Maintenance Manual

Published by Technical Support,
UMI Ltd.,
UMI House,
St James Road,
Surbiton,
Surrey.
England
KT6 4QN

First published 3rd August1987.

Issue no 1.00, 3rd August 1987.

Contents

WARNING

BEFORE REMOVING ANY COMPONENT, OR SERVICING RTX IN ANY WAY, DISCONNECT RTX FROM THE ELECTRICAL MAINS SUPPLY. ANY CIRCUIT TESTING MUST BE CARRIED OUT BY EXPERIENCED PERSONNEL

CAUTION
Do not make adjustments other than those recommended for preventive maintenance if the machine performs satisfactorily. You should not carry out stripping and reassembly unless it is considered to be necessary.

CAUTION
Do not attempt to diagnose faults or carry out repairs to printed circuit boards unless you are fully conversant with the correct procedures.

Semi-conductor devices are prone to damage by static discharge. Assemblies containing such devices should be stored, handled or repaired only in a special handling area free of electrostatic charge. If such an area is not available the following precautions MUST be taken

The assembly containing the device should be enclosed in a conductive material.

The terminals of such devices must not be touched.

Radio Interference - FCC Statement

This equipment generates, uses and can radiate radio frequency energy and if not installed and used in accordance with the instruction manual, may cause interference to radio communications. Most importantly, the equipment must be used with the supplied cables and with covers securely fixed in position. Any additional cables (user I/O, emergency stop, etc.) must be obtained from the supplier or made to the equivalent specification in order to maintain FCC emission limits.

This equipment has been tested and found to comply with limits for a Class A computing device pursuant to Subpart J of Part 15 of the FCC Rules, which are designed to provide reasonable protection against such interference when operated in a commercial environment. Operation of this equipment in a residential area is likely to cause interference in which case the user at his expense will be required to take whatever measures may be required to correct the interference.

1. Introductory Sections

Introduction

This manual is written to augment the other manuals that are supplied with RTX and should be read in conjunction with them.

It is written with the following aims.

(a) to help you understand how RTX operates and get the most out of RTX.

(b) to allow you to perform preventive maintenance on RTX and locate and repair simple faults.

(c) to help you identify and order spare parts.

Build States

There have been 3 build states of RTX.

Serial numbers 1825-1849. The first batch of (pre-production) 25 RTXs have serial numbers 1825 to 1849 (March '86 onwards).

Serial numbers 30-129. The second batch of 100 have serial numbers 30 to 129 (July '86 onwards).

Software was expanded to include the new FRTX teach & replay.

Electrical improvements were made to protect the motor drivers from back EMF generated when the arm was moved with the power off. Other minor electrical changes were made.

The covers were changed to reduce radio interference (to conform to FCC standards) and the yaw movement was increased. Other minor mechanical changes were made.

Serial 130-629. The third batch of 500 have serial numbers 130 to 629 (April '87 onwards) and are basically the same as the second batch. Minor mechanical improvements were made to improve operation but none of these affects the basic RTX specification. All parts are directly interchangeable with 30 onwards.

International Differences

No territorial differences exist except for the factory setting of the mains voltages and the type of mains lead supplied.

Routine Maintenance

Checklist

Routine maintenance should be carried out every 100 hours use or monthly, which ever is more frequent. You should:

Check the zed carriage:
* carriage compliance
* backlash

Check the friction:
* shoulder
* elbow
* yaw

Check the backlash:
* shoulder
* elbow
* yaw

Check the belt tensions:
* zed
* shoulder
* elbow
* yaw

Check the zed brake

Lubricate every 6 months/500 hours:
* combined pulleys
* gripper screw
* wrist gears

Appendix A may be photocopied for your own maintenance record.

Checking the Zed Carriage

The zed carriage should be tested for compliance and backlash by using a clock gauge to detect movement at the shoulder when force is applied to the fully extended arm, The arm should be powered up and fully operational for these tests and therefore needs to be driven into the required positions using the FRTX or DRIVE programs.

The following diagrams show where to apply the force and measure the deflection for carriage compliance (figs 1,2 & 3) and backlash (fig 4). For the given forces the deflection should be less than shown.

See the section on the zed carriage assembly in "Stripping and Reassembly" for instructions on how to adjust the carriage.

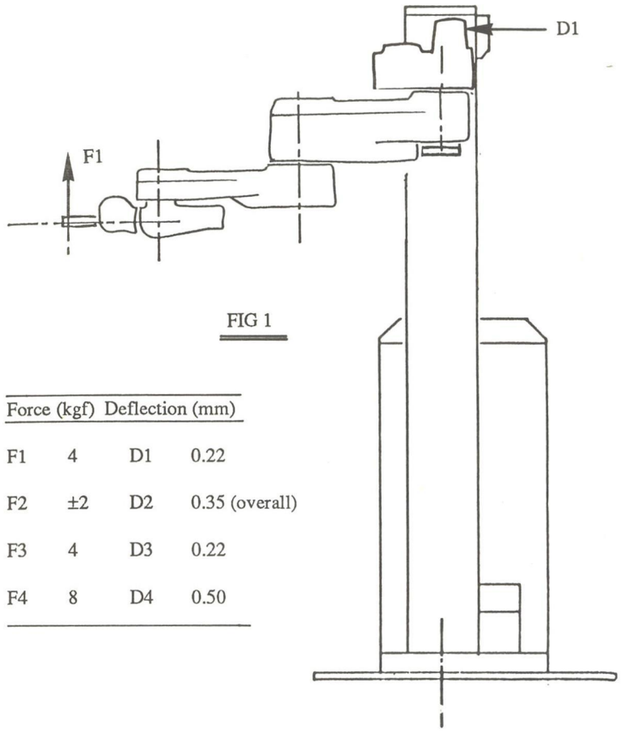


FIG 1

Force (kgf)		Deflection (mm)	
F1	4	D1	0.22
F2	±2	D2	0.35 (overall)
F3	4	D3	0.22
F4	8	D4	0.50

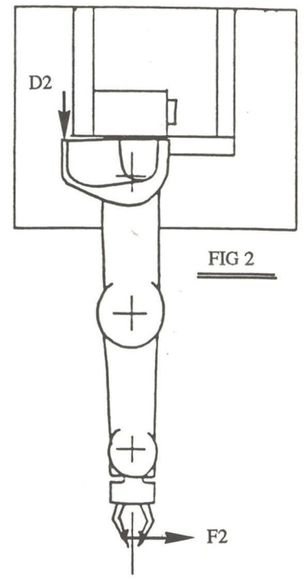


FIG 2

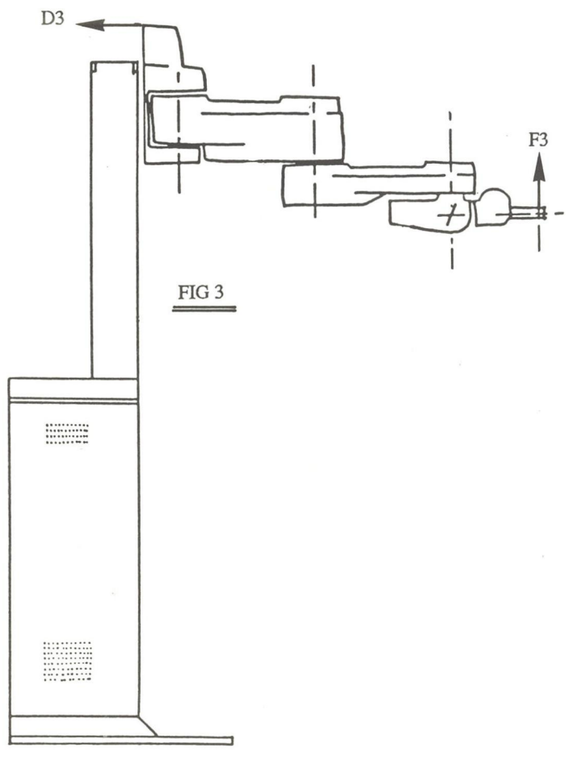


FIG 3

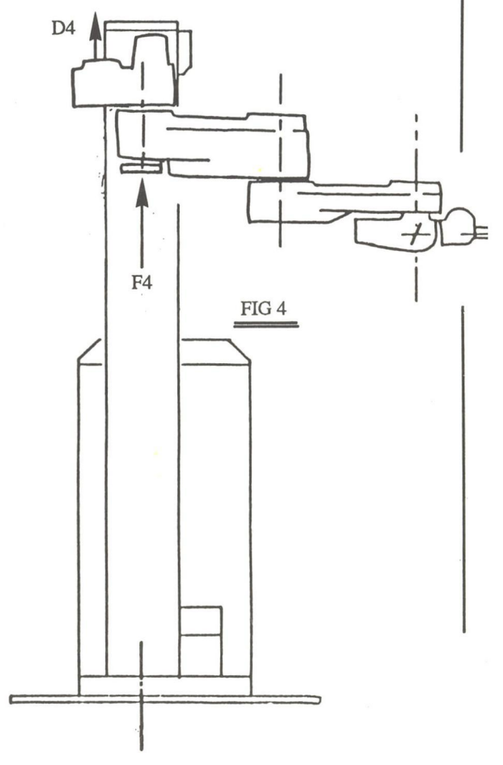
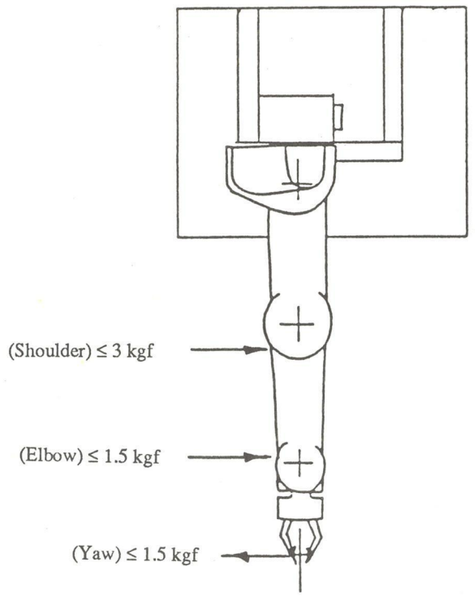


FIG 4

Checking the friction

The elbow, shoulder and yaw should be tested for excessive stiction (static friction) that can indicate tight belts, for instance. The arm should be completely unpowered for these tests.

The following diagram shows where to apply the forces. The force required to start an axis moving should be less than shown.



Checking backlash

Important fixings for the movement and accuracy of RTX are secured with loctite to prevent them coming loose. However if the backlash of RTX seems excessive and the belt tensions have been checked and found to be correct, check:

(a) grub screw on elbow spindle to lower arm (units pre 130)
(b) motor mounting screws
(c) eccentric shafts (shoulder & elbow)
(d) grub screws on pulleys and retaining screws on shoulder 60XL pulley

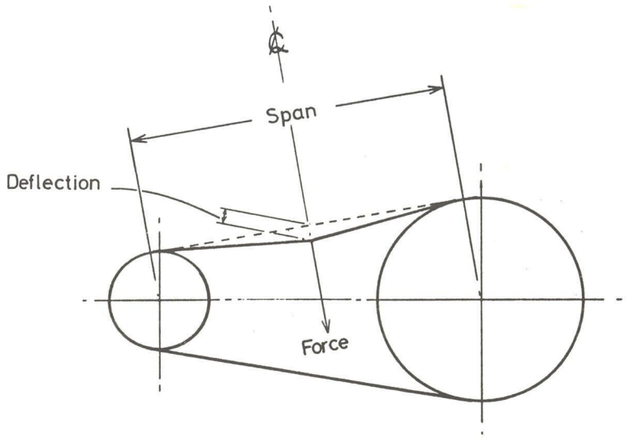
Belts

Belt tension is important to the performance of RTX. If the belts are loose, backlash will become excessive, while if the belts are tight friction will increase and bearings, housings and other parts of RTX may be damaged. Belt tensions should be as follows:

Axis	Belt	Deflection force	Deflection in mm
Shoulder	140 XL (large)	400 gmf	0.5 - 0.7 mm
	175 mp (small)	130 gmf	1.6 - 1.8 mm
Elbow	130 XL (large)	400 gmf	1.0 - 1.2 mm
	140 mp (small)	130 gmf	1.0 - 1.2 mm
Yaw	260 XL (large)	400 gmf	5 - 7 mm
	284 mp (small)	130 gmf	3.1 - 3.7 mm
Zed	55505 HTD	500 gmf	9 - 11 mm

Notes:

* These deflections are measured at the mid span position.
* The yaw XL belt is adjustable by adding a spring clip which is available from UMI.
* The zed belt. The reading should be taken from a position adjacent to the hole in the side of the column, with the arm at the top of the column.
* For shoulder and elbow axes the XL belts must be adjusted before the minipitch belts or damage may occur.



Zed Brake

If the zed motor buzzes when the arm is stationary, with a load of less than 0.5kg, the zed brake may require attention. Ensure that the steel disc and the friction surfaces of the zed brake are dry and free from lubricant. In most cases problems can be resolved by simply cleaning these parts. On units 1825-1849 only, the spring tension on the friction pad will need to be increased to prevent this buzzing.

The brake is factory set and adjustment should not be attempted. If the brake has been cleaned and still does not function correctly then replacement is recommended.

Lubrication

The following components should be lubricated:

* combined 130mp/20XL pulley bore - Aeroshell 6
* combined 130mp/10XL pulley bore - Aeroshell 6
* gripper screw - Aeroshell 6
* wrist gears - Rocol BG622 (Note: this must be applied without separating the wrist castings or removing the motors.)

Cleaning

Ensure that RTX is disconnected from the mains. RTX may be cleaned with a damp rag. Do not use excessive water or any solvent based cleaners.

Fuses

Always disconnect RTX from the mains before replacing any fuses.

The following fuses are fitted. They may be replaced when blown but if the replacement fuse blows immediately you should assume that there is some fault and investigate further. Do not exceed the recommended fuse ratings or further circuit damage may occur.

Circuit	Location	Rating
mains supply on 220v (UK only)	wall plug	5A (1") - mains leads only
mains supply	mains receptacle on RTX inlet	2A (20mm)
mains supply	within PSU	4A (1")
24v supply	Connector Panel (FS1)	4A (20mm)
5v supply	Connector Panel (FS2)	3A (20mm)
Ancillary power	Connector Panel (FS3)	200mA (20mm)

To replace the two fuses in the mains receptacle: first remove the mains lead and then use a small screwdriver to lever off the cover to reveal the fuse holders which may then be slid out.

To gain access to the other fuses the main enclosure must be removed.

To replace the power supply fuse it is necessary to remove the cover from the supply. Please note, however that this fuse is slow blow and also rated higher than the fuses in the mains receptacle and is not likely to blow.

Tools

Tools required for performing minimal operations on RTX are:

- Allen keys standard or long reach (1.5mm, 2.5mm, 3mm and 5mm)
- Circlip pliers (90 degrees)
- Offset screw driver (4mm)
- Open end spanner (10mm)
- Ring or open-end spanner (7mm)
- Side cutters
- Tiewraps

2 Technical Information

Specification

Lifting capability

The shoulder, elbow and yaw do no work against gravity.

The zed motor can lift 4 kg in addition to the weight of the arm, at 100 mm/s.

The wrist motors can pitch and roll a 2 kg cylinder centrally held in the gripper at 35 degrees/s.

Motor speeds & gearing

Angular Movement

	Elbow	Shoulder	Wrist1	Wrist2	Yaw
Counts/rev	12.000	12.000	12.000	12.000	12.000
Motor gearbox	20.230	20.230	20.230	20.230	20.230
Other gearing (1)	7.222	7.222	20.000	20.000	7.222
Other gearing (2)	3.000	6.000	-	-	2.000
Total gearing	438.317	876.633	404.600	404.600	292.211
Degrees/count	.068	.034	.074	.074	.103
Counts/degree	14.611	29.221	13.487	13.487	9.740
Default 'speed'	100	100	100	100	100
Max speed					
As stored in 'speed	160	160	160	160	160
Counts/timeslot	20	20	20	20	20
Degrees/sec	85.555	42.777	92.684	92.684	128.332
Motor RPM	6250.000	6250.000	6250.000	6250.000	6250.000

Gripper

The gripper movement is non-linear, an approximation to within 3mm is as follows ...

counts/mm	14.7
mm/count	0.068

Zed

Metric		Imperial	
Counts/rev	24.000	Counts/rev	24
Motor gearbox	25.000	Motor gearbox	25.000
Teeth/rev (pulley)	32.000	Teeth/rev (pulley)	32.000
Teeth/mm (belt)	.200	Teeth/in (belt)	5.080
mm/count	.267	in/count	.010
counts/mm	3.750	counts/in	95.250
Default 'speed'	100	Default 'speed'	100
Max speed (theoretical)			
As stored in 'speed'	160 (*)	As stored in 'speed'	160
Counts/timeslot	10.000	Counts/timeslot	10.000
mm/sec	166.667	in/sec	6.562
Motor RPM	1562.500	Motor RPM	1562.500
Max speed (practical)			
Motor RPM	975.000 (*)	Motor RPM	975.000
Counts/timeslot	6.240	Counts/timeslot	6.240
mm/sec	104.000	in/sec	4.094
As stored in 'speed'	100	As stored in 'speed'	100

(*) These are the governing values for the 'max' speed and should not be exceeded or the arm might overshoot programmed points

Repeatability

Motor control gives repeatability at the motors to +1 count which represents ±0.5mm at the gripper tip with the arm at full extension and with the deadbands set to 1.

Speed

The following are maximum angular or linear speeds.

movement	maximum rated speed	motor speed
zed	104.2 mm/s	975 rpm
shoulder	42.8 degrees/sec	6250 rpm
elbow	85.6 degrees/sec	6250 rpm
wrist yaw	128.4 degrees/sec	6250 rpm
pitch & roll	92.7 degrees/sec	6250 rpm
gripper	84.9 mm/s	6250 rpm

Mechanics

The mechanics of RTX are described in "Inside RTX". The reader should refer to that manual for information on how RTX was constructed and how it operates.

As mentioned previously the third batch of 500 RTXs (130-629) are basically the same as the second batch (30 - 129). The minor mechanical improvements refered to include:

* the length of the upper and lower arms, increased from 253.5mm to 254mm
* the upper and lower arm mouldings are now manufactured from a higher grade polyurethane which improves both structural integrity and appearance. All arm inserts are moulded in to improve pull-out performance
* the elbow shaft is now moulded into the lower arm to improve rigidity
* support washers have been added to the zed belt & carriage assemblies to improve load distribution
* the yaw pulley (40XL) now has a quadrant retaining flange to stop "belt walk" and improve drive performance
* the wrist shaft bracket is now a one piece manganese bronze casting (instead of a 3-piece assembly) improving rigidity and life expectancy.

Mains & PSU

Connector Panel Assy

Emergency stop

Emergency stop wiring is through a 9-way D type connector on the connector panel.

Pins 1 & 2 should be connected by a normally closed push switch to form the remote stop circuit.

Pins 4 & 5 may be connected by a normally open push switch to form a remote circuit for turning on the 24v supply to the motors for units 130 onwards.

Mains

The mains receptacle in the connector panel accepts a standard IEC/CEE plug. Earth connections are made to the connection panel and the power supply unit.

PCB

The connector panel PCB assembly accepts all outputs from the power supply unit. It protects, with fuses, the 24v to the motors, the 24v to the ancillary connector and the 5v to the external motor driver. The 5v to the IP is not protected.

The 24v is switched by relays which are controlled by the two push switches. LEDs indicate the state of the 24v supply.

Power Supply

The power supply is a model HSS100 by Weir. Input is 110vac or 220vac selectable by jumpers. Total capability is 150 watts, supplying +5v +12v and +24v. All outputs are short circuit protected.

Electronics

Distribution Board

connector number	number of pins	links to ...
1	40	ribbon cable
2	6	wrist 1
3	6	wrist 2
4	6	yaw
5	6	shoulder
6	6	elbow
7	6	gripper
8	10	ancillary

EMD

Supply (large black)

1	0v(m)
2	5v(mr)
3	24v(mr)

Connection to IP (IDC)

1	encoder (phase 1)
2	0v
3	encoder (phase 0)
4	5v
5	enable
6	direction
7	0v(mr)
8	5v(mr)

Connection to motor/encoder assy. (molex)

1	encoder (phase 1)
2	0v
3	encoder (phase 0)
4	5v
5	motor -
6	motor +
7	motor -
8	motor +

Supply connections (PL8)

Pin	Supply	Colour
1	24v(m)	red
2	0v(m)	black
3	0v(micro)	black
4	+12v	yellow
5	-12v	violet
6	5v	orange
7	5v(m)	white

Ancillary connections (PL5)

For details of PL5, see explanation of user configurable IC30 in "Inside RTX"

I/O (PL6)

Pin	IP	I/O
1	0	0
2	0	1
3	0	2
4	0	3
5	0	4
6	0	5
7	1	0
8	1	1
9	1	2
10	1	3
11	1	4
12	1	5
13	Ov	
14	Vcc	
15	Ov	
16	no-connection	

RS232 connections (PL4)

(a) RTX is configured as DCE and thus connects to the IBM with a 1-to-1 cable
(b) RTX links RTS back to CTS
(c) RTX links DTR back to DSR
(d) the arrows In/Out mimic the IBM on the left and RTX on the right

IBM (25way DIN male)

Pin	In/Out	Name
1		
2	out ---->	TxData
3	in <----	RxData
4	out ---->	RTS
5	in <----	CTS
6	in <----	DSR
7		Signal Ground
20	out ---->	DTR

IBM <---> RTX Cable

25way DIN female <---> 25way DIN male
wiring : 1 to 1

RTX Name	In/Out	Pin	Internal links
TxData	----> in	2	
RxData	<---- out	3	
RTS	----> in	4	4 & 5 linked
CTS	<---- out	5	
DSR	<---- out	6	6 & 20 linked
Signal Ground		7	
DTR	----> in	20	

RTX Connector Panel <---> IP Card

Pin (panel)	Name	Pin (IP)
1		1
2	TxData	3
3	RxData	5
4	RTS	7
5	CTS	9
6	DSR	11
7	Signal Ground	13
20	DTR	14

IP Card

Name	In/Out	Pin	Internal links
TxData	----> in	2	
RxData	<---- out	3	
RTS	----> in	4	4 & 5 linked
CTS	<---- out	5	
DSR	<---- out	6	6 & 20 linked
Signal Ground		7	
DTR	----> in	20	

Motor/Encoder Assy

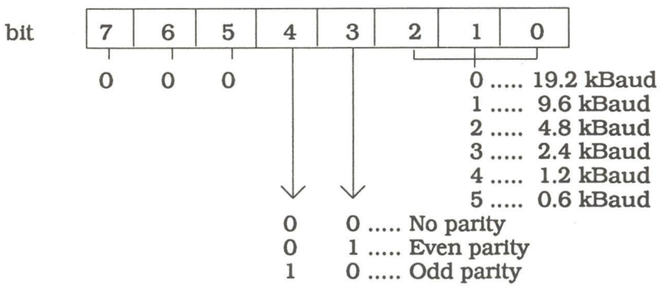
Encoder board connection	Function
1	motor+
2	motor-
3	5v
4	channel 1
5	0v
6	channel 2

Firmware

Baud Rate setting (IPC)

The Baud rate of the IBM must be changed by modifying the START program. The Baud rate of the IP may be altered by an IP command.

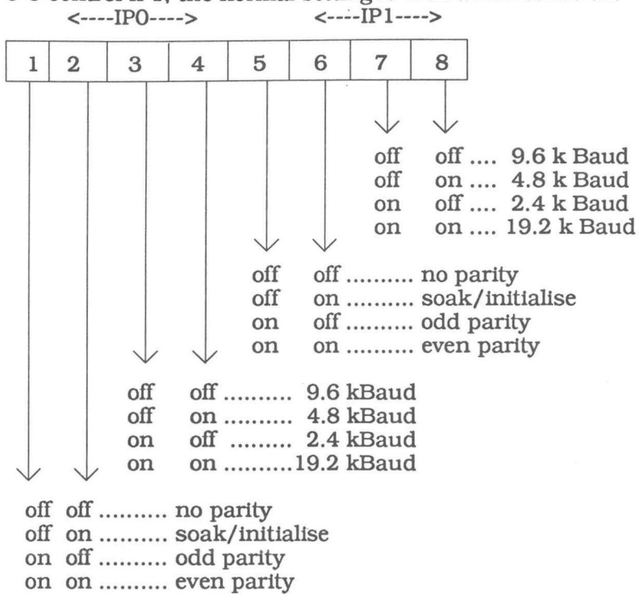
Command type code:48 ($30)
Command byte 0:



Command byte 1: ignored
Response: Ack ($00).
NB: The response is given at the old Baud rate after which Baud and parity change to the new settings.

Baud Rate setting (switches)

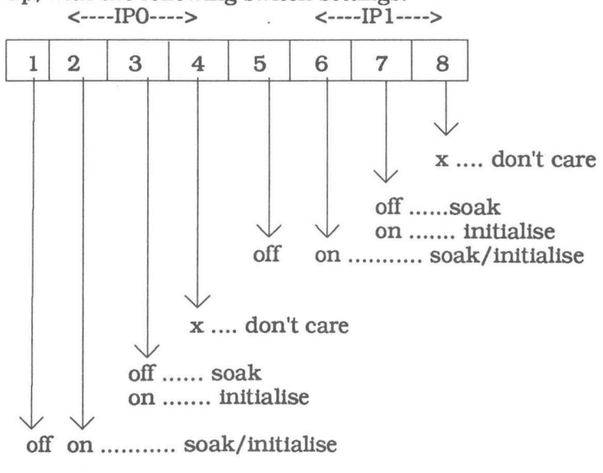
The Baud rate of the IP is set from SW1 on power up. Switches 1-4 control IP0, switches 5-8 control IP1; the normal setting is with all switches off.



For more information on the soak and initialisation selection, see the following section.

ROM Soak & Initialisation

The ROM based initialisation and soak sequences may be selected from SW1, on power up, with the following switch settings:



Note: RTX should be intialised before using the soak sequence.

The switches are read on power up; however, if switches 3 & 7 are changed from initialisation to soak once the initialisation has begun RTX will follow the initialisation by the soak.

3 Fault finding

Symptoms & Faults

Electrical

Axis out of control

If an axis goes out of control first check:

* the soak option is not selected, or
* the motor is not being driven in the force mode

Faults may occur if the IP card is not getting feedback from the encoder due to either faulty encoder or faulty wiring.

It is possible to isolate the motor/encoder assemblies by temporarily substituting a spare assembly and connecting it to the wiring loom. If the loom is suspected test by changing the motor connections at the distribution board.

For instance, suppose that the gripper drives fully open whenever an attempt is made to drive it.

* first check the motor/encoder assembly by removing the gripper cover and connecting a spare assembly.
* check the wiring loom in the arm by swapping the shoulder and the gripper connections at the distribution board and driving the gripper using the shoulder keys in TEST, FRTX or DRIVE. If the fault persists it is between the connection board and the gripper.
* In the case of the gripper and wrists, it is possible to further isolate the wiring loom by swapping wrist and gripper motors at the connection point in the lower arm. Further investigation could reveal the flexible cable leading from the end of the arm to the wrist is faulty.

No movement

An axis may not move if:

* the 24v motor supply has not been turned on
* the emergency stop circuit is incomplete, or
* the 24v motor supply fuse has blown

More seriously, the motor may be faulty or the drive from the IP card (or the EMD board in the case of the zed motor) may not be getting to the appropriate motor due to either faulty drive electronics or faulty wiring.

If only some of the axes have failed then bear in mind the following:

* all motors are driven directly from the IP card (through the 40way ribbon cable) except zed which has its own 24v supply and EMD (external motor drive) card.
* the wrist motors share a driver chip (IC38 on the IP)
* the elbow and shoulder share a driver chip (IC34 on the IP)
* the yaw and gripper share a driver chip (IC36 on the IP)
* the wrist motors are controlled by IP0 while all other motors are controlled by IP1

It is possible to isolate the motor/encoder assemblies by using the technique describing motor faults.

Erratic IP responses

Erratic IP responses can occur if you have left the IP switched into either test or soak mode. Selecting the wrong Baud rate or parity would also give a similar fault. Electrical interference on the RS232 cable should not be ruled out if the cable is long and runs near to electrically noisy machinery.

No IP responses

If the IPs fail to respond at all, the obvious causes are that the RS232 cable is disconnected or that RTX is not turned on!

More seriously, the RS232 link from the connection panel to the IP card may have become disconnected or damaged, the power supply could have failed or either or both of the IPs may have failed.

Also note that the IP card has the ability to accept 8051 microcontrollers with integral ROM. Switch bank 3, switches 2 & 3 are used to select the internal or external ROM. When using 8031 controllers (as RTX does in its standard configuration) these switches must both be **on**, or the IPs will fail to operate.

Mechanical

Axis out of control

Rarely will a mechanical fault cause a motor to go out of control with one exception. If an encoder disk slips on the motor shaft the IP will fail to get the correct feedback and the motor will go out of control.

No movement

As the belts are the major drive transmission medium in RTX they are usually the mechanical cause of axes not moving. Belts can either become worn, loose or mislocated. You can check the motors are operating by removing a belt or pulley and driving the motor on its own.

The gripper may become jammed at its endstop (open or closed) if it driven at full force and full speed into the endstops. The gripper may be released from its endstop by removing the cover (4 snap rivets) and rotating the gears. Looking at the gear mounted on the motor shaft: clockwise opens the gripper jaws while counter-clockwise closes the gripper jaws.

Excessive sloppiness

RTX is capable of positioning the gripper tips to within ±0.5mm; if there is excessive backlash you will be able to move the arm and (with RTX powered up) the original position will not be regained. This can be caused by either loose/worn belts or loose grub screws attaching pulleys to shafts. On units 30-129 the grub screw retaining the elbow spindle to the lower arm moulding should also be checked.

Another sloppy movement that can cause loss of repeatability is in the carriage. This can be caused by poor adjustment of the carriage rollers onto the zed column extrusion.

Noises

If yaw hits an endstop when the elbow joint is moved the minipitch belt will jump with a clicking noise (and the arm will have to be re-initialised), If the belt jumps for any other reason then the belt tension should be checked.

If RTX makes more violent noises or fails to move at all it is most likely to be a failed belt. Belts can break under excessive strain and if the broken belt is still fouling the driven gear slight noise may occur. Belts can become worn if used excessively with the wrong belt tension. If the noise and movement is intermittent this is most likely to be the cause.

A continuous clicking noise associated with an axis may be the encoder disk catching the slotted opto-switches. In this case the encoder assembly or disk should be adjusted to prevent this happening.

Two other known causes of noise are associated with the zed axis. A foreign body getting behind the blind can foul the blind rollers; in extreme cases this may cause the blind to tear off or zed to seize. If RTX is dropped it is possible for the zed motor to pull the mounting plate off the zed column. RTX may continue to operate but the zed motor may rattle against the column.

Stiff axis

If an axis is stiff it is likely that the belt is too tight which may occur after poor adjustment. The indications of this might be that RTX is taking a long time to get to a position or that FRTX gives the error "AXIS STOPPED DUE TO ERROR LIMIT EXCEEDED". Adjust the belt tension.

If an axis is stiff at regular intervals in its movement, it may be that a motor shaft has become bent. This may occur if the minipitch belt has been tensioned excessively.

The TEST Program

The test program may be used for driving individual motors to check the drive and the feed-back. The following are some hints on how to get the best out of TEST.

* When checking that the drive signal is getting to a motor set that motor into FORCE mode with a MAX FORCE of 16. This will give you a drive PWM with a mark:space ratio of 1:3 - an easy signal to spot with an oscilloscope.

* Disconnect a pulley/gear and use the FORCE mode as described above to give you a fairly constant speed for the chosen motor. You can then check the encoder feedback signals are getting back to the IP without RTX continually hitting its endstops.

Testing on completion

INIT is a good indication that RTX is operational as it uses all motors and different modes (manual, numeric & force).

SOAK is a good all round driver to show that all motors are working. RTX should be put into an initialised position before SOAK is run (approximately, by hand will suffice). This ROM based program was not designed for extended testing of RTX, it should not be used for more than 30 minutes continually.

The DEMO program and then FRTX may be used for extra confidence.

4 Stripping & Re-assembly

Warning

The following sections describe how to strip and re-assemble the various parts of RTX. They should not be used as a complete sequence; you should first decide which part of RTX needs to be stripped, repaired and re-assembled and then use the appropriate section.

Don't follow these sections blindly.

Encoder Disks

The encoder disks are a push fit onto the motor shaft. If they become loose and slip on the motor shafts the servo loop control will not operate correctly. To avoid this **do not turn the motors using the encoder disks.**

Snap rivets

Several snap rivets are used in RTX; they are removed by first removing the inner core and then removing the main core. Replacement is the reversal of removal.

Screws

Most screws are secured with loctite to prevent them shaking loose. When replacing screws the use of loctite or an equivalent is recommended.

Several screws fix into insert threads in the mouldings; these insert threads can be pulled out of the mouldings if screws are overtightened. **Do not overtighten screws.**

Covers (Fig. 1)

Top Cover

removal

* move arm to top of column
* remove (8) screws from top cover
* lift cover upwards until it is free of the main enclosure taking care not to scratch the column
* top cover will come away free

replacement is the reversal of removal

Main Enclosure

removal

* remove the top cover
* remove (4) screws surrounding the connector panel
* remove (2) screws from the front of the enclosure
* remove (3) screws from the side of the enclosure
* slide the enclosure vertically until the bottom is free of the IP card
* it may then be removed completely

replacement is the reversal of removal

Arm Covers (Figs. 1 & 2)

The shoulder, wrist and gripper covers are held on with snap rivets.

All other arm covers are held on with screws.

Arm

Complete assembly (Figs. 1 & 2)

To remove the arm:

* remove the shoulder cover
* remove the plate under the shoulder (1 screw)
* carefully remove the (7) molex connectors
* fully support the weight of the arm - it's best to get help for this
* remove the (4) screws connecting the arm to the carriage - its best to remove the lower ones first
* the arm will come away free

To replace the arm:

* position the arm against the carriage - again it's best to get help for this
* fix arm to the carriage with the (4) screws - its best to fix the upper ones first
* reconnect the (7) molex connectors - making sure they go in the right places
* test the arm
* replace the plate under the shoulder (1 screw)
* replace the shoulder cover

Shoulder (Fig. 2)

motor removal

* remove the shoulder cover
* cut the cable tie
* remove molex connector
* remove 4 motor plate screws
* release belt from motor
* remove motor / encoder assembly completely

Minipitch belt removal

* release 4 motor plate screws
* undo the screw at the top of the eccentric shaft and rotate the shaft until the large (XL) belt can be walked off the large pulley and released from the small pulley
* remove the minipitch belt by working it between the pulleys

XL (large) belt replacement

* remove the minipitch belt as above
* remove the circlip and 'E' clip from the eccentric shaft.
* pull the shaft up through the casting and free the combined pulley which can be placed to one side - burrs on the eccentric shaft screwdriver slot should be removed with a file before removing the spindle or the burrs will tear the plastic bearing surface
* get some assistance and support the arm; remove the circlip and 'E' clip from the shoulder shaft. push the shaft down to be level with the top of the shoulder pulley
* remove the old XL belt
* replacement is the reversal of removal

  Note that the XL belt must be adjusted for tightness before adjusting the mini-pitch belt

minipitch belt & motor replacement

* connect motor / encoder assembly to molex connector
* loosely position motor / encoder assembly with 4 motor plate screws
* replace belt around motor pinion and then pulley at elbow
* adjust belt for correct tension (the XL belt must be adjusted first)
* tighten 4 motor plate screws
* check belt tension (see the appropriate section in "Routine Maintenance")
* affix cable to motor with tiewrap
* replace all covers

Elbow (Fig. 2)

belt & motor removal

* remove both top and bottom covers from upper arm
* loosen (4) screws securing motor mounting plate
* use long, large screwdriver to remove eccentric locking screw from underside of arm
* remove (large) XL belt
* remove eccentric shaft / composite pulley combination
* remove minipitch belt
* note orientation of motor mounting plate
* partly remove motor/encoder assembly
* disconnect motor/encoder assembly from loom

  NB: If the combination pulley needs to be removed from the eccentric spindle (eg: for lubrication) any burrs on the screwdriver slot should be removed with a file to prevent the plastic bearing surface from being damaged.

motor & belt replacement

* reconnect motor encoder assembly to the loom
* loosely remount the motor/encoder assembly and replace (4) screws & washers. Be sure to get the correct orientation of the motor plate - motor away from pulley
* loosely locate minipitch belt and eccentric shaft / composite pulley combination
* fix screw and both (large and small) washers to the underside of the eccentric shaft. This may be difficult with the arm attached to the column - it may ease matters to use a screw gripping screwdriver to help position the screw.
* first tension the (large) XL belt and then the minipitch belt (see the section on "Routine Maintenance")
* check operation of the elbow
* replace the covers.

  NB: The motor plate screws should not be overtightened. On units 30-129 washers should be used under the motor mounting plates to prevent the inserts from being pulled out of the moulding

Yaw (Fig. 2)

The yaw motor encoder assembly and minipitch belt are not shown in fig. 2, but are located on the underside of the upper arm in the view marked "X"

combined pulley lubrication

* remove the top and bottom covers from the upper arm
* slacken elbow combined pulley eccentric shaft
* remove the XL belt from the wrist pulley

* remove the minipitch belt
* slacken the elbow 30XL pulley by undoing the grubscrew until the dog point clears its location hole
* ease the elbow pulley off its spindle and gently lower the spindle until it is flush with the top bearing
* the combined pulley can now be moved up to allow the shaft to be greased
* reassemble in reverse order

motor removal
* remove top & bottom covers from upper arm
* release belt tension by slackening 4 motor plate screws
* release belt from pulley at elbow and then motor pinion
* remove motor / encoder assembly part way
* remove molex connector
* remove motor / encoder assembly completely

minipitch belt removal
* proceed as above to release belt
* remove top cover from lower arm
* the belt may then be removed by working it between the gap at the elbow between the upper and lower arms (take care not to snag the belt on the elbow stop bracket)

motor replacement
* connect motor / encoder assembly to molex connector
* loosely position motor / encoder assembly with 4 motor plate screws
* replace belt around motor pinion and then pulley at elbow
* adjust belt for correct tension
* tighten 4 motor plate screws
* check belt tension (see the appropriate section in "Routine Maintenance")
* replace all covers

NB: The motor plate screws should not be overtightened. On units 30-129 washers should be used under the motor mounting plates to prevent the inserts from being pulled out of the moulding.

minipitch belt replacement
* feed belt along the arm and work through the gap at the elbow between the upper and lower arms (take care not to snag the belt on the elbow stop bracket)
* proceed as in motor replacement

(large) XL belt removal
* remove the retaining flange on the wrist pulley by undoing the screws (if fitted)
* note the position of the torsion spring if fitted on the belt relative to the grub screw on the wrist pulley.
* remove the spring (if fitted)
* gently "walk" the belt off the pulley by maintaining an upward pressure whilst rotating the pulley from side to side
* the belt may then be removed by working it between the gap between the upper and lower arm at the elbow

(large) XL belt replacement
* replacement is reversal of removal
* take care if (re)fitting the torsion spring that it does not foul, whilst allowing the wrist yaw full rotation.

Wrist (Fig. 2)

It is not recommended that you disassemble the wrist unit, as it is factory set; the only items that may safely be replaced on the wrist unit are the encoder PCBs on the motors and the plastic spiroid bevel gears.

removal of complete wrist
* remove cover from lower arm
* cut cable tie nearest yaw
* disconnect wrist loom (connectors ske,skf & skg)
* support the wrist unit
* undo the support screws between the lower arm and the wrist
* remove the wrist, carefully feeding the connectors one by one through the hollow shaft
* replace screws and washers in wrist assembly for safe keeping

replacement of complete wrist
* this is the reversal of removal
* you will need a new cable tie

removal of plastic spiroid bevel gears
* undo the (3) screws holding together the wrist housing
* separate the two halves
* remove and inspect the spiroid bevel gears
* replace if necessary

replacement of plastic spiroid bevel gears
* grease the cross shaft and spiroid bevel
* reassemble the housing with the gear set the same way up as it was when it was removed (if in doubt remove one spiroid bevel and look for "top" marked on the cross shaft)
* replace the housing screws

Gripper (Fig. 3)

removal of complete gripper
* remove the cover (4 snap rivets)
* cut the cable tie
* remove the 6-way molex connector from the pcb
* feed cable under motor
* remove (2) support hex bolts from underside of gripper unit
* remove gripper assembly
* replace bolts and washers for safe keeping

stripping the gripper
* remove the gripper as described above
* remove the (6) screws attaching the containment plate to the base
* lift the drive unit clear of the base
* remove the central locating pin
* remove the two spur gears by gently prising them from their shafts
* remove the motor encoder assembly by removing the (3) screws clamping the motor to the containment plate (this also separates the two plates)
* release the gripper jaws by rotating the lead screw until the trunions run off either end
* to dismantle the gripper tips from the jaws first remove the tension spring by pushing it off the pivot pin with a screwdriver, the pivot can olso be pushed out with a screw- driver

Reassembling the gripper is the reversal of the above; however a couple of points should be noted
* both trunions should be started as near as possible to symmetrical positions on the leadscrew
* the containment & motor plates should be mounted with their sides flush

Zed

Belt (Fig. 4)

Adjustment

Move the arm to the top of its travel and remove the zed blind from its right hand groove to reveal the zed belt half way up the column. Proceed as follows:

* unscrew the tensioning bolt at the top of the column by approximately 4 turns.
* loosen the (4) clamp nuts at the top of the column (using a 7mm spanner). Do NOT loosen them by more than half a turn.
* check that the idler pulley is able to move up and down.
* tighten the tensioning bolt until the belt tension is taken up and is within the values previously given.
* refit the blind.
* tighten clamp nuts.

Removal

* refer to the appropriate section to remove the motor/clutch/encoder assembly
* position the carriage over the access hole half way up the column
* remove the lock nuts and screws retaining the ends of the zed drive belt
* remove the belt. Reassembly is the reversal of removal. A couple of points:
* Don't forget to reset the tension of the zed belt.
* If you replace the screws retaining the end of the zed belt be sure to use high tensile steel replacements (available from UMI)

Blind

Changing a blind is not a case of removal followed by replacement. Inserting a new blind without an old blind in position to help involves a lot of disassembly.

Removal

* remove the arm from the zed column
* remove the upper blind support shaft from the top of the carriage
* remove the lower blind support shaft and the springs
* do not continue in this section if you are simply changing a blind
* pull out the blind from the base of the column
* the blind should be rolled when stored

Changing a blind

* remove the arm from the zed column
* remove the upper blind support shaft from the top of the carriage
* remove the lower blind support shaft and the springs
* attach the new blind to the top of the old blind with a good length of adhesive tape (wide packing tape is ideal)
* carefully pull out the old blind from the bottom of the column feeding in the new belt at the top of the column
* attach the lower blind support shaft and the springs to the bottom of the carriage
* attach the upper blind support shaft to the top of the carriage - a snap fit.

Replacing a blind

* remove the column
* feed the new blind in
* attach the lower blind support shaft and the springs to the bottom of the carriage
* attach the upper blind support shaft to the top of the carriage - a snap fit.
* replace the column

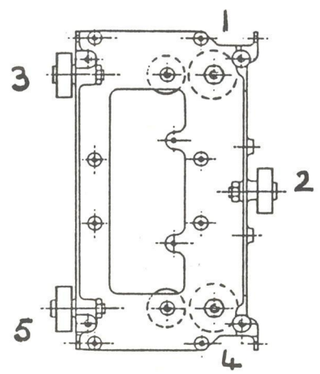
Carriage assembly

Removal

* remove the arm
* remove the top cover
* remove the main enclosure
* partially remove the blind assembly
* position the carriage so that the screw/nut above the right-hand nylon roller bearing is adjacent to the hole in the right-hand side of the column (near the EMC filter assembly)
* loosen but do not remove the (4) nuts on the zed belt cog plate
* release the tension in the zed belt by undoing the hexagonal head screw on the very top of the zed column
* remove nut and washer from upper zed belt anchor screw - see diagram
* through the hole in the zed column unscrew the upper anchor screw - the carriage will be able to be lowered easily
* remove the zed axis stop bar by undoing and removing the (2) hex key screws and washers on either side - see diagram
* remove the idler pulley assembly, replace screws
* position and support the carriage so that the lower belt support screw is accessible through the zed hole
* remove nut and washer from lower zed belt anchor screw
* remove the lower belt anchor screw
* remove the distribution board and cable guide strip from the carriage
* the carriage will now move freely up and down the column and may be removed from the top of the column

Carriage assembly (adjustment)

* remove the carriage
* inspect and clean the runners. On units 30-129, 4mm washers should be fitted under the small rollers by unscrewing the retaining screw and adding a washer between the bearing and the carriage and 6mm washers should be fitted between the carriage and bearing on the eccentric screws.
* for pre production units and units 30 -154 slacken the (5) locknuts slightly (with a 10mm spanner) to allow the eccentric screws to turn when moderate force is used (with a 5mm screwdriver)
* adjust all (5) wheels in turn to have between 2.3 and 2.35mm gap between the rollers, locking the eccentric with the locknut.



For units 155 onwards, the locknut has been loctited in the eccentric screw, allowing adjustment using the spanner alone. For these units a screwdriver is not required and should not be used.

* test the adjustment by removing and replacing the carriage. The adjustment is correct when light springyness is felt when the runner enters between each pair of wheels. A force of 0.5 kgf is typical for this insertion. The adjustment is too tight if any cogging or roughness is found in the movement. Re-adjust if necessary using small fractions of a turn.

* having adjusted all (5) wheels, the movement should be smooth over its whole travel and the carriage should fall under its own weight

NB: It is possible to adjust the carriage without removing the carriage, belt & blind. However, care must be taken not to overtighten the rollers.

Column

Removal

* referring to the appropriate sections:
  - remove the top cover and main enclosure
  - remove the arm
  - remove the blind
  - remove the IP card
  - release the zed belt tension
  - remove the zed motor/brake/encoder assembly
* following the removal of the zed motor/brake/encoder assembly the column will be raised by 10cm and temporarily clamped in place with one of the screws
* release the securing screw and remove the column completely

Reassembly is the reversal of removal. Don't forget to reset the tension of the zed belt.

Motor / Clutch / Encoder Assembly (Fig. 5)

Removal

* refer to the appropriate sections to remove the following:
  top cover and main enclosure
  the arm
  the blind
  the IP card
* refer to the appropriate section to release the zed belt tension
* remove the (2) screws from the bottom of the connector panel
* remove the (2) cap head screws securing the stiffener plate to the column
* rotate the zed drive pulley to gain access to the grub screw and unscrew it 7 or 8 turns
* loosen the (4) cap head screws securing the column to the large bracket
* slide the column upwards by 10cm and temporarily clamp in place with one of the screws
* remove the (3) motor fixing screws and slide the motor away from the pulley, disconnect the motor from all cabling, the motor may now be removed

Reassembly is the reversal of removal. Don't forget to reset the tension of the zed belt.

Upper Blind Rollers (Fig. 4)

* remove the arm
* disconnect the blind from the carriage but do not remove it from the column
* remove the (2) circlips on the (2) roller shafts
* one at a time, hold the rollers and remove the shafts to free the rollers
* store the shafts in the rollers and replace the circlips

Power & control

Connector Panel Assy (Fig. 5)

* disconnect RS232 cable, emergency stop cable, etc
* ensure RTX is disconnected from the mains
* remove the top cover
* remove the main enclosure
* remove the (2) large black connectors
* remove all IDC connectors from the IP and EMD boards
* remove (2) screws/nuts from the top of the connector panel
* remove (2) screws/nuts from the bottom of the connector panel
* remove the mains leads spade receptacles from the top of the mains switch
* remove 5.5mm nut from earth post and remove green earth cable
* connector panel is now free

Distribution Board (Fig. 4)

* remove the complete arm assembly
* remove the (4) screws securing the board to the carriage
* remove PL1

EMC Filter (Fig. 6)

* remove the top cover
* remove the main enclosure
* release PL3 idc connector from the IP card
* remove the (4) cross-headed screws from the EMC filter
* pull out the pcb and disconnect the idc ribbon connector
* remove the (3) EMC housing support screws
* remove the EMC housing and replace all screws for safe keeping

EMD (Fig. 6)

* remove the top cover
* remove the main enclosure
* The EMD board is small pcb with a large heat sink mounted on the side of the column.
* remove the IDC at the top of the board
* remove the molex connector
* remove the black connector by squeezing the lugs top and bottom
* remove the four hexagonal bolts that hold the complete assembly to the column

IP Card (Fig. 5)

removal

* remove the top cover
* remove the main enclosure
* the IP card is the large double euro pcb.
* remove the molex connector
* remove the (5) IDC ribbon cables
* remove the IP by sliding it to the left (as viewed from the back of RTX)

Motor/Encoder Assy

Stripping is simply a case of removing the (2) screws and (1) connector. For reassembly, however, please note that the orientation of the encoders varies between axes.

PSU Assy (Fig. 5)

* remove the top cover
* remove the main enclosure
* ensure RTX is disconnected from the mains
* the PSU is mounted on a plate attached to the base unit
* undo and remove the (3) nuts and spring washers on the mounting plate
* remove the PSU assembly and support it, mounting plate down.
* undo and remove the (7) eyelet screws marked PF to 24v, remove the cables then replace the screws for safe keeping.

A. Routine Maintenance Checklist

Serial No: _____
Date: _____

Check	Done	Comments
Zed carriage:		
* carriage compliance	[ ]	
* backlash	[ ]	
Friction:		
* shoulder	[ ]	
* elbow	[ ]	
* yaw	[ ]	
Backlash:		
* shoulder	[ ]	
* elbow	[ ]	
* yaw	[ ]	
* pitch/roll	[ ]	
* gripper	[ ]	
Belt tensions:		
* zed	[ ]	
* shoulder	[ ]	
* elbow	[ ]	
* yaw	[ ]	
Zed brake	[ ]	
Lubricate every 500hrs/6 months		
* Yaw pulley	[ ]	
* Elbow pulley	[ ]	
* Shoulder pulley	[ ]	
* gripper screw	[ ]	
* wrist gears	[ ]	
Condition of covers	[ ]	

General Comments: _____

_____

_____

_____

Signed: _____

B. Spare Parts

Part No.	Description	Quantity (*)
7038/00/00#23	SNAP RIVETS	20
7038/00/00#24	SNAP RIVETS	30
7038/02/00#17	TENSION GUIDE STRIP	1
7038/03/00	I.P. BOARD ASSY	1
7038/06/00#27	SEAL	1
7038/06/00#29	PULLEY	3
7038/06/00#33	E CLIP	5
7038/06/00#34	CIRCLIP	10
7038/06/00#35	CIRCLIP	5
7038/06/00#38	BELT	2
7038/06/00#39	BELT	2
7038/06/00#40	BELT	2
7038/06/00#41	BELT	2
7038/06/00#42	BELT	2
7038/06/00#43	BELT	2
7038/06/10	COMBINATION PULLEY,ELBOW	1
7038/06/12	PULLEY,ELBOW	1
7038/06/13	PULLEY,WRIST	1
7038/06/14	COMBINATION PULLEY	2
7038/06/18	ARM CABLE LOOM	1
7038/08/05	GRIPPER JAW	2
7038/08/08	GRIPPER SCREW	1
7038/08/23	SPUR GEAR(MOTOR)	1
7038/08/24	SPUR GEAR(GRIPPER SCREW)	1
7038/08/26	GRIPPER JAW TIP	2
7038/08/27	PIVOT PIN	2
7038/08/28	TENSION SPRING	2
7038/09/00	WRIST ASSY	1
7038/10/00	MOTOR ENCODER ASSY	2
7038/10/01	ENCODER DISC	1
7038/10/03	CLAMP	1
7038/10/04	BASE	1
7038/13/00#7	WEIR PSU	1
7038/15/00#14	FUSES	5
7038/15/00#15	MAINS ROCKER SWITCH	1
7038/15/00#17	PUSH BUTTON SWITCH	1
7038/15/00#18	RED LENS	1
7038/15/00#19	GREEN LENS	1
7038/15/00#20	RED LED & SWITCH INSERT	1
7038/15/00#21	GREEN LED & SWITCH INSERT	1
7038/15/04	CONNECTOR PANEL PCB	1
7038/15/12	FLAT CABLE LOOM ASSY	1
7038/15/13	EMERG.STOP TO CONN PAN PCB LOOM	1
7038/16/00#10	SPRING	2
7038/16/04	BLIND ROLLER ASSEMBLY	1
7038/16/05	BLIND ROLLER SHAFT(TOP)	1
7038/16/06	BLIND ROLLER SHAFT(BOTTOM)	1
7038/16/09	FLAT CABLE GUIDE STRIP	2
7038/16/10#30	RICHCO SPACER TYPE SS4-3	4
7038/16/10#31	RICHCO SPACER TYPE SS8-3L	4
7038/16/10#32	RICHCO SPACER TYPE SS10-3	4
7038/17/00	Z DRIVE ASSY(motor,clutch etc)	1
7038/18/00	BLIND ASSEMBLY	1
7038/19/01	EXTERNAL MOTOR DRIVE BOARD	1
7038/20/00	DRIVE BELT ASSEMBLY	1
7038/22/00	EMC FILTER BOARD	1
7038/22/00#4	RIBBON CABLE CLAMP 40 WAY	5
7038/23/01	DISTRIBUTION BOARD	1
7038/23/02	FLAT CABLE ASSEMBLY	2
7038/24/00	CARRIAGE ASSEMBLY	1
7038/24/05	TYRED BEARING ASSY	2
7038/24/06	TYRED BEARING ASSY	2
7038/25/09#18	MAINS CABLE ASSY	1
7038/25/09#8	FLOPPY DISK CARTON	1
7038/25/16	CABLE RS 232	1

(*) quantity recommended for warranty kit

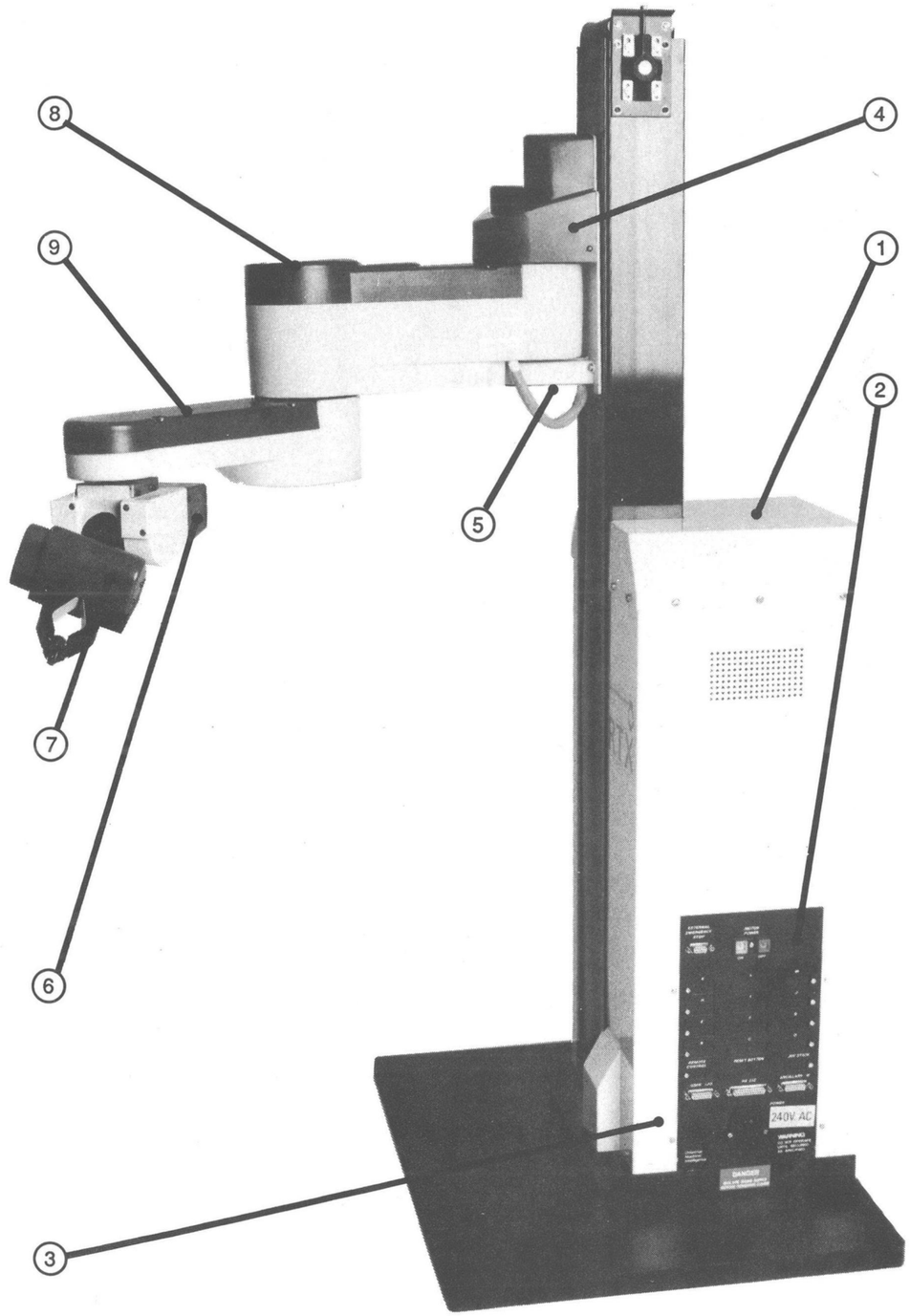
The following shorter list would normally be adequate.

Part No.	Description	Quantity
7038/00/00#23	SNAP RIVETS	20
7038/00/00#24	SNAP RIVETS	30
7038/06/00#29	PULLEY	3
7038/06/00#38	BELT	2
7038/06/00#39	BELT	2
7038/06/00#40	BELT	2
7038/06/00#41	BELT	2
7038/06/00#42	BELT	2
7038/06/00#43	BELT	2
7038/06/10	COMBINATION PULLEY, ELBOW	1
7038/06/12	PULLEY, ELBOW	1
7038/06/13	PULLEY, WRIST	1
7038/06/14	COMBINATION PULLEY	2
7038/06/18	ARM CABLE LOOM	1
7038/10/01	ENCODER DISC	1
7038/10/03	CLAMP	1
7038/19/01	EXTERNAL MOTOR DRIVE BOARD	1
7038/24/05	TYRED BEARING ASSY	2
7038/24/06	TYRED BEARING ASSY	2
7038/10/00	MOTOR ENCODER ASSY	2
C29254	WRIST LOOM	1

C. Part Location Figures

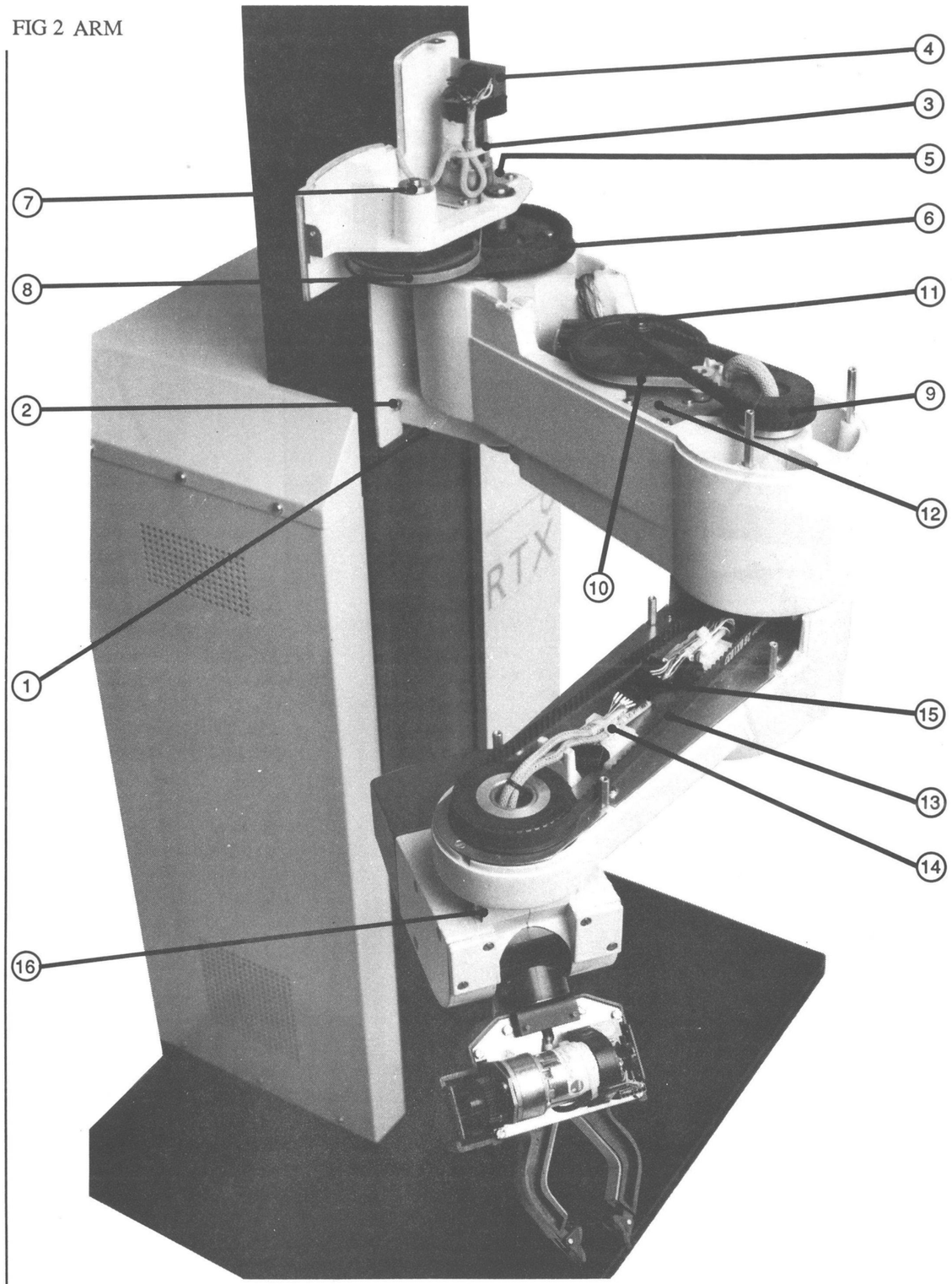
1. RTX Covers
2. Arm
3. Gripper
4. Column & Carriage
5. Electronics & Wiring (rear view)
6. Electronics and Wiring (side view)

FIG 1 RTX COVERS



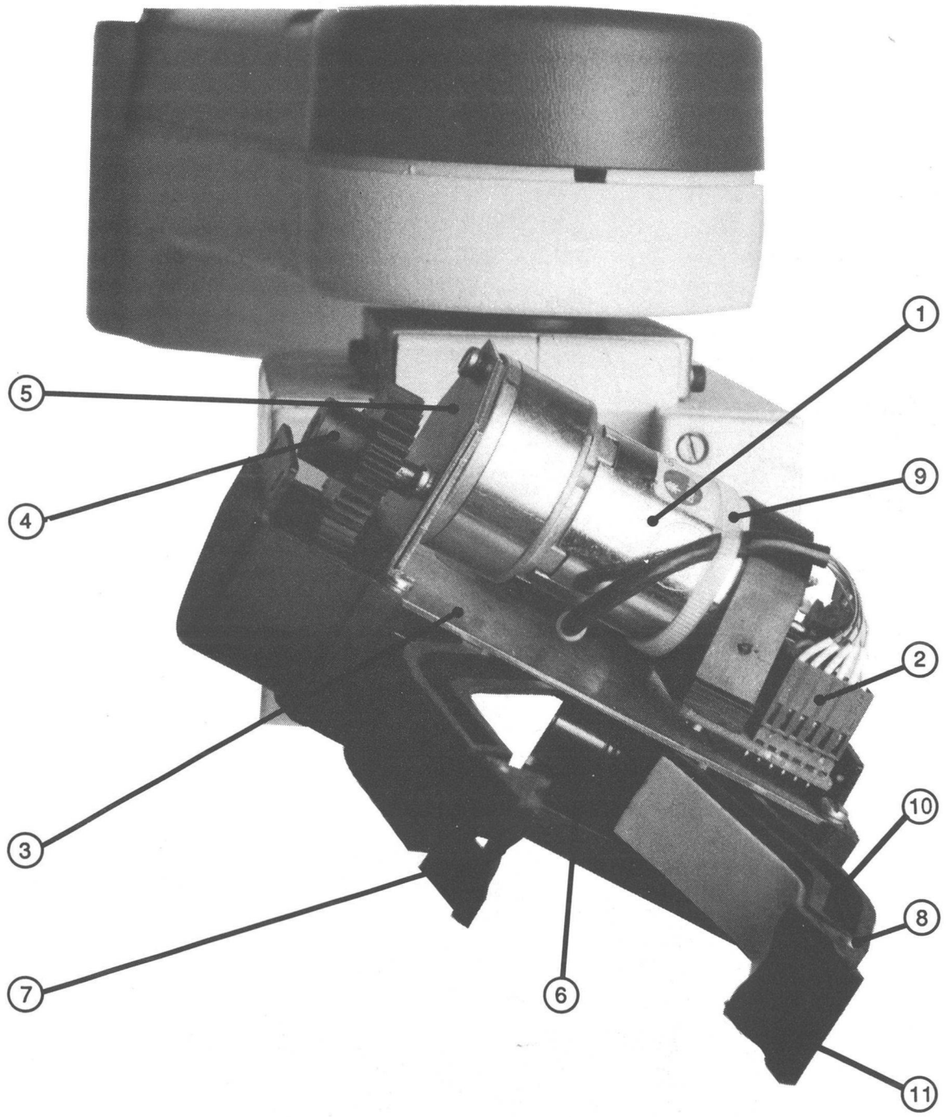
1 TOP COVER
2 CONNECTOR PANEL
3 ENCLOSURE
4 SHOULDER COVER
5 SHOULDER PLATE
6 WRIST COVER
7 GRIPPER COVER
8 UPPER ARM COVER
9 LOWER ARM COVER

FIG 2 ARM



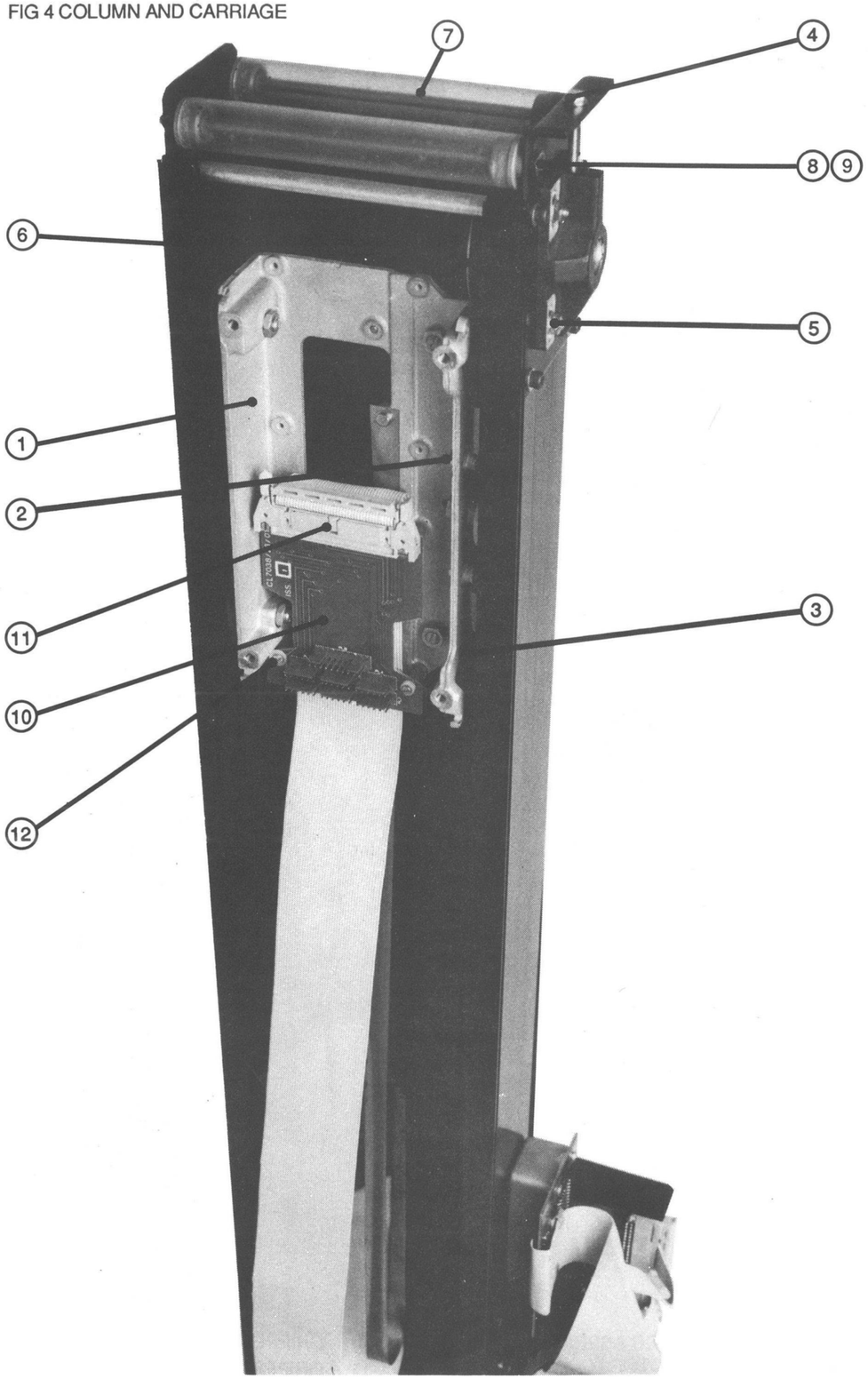
1 ARM MOLEX CONNECTORS (7)
2 ARM CONNECTION SCREWS (4)
3 CABLE TIE
4 SHOULDER MOLEX
5 SHOULDER MOTOR ENCODER/PLATE ASSEMBLY
6 SHOULDER XL BELT
7 SHOULDER ECCENTRIC SHAFT
8 SHOULDER M.P. BELT
9 ELBOW XL BELT
10 ELBOW MP BELT
11 ELBOW ECCENTRIC SHAFT
12 ELBOW MOTOR ENCODER/PLATE ASSEMBLY
13 YAW XL BELT
14 YAW CABLE TIE
15 WRIST LOOM CONNECTORS (3)
16 WRIST SUPPORT BRACKET

FIG 3 GRIPPER



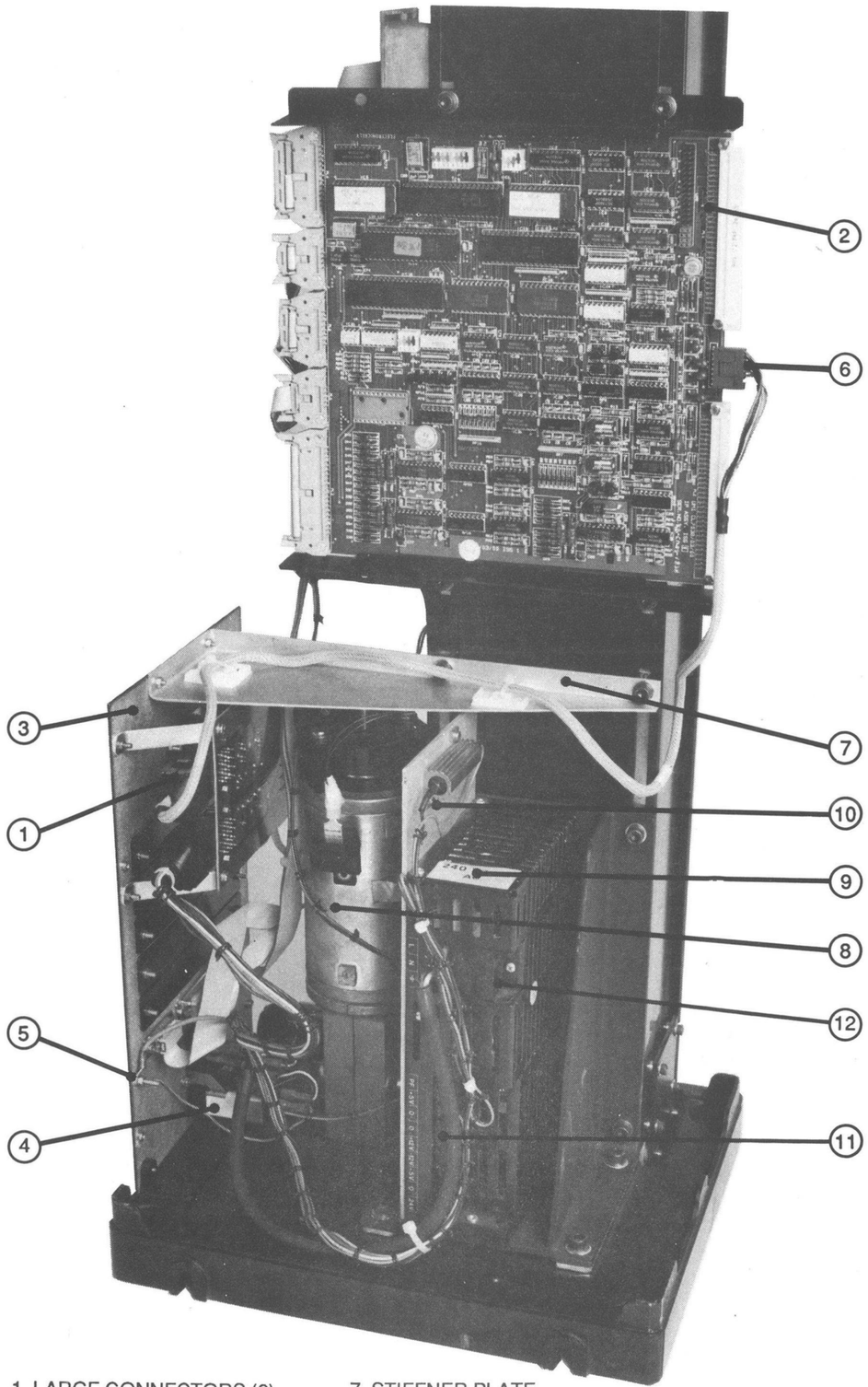
1 MOTOR ENCODER ASSEMBLY
2 MOLEX CONNECTOR
3 CONTAINMENT PLATE
4 SPUR GEARS (2)
5 MOTOR PLATE
6 LEAD SCREW
7 TENSION SPRING
8 PIVOT PIN
9 CABLE TIE
10 GRIPPER JAW
11 GRIPPER TIP

FIG 4 COLUMN AND CARRIAGE



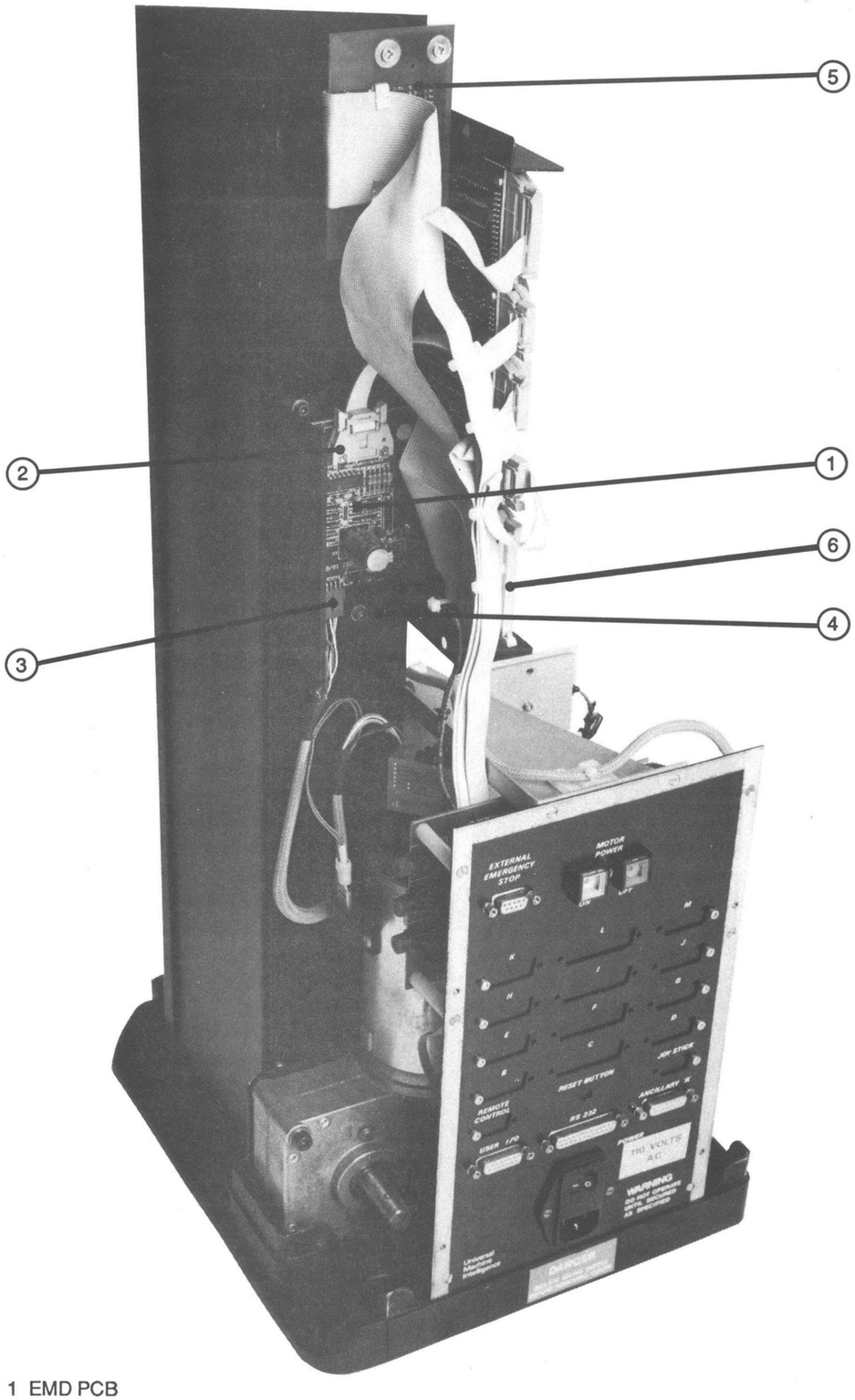
1 CARRIAGE
2 ZED BELT LOCK NUTS (2)
3 ZED BELT
4 ZED TENSION BOLT
5 CLAMP NUTS (4)
6 ZED IDLER PULLEY
7 BLIND ROLLER (4)
8 BLIND ROLLER CIRCLIP AND 'E' CLIPS (8)
9 BLIND ROLLER SHAFT (4)
10 DISTRIBUTION PCB
11 DISTRIBUTION BOARD IDC CONNECTOR
12 DISTRIBUTION BOARD SCREWS

FIG 5 ELECTRONICS AND WIRING. REAR VIEW



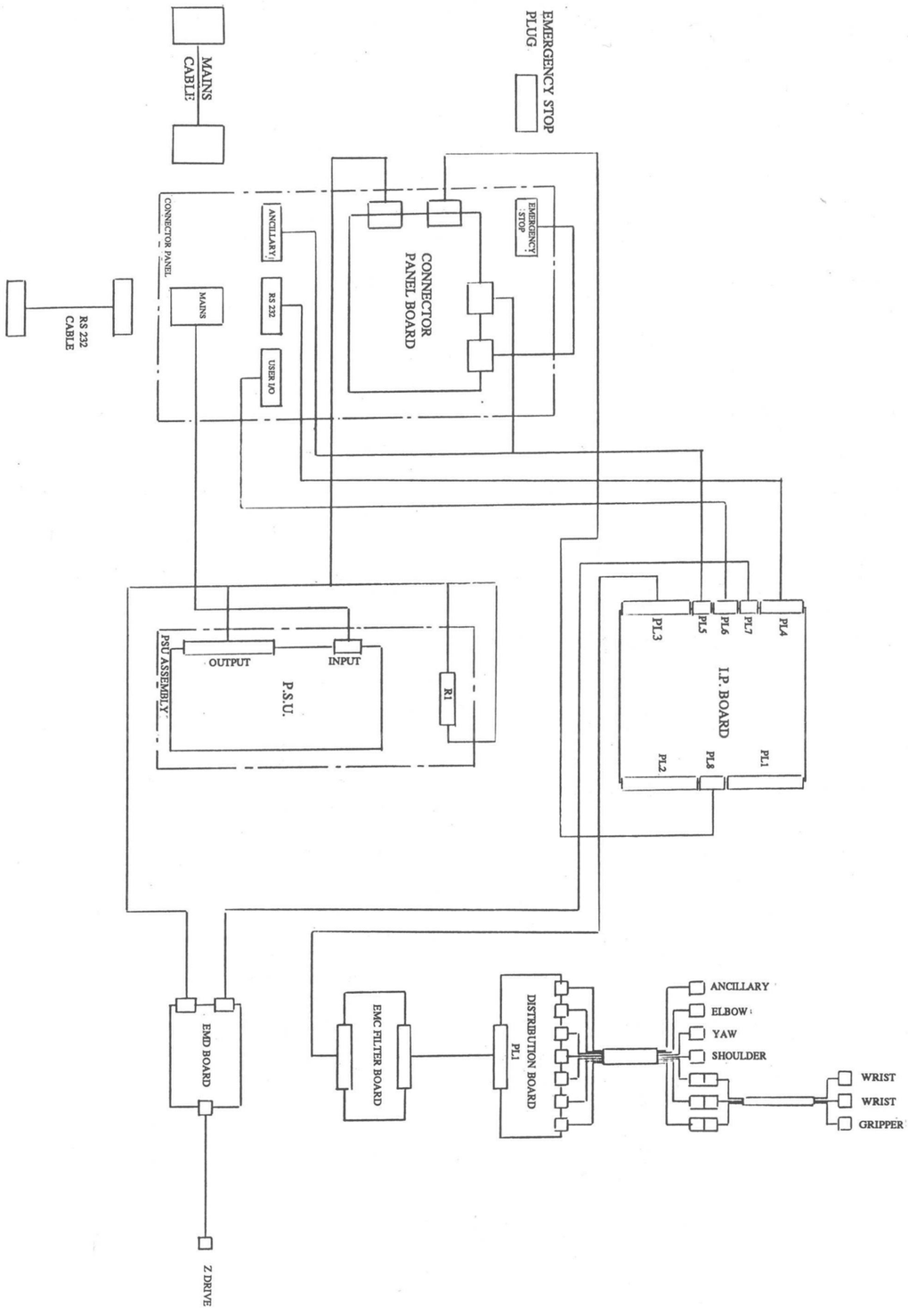
1 LARGE CONNECTORS (2)
2 I P BOARD
3 CONNECTOR PANEL
4 MAINS SWITCH
5 EARTH POST
6 IP MOLEX
7 STIFFNER PLATE
8 ZED MOTOR/CLUTCH/ENCODER ASSEMBLY
9 P S U
10 P S U PLATE
11 EYELET SCREWS (7)
12 MAINS COVER

FIG 6 ELECTRONICS AND WIRING. SIDE VIEW



1 EMD PCB
2 EMD IDC
3 EMD MOLEX
4 EMD 'BLACK' CONNECTOR
5 EMC PCB
6 EMC IDC (PL3)

D. Circuit Block Diagram



E. IPC commands & responses

Command	CTC	CB0	CB1	Ok?	RTC	RB0	RB1
Go Active	$00	-	-	Y/N	Simple Response	-	-
Interrogation	$01	-	-	Y	$20 + IP number	-	-
				N	Simple Response	-	-
Init, etc	$08-$0B	-	-	Y/N	Simple Response	-	-
Status	$10-$17	-	-	Y	$10 + controller no.	Status	$XX
				N	Simple Response	-	-
Set mode	$18-$1D	-	-	Y/N	Simple Response	-	-
Resets	$20-$22	-	-	Y/N	Simple Response	-	-
Stops	$24-$27	-	-	Y/N	Simple Response	-	-
Toggles	$28-$2A	-	-	Y/N	Simple Response	-	-
Baud / Parity	$30	-	-	Y/N	Simple Response	-	-
Version No.	$38	-	-	Y	$20 + IP no.	LO(version)	HI(version)
				N	Simple Response	-	-
Imm. read	$40-$44,	-	-	Y	$80 + Checksum	LO(data)	HI(data)
	$48-$4C			N	$80 + Checksum	LO(data)	HI(data)
				N	Simple Response	-	-
Imm. Write	$50-$54,	LO(data)	HI(data)	Y	$A0 + Checksum	-	-
	$58-$5C			N	$A0 + Checksum	-	-
				N	Simple Response	-	-
Define read	$60	Data code	$xx	Y	$C0	-	-
				N	Simple Response	-	-
Define write	$70	Data code	$xx	Y	$E0	-	-
				N	Simple Response	-	-
Do def. read	$68 +	-	-	Y	$D0 + Checksum	LO(data)	HI(data)
	controller			N	$D0 + Checksum	LO(data)	HI(data)
				N	Simple Response	-	-
Do def. write	$78 +	LO(data)	HI(data)	Y	$F0 + checksum	-	-
	controller			N	$F0 + checksum	-	-
				N	Simple Response	-	-
Go (manual)	$80	Go bits	$xx	Y/N	Simple Response	-	-
Go (numeric)	$A0 +	-	-	Y/N	Simple Response	-	go bits
Interpolation	$C0 + inc for 5	Incs	Incs	Y/N	Simple Response	-	-