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## MECHANICS

### 2.1 Description

The ARMDROID consists of five main parts.

#### The base

The base performs not just its obvious function of supporting the rest of the arm. It also houses the printed circuit boards and the motor that provides the rotation.

#### The Shoulder

The shoulder, which rotates on the base by way of the main bearing, carries five motors and their reduction gears which mesh with the reduction gears on the upper arm.

#### The Upper Arm

The lower end of the upper arm carries the gears and pulleys that drive the elbow, wrist and hand. It rotates about a horizontal axis on the shoulder.

#### The Forearm

The forearm rotates about a horizontal axis on the upper arm and carries the wrist bevel gears.

#### The Wrist and Hand

The two wrist movements, the rotation about the axis of the hand ("twist") and the rotation of the hand about a horizontal axis ("up and down"), depend on a combination of two independent movements. The twist is accomplished by rotating both bevel gears in opposite directions, while the up and down movement is done by turning the gears in the same direction. Combinations of the two movements can be got by turning one bevel gear more than the other.

The three fingered hand with its rubber fingertips has a straightforward open and shut movement.

## 2.2 Technical Hints

### 1. FITTING BELTS ONTO PULLEYS

Fit belt over small pulley first and then work onto unflanged edge of large pulley a little at a time - do not attempt to get belt fully onto pulley until you have got it on by one or two millimeters all round. (Belts can be damaged if they are crimped). When fitted belts should not be drum tight there should be just a little play, or friction will rear its ugly head again.

### 2. FITTING SWITCHES

On initial fitting do up bolts only enough to hold switches in position. Finally after gears are fitted swing switches so that they clear gears by approximately one millimeter and finally tighten.

### 3. FITTING PULLEYS TO MOTORS

You will find the motor shafts have end float with a light spring action pulling the shaft in. Do not pull shaft out against this spring when fitting pulley as this will cause friction and loss of effective motorpower.

### 4. LUBRICATION

Use light oil (three in one or similar), just a drop on all parts that slide or pivot. DELRIN is a self lubricating material but the friction is a lot lower with a drop of oil. We only have limited power from the motors so we want to make the most of it so work spent on eliminating friction which will pay performance dividends. Check all bores and bearings for free running - any tightness is usually caused by burrs or stray bodies in bores. Remove burrs from Delrin with a sharp knife, from metal with a scraper.

Disposable hyperdermic is ideal for lubricating - scrounge one from your local friendly GP or Hospital.

## REED SWITCH POLICY

Micro-switches are included in the assembled and unassembled Armdroid packages as optional extras. It must be stressed, however, that the machine will function perfectly well without the micro-switches, but a check must be kept on the number of complete revolutions of the base. Any more than  $1\frac{1}{2}$  turns will put a strain on the stepping motor leads where they connect to the printed circuit boards.

To prevent any difficulty in the fitting of reed-switches after the initial assembly the magnets will be inserted during manufacture. This will save the dismantling of the Armdroid in the field. Magnets will be included in all the kits.

There will be a nominal charge of £15 for the inclusion of reed-switches in both the assembled and unassembled Armdroids.

PART NUMBERS INVOLVED: \*09\*10\*15\*16\*18/16\*18/12\*

2.3 TOOLS LIST INC. Lubricants etc

General and small circlip pliers

7mm spanner - supplied

5.5mm spanner - supplied

Metric steel rule, (part identification)

Hyperdermic syring or small oilcan and 3 in 1 oil

"Superglue" and if possible "Loctite"

Cold vaseline or cycle bearing grease

Tweezers

Allen keys for M3 grub screws - supplied

M4 grub screws - supplied

M4 bolts - supplied

Light weight hammer (fitting rollpins)

## 2.4 ASSEMBLY

<u>Description of item</u>	<u>Part No</u>
✓ Base	01
✓ Base Bearing support column	02
✓ Base motor	03b
✓ Base motor short pulley 20 tooth	04b
Base reduction gear spindle	05
Turned thick wide washer 16mm x 2mm	06
Reduction gear	07
Base belt (medium length) 94 teeth	08m
Base switch support 12mm x 11mm	09
Base switch	10
Shoulder pan	11
Shoulder bearing ring	12
Base gear (large internal dim)	13
Bearing adjusting ring	14
Hand motor support bracket	15
Hand motor	03h
Hand switch bracket	16
Motors - Upper arm	03u
Fore arm	03f
Wrist action	03w
Motor pulleys - Upper arm	04u
Fore arm short 14 tooth	04f
Wrist action long 20 tooth	04w
Hand short 20 tooth	04h

DESCRIPTION OF ITEM	Part No	
Shoulder Side Plates	017	
Switch support bar 107mm x M3 at ends	019	
Support bar spacers M3 clearance X	018/16	
	018/12	
Motor support bracket stiffener 107mm x M3 at ends	019	
Support Bar spacers	018/54	
	018/41	
Reduction gears	020	
Reduction gear spindle 96mm x 6mm	021	
Drive belts long = 114 teeth	08/1	Hand
medium = 94 teeth	08/m	Fore/Upper arm
short = 87 teeth	08/s	Wrist action
Upper Arm Drive Gear small internal dim no drum	021	
Upper arm side plates	022	
Upper arm brace	023	
Gears wrist action	024	
hand action	025	
fore arm	026	
Idler pulley	027	
Shoulder pivot 96mm x 8mm spindle	029	
Fore arm side plates	030	
Fore arm brace	031	
Fore arm pulley	032	

DESCRIPTION OF ITEM	Part No.
Elbow Idler pulleys hand wrist	033
Elbow spindle 65mm x 6mm	034
Wrist bevel gear carrier	035
Wrist guide pulleys	036
Wrist bevel gears (flanged)	037
Wrist pivots	038
Hand bevel gear (no flange)	039
Finger support flange	040
Hand pivot	041
Finger tip plates	041
Finger cable clamp	042
Small finger spring	043
Finger tip pivot	044
Middle finger plates	045
Middle finger pivot	046
Large finger spring	047
Finger base	048
Long finger pins 16mm x 3mm	050/l
Short finger pins 13mm x 3mm	050/s
Small finger pulleys	051
Large finger pulleys	052
Large hand sheave pulley	053
Small hand sheave pulley	054
Hand sheave pin	055
Finger tip pads	056
Base pan	057

DESCRIPTION OF ITEM	Part No.
Board Spacers	018/41/54
Spacer bars for boards	058
Rubber feet	059
Cable springs wrist action short	060
Cable springs grip, elbow long	061

PREPARATION AND FIXINGS ETC

DESCRIPTION OF ITEM	Item No.
Magnets	101
Bearing adjustment ring grub screws M4 x 8mm NB + self made plug to protect the fine bearing thread	102
Turned cable clamps 6 x 6mm M3 tapped	103
Cable clamp grub screws M3 x 4 pointed head	104/105
Crimped type cable clamps crimped eyelets	106
Gear Cable grub screws M4 x 6mm flat head	107
Bushers 8mm bore long with flange - shoulder	108
Shoulder pivot spindle spacer	108a
6mm bore short with flange - elbow	109
8mm bore long with flange - wrist	110
8mm bore no flange main gear inserts	111
Gear to sheet metal screws M3 x 6 slot hd CSK	112
Spring pillar and base switch M3 x 10 cheese head	113
Base bearing to shoulder pan M4 x 16 CSK socket head	114

DESCRIPTION ITEM	Item No.
Motor bolts, Base bearing to base M4 x 10 Elbow spindle hex hd	115
Hand to finger, hand to bevel gear M3 x 6 cheese hd	116
Shoulder spindle M5 x 10 hex hd	117
General sheet metal fixing M3 x 6 hex hd	118
M4 Nuts	119
M4 Washers	120
M4 Shakeproofs elbow spindle	121
M5 shakeproofs shoulder spindle	122
M3 Nuts	123
M3 washers - switches	124
6mm steel balls - base bearing	125
Magnetic reed switches	010
Driver board	126
Interface board	127
Edge connector	128
6mm Washers	129
Roll pins	130
4.5mm circlips	131
3mm circlips	132
Elbow spacer	133

## 2.5 ASSEMBLY

### Preparation

Study the parts list, drawings and the parts themselves until you are sure you have identified them all. Assemble the tools suggested in the list of tools (2.3). Read carefully technical hints section. Solder 12 in o ribbon cable to each motor. Glue magnets (101) into the slots in the reduction gears, noting that the hand gear (25) needs no magnet. Check that the adjusting ring 14 of the main bearing screws easily onto its base. Clean both if necessary. Insert bushes into the arms, if necessary using a vice, but taking care not to distort the sheet metal.

### Construction

Fit base bearing support (2) column inside base (1). (M4 bolts, nuts.) NB NUTS INSIDE BASE

Bolt 1 motor (shorter cable) inside base. (M4 hex bolts, washers on motor side - nuts on inside). Fit pulley to spindle base of motor with the grub screw at the top (046). Fit base reduction gear spindle (07) to base. (Thick turned washer, M4 hex bolt) Fit reduction gear and belt. Place a small drop pf oil on the reduction gear spindle before fitting reduction gear.

When fitting belts they should be placed fully on the motor spindle and worked gently onto the reduction gear, a small section of their width at a time. (see general hints on lubrication)

Fit base switch support. (M3 hex bolt) NB DRAWING FOR POSITION. Fit base switch and run wires through adjacent hole. (M3 x 10 cheesehead, washer)

Fit bearing ring (12) (long spigot down) through shoulder base pan (11) from inside. The base gear (13) fits on the lower face of the pan with the magnet at 2o'clock as seen from inside the pan with the flange at the top. (M4 countersunk x 16mm bolts, nuts)

(This step and the next are simpler with some help from an assistant). Put shoulder base pan (gear side up) on to 3in supports (books etc,) so that the bearing support column can be inserted. Practise this movement to make sure all is well. Smear vaseline from a fridge, or grease on the bearing track of the flange, and using tweezers to avoid melting the vaseline carefully place 24 ball bearings round the flange, embedding them into grease. There will be a slight gap when all the balls are in place. Invert the base and inser the threaded bearing support column inside the bearing ring taking care not to dislodge any of the balls so that the base pan meshes with the base gear. Keep the two parts level in the same relationship by taping the parts together with a piece of wood or a spanner 5mm thick between the motor pulley and the shoulder base pan.

Large rubber bands can be used instead of tape. An assistant to hold the parts for you will be useful here.

Turn the assembly the other way up (the base is now on the bench with the shoulder base pan above it. Put more grease round the bearing track and embed 24 more ball bearings in it. Gently lower the adjusting ring (14) on to the threaded base and then screw the finger tight, remove with tape, adjust the ring until the base pan moves freely without play then tighten the grub screw, inserting a small wood plug to protect the bearing thread. (M4 grub screws) (102). The bearing may need adjusting after some use as it beds in.

Fit hand motor bracket (15) to shoulder base pan (M3 bolts) then the hand motor O3h(M4) and the hand motor pulley. Then fit the hand reed switch bracket (M3) and the switch (M3 x 10 cheesehead bolts).

Fit motors to the shoulder side plates (17) and feed the cables through the holes towards the inside. The bolts which are next to the reduction gears should be placed nut out to prevent the reduction gears catching on the end of the bolts. Fit correct pulleys (O4u/f/w) to the motor spindles noting which pulleys from the drawing, tighten the grub screws.

Fit the shoulder plates. This is simplified by loosely tightening the end bolts to support the weight. Feed the motor cables down through the main bearing (M3).

Slide switch support (19) bar through spacers (18), switches (101) and motor support bracket (see drawing for correct order of spacers). You will need to be able to adjust the position of the reed switches after the arm is fitted so that they clear the gear wheels ie tangential to shoulder pivot. Fit the motor support stiffener bar and spacers. Leave nuts finger tight. (M3 nuts).

Assemble reduction gear support bar (21), assemble with the correct length drive belts (O8s/m/l) over each gear, reduction gears facing in correct direction and the thin metal M6 washers at either end. (see drawing) Slide gently into position and bolt in the support bolts (M4 a 10mm) Fit the belts round the motor pulleys.

Put upper arm drive gear on the outside of the upper arm side plate. The magnet should be at 1 o'clock, viewed from the gear side of the arm. (M3 CSK screws x 6mm) Fit a brace to one upper arm side piece (22), then fit the other side piece to the brace. Fit all bolts and nuts before tightening any of them. Check 8mm shoulder spindle (29) slides freely through acute bushes in upper arm side pieces and through bores of drive gears, pulleys and spacers. Assemble by sliding shaft from one side and threading gears, pulleys and spacers on in the correct order of orientation - use drawing.

Fit pulley (32) to the outside of the forearm side plate (30) (M3x6mm) (countersunk screws). Fit a brace to one forearm side plate, then fit the other side plate to the brace. Check for squareness before finally tightening bolts.

Put elbow pivot through bushes and an 8mm bar through wrist bushes. (M3 bolts, nuts) Check fit before assembly. Assemble the pulleys (33) on the elbow spindle (34), lubricate and fit it to the large arm, and bolt through into spindle. (M4 bolts, washers)

Assemble the wrist bevel gear carrier (35) and wrist pulleys (36) and then tap the roll pins gently home with a small hammer, supporting aluminium gear carrier to prevent distortion.

Fit the wrist gears on the bushes (37) from the outside. Fit bevel gear carrier (35) between the wrist bevel gears (37), line up holes in end of wrist pivot (38) bores with tapped hole in carrier by peering down pivots. If you do not have a screw gripping or magnetic driver use a little piece of masking tape or sellotape to fix M3 cheesehead screw to the end of your screwdriver in such a way that it will pull off after tightening - check gears pivot freely on pivots and that the whole assemble can pivot in oilite bushes (drops of oil on faces of gears and pivots)

Screw the finger support flange (40) to the hand bevel (39). (M3 x 6mm cheesehead screws) Screw the hand pivot (41) to the bevel gear carrier (35). Tighten on a drop of loctite if available, gently by turning a pair of pliers inside it. The bevel gears should be positioned with their grub screws pointing towards the hand when the hand and the forearm are in line (see drawing).

Assemble the fingertip (42) and cable clamp (43) with the small spring (44) on the pivot (45), and clip together with large circlips on the cable clamp. The spring should be positioned so that the "back" of the spring is on the knuckleside of the fingertip, thus tending to open the hand.

Assemble the middle finger (46) and its pivot (47) with the large spring (48). Fix to the finger base (49) with the long pin (50/L) (16mm x 3mm) and two small circlips (see drawing). Fix one circlip to the pin before one begins to assemble.

Join the fingertip to the middle section with the short pin (50/S) (13mm x 3mm) and two small circlips.

Cut off one end of the tip spring about 8mm-10mm beyond its hole. Level with its hole bend the spring through a right-angle to secure it. Repeat at the other end. Trim the inner end of the middle finger spring flush with the end of the finger end and treat the outer end as above.

Fit the small pulley (51) to the finger middle section using a short pin (13mm x 3mm) and two small circlips. Fit the larger pulley (52) to the finger base with a long pin (16mm x 3mm) and two small circlips.

Screw the finger base to the finger support flange. Make sure that the fingers are evenly spaced and do not interfere with each other, and then tighten. (M3 x 6mm cheesehead)

Assemble the large and small hand sheave pulleys using the large circlip on hand sheave pin (55).

## CABLE THREADING

Slide arm into shoulder, you will need to align the reduction pulleys between the main drive gears as you lower the arm into place, and assemble using M5 hex head bolts and shakeproof washers. Tighten and check the reduction gears "mesh" correctly and the arm moves freely.

Connect grip action cable tail to shoulder base pan via the spring correctly placed over the pulley and tension using the normal method with the cable clamp.

Glue strips of rubber to finger tips using superglue.

The driver and interface board should be bolted to the base pan using the spacer bars (58) and spacers. Bolt base pan (57) to base (M3 x 6mm hex head).

Hints: Useful tools are:

- a) 2 or 3 'bulldog clips' to maintain the tension in the cable over completed sections of each cable while the remainder is threaded. Masking tape can also be used for this purpose.
  - b) Ends of the cable can be prevented from fraying by placing a drop of 'superglue' on the end of area where it is to be cut. The excess should be wiped off on a piece of paper.
- NB. This process also stiffens the end which is useful when threading the cable through the pulleys.
- c) Ensure all grub screws are in position but are not obstructing the cable holes. Also check there are no burrs remaining from machining blocking the holes.
  - d) The cables can be threaded before the arm is bolted for the shoulder which eases the problems of access considerably. The 'grip action' cable tail can be taped or clipped to the arm and connected and tensioned with its spring after the arm is fitted to the shoulder,
  - e) When tensioning the cable, if it is passed through the clamp and back, then connected to the spring adequate tension can be applied by pulling the 'free tail' and then nipping it with the grub screw. A frined will be useful if around, but it is quite possible without. The correct tension can be easily judged, as when completed the coils of the spring should be just separated, though this is not critical.

- f) During threading the correct 'route' can be ascertained from the expanding drawings. It is very important these should be followed exactly especially the position of the grub screws when they are tightened on the cable. If this is wrong it will effect the performanc of the arm.
- g) Care should be taken to avoid the cable kinking or crossing itself on the drums.
- h) Experience has shown that the best order to thread the cables and lenth's to use. (Excess can be trimmed easily later but makes tensioning simpler)

First	- Wrist cables one at a time	1.47m (each)
Second	- Elbow cable (set up the spring pillar first - M3 x 10mm cheesehead and 2 M3 hex full nuts) attach crimped cable clamp to forearm first using M3 x 10 chhese head and two nuts as a cable pillar	0.95m
Third	- Single finger cable (fix to the hand sheave pulley using M3 x 6mm cheesehead and crimped cable clamp	0.18m
Fourth	- Double finger cable (loop over small hand sheave pulley on grip action pulley and adjust so that G A P is even when pulleys are evenly positioned)	0.36m
Fifth	- Grip action cable (start at end fixed in cable drum and stick other end to arm while fitting it to the shoulder then tension with the spring to the shoulder base pan.	1.3 m

- i) Ends using the crimped cable eyelets should be threaded through the eyelet and a small thumb knot tied to prevent the cable slipping before crimping the bracket using crimping or ordinary pliers. So not crimp too light or you may cut through cable, though KEVLAR is very tough.