6-9 MACHINE CONTROLLER PCB

This board is located inside the PC unit, plugged into a motherboard expansion slot. It acts as the mechanical control for the scanner, driving all motors, and also performs general safety and monitoring functions, as follows:-

- Stepper motor drive and control for the:-
  - Illumination aperture selection
  - Resolution aperture selection
  - Focus lens movement
  - Reflection copy illumination
  - Door locking mechanism
- Microcontroller - based (PIC) control for:
  - Rotate motor speed and position (encoder) monitoring
  - Traverse motor speed, drive and position (encoder) monitoring
- Safety interlock monitoring
- STOP button monitoring

Power for the board and the motors driven directly by it is derived from the PC power unit via the flying connection normally reserved for a second disk drive.

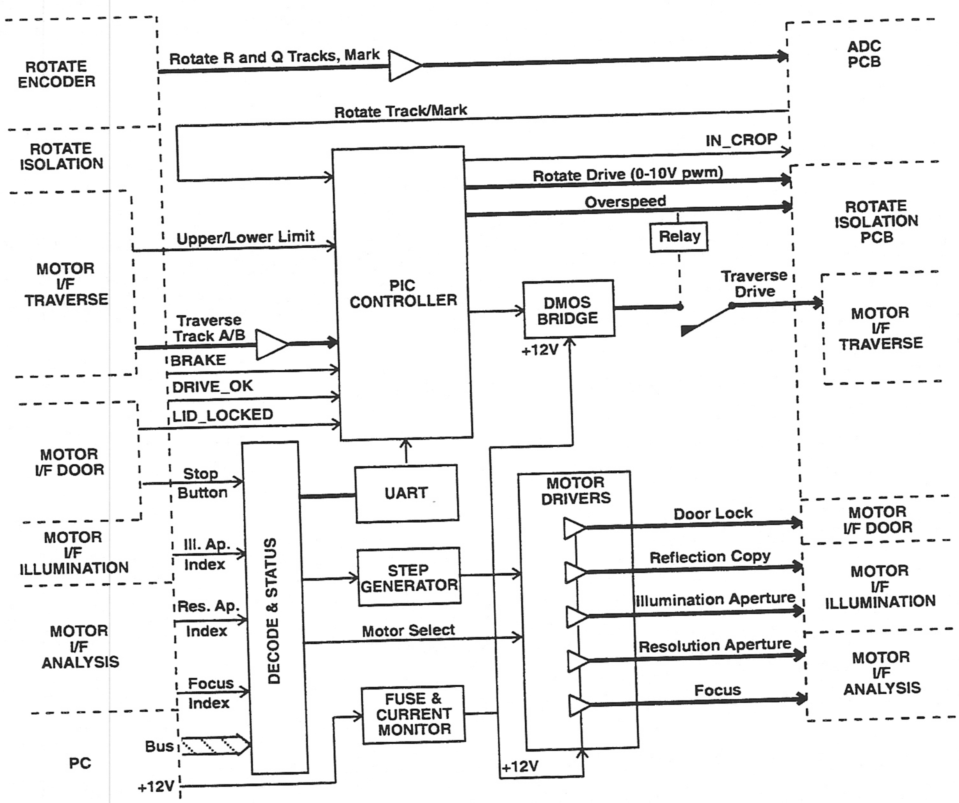

Fig 6.30: Machine Controller Overview

STEPPER MOTOR CONTROL MODULES

Stepper motors control the illumination and resolution aperture wheels, the focus lens, the reflection copy selection, and the door lock. The motors are driven from driver IC's which put the motors in low power mode or disable mode when not in use to save current on the +12V line, generally allowing a mechanical detent mechanism to take over. Only one motor is driven at a time. The circuits driving the stepper motors are able to stand a permanent stall indefinitely although they may be subject to thermal shutdown. With the exception of the door locking system and the reflection copy illumination, all motors generate a positional Index (marker) which is fed back as a readable status bit.

The motor interfaces are provided through three ACTQ574 latches with 'direction' and 'half-step' control bits for each motor. The command to step is performed by writing to a motor address latch (indicating which motor is to be driven) then performing a memory cycle. A hardware timer generates 10uS strobes and helps with the inter-step timing required. The number of steps required to obtain a given position is defined in the appropriate DOS parameter (.350) files.

A status byte ('Phase A' status) corresponding to 1 of 4 or 8 steps, dependent upon full step or half-step mode, is read by software through a motor status latch. This signal is used to determine when a motor may be switched off and thus remain in a known position when switched on again. If the motor is in an unknown position, the software takes appropriate action by moving to an index point or to the nearest 'Phase A' position.

The Reflection Copy and Door Lock motors have no direct index flag. It is assumed that the mechanical conditions will be met by rotating the motors by more steps than technically required, any excess movement being accomodated by the ability to take a stall current. The motors are moved to the default condition by rotating backwards to step 0.

PIC®17C42 SYSTEM

A PIC17C42 microcontroller located on the board is used to control the rotate and traverse motor systems. The PIC17C42 is a high performance EPROM based 8-bit CMOS microcontroller. It integrates a powerful CPU (250nS instruction cycle) with an array of peripheral resources making it ideal for the complex real-time motor control. It contains:-

- 64K x 16 of addressable program memory space,
- 2K of EPROM memory,
- 232 x 8 general purpose registers (SRAM),
- 48 special function registers,
- 16 x 16 hardware stack,
- 11 external/internal interrupts,
- 33 I/O pins,
- Three 16-bit timer/counters,
- Two 16-bit capture registers, (RTCC and Capture 2)
- Two highs speed PWM outputs (10 bit),
- A serial port (UART) with baud rate generator.

The controller requires a 16 Mhz oscillator for its basic timing. Communication with the PC is established by configuring a **UART** to Com3 running at 9600 baud. Interrupts are generated by the UART when it receives signals from the PIC, for example when the PIC has a condition it wishes to report or when the PIC responds to requests from the PC. *A breakdown of the code used for PIC communication is listed in the "Debug". Chapter 4-4.* Signals such as "In Crop" are computed and latched out.

Timer t1 runs continuously from a 4 Mhz clock to provide two channels of 8 bit pulse width modulation for rotate and traverse directly from the chip. The rotate pulse width modulation is divided to give a nominal 4 mS tick signal which is used as the primary timing signal for drum speed, for measuring over/underspeed timeouts, and for synchronising the traverse servo.

Timer t2 runs from the rotate encoder pulses and has a period register which is set to give 32 timeout interrupts per revolution. It is not reset by the mark, only by software, and is used to measure the rotate speed for the rotate servo and to generate the crop start signal when initialised by the machine software.

The cropping system uses timer t2 to count the distance between the mark on the drum and the round drum crop. No errors are allowed in this counting as a single slip will ruin a scan. The phase of t2 determines the crop start, and a particular t2 interrupt is the crop position. The phase of the interrupt is set by loading timer t2 at the mark interrupt, and is set once only, disabling the mark interrupt. The crop can only be set when the drum is rotating and takes 2 revolutions of the drum to set.

Timer t3 is used either to count pulses in the traverse fast positioning mode, or is driven directly by a 4 Mhz clock during slow speed travel. In the fast positioning mode the resulting sampled count is held in the RTCC capture register. At slow speeds, the number of counts per sample is small and the servo is set into a phase lock loop mode, where the speed is measured by switching timer t3 to the 4 Mhz clock and taking a snapshot of t3 every 4th encoder edge, holding the sample in register Capture 2. In both cases t3 has a period of FFFF and interrupts the processor on overflow.

Capture Register RTCC is used with t3 to determine position during fast positioning. The count is modulo FFFF and interrupts the processor on overflow. The interrupts are subsequently counted to extend the length of the counter.

Capture Register Capture 2 is used when t3 is driven by the 4 Mhz clock when the traverse is running slowly. In this mode the servo is a phase locked loop type, the servo error depending on a period measurement. It takes periodic snapshots of timer t3 and interrupts the processor to control the loop.

ROTATE MOTOR CONTROL

The rotate motor speed is controlled by the PIC motor controller responding to serial commands and status link to the PC.

When the drum door is closed the door microswitch will enable the overspeed relay on the Rotate Isolation board, feeding 240V to the Motor Drive 3Ø. This in turn sends back a "drive OK" to the PIC controller. Providing the door bolt is sensed as being engaged, ("lid locked") the PIC allows rotate drive and a analogue output of 0 to 10V DC is sent via the Rotate Isolation board to the Motor Drive 3Ø unit, to drive the 3Ø motor.

The rotate encoder signals (Track and Mark) are received as differential signals and passed to the ADC board as single-ended signals via a 10 way interconnecting ribbon cable. The two tracks and the marker are fed back to the PIC to give speed sensing.

The rotate servo uses a simplified PIC program with fixed constants and one variable, the target speed. The rotate system sequence showing its rise to target speed, stall monitoring, slowing down and stopping is described in Chapter 6-3 and illustrated in Fig 6.12.

The rotate speed, monitored by PIC timer t1 is used to produce a 4mS "tick" signal used as a master timing for the traverse servo to ensure that the head movement is locked to drum rotation to give perfect synchronisation.

In the event of an "overspeed" the overspeed relay drive is removed, and the 240V removed from the Motor Drive 3Ø. This action also disables the traverse drive via a load relay on the Machine Controller.

TRAVERSE MOTOR SERVO CONTROL

Control of the traverse motor is from the PIC, with full servo control effected to the traverse DC motor using pulse width modulation (PWM), via a DMOS bridge module driving the leadscrew through a gear box. Nominal speed is soft setable for resolution ranges from 0.05 to 22 mm/s, with a full fast positioning speed of 30mm/s. The motor's integral encoder, powered from the controller, provides feedback for speed monitoring. Differential receivers are used for encoder buffering for the traverse system track and quad track (track A/B). Variations in the rotate speed during scan are monitored, and corresponding adjustment made to traverse speed to maintain perfect synchronisation.

An upper and lower limit switch prevents erroneous overdrive in the up or down direction. The drive is normally held disabled by a load relay in the rotate overspeed line until the door (lid) is shut and the rotate speed is correct.

The traverse servo is a proportional/integral/derivative (PID) position servo, i.e. the drive applied to the motor is made up of a proportional term, which drives it towards the target position; a derivative term, which stabilises the servo; and an integral term, which returns the head to the exact position set.

PIC counter t3 is used to count traverse motor encoder pulses for full range of travel, to be reset by the traverse initialisation switch (lower limit switch). Pre-loadable counts define the traverse cropping start and stop positions, and provide an 'In Crop' signal for the ADC board. The traverse crop flag is set internally half a revolution before the rotate crop start.

During a scan an aim position profiler in the PIC17C42 causes the motor to ramp up to speed, travel at a fixed speed (by incrementing the position), and finally ramp down. The forward movement position can change either at the 4 ms "tick" rate or when timer t2 times out (i.e. once every drum revolution), to maintain rotate/traverse synchronisation.

DATA SYNCRONISATION

To ensure data synchronisation the signal "In Crop" is generated by the PIC by counting rotate encoder tracks (all edges, 4096 per revolution). This signal is buffered and sent back to the ADC board where it is used to synchronise the high frequency ADC data clock.

DOOR LOCK AND SAFETY INTERLOCK MONITORING

The primary safety interlock requires that the drum will not rotate with the drum access door open and that the door is locked shut until the drum stops, *see Chapter 6-4 for further information.* A door micro-switch inhibits power to the rotate motor when the door is open by disabling the 230V feed relay (over-speed relay). In addition the door bolt stepper motor locks the door and a relay lever operates an independent sensor to check for the door being closed and locked. Until the door is safely locked, monitoring of its status ("lid locked") ensures that a PIC reset is asserted to initialise the rotate and traverse motor drive systems. The door bolt and detect flag system may be bypassed for service purposes only, by using the special test tool (Part No. 3500902 -350i/355i or 3300906 - 330i), supplied as part of the service test kit. The microswitch must be taped closed.

INTERNAL INTERLOCKS

Internal interlocks are required to save the scanner from damaging itself if any mechanism runs into a mechanical limit, these are distinct from the door safety interlock which protects the user.

- The rotate motor system is current limited in the event of a "stall" condition by the Motor Drive 3Ø unit, and the absolute maximum rotate speed is governed by limiting the drive signal to 10V (at which the rotate speed is safe, giving approximately 1800 rpm).
- Isolation to 3750V is provided between the Machine Controller PCB and the Motor Drive 3Ø unit by the Rotate Isolation board.
- A mechanical 'fuse' is used to protect the dc motor and the traverse motor drive.
- All stepper motors cope with stall condition if they encounter a limit of travel, and if the traverse motor hits a 'hard' stop it will have activated a sensor first.

STOP SWITCH (350I/355I)

Operating the STOP switch on the front of the 350i/355i scanner will return a status byte "Stop" to the PIC controller. This will initiate a controlled rotate stop, leaving the traverse stationary and disabled.

The scanner must be powered down or the PC reset to restore operation.

SELF TESTING

For diagnostic testing (Chapter 4), each stepper motor drive is taken out and back via the ribbon cable outer wires to verify correct plug socket location, and to enable current sensing to detect open circuits on power output e.g. motor failure.

The voltage drop caused by a motor is monitored by a sense resistor switched into the +12V line by a relay. The relay is powered from 5V and when de-energised shorts out the sense resistor; this is the normal working case, the relay being powered and opened during testing. The voltage drop is measured by an 8-bit ADC. The same system also tests whether the connector is fully mated or not, as the stepper motor drive wires are at the outers of the cable/connectors.

BUS INTERFACE

The PCB is an ISA standard bus interface, and is an 'add-on slave' only. It uses COM3, addressed as I/O 0x3E8. Address decoding is similar to the ADC board using the top Mbyte of the 16Mbyte PC address space allowing communications to the following:-

- PIC system UART
- Motor & machine control and status
- ADC board LUT
- ADC board control & status

The ADC LUT and ADC control & status are used by the Machine Controller for information only.

FUSES

FS1	3A or 3.15 AT	*Replacable*	+12v Stepper motor power.
FS2	2A	*Soldered in*	+5v Board supply

SIGNAL MNEMONICS

Mnemonic	Meaning
AEN	Access Enable
AFINDEX	Auto-Focus Index
BCLK	Bus Clock
D	Data
DINSTRB	Data In Strobe
DOTSTRB	Data Out Strobe
IOR	I/O Read
IOW	I/R Write
M	Mark
PWM	Pulse Width Modulation
QT	Quadrature Track
RT	Reference Track
SA	PC Bus Address
SD	PC Bus Data

TEST POINTS

Tp1	0V, PC Bus
TP2	FREEZE
TP5	GATED MARK
TP7	Motor Step Pulses
TP8	0V, PC Bus
TP9	Stepper Motor Busy
TP10	INCROP
TP11	ROTATE TRACK
TP12	Interrupt
TP13	0V, PC Bus
TP14	+2.5V Reference
TP15	+12V Current
TP16	0V, Rotation Isolation PCB
TP17	Rotate Speed
TP18	0V, PC Bus

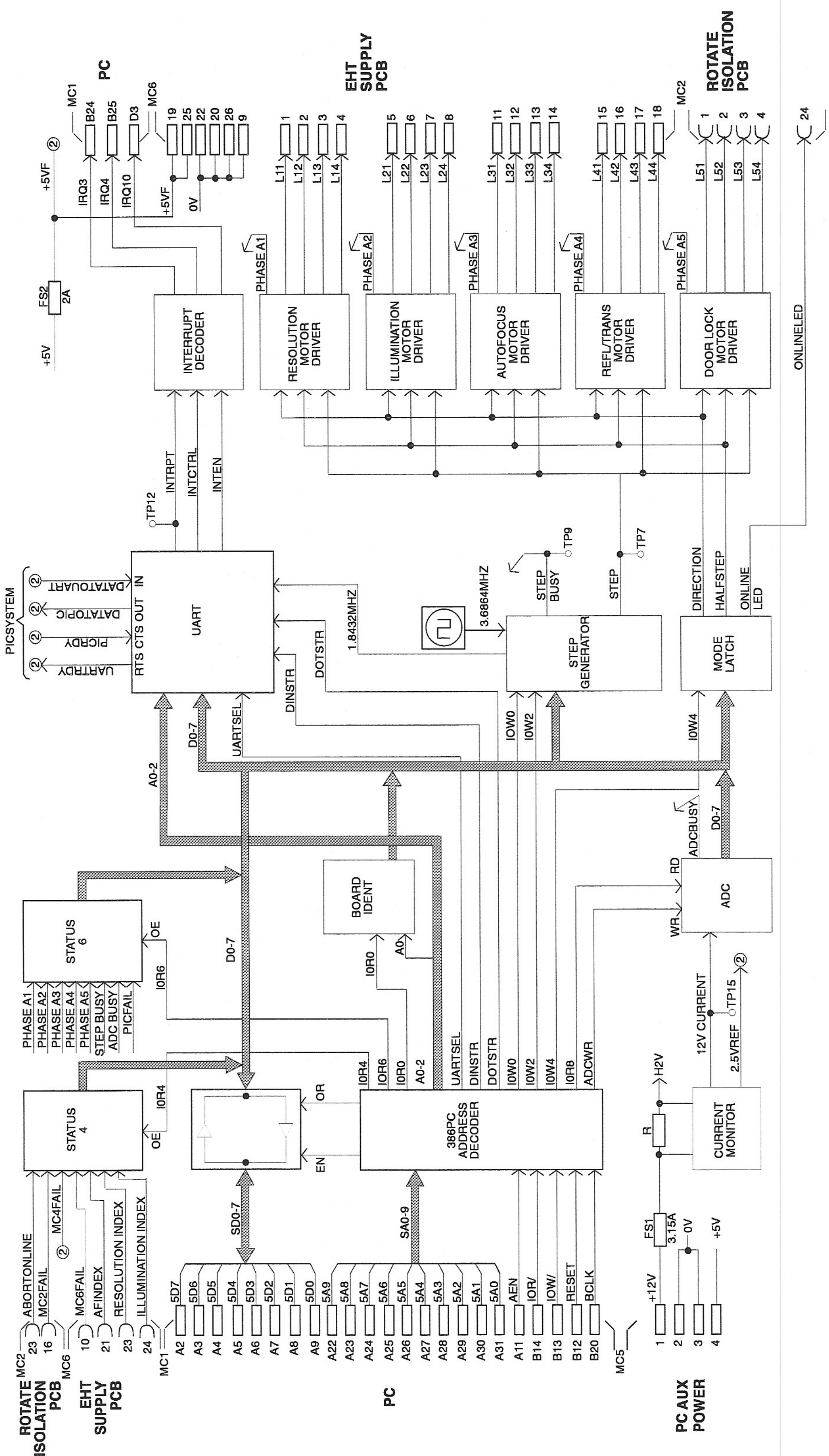

Fig 6.31 (a): Machine Controller PCB Sht. 1

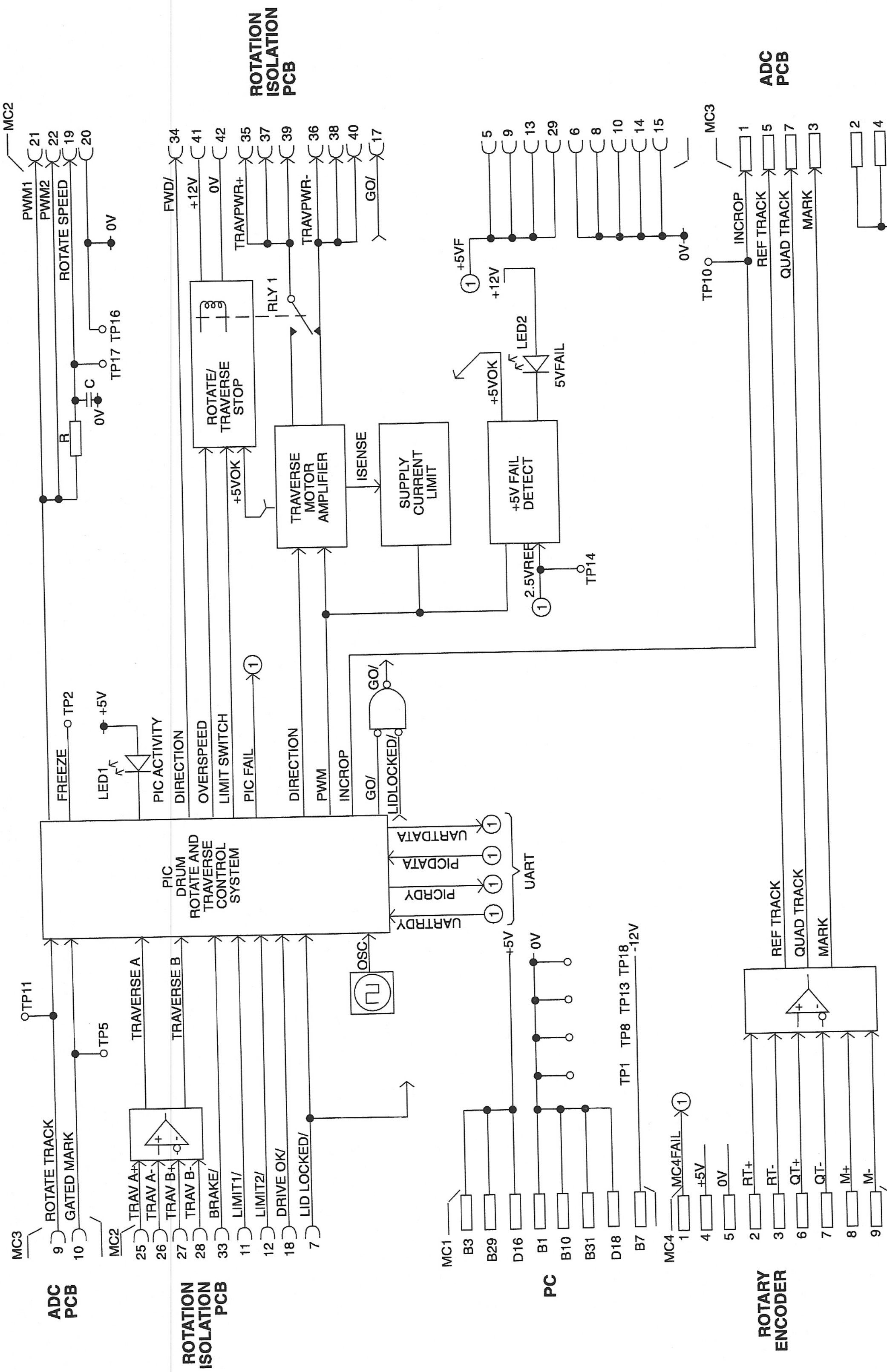

Fig 6.31(b): Machine Controller PCB Sht. 2

6-10 MAINS ASSEMBLY

Two types of Mains Assembly are used on the scanner. Prior to mid -1997 the scanner was not auto-ranging and required an integral auto-transformer to accommodate different mains input voltages. The Mains Assembly used (OK 3500111) is identified by the voltage selection switches located on the rear of the unit, *see fig. 5.30*. After mid -1997 an auto-ranging Mains Assembly (OK 3600111) and PC are normally fitted to the scanner, and the transformer removed.

The Mains Assembly is mounted at the rear of the machine and consists of three integrated modules:

- A Rotate Isolation PCB providing a mains power distribution and voltage selection system, and also providing safety extra low voltage isolation (SELV) for the motor driving circuit.
- A Rotate Inverter module (Motor Drive 3Ø) to provide a controlled power drive for the rotate motor.
- A 12V power supply to drive the lamp and photomultiplier EHT unit.

ROTATE ISOLATION PCB

The Rotate Isolation PCB by definition provides safety isolation between the rotate motor low voltage control signals derived from the Machine Controller PCB in the PC, and the high voltage required to drive the rotate motor from the Rotate Inverter (Motor Drive 3Ø). SELV isolation is provided by five opto-isolators. The traverse motor low voltage control lines also pass directly through the board.

In addition to the SELV isolation, the PCB also acts as a mains distribution board, taking mains input either directly or via the auto-transformer if fitted *see Chapter 5.6*, filtering it and distributing it out to the PC unit and locally to the Rotate Inverter (Motor Drive 3Ø). After mid-1997 the Rotate Inverter (and PC) are auto-ranging. Prior to this, to accommodate alternative mains voltage inputs, it was necessary to use an auto transformer with input mains voltage selection switches connected directly to this board (fitted to the rear of the Mains Assembly). In this case 230V is always sent to the PC.

The input power to the Rotate Inverter (Motor Drive 3Ø) is fed via a solid state relay which is energised by a rotate motor overspeed detector line from the Machine Controller PCB via the drum door microswitch. If the door is opened, or if the drum speed is excessive, the supply is broken and the motor power removed.

ROTATE INVERTER (MOTOR DRIVE 3Ø)

This is a proprietary motor control module which should be considered an integral part of the Rotate Isolation PCB. The unit accepts the mains input, rectifies it, and using pulse width modulation and fet switching, produces a 3Ø variable width voltage output pulse (nominally 200V at full speed), which is used for motor speed control.

Two types of units are used on the scanner. Prior to mid -1997 the Rotate Inverter was an open assembly, preset to run from 230V supplied from the auto transformer.The control circuit to achieve this is complex and all switches and potentiometers on the module are preset, *refer to Chapter 5.6 for details*.

Mains Assembly

After mid -1997 an auto-ranging sealed unit (coloured blue) is normally fitted to the Mains Assembly. This unit is pre-programmed to control correctly and contains a digital display for diagnostic purposes, *refer to Chapter 5.6 for details.*

LAMP POWER SUPPLY MODULE

The Lamp Power Supply module is a DC/DC converter sandwiched between the Rotate Isolation PCB and the Rotate Inverter. It produces the 12V needed for the lamp from the rectified mains input to the Rotate Inverter used to produce the power drive for the rotate motor. Configured this way the DC/DC converter (with a lamp connected) acts as power dump during motor braking.

The 12V is also routed via the Motor Interface Illumination PCB (on the Illumination Optical Assembly), to provide power for both the lamp fan and for the photomultiplier EHT module on the EHT Supply PCB.

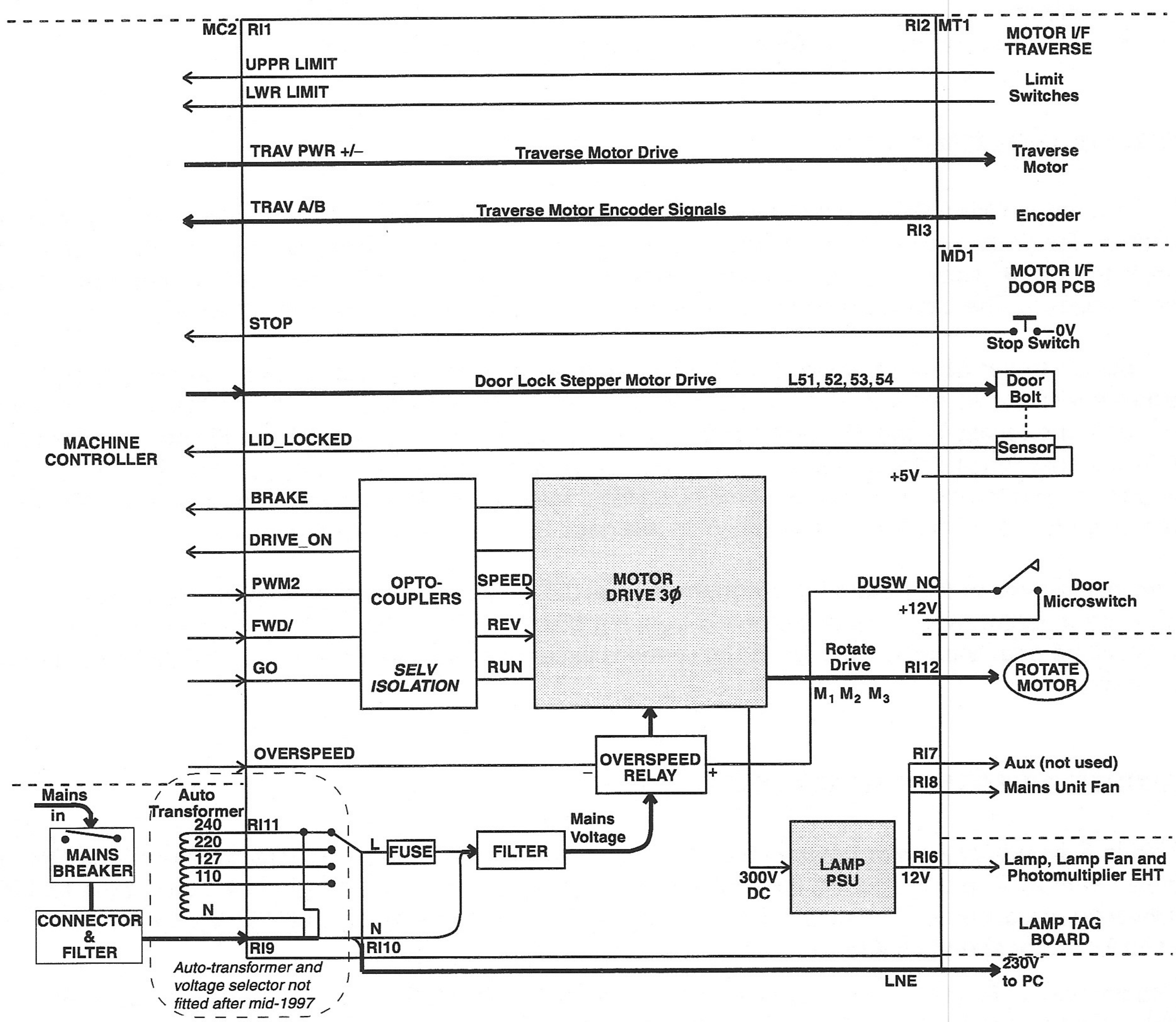

Fig 6.32: Rotate Isolation Board

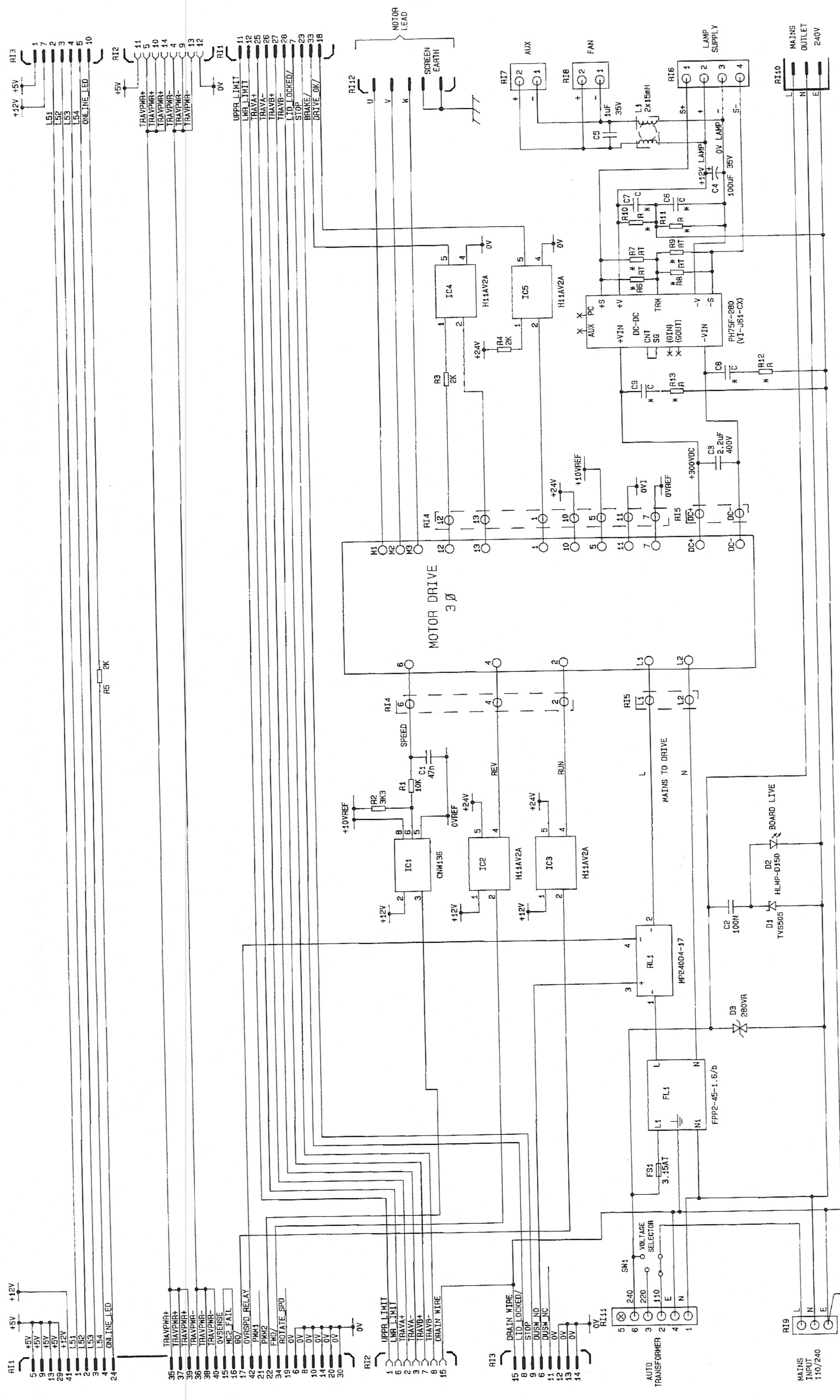

Fig 6.33 (a): Rotate Isolation PCB K3500211 Iss 2

ICG

Mains Assembly

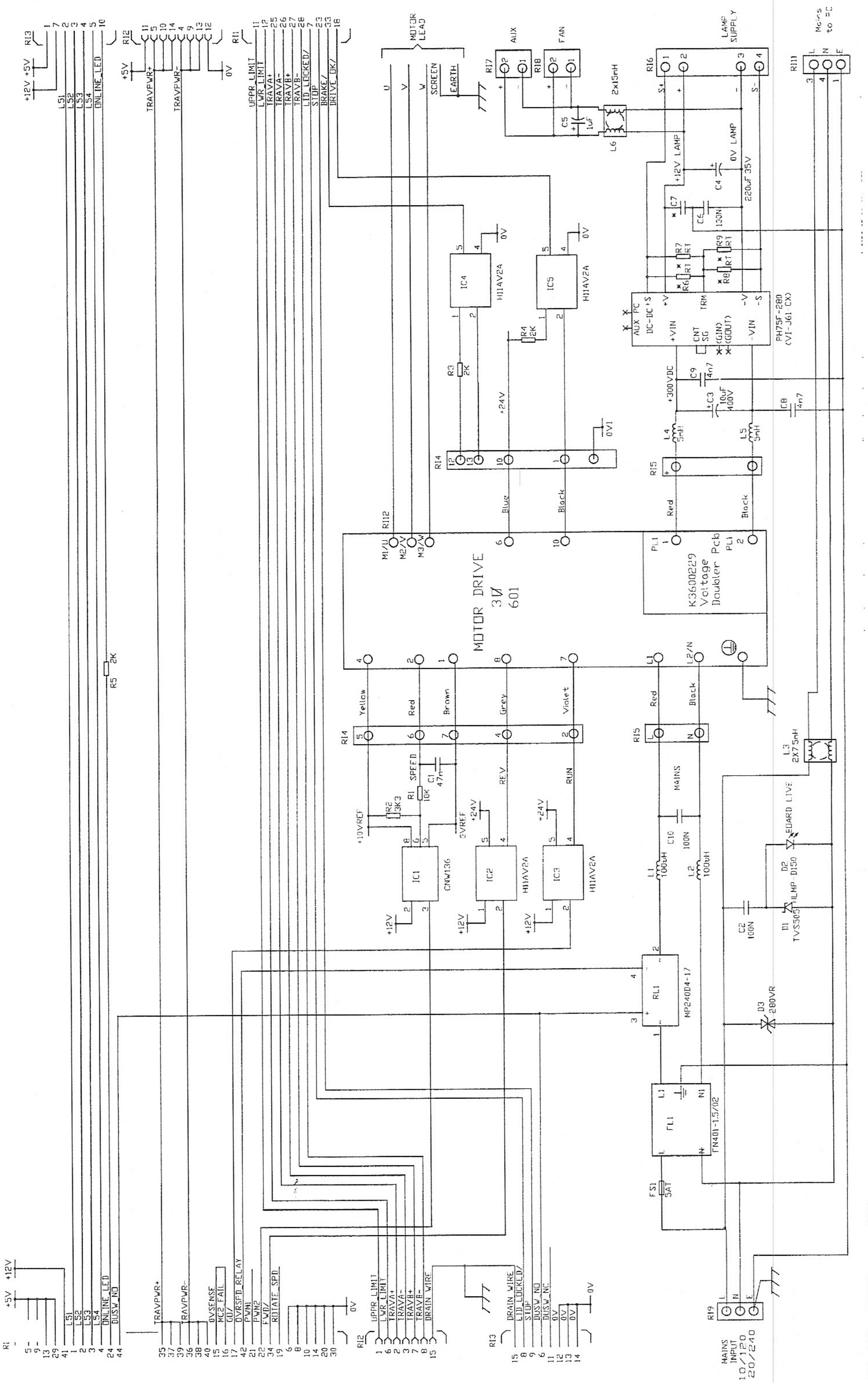

Fig 6.33(b): Rotate Isolation PCB (Auto-ranging) K3600231 Iss 1

6-11 MISCELLANEOUS PCBs

The following small PCBs are required to interface between the major control boards and local functions.

MOTOR INTERFACE TRAVERSE PCB

This PCB is mounted on the lower part of drive assembly adjacent to the traverse motor. Its function is to route the drive power from the Machine Controller in the PC unit to the traverse drive motor, to route back and buffer the traverse encoder signals, to provide power to the upper and lower limit flags and to route back the state of the flags.

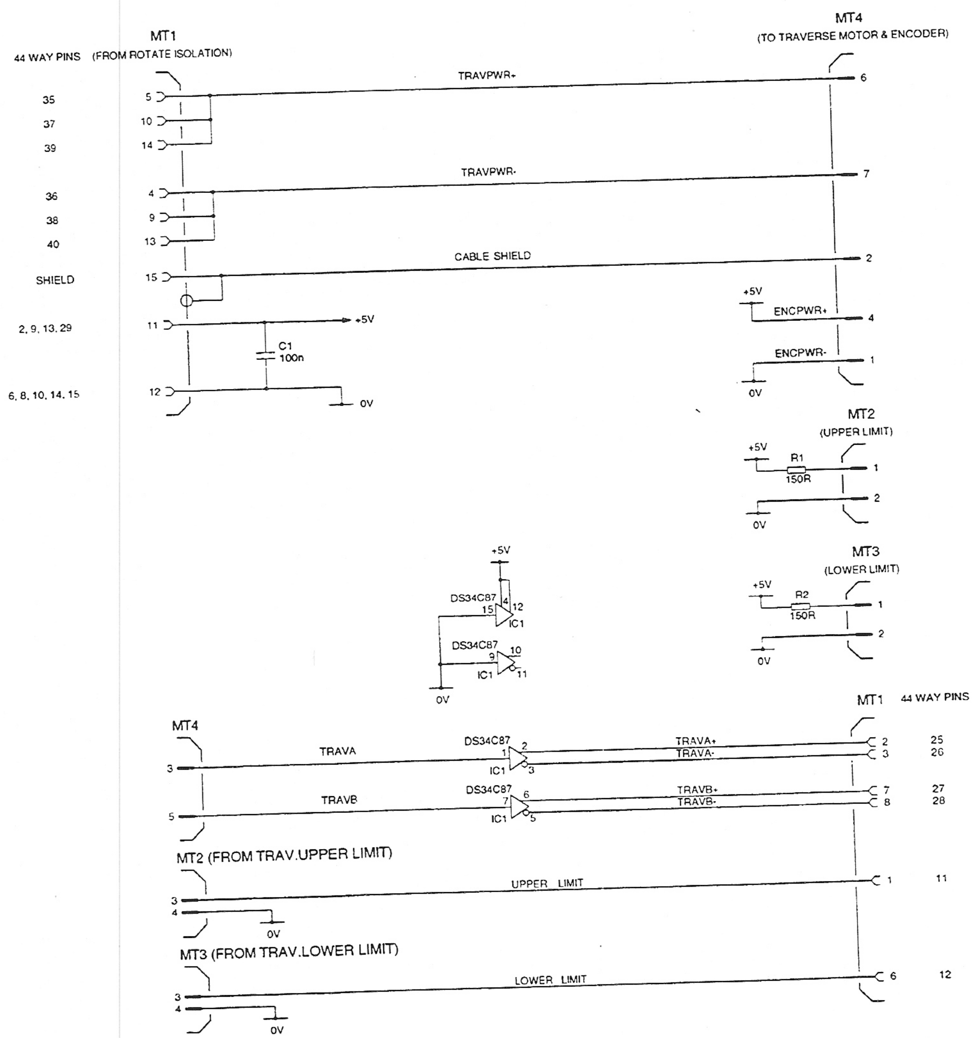

Fig 6.34: Motor Interface Traverse 3500223 Iss 1

MOTOR INTERFACE ANALYSIS PCB

This PCB is located inside the Analysis Optical Assembly and is used to route the eight stepper motor drive signals from the Motor Controller PCB in the PC (via the EHT Supply PCB) to the Autofocus Motor and the Resolution Aperture Motor. It also contains the flag sensors for these motors and buffers their signals prior to routing them back to the Motor Controller PCB (via the EHT Supply PCB).

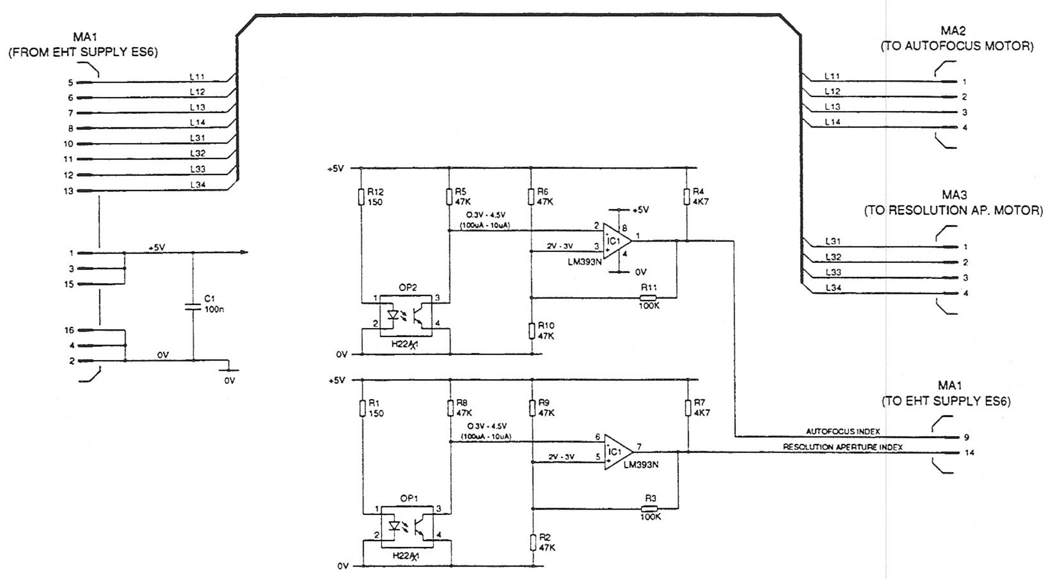

Fig 6.35: Motor Interface Analysis 3500215 Iss 1

MOTOR INTERFACE ILLUMINATION PCB

This PCB is located inside the Illumination Optical Assembly and is used to route the eight stepper motor drive signals from the Motor Controller PCB in the PC (via the EHT Supply PCB) to the Reflection Copy/Transmission change over Motor and the Illumination Aperture Motor. It also contains the flag sensors for the Illumination Aperture Motor and buffers its signals prior to routing them back to the Motor Controller PCB (via the EHT supply PCB).

The board also receives the 12V lamp supply and routes it back out to the lamp fan and to the EHT Supply PCB, where it is used to drive the EHT power module supplying the photomultipliers.

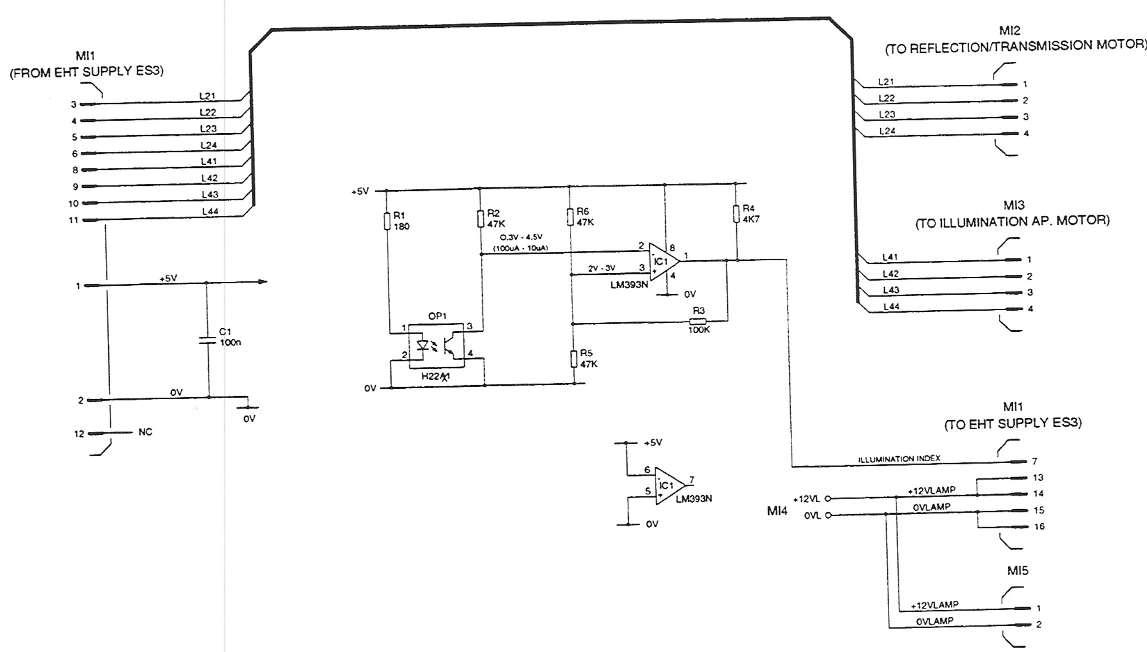

Fig 6.36: Motor Interface Illumination 3500217 Iss 1

ENCODER INTERFACE PCB

This PCB is only currently required on machines using the Heidenhain encoder with a separate reading head. When required it is fitted on top of the centre cross strut of the mainframe assembly, in front of the Mains Unit.

The Reference (mark), A and B track signals from the encoder are differently received and filtered before being driven out to the Machine Controller PCB in the PC. The output reference signal may be monitored on TP2 (Mark 1). The board also routes the +5V power to the encoder.

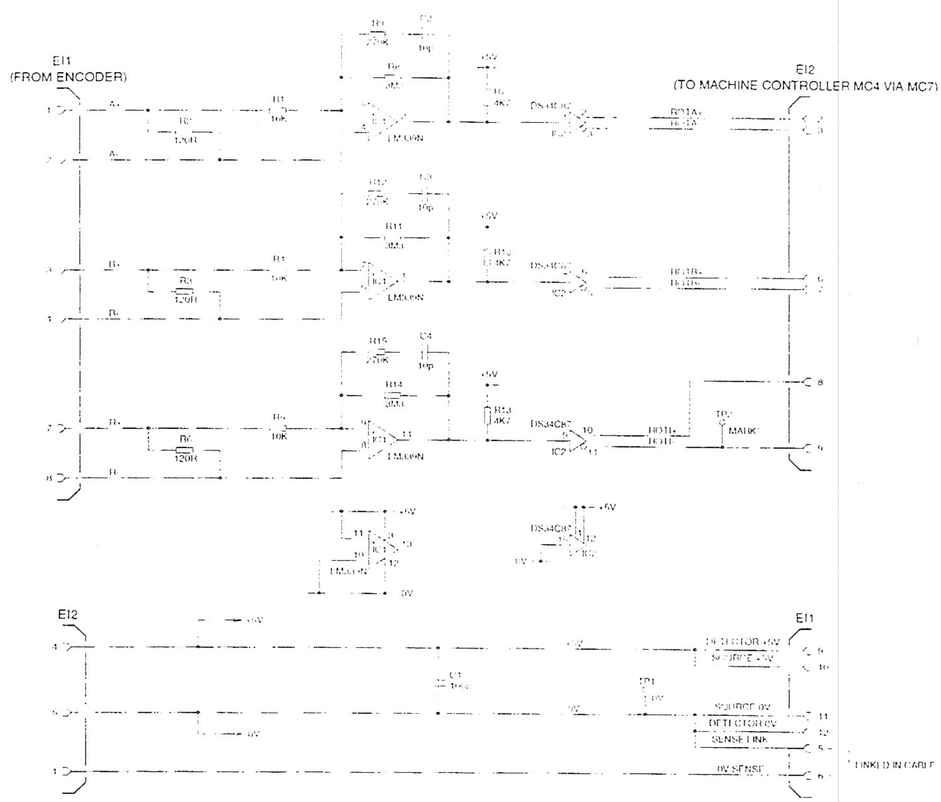

Fig 6.37: Encoder Interface PCB 3500221 Iss 1

MOTOR INTERFACE DOOR

350i/355i Scanners (K3500213)

This PCB is for part of the door locking assembly and is mounted behind the centre bracket to the left of the "Stop Scan" button.

It routes the door bolt supply from the Machine Controller PCB in the PC (via the Rotate Isolation board), and monitors the associated door locked flag (which is activated by the bolt operation - see chapter 6.4). With the door locked the board returns a current of 2.3 mA (0.1V), with the door unlocked current is minimal and the voltage rises to 4.99V.

The board also routes the door microswitch connection and the Stop Scan Switch back to the Rotate Isolation board. A drive path for a status indicator LED is also provided but not implemented.

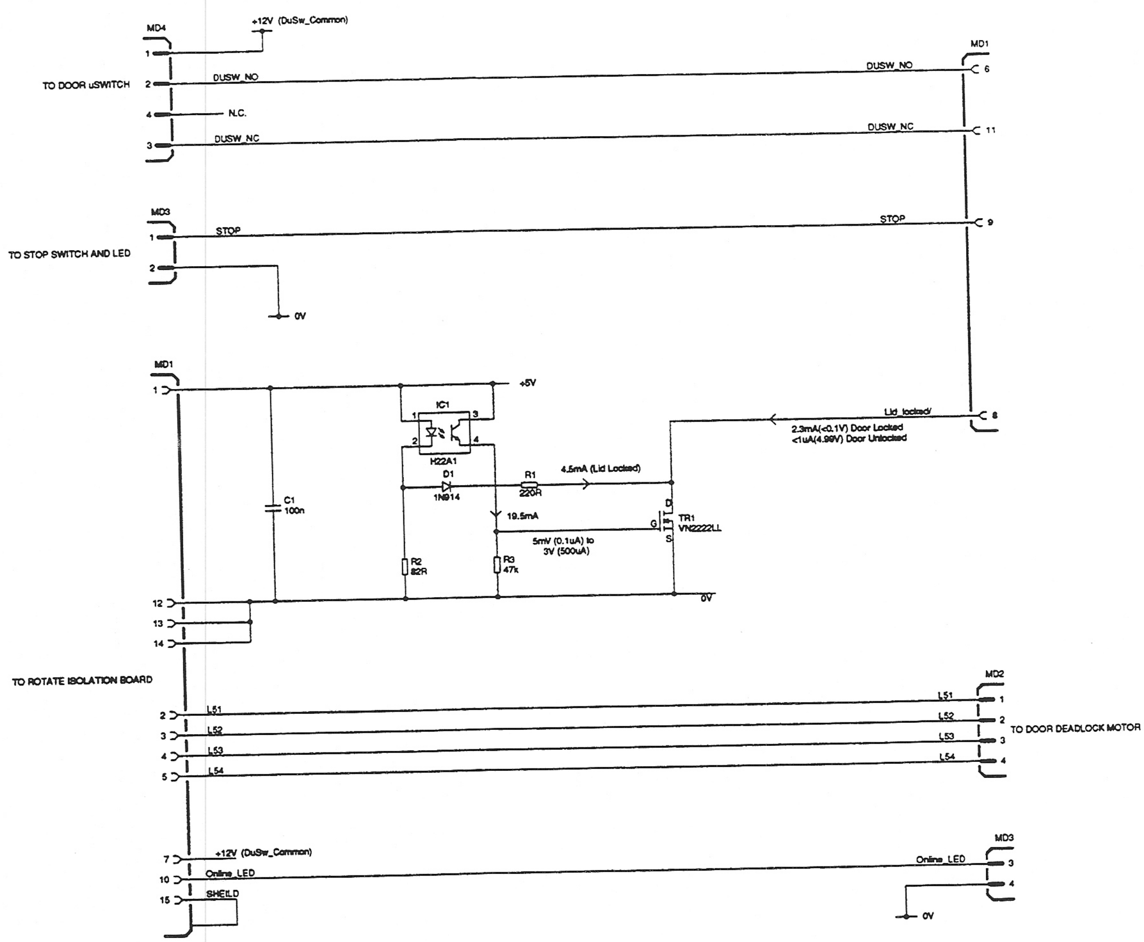

Fig 6.38: Motor Interface Door 3500213 Iss 1

330i Scanners (K3300203)

This PCB is for part of the door locking assembly and is mounted on the main chassis on the right-hand side of the door.

It routes the door bolt supply from the Machine Controller PCB in the PC (via the Rotate Isolation board), and monitors the associated door locked flag (which is activated by the locking bar operation - see chapter 6.4). With the door locked the board returns a current of 2.3 mA (0.1V), with the door unlocked current is minimal and the voltage rises to 4.99V.

The board also routes the door microswitch connection and the Stop Scan Switch back to the Rotate Isolation board. A drive path for the status indicator LED is also provided.

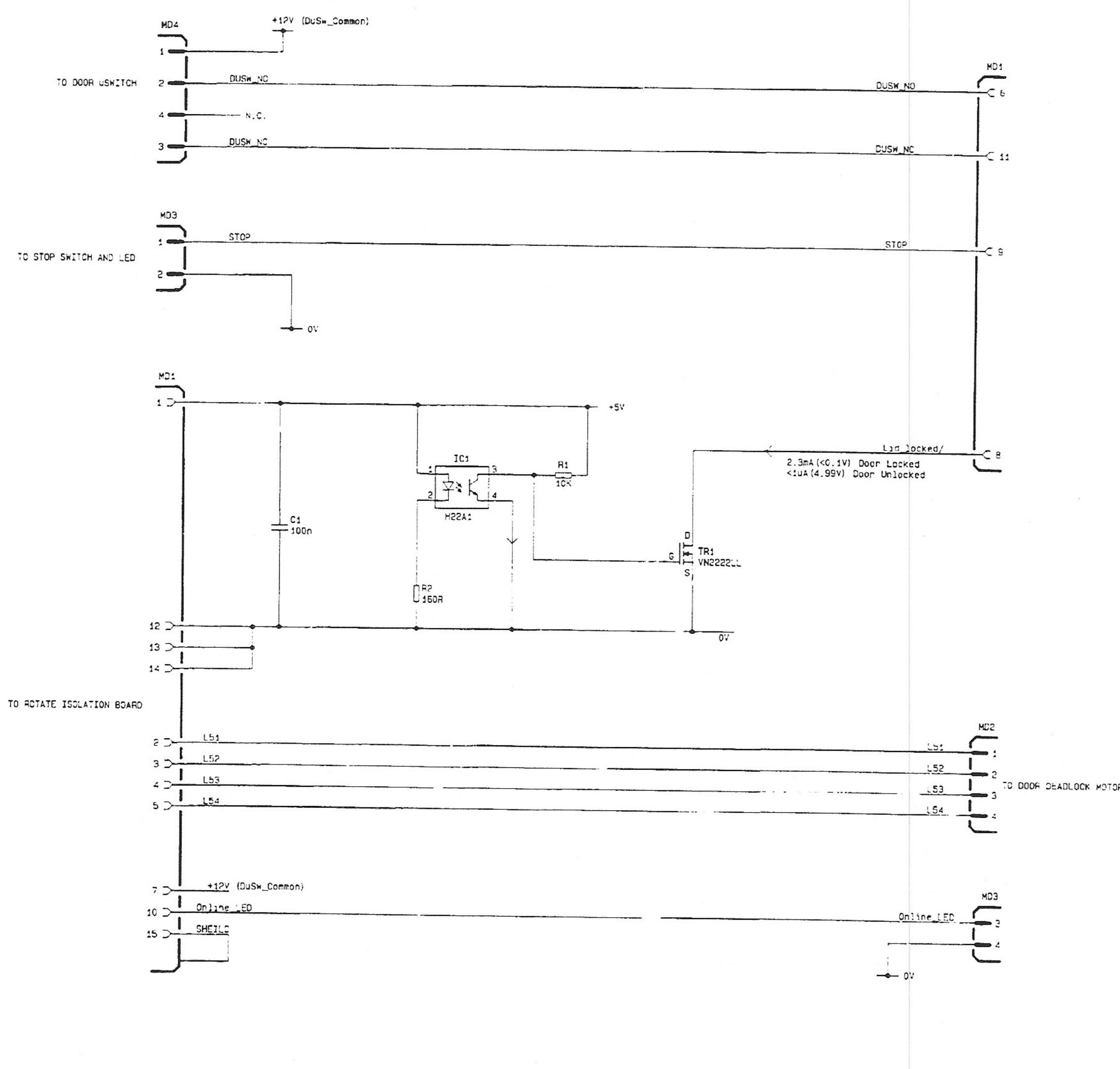

Fig 6.39: Motor Interface (330i) 3300203 Iss 1

360 Scanner Motor Interface Door (OK3600239 *Part of OK3600139*)

This PCB is for part of the 360 door lock assembly (OK3600139) and is mounted on the main chassis on the right-hand side of the door.

It routes the door lock motor supply from the Machine Controller PCB in the PC (via the Rotate Isolation board), to the motor which is mounted on the PCB (but not hard-wired). A sensor on the board monitors the state of the door locked flag (an extension to the locking bar catch - see chapter 6.4). With the door locked the flag is located in the sensor and the board returns around 0.1V. With the door unlocked or open the flag will be out of the sensor and the voltage rises to 4.99V.

A push-button switch is fitted which, when operated, signals the Machine Controller to unlock the door. The status of the door lock is indicated by illuminating the user's door lock button by a single red LED (unlocked) or by three green LEDs connected in series (locked),

The "door closed" microswitch is also fitted on this PCB and its status (DUSW) is routed back to the Rotate Isolation board. The switch also controls the return for the fluorescent viewing lights which are off when the door is closed and turned on when the door is open.

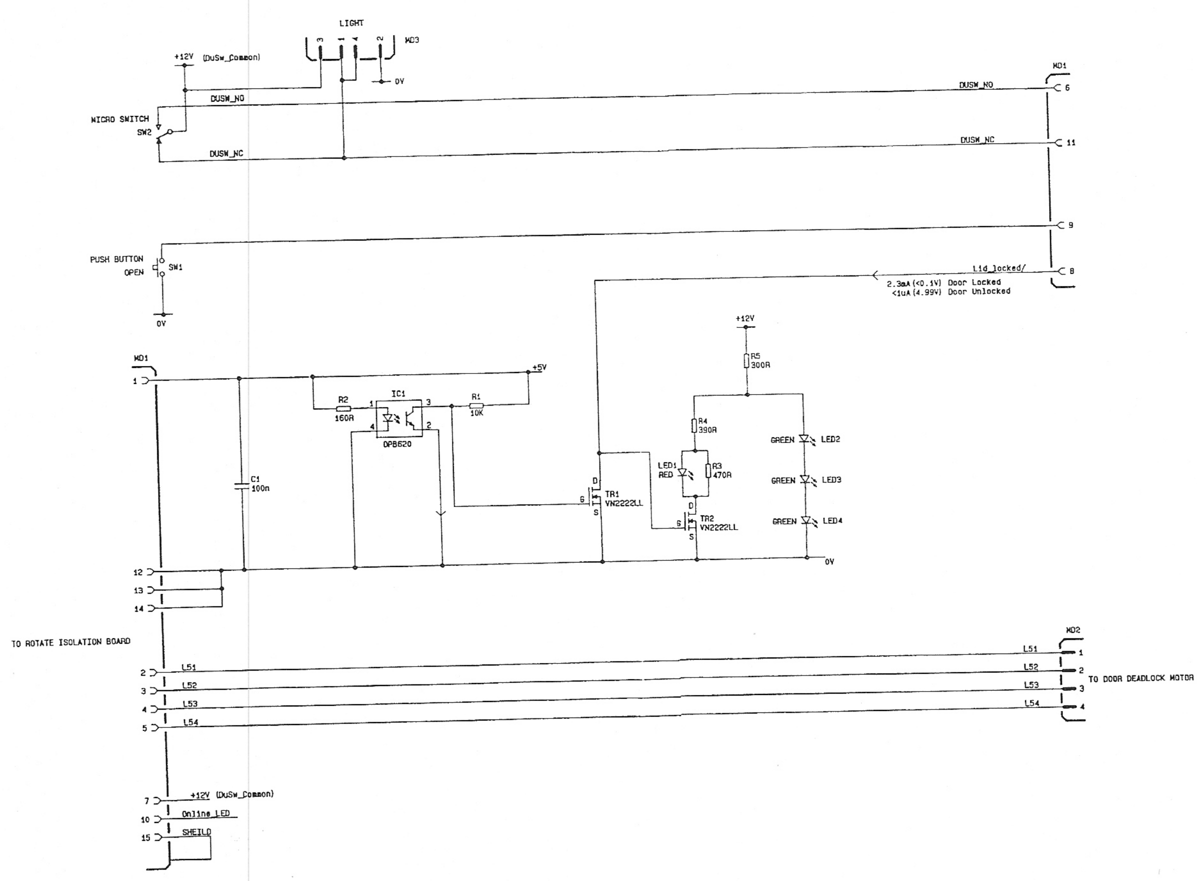

Fig 6.40: Motor Interface (360) OK3600239 Iss 1

FLUORESCENT INVERTER PCB (K3600604)

This is a proprietary PCB is only used to drive the fluorescent viewing lights on 360 scanners. It is powered by a switched and fused 12V supply derived from the PC auxiliary (fan) supply.