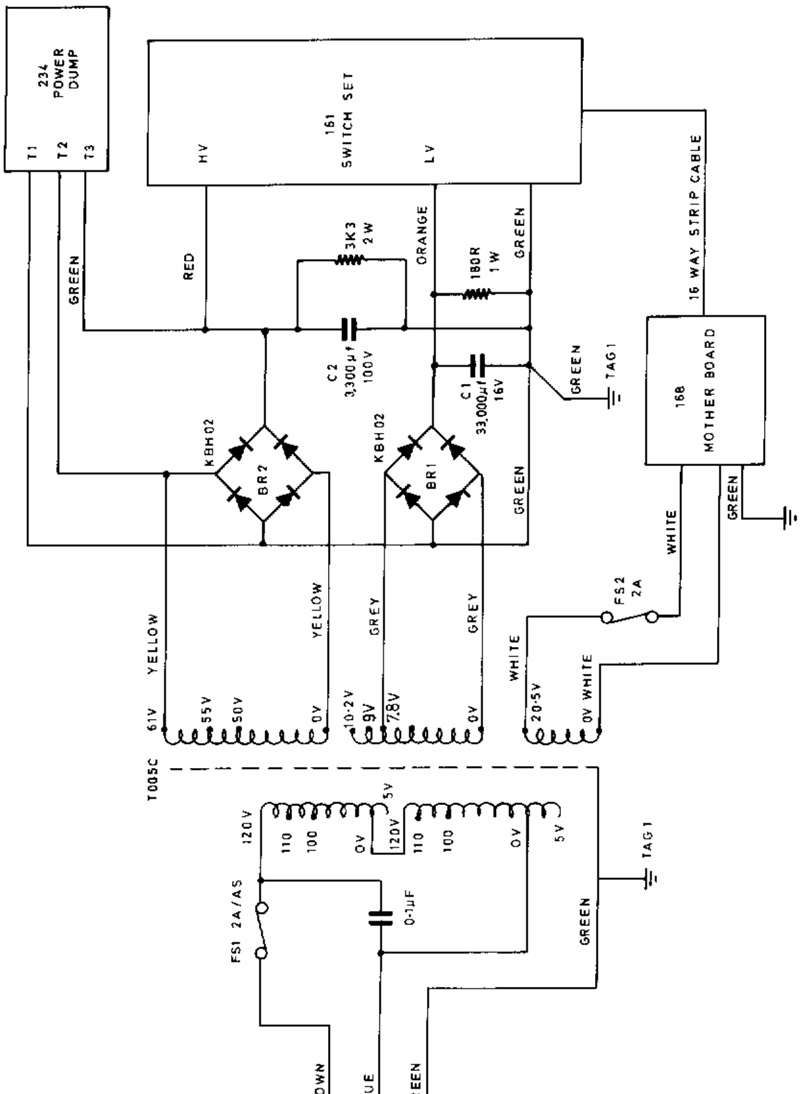


FIG.15. POWER SUPPLY CIRCUIT

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. peak, regulated, boost and standby) are programmable by means of resistors on the translator board. Tables 3—6 give values of the programming resistors for a range of operating currents.

The translator board also incorporates circuitry to protect the switching components against excessive motor current or power supply failure. An overload detector monitors the motor current against a fixed reference, and in the event of excessive current flowing it de-energises the four power switches S2 — S5 and inhibits operation of the high-voltage switch S1. An L.E.D. on the translator board gives a visual indication of this condition and a fault signal is available for use by the control system. The protection circuit can only be reset by disconnecting the mains supply, and power should only be re-applied after 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.

See Appendix 1 for details of the 208 Multistep Translator Option.

3.4 The Power Supply

The circuit of the 350-watt power supply is shown in Fig. 15. It generates the high and low voltage rails for the switch set and also a separate logic supply.

A 20.5-volt winding on the mains transformer feeds the 168 Mother Board which incorporates a rectifier and smoothing capacitor for the +24V supply (see Fig. 16). 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.

The low-voltage supply for the 161 switch set is derived from a 7.8-volt winding on the transformer via rectifier BR1 and capacitor C1. The winding has alternative tappings which may be required with high-voltage motors or when very long motor leads are used. The higher tappings should not be used unnecessarily as the drive dissipation will be increased.

A 61-volt transformer winding provides the high voltage for the switch set via rectifier BR2 and capacitor C2, the nominal supply voltage being 85 volts. Across this rail is connected the 234 Power Dump circuit which protects the drive during rapid deceleration of the motor. When the motor is running at high speed there is energy stored in the rotor which must be dissipated during deceleration, and if an inertial load is being driven this will also have stored energy. During the deceleration period the motor therefore behaves as a generator and pumps power back into the drive, which has the effect of raising the high-voltage rail. If the deceleration rate is very high the increase in rail voltage may be considerable and cause the power switches to break down. The regenerative power dump 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.

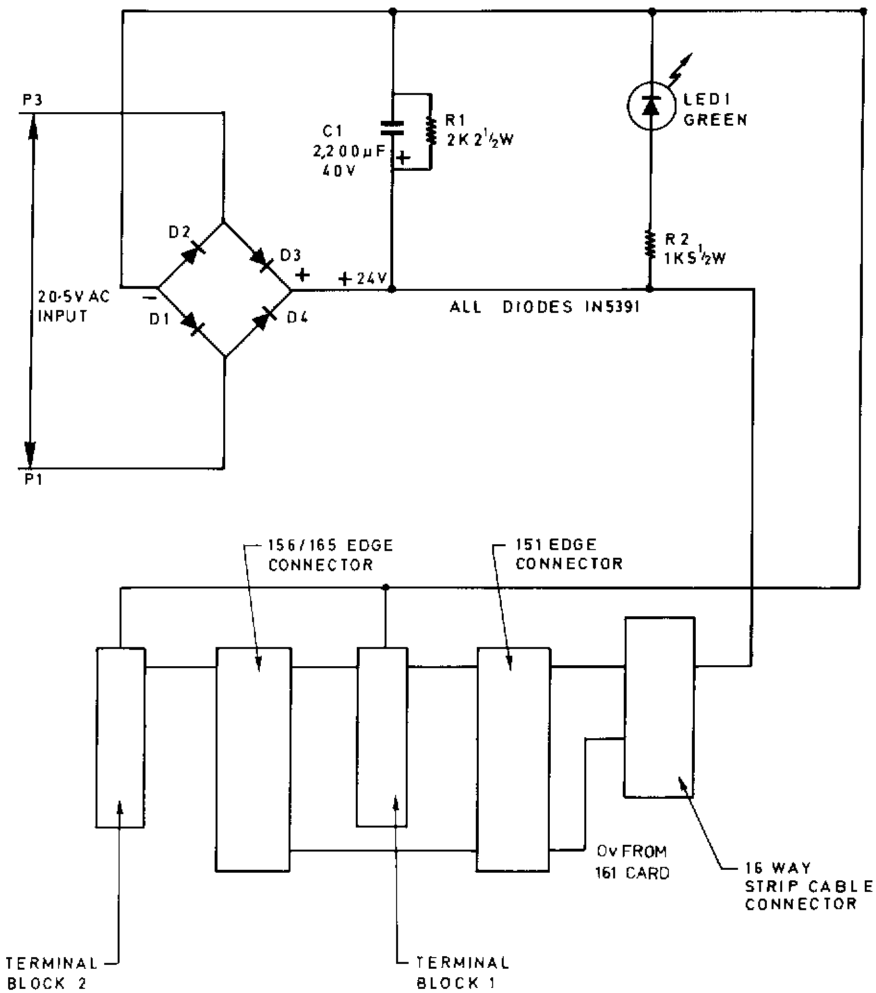


FIG.16. 168 MOTHER BOARD SCHEMATIC

3.5 Oscillator Options

Digiplan currently manufacture two types of oscillator card which may be plugged directly into the 1054 drive. They simplify the problem of generating clock pulse sequences which will run the motor up to its maximum speed without loss of synchronism.

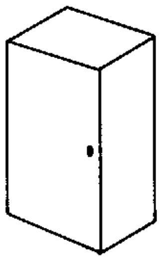
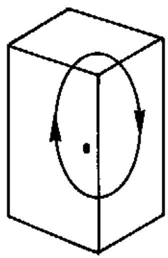
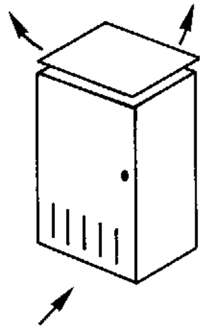
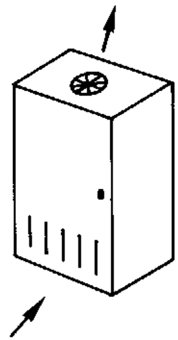
ENCLOSED		VENTILATED	
NO INTERNAL FAN	FORCED CIRCULATION BY INTERNAL FAN	THROUGH VENTILATION BY NATURAL CONVECTION	THROUGH VENTILATION BY FAN
			
UP TO APPROX 175 W LOCALISED HEATING MAY BE HIGH AT TOP OF CUBICLE	UP TO APPROX 350 W FORCED CIRCULATION MINIMISES LOCAL HEATING	UP TO APPROX 500 W WITH AIR SLOTS TOTALLING $0{\cdot}3\,m^2$ AREA	UP TO APPROX 2000 W ACCORDING TO TYPE OF FAN AND FILTER USED

FIG. 17 HEAT DISSIPATION FIGURES FOR A TYPICAL FREE-STANDING ENCLOSURE 600 X 600 X 1500 mm. MAX. TEMP. RISE 25°C

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 included with the drive, the appropriate instruction manual will be supplied.

4. INSTALLATION

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

$$W = 0.9T + 32$$

where W is the dissipated power in watts and T is the difference between the 161 power-card heatsink and ambient temperatures in degrees Centigrade. The equipment is designed for a maximum operating heatsink temperature of 80°C, 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. 17 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 spacing of 3" (75mm) between units. Tapped fixing holes are provided in the base of the unit as shown in Fig. 18 and it is envisaged that the fixing screws will normally pass through rails underneath the drive. Other mounting orientations are permissible but it is advisable to keep the heatsink in a vertical plane, i.e. it shoud not form the top or bottom surface of the drive when mounted.

b) Where there is a 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 both

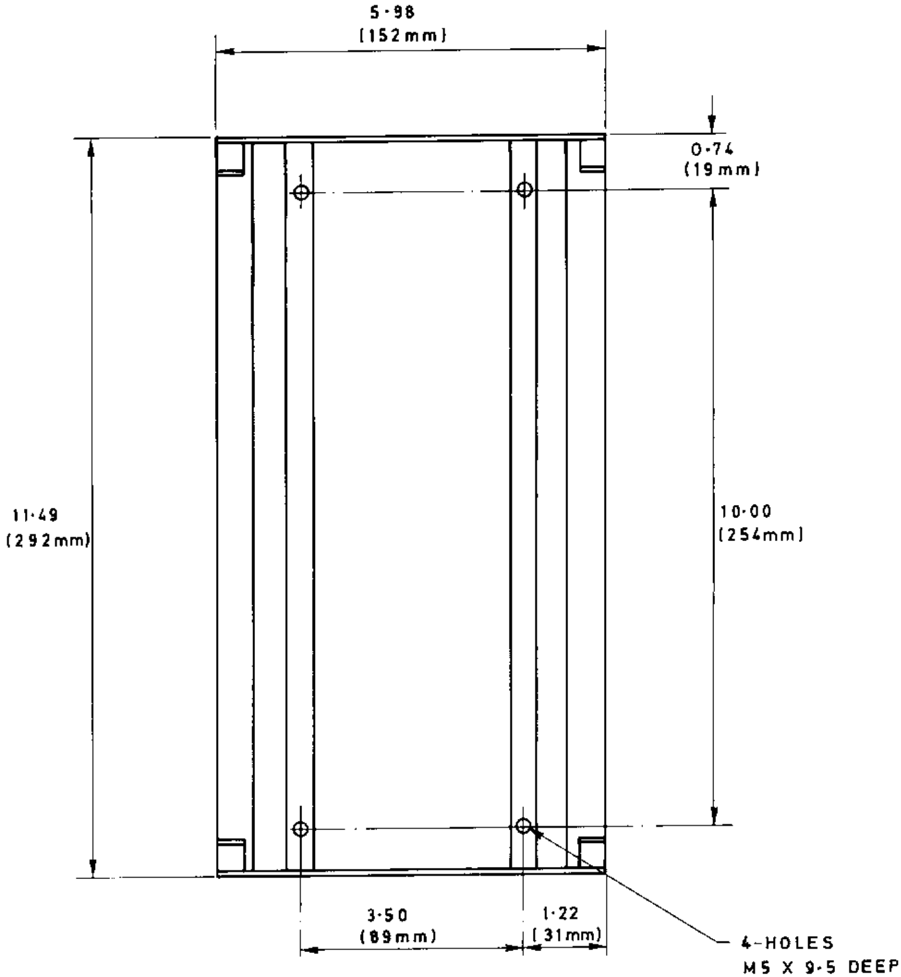


FIG.18. LOCATION OF MOUNTING POINTS

the top and the heatsink side 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.

4.2 AC Supply Connections

Units are normally wired for operation from a 240-volt supply. If the nominal supply voltage differs from this by more than 10 volts, refer to Table 1 which shows the mains transformer connections for various voltages. Select the nearest voltage to the local supply and reconnect the leads accordingly, referring to Fig. 19 which shows the transformer terminal positions. Note that the 0.1 μF filter capacitor should be connected to the same terminals as the brown and blue leads. Ensure that the transformer cover plate is replaced after changing connections.

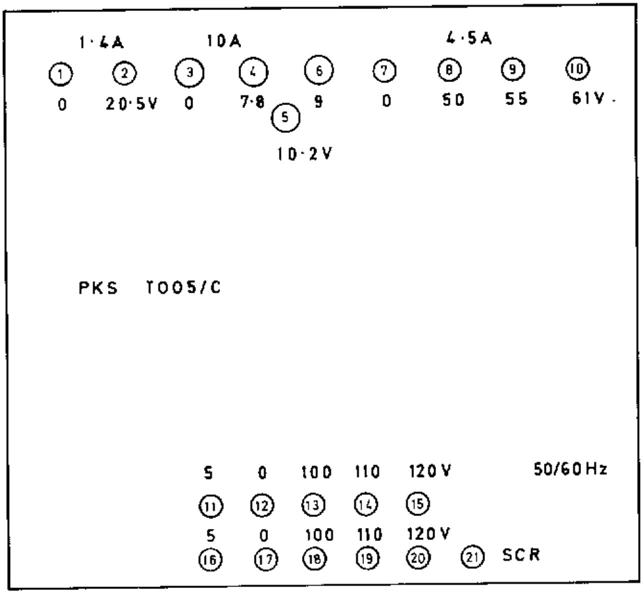


FIG.19. MAINS TRANSFORMER TERMINAL LAYOUT

If the drive is to be operated from a supply in the 100-125 volt range, the mains fuse FS1 (see Fig. 11) should be replaced by one of 5-amp rating. The fuse is a 20mm semi-delay type. A unit which has been reconnected for this voltage range should be suitably identified to minimise the risk of damage should it become necessary to return it for repair.

Cable used for connecting the AC supply should be of nominal 5-amp rating such as 24/0.2 or similar. Ensure that there is a sound earth connection and that any metalwork to which the drive is attached is separately earthed.

The maximum input power to the unit is 350 watts. This figure should be used when assessing overall system power requirements and fuse ratings.

TABLE 1. Mains Transformer Connection Data

Nominal Supply Voltage	*Brown Wire*	*Blue Wire*	*Link*
100	13	17	12&17; 13&18
105	13	16	11&16; 13&18
110	14	17	12&17; 14&19
115	14	16	11&16; 14&19
120	15	17	12&17; 15&20
125	15	16	11&16; 15&20
200	13	17	12&18
210	13	17	12&19
220	14	17	12&19
230	14	17	12&20
240	15	17	12&20
250	15	16	11&20

NOTE: 0.1μF capacitor should be connected to the same terminals as the brown and blue leads.

4.3 Motor Connections

Four connections are required between the motor and the short terminal block 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. In the series mode the phase resistance will be increased, and if this amounts to more than 0.75 ohm the low-voltage transformer tapping will have to be raised. Refer to Section 4.6.2.

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 horsepower obtainable from the motor is greater in this mode.

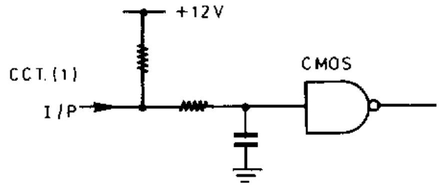
Two motors may be driven in synchronism by connecting the corresponding windings in series. The motors should be of the same type and may deliver up to 100 watts each.

Wire used for the interconnections between motor and drives should generally be not less than $0.75mm^2$ in area; 24/0.2 stranded cable is recommended. 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.

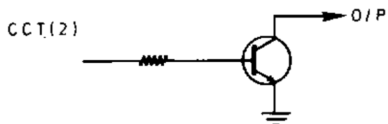
It is most important that any unused motor leads are individually insulated, and under no circumstances should they be joined together unless this is specified in the motor connection data. Do not attempt to use a 5-lead motor with this drive.

4.4 Control Signal Connections

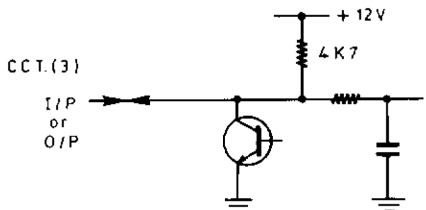
The main part of this section lists the low-level signals appropriate to the basic drive with translator; those which relate to the optional clock cards are shown in the relevant manual. Fig. 20 shows the interface circuits used on the drive and these should provide sufficient information for the signal 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 system are housed separately, it will normally



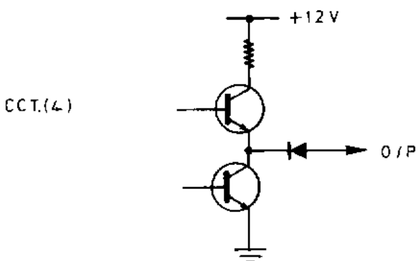
IMPEDANCE TO +12V IS GREATER THAN 4K(A) OR 1K(B)
LOGIC HIGH = +11 TO +13
LOGIC LOW = 0V TO +1V



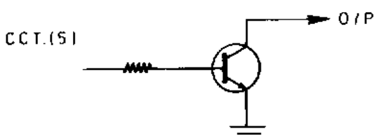
LOGIC HIGH = O/C (30V MAX)
LOGIC LOW = 1V MAX AT 30mA



LOGIC HIGH = +11 TO +13V
LOGIC LOW = 1V MAX AT 15mA



LOGIC HIGH = O/C (12V MAX)
LOGIC LOW = 1V MAX AT 30mA



LOGIC HIGH = O/C (30V MAX)
LOGIC LOW = 1V MAX AT 15mA

FIG. 20 INTERFACE CIRCUITS USED INTERNALLY ON DIGIPLAN DRIVES 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 one 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. 20). 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 $\overline{\text{Motor Clock In}}$ will respond to a 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. 20 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. $\overline{\textit{Boost}}$. Taking this input low (i.e. short-circuiting it to Ov) increases the peak, regulated and standby currents. The amount by which these currents are increased is programmable by means of resistors R4 and R5 on the 151 translator board; refer to Tables 5 and 6 for information on the programming resistor values.

3. $\overline{\textit{Energise}}$. 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 overridden 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. Link 3 on the 151 translator board is normally inserted to hold this input permanently low and it must be removed if the de-energise facility is required (see Fig. 21)

4. $\overline{\textit{Zero Phase}}$. 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 module. The current drawn should not exceed 500mA.

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

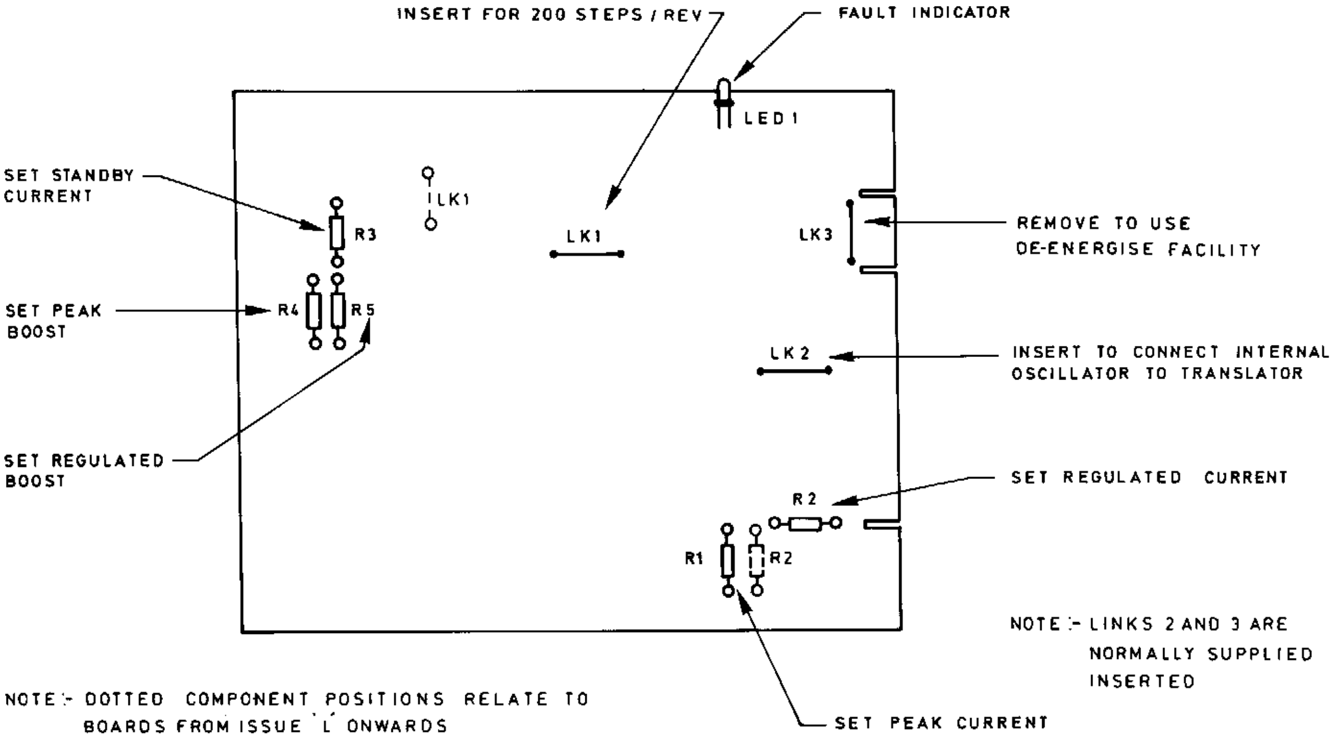


FIG. 21. LINKS AND CURRENT — DETERMINING RESISTORS ON 151 TRANSLATOR

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. The input should remain at logic 0 for not less than 5μS and not more than 30 μS and another low-going pulse should not occur within 50 μS (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. Note that the clock frequency must be ramped if speeds within the motor slew range are required.

13. Fault. Operation of the overload cutout 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.

TABLE 2. Connections for basic drive with translator

Function	*Terminal Strip Number*	*Interface Circuit (See Fig. 20)*
Ov	1	–
Boost	2	1A
Energise	3	1A
Zero Phase	4	2
+24V	5	–
Motor Dirn	6	1A
Motor Clock In	7	1A
Fault	13	5

4.5 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 almost certainly result in permanent damage.

1) Check that the AC supply voltage is correct. Units are normally supplied wired for 240-volt operation; for use on other supply voltages refer to section 4.2. and ensure that if necessary the correct replacement fuse has been fitted.

2) Check that there are no short circuits between any of the motor connections. With low-impedance motor windings this may be difficult, and in this case 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 1054 they must be kept separate. Note that 5-lead motors are not suitable for use with this drive.

4) Check that ALL unused motor leads are individually insulated and suitably anchored mechanically.

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

6) Check 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 4.6.

7) Ensure that the printed circuit cards are firmly located in their sockets, that the 16-way strip connector between translator and switch set is intact and that all external connections to the unit are sound and tight.

8) Before applying power to the drive, remove the high-voltage fuse from the 161 switch set (see Fig. 11). Switch on the drive and check that the motor rotates correctly at low speeds. This checks that the wiring is correct with minimum risk to the drive. If all is well, switch off the drive and refit the high-voltage fuse. The system is now ready to be checked over the full operating range and set up as necessary.

4.6 Setting Up

The drive as supplied will be found suitable for the majority of small motors, 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 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.

1. Motor Resolution. The 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 1 on the 151 translator board (see Fig. 21). Note that the maximum obtainable RPM is unaffected by the stepping mode, so at 200 steps/rev. the maximum stepping rate is halved.

2. Low-voltage Transformer Tapping. The drive is usually supplied with the low-voltage supply connected to the 7.8-volt transformer tapping (terminal 4 – see Fig. 19). This will be adequate when the voltage across each motor phase is less than about 3 volts at full current. If the motor phase voltage is between 3 volts and 4 volts, transfer the grey wire from terminal 4 to terminal 6 (9-volt tapping). If the phase voltage is between 4 volts and 5 volts, transfer the wire to terminal 5 (10.8-volt tapping). Motors with a phase voltage between 5 volts and 10 volts may be used with the 1054 but the best performance will not be achievable. If long motor leads are used with a significant resistive loss it may also be necessary to select a higher tapping. Do not use a higher tapping unnecessarily as the drive dissipation will be increased.

3. Regulated Motor Current. This is determined by resistor R2 on the 151 translator card (see Fig. 21) and Table 3 gives approximate resistor values for a range of motor currents. The motor manufacturer's current rating may be used as a guide when selecting the regulated current. Unless otherwise stated the rated current per phase normally refers to unipolar operation with two phases energised. With a bipolar drive the maximum current rating 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% of the unipolar 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 unipolar rating. 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.

4. Peak Motor Current. Resistor R1 on the translator controls the peak motor current, i.e. the current at which the high-voltage drive is switched off and the current falls to the regulated value. Table 4 gives the current levels corresponding to different values of R1. A suitable value for the peak current is normally about 50% higher than the regulated current. As before, the dissipation and resonance effects may be minimised by reducing the peak current where possible.

5. Peak and Regulated Boost Currents. By using the Boost facility the peak and regulated currents may be increased when extra torque is required, for instance during acceleration. Resistors R4 and R5 on the translator board determine the boosted peak and regulated currents respectively, and Tables 5 and 6 give resistor values for various percentage boost levels. It is not normally necessary to change the ratio of peak to regulated current when the boost is in operation, so the percentage boost will generally be similar for each. 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 6), alternatively it may be possible to reduce the regulated current.

6. 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 R3 on the translator card (see Fig. 21) and the drive is normally supplied with R3 set to 4K7 which gives a standby current of about 1 amp with a regulated current of 3 amps. The value of R3 for 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. Note that if R3 is left out altogether the standby current becomes the same as the regulated current, but this will result in a holding torque some 40% greater than the maximum running torque and this is seldom needed.

TABLE 3. Value of R2 for various regulated currents.

Regulated current (amps), two phases on	*Maximum phase current, one phase on*	*R2*
0.8	1.1	3K3
1.2	1.6	5K6
1.5	2.0	8K2
2.0	2.8	18K
2.5	3.5	47K
3.1	4.1	open-circuit

TABLE 4. Value of R1 for various peak currents

Peak current (amps)	*R1*
1.7	5K6
2.1	8K2
2.7	15K
3.1	22K
3.7	47K
4.3	open-circuit

TABLE 5. Value of R5 for various degrees of regulated boost.

Approximate increase in regulated current	*R5*
10%	1M5
20%	820K
30%	560K

TABLE 6. Value of R4 for various degrees of peak boost.

Approximate increase in peak current	*R4*
10%	1M5
20%	820K
30%	560K

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, that the cards are all securely located and that the 16-way strip connector between translator and switch set is properly fitted. 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 7. Power supply voltages (relative to Ov.)

Test Point	*Nominal Voltage*
C1 positive terminal	+9V (using 7.8 volt tapping.)
C2 positive terminal	+85V
Control signal connector terminal 5	+24V

Refer to Fig. 11 for test point locations.

SYMPTOM	*POSSIBLE CAUSE*	*ACTION*
Motor fails to rotate but can be turned by hand.	AC supply failure.	Check incoming AC supply, mains fuse FS1.
	Power supply fault.	Check voltages at test points in Table 7. If incorrect, check fuses, bridge rectifiers and capacitors.
	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.
	Switch set or translator fault.	Replace (see Note 1).
Motor fails to rotate and cannot be turned by hand.	Motor or load siezed.	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 stays low for at least 5μS, is not more positive than +1V during the pulse and is at least +11 volts between pulses.
	*'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.
	Switch set 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.

SYMPTOM	*POSSIBLE CAUSE*	*ACTION*
	Phase connections crossed	Check as above
	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 7. 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.
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, e.g. 1A and 1B.
Motor will only run at low speeds, stalls if speed increased	High-voltage supply fault	Check power supplies 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.
	Switch set 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.

SYMPTOM	*POSSIBLE CAUSE*	*ACTION*
	Acceleration rate too high	Reduce acceleration rate and re-check.
	Excessive load at high speed	Check as above for tight bearings etc.
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 link 3 has been removed 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 4.6.)
	Unsuitable type of motor specified.	Refer to specifications (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	If motor still hot after long period at standstill, connect current meter in series with one phase and check standby current. Check value of R3 (see section 4.6.)

Note 1: The switch set 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 cards to Digiplan Ltd. or their local Agent.

6. MOTOR CONNECTIONS BIPOLAR DRIVES

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 3 6 (not used)
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	
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.

APPENDIX 1. 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.

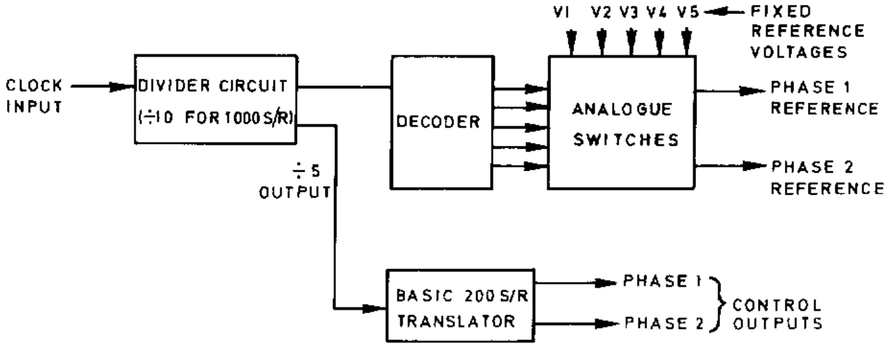


FIG. 22 STEP DIVIDE CIRCUITRY

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 sub-division 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. 22 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 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. 23. 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. 23. 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.

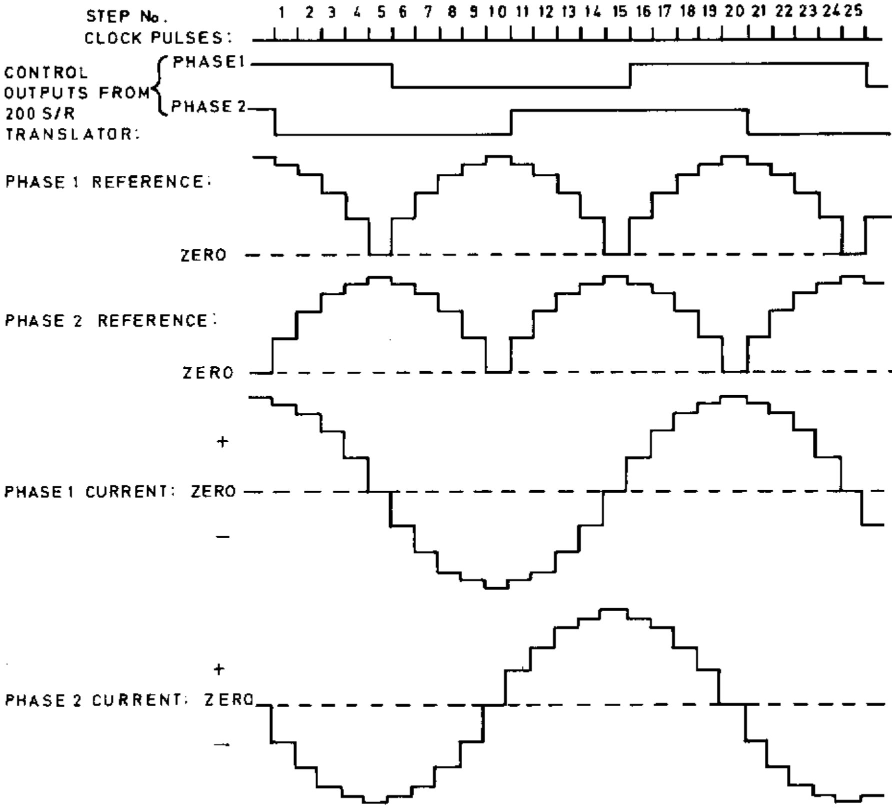


FIG. 23 MULTISTEP TRANSLATOR WAVEFORMS (1000 STEP/REV.)

Setting up the 208 Translator

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. 24). Table 8 gives approximate resistor values for a range of motor currents (note that both resistors must be of the same value). With this translator the peak current is the same as the regulated current.

3. Boost current. When boost is applied, the one-phase-on regulated current is increased to 5.3A.

4. Standby current. R5 and R6 on the 208 board determine the standby current (see Fig. 24). 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 151 translator, the resistance value for a given reduction depends also on the regulated current. Insert link 10 to completely de-energise the motor at standstill.

TABLE 8. Resistor values for regulated current – 208 translator.

Value of R82 & R83	*Regulated Current (one phase on)*
2K2	2.4A
3K3	2.9A
4K7	3.4A
5K6	3.8A
10K	4.2A
15K	4.5A

Note that the RMS regulated current (equivalent to the unipolar rating of the motor) is approximately 70% of the value shown in the table.

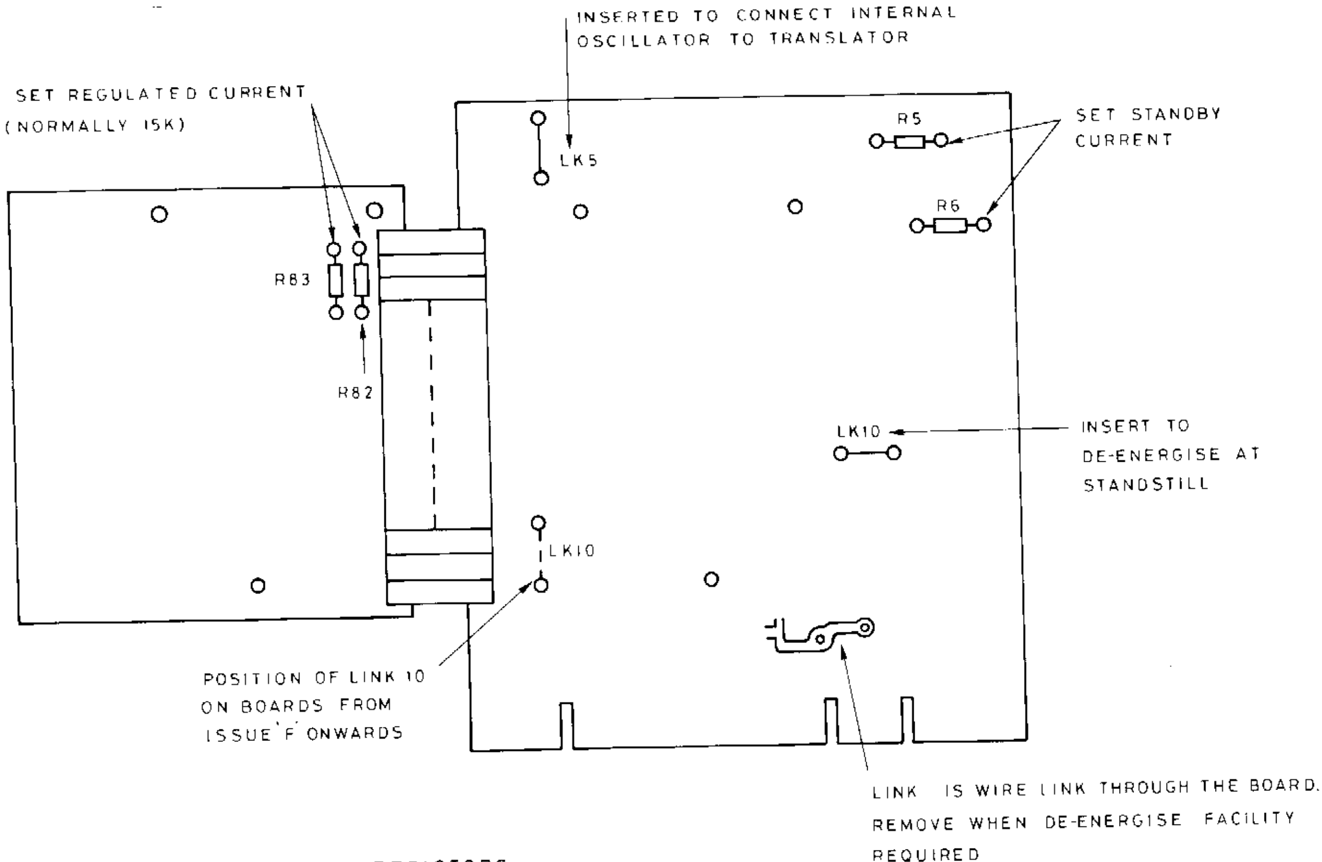


FIG. 24 LINKS AND PRESET RESISTORS
ON 208 TRANSLATOR

DIGIPLAN LIMITED
21/22 BALENA CLOSE, CREEKMOOR,
POOLE, DORSET, BH17 7DX.
Tel: Broadstone (0202) 690911. Telex: 417217
A company associated with PKS Designs Limited

1054.046.01
6/81