Welcome!
to the R18 robot arm

R18 DELTA ROBOT SYSTEM

User Manual

We hope you enjoy your experience.
Any problems at all just contact us.
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preface: R18 is a new robot in our range. The manual is also new.
If any part of this manual is not clear please do contact us.

System Components:

A basic R18 robot system comprises the following:-

1 R18 Robot arm

This is supplied from Igus to ST dis-assembled and must be assembled by the user. However it has been temporarily assembled for testing.

Fitted with any options:

- Pneumatic or electric gripper
- Vacuum pickup
- 4th axis

1 Controller K11R

Fitted with any options:

- I/O expansion
- Gripper drive module

1 Teach box
1 Cable 9-way D-type each end (M-M) - K11R to teach box
1 Motor cable - K11R MS connector to robot 25-way D-type
1 Sensor and encoder cable - 25-way each end (M-F)
1 Cable, D-type 25-way male to 9-way female - K11R to PC RS232
1 Power cable to K11R
1 Pack of CONNECTORS:
- 1 output connector
- 1 input connector

1 Disk with software and manuals.
1 optional USB/serial adaptor
1 optional Android teach console.
1 Gripper pneumatics kit
1 Quickstop pneumatics kit

Manual Contents:

1. INTRODUCTION

The R18 is a robot arm of the delta format. This comprises 3 pairs of arms connected to a carrier. It is normally mounted over the workspace and the carrier is positioned under the robot but over the workspace. Delta robots are very fast but have limited workspace. The carrier has an end effector attached, usually a vacuum pickup or a pneumatic gripper. An optional 4th axis can rotate the end effector as the robot moves.

Each arm is driven by a high power stepping motor with built-in encoder. The 4th axis if fitted is a very light stepping motor with no gearing (direct drive). It is therefore fast but low torque.

If fitted the pneumatic gripper is operated by compressed air from 3 to 7 bar. This may be supplied by a compressor purchased by the user, or from a 'shop' (central) air supply. If vacuum pickup is fitted this has a vacuum ejector and valve on a mounting plate and requires 7 bar to operate.

The R18 robot system comprises 3 main units:- the robot, the controller, a user supplied computer. The computer is used to program the controller. Once programmed the controller will run the robot independently without the need for a computer but it is a good idea to leave a low cost terminal connected while the robot is in use.

OVERVIEW

The controller controls all movement of the robot. As the controller may be both reading sensors and signals from and controlling associated equipment it follows that all decisions about robot activity are usually made by the controller which is capable of running without any host computer. The function of the computer is to (a) program the controller, (b) to copy (back up) the contents of controller memory to disk and optionally (c) to perform a supervisory role sending commands to the controller through the serial interface.

To program the controller with a computer you need to run RobWin 7. When ROBWIN is executed it immediately opens a communications window. Once communication is established all your commands go to the controller not to the computer you are typing on. Programming the controller involves programming the robot and the interaction with other equipment. The robot and interfacing are programmed using ROBOFORTH II © and Forth. There are two main manuals, ROBOFORTH covering robot programming and the system manual, which describes the controller and interfacing. The software manuals are on the included usb drive and written in HTML so you can use dynamic links to see connected concepts. There is also a glossary on disk, which gives a brief description of every command and a tutorial. Some commands are used only by ROBWIN or are not very useful and these are in the glossary but not in the ROBOFORTH manual.

All FORTH and ROBOFORTH commands are in UPPER CASE (press caps lock). You can add commands written in lower case but these would be different commands from those spelled in upper case.

2. IMPORTANT DOS AND DON'TS

(1) DON'T ever disconnect *or connect* the robot while the controller is switched on. This will result in damage to the electronics and the connectors themselves. Warranty claims will not be accepted for damage resulting from this.

(2) DO be very careful not to "crash" i.e. drive any joint against a solid object so that it stalls. Depending on the speed damage may result. At lower speeds the motors generate higher torques so can do more damage.

(3) DO have your hand poised over the emergency stop button whenever testing a program. Remember that because of its geometry a revolute arm will describe wide arcs from far apart points, and may collide with objects within its reach.

(4) DO take appropriate measures to assess the risks and protect personnel from injury (see next section)

(5) DON’T try to save a project if the controller is switched off.

(6) DO make a back-up of the usb drive supplied as soon as possible.

(7) DO warm up the robot for best repeatability. After switching on from cold run the robot some simple all axes routine for 10-20 minutes.

SAFETY IS YOUR RESPONSIBILITY

Risks
Because stepping motors raise more torque at low speeds a substantial low speed force can be brought to bear especially on fingers which may become trapped under or between axes. Robot end effectors typically have sharp edges or fingers made of thin metal which can cause injury at the low speed high forces or at the higher speeds.

The biggest risk comes from the element of surprise. If the system is active and receives a command from a supervising scheduler or a signal from an associated machine the robot will appear to move unpredictably. A human being caught in the way can receive injury, especially if the end effector has sharp edges.

However, because the robot is stepper motor driven, once stalled the system raises an error and does not attempt further motion.

Safety measures

- Where possible a robot system should be guarded. Any gate in the guarding can be fitted with a switch, which is connected to the controller stop circuit.
- If physical guards cannot be provided then light curtains are easily connected to the robot controller or the ST Sentry sensor system.
- Where guarding is not appropriate and bench-top robots work closely with human workers interlocks should be provided. For example if the user has access to the workspace then he/she should be required to press a switch or keyboard key after clearing the area.
- Statistically the highest incidence of contention between human and robot is when both are accessing the same object. End effectors often have sharp edges which can cause injury.
- At the end of this manual you will find a form with which to do your own risk assessment of the robot *in your application*. There are two concepts to consider: hazard, which is the robot or robot fingers or the product etc. and risk, which is the probability of someone being harmed by the hazard. The form enables you to identify the hazards, the risks and ways of minimizing the risks. After completing the form and carrying out any safety measures that the form has helped you identify, do the assessment all over again.

3. SETTING UP

The Delta robot should be assembled using the Igus instructions provided. Use the included torque spanner/wrench for correct tightness and use the glue provided according to the instructions. You will assemble the robot upside down, like a pyramid. This is upside down from the intended way of working but is good for initial test. You can initially test the robot without the 4th axis mounted on the robot. See separate instructions for that. Ultimately the robot will be mounted in a frame, with the peak of the pyramid pointing down. Note that all Z values are negative and have a higher negative value the lower the robot reaches.

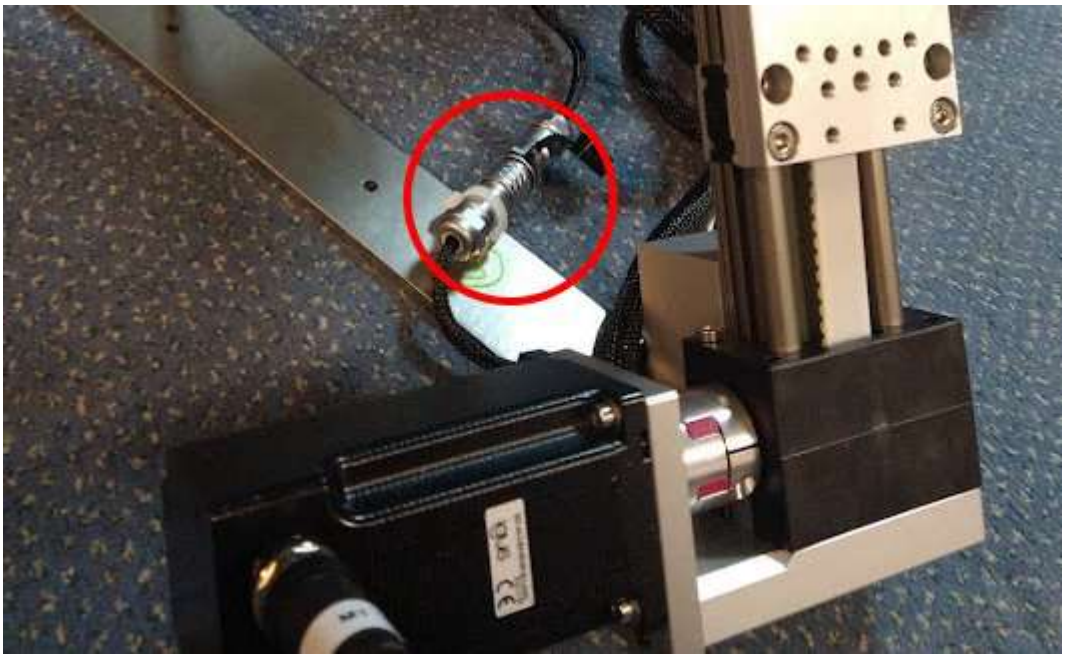
4th Axis

The 4th axis is integral with the mounting plate of the delta robot. The motor is direct drive, set to 10 micro-steps. This results in 2000 steps per rev. However because of a physical stop it is not possible to do a complete 360 rev.

Next connect up all cables - their positions should be self-evident. Cables to the robot connect to the rear of the controller. From the controller the cables connect to a connector box mounted on the robot. You will have to mount that yourself in the optimum position.

Cables:

Internal cables – these go from the connector box to each motor on the robot. There are two sub-cables for each motor – motor drive and encoder. Each sub-cable has one wire that indicates which channel to conect to: brown:ch1, red: ch2, orange: ch3**.**The wiring to the motor is loosely arranged and you can fasten it as you wish. It connects via an inline connector as below. Drop the wire down through the robot then push the connectors together. To part the connectors push the ring back with one hand and pull the connector out with the other.



Motor power – the metalized cable from rear of controller to the connector box, 26wMS to 25wD
Sensor cable – from rear of controller to connector box (25wD male to 25wD female)**.** This carries the encoder signals to the controller. There are no calibration sensors.
Gripper cable (if supplied) - from rear of controller 15w to gripper valve
Serial cable – from front of controller to computer (usually 25wD male to 9wD fem)
OR USB to serial converter cable – from computer USB port to front of controller
Teach pad cable – from front of controller to teach pad (9wD to 9wD male to male).
There is also a **Stop Jack** for connecting an external stop circuit. Even if there is no external stop circuit the jackplug must be plugged in at the rear of the controller. The plug has a shorting link, which is removed when connecting an external circuit.
The serial (RS232 null modem) cable from a computer to the controller should plug into the 25-way D connector on the front of the controller. The other end (usually 9wD) connects to the rear COM1 serial connector of the computer. If COM1 is already in use you can use any COM port or the USB serial adapter (see later for configuration). The serial speed is 19200 Baud, 8 bits, 1 stop bit.

Pneumatic connections
Connect the air line by pushing it into the middle push-fit connector on the air valve and two from the valve to the connector panel. If there is no compressor then connect the shop air supply to the air valve. The air supply must have a bowl filter and a pressure regulator. Ideal pressure is from 3 to 7 bar.

The pneumatic gripper uses a twin tubing which routes back to the control valve. The control valve has a cable to the 15w connector on the back of the controller.

Pneumatic gripper or vacuum pickup
If a pneumatic gripper is fitted the robot will have two airlines through it. Vacuum only requires 1 airline. The control valve is a Mead Isonic valve operated from output port PA bit 0.

4. COMPUTER

Note: Commands to computer or controller are in the form of a string of characters followed by the enter key. In all my examples of dialog between man and machine I will underline text typed in by the user. I won't keep mentioning the need for the enter key. A machine response will be in upper case but not underlined. My comments will be in lower case.

Before switching on the controller switch on the computer and proceed as follows:-

1. Create a directory (folder) ROBOT on C: drive
2. Copy all the files to your ROBOT directory
3. If you have a **USB-serial converter** first install its software. It should install itself as most versions of Windows have the FTDI driver already included.
4. Plug in the USB converter and use either the serial cable or the adaptor to connect to the controller. Windows 7 will probably want to go online for the drivers, select skip for both drivers, USB serial converter and USB serial port. Once installed it should tell you what port number it has selected. If less than 10 then skip step 5.
5. If you are not told what the COM number is you will need to find out. Go to control panel, device manager, COM ports. You will see USB serial port - note the port COM number.
6. RobWin will only work up to com9 so if your converter has been mapped to higher than com9 then double-click that port, then go to settings, advanced. You will see COM Port Number; click the drop-down. You might see a lot of COM ports marked "in use". It's usually incorrect unless in use by bluetooth. Pick com3 anyway (or next available after bluetooth) up to 9 as indicated in the device manager). It will say it's in use do you want to continue, click Yes.
   Whatever com number you choose, make a note.
7. Find SetupRobwin.msi (or later) and install RobWin 7. You may also use earlier versions robwin6x.exe on the CD
8. Double-click robwin.exe to run.
9. RobWin defaults to COM1. If you have a computer with a regular serial port and have been supplied with a 25/9 modem cable then COM 1 is correct. But for a USB COM port change to the active com port (see 6 above). Click comm at the top, then configure and make that the same number. Baud rate should be 19200.
10. Click Settings, Open file then enter R18.cfg

5. POWERING UP THE CONTROLLER

To power up the controller, connect the power cord at the rear and operate the power switch, which is integral with the power connector. You may have all other cables disconnected if you wish. However be sure to turn off the power before you connect any **rear** cable, especially the motor cable. When power is switched on the front TX light should flash which means it has sent the opening message to the computer, which you should see, in the communications window of ROBWIN. If the light flashes but nothing appears on the screen then this indicates a problem with the computer. Try clicking comms and select another COM port. If you have a USB-serial converter make sure the COM port selected matches the port shown in the device manager. Also make sure the baud rate is 19200.

The Mk5 controller CPU has Flash ROM and static RAM on the same PCB. Cold/warm/start selection is a front panel key switch. The memory image is in flash ROM which is loaded to RAM when you power up (or press reset). When powering up for the first time select COLD start before you switch on. You will see a herald on screen that should include the words COLD START.

Front panel designations:
Fail: indicates power supply problem e.g. low mains voltage. When power is turned on it stays lit until power supply is secure. Also lights when reset is pressed.
OK: opposite of fail, indicates good power supply.
TX: lights when serial data is passing from controller to computer
RX: lights when serial data is passing from computer to controller
STOP: stops robot motion (provided CPU is in control – see software manual)
RESET: resets CPU, DSP and other logic.
TEACH: teach pad input
COLD/WARM/AUTO switch – selects start-up mode when power is turned on or reset is pressed. (see section 7)
RS232 – connects to computer.

If there is no message on screen press the reset button on the front panel and watch the lights. The red led should light as you press the button. As you release the button the red led goes out, the green light comes on and the yellow TX light should flash. If it flashes the controller has sent characters up to the computer. Check the screen. If there is nothing there check com port and baud rate.

Assuming you have the herald press the enter key and you should see
> OK

Press caps lock and you should now be able to type commands into the communications window. The first command is ROBOFORTH

Rear Fuses
Viewed from the rear of the controller from right to left:
Power connector has 2 fuses. These should be 6.5A anti-surge for 110v power and 3.5A ant-surge for 220-240 power.
12v unregulated DC fuse. This should be 3 amp quick blow. The 5v logic (and lower) all comes from the 12v regulated supply so if this fuse blows the whole controller is dead. This supply emerges from the 9 way input and 15 way output connectors for users sensors etc so if you are blowing 12v fuses the fault would be there.
24v unregulated DC fuse. 24v is an alternative for users external circuitry as most industrial contactors etc are all 24v DC. Pneumatic valves can be 12v or 24v.

Stop Jack
Also on the rear panel is a jack plug. This is for the external stop circuit and has it's terminals linked inside the plug. If the jack plug is removed the robot will not run.

6. GETTING STARTED

WARNING

Before trying any of the following commands be sure to KEEP OUT OF THE ROBOT ENVELOPE

Note: **ALL FORTH and ROBOFORTH COMMANDS ARE IN UPPER CASE.**

1. With power off first set the robot in the HOME position. Pull all 3 slides up towards the motors. For the 4th axis manually rotate it ACW to the stop. ACW is as viewed by the 4th axis motor.

Assuming ROBWIN is loaded and running and that the robot is in the home position as above (all slides pushed to top).

2. Switch on the controller

3. Press caps lock and you should now be able to type ROBOFORTH commands into the communications window.

4. Type

ROBOFORTH <enter>

(if the key was set to 'cold')

5. In the communications window type

START <enter> or click the  button

A herald will appear announcing ROBOFORTH and it's version.

Enter WHERE and you will see axes 1,2,3 reported at 0 counts and the 4th axis, M4 at -1000 counts.

You can now check out the axes with the teach pad.

6. To start moving the arm click the  button or type TEACH then press <enter> two times. Ignore any "FN=" message.

The red "TEACH" and green "ON" lights should be on.

With this method pressing a key on the teach box moves the arm.

After entering TEACH you are now in "TEACH mode". To move the arm first select the joint to move, J1 for slide 1, J2 for slide 2, J3 for slide 3, J4 for the rotate axis 4.

Note that J4 can only do + away from the physical stop. If you use – while at the stop the motor will stall. If this happens you will have to switch off and repeat the setup from step 1.

On selecting an axis the terminal/computer will beep. Then press either **+** or **-** for motion in a positive or negative direction.

To test the gripper press the key marked 'GRIP', then to close the gripper press the **+** key and to open the gripper press the **-** key. Do not try other keys for the moment. Use TEACH mode to test all the joints and finally drive the robot to an approximate home position. Exit TEACH mode by pressing the escape (ESC) key on the computer/terminal.

7. Press the Home key on the teach pad or the esc key on the computer and enter

HOME

which drives the whole arm to the HOME (0 0 0 0) position. Axis 4 should rotate to its mid travel, 1000 counts from ACW stop.

7. CARTESIAN MODE

Since JOINT mode is counter-intuitive robot positioning should always be in Cartesian mode.
Assuming the robot is at HOME position (if not repeat section 6) enter
CARTESIAN
WHERE
You should see

```
          X        Y        Z     W(YAW)    LEN.  OBJECT
        0.0      0.0   -174.2      0.0      0.0
PREV    0.0      0.0   -174.2      0.0      0.0
```

Z is always negative and -174.2 is the highest it will go.
See section 10

You can now enter Cartesian commands of the form
100 100 -300 MOVE
which would move the robot 10mm in X, 10mm in Y and -30mm (down) in Z

You can also use the teach pad in Cartesian mode.
Click the J icon and select X, Y or Z. then + or -. Bear in mind that a movement in X or Y from the home position won't work because one or more slides would move up against the hard stop. So it's always safer to start with Z and -
The default increment is 10.0 mm but can be changed in RobWin.

The 4th axis goes by angle. The default increment is 10.0 degrees.

8. CONTROLLER SETTINGS

Changing default values

All the robot parameters revert to their original values when the controller is powered up or the reset is pressed. If you want to change these values and make the changes permanent you need to write them to flash ROM with the command

USAVE

Changes to any variable in the RoboForth itself are saved with PSAVE. Be very sure you have not made a mistake before you use this command because if the flash ROM is corrupted it is very difficult to recover (see below).

FLASH ROM

Cold start mode

When power is switched on, or the reset button is pressed all RAM contents are refreshed from flash ROM. All the user programming, whether entered in immediate mode or using ROBWIN will be lost.

After you see the herald and the words ‘cold start’ enter

ROBOFORTH

Warm start mode

If power goes off/on or the reset button is pressed all RAM contents are refreshed from flash ROM including the user program area. Therefore your user program will be over-written with any older program previously saved. To ensure that the new program is reloaded after a power-up or reset type the command

USAVE

Or click USAVE in ROBWIN.

If you forget to do this and accidentally lose power or press reset (or are forced to press reset because of a bug) then in ROBWIN save the project and re-open it.

The very core of the system is Forth and this is in a protected sector so can not be changed in Flash. You can however make temporary changes while it is in RAM but after the next reset or power-up it will revert to original.

9. ROBOT PARAMETERS

 **WARNING – there should be no reason to alter these constants unless some change has been made to the robot, for example a repair.**

Micro-stepping
Each motor is 'micro-stepped' and the micro-step setting depends on the type of drive module fitted in the controller. Geckos are set to 10 while IM805s are set to 5 but may changed to 10 or any value. There is an array MICROS which has values of 4 for axes 1,2,3 and 1 for axis 4.
You can enter VIEW MICROS

Encoders
The encoders are fitted as watch-dogs not as feedback devices as such. After a move the encoders are checked to see if the motor did what it is told. If the error is small a correction may be made (see software manual) or if it is big then clearly some collision must have occurred and the robot stops with 'ENCODER-STEPPER MISMATCH' and the axis number.
These are the conversion factors determined by the encoder resolution and the gear ratio between motor and encoder. They are a group of 6 16-bit values located at ENCRATIOS
You can enter VIEW ENCRATIOS

Maximum speed and acceleration
Speed is set by a variable SPEED and acceleration is set by a variable ACCEL
See the RoboForth manual for details on how to change these and how they function.
The command SETTINGS allows you to put up to 65000 for SPEED and 8000 for ACCEL however no robot will go that fast. The maximum advisable ACCEL is 5000.

Collisions
In case of a collision or any axis slide driven beyond its limit then one or more motors can stall. A stepping motor will come out of synchronism and no further motion will take place. The encoders then detect the stall and an error is declared: "ENCODER-STEPPER MISMATCH" followed by the axis number.
In many cases it is possible to recover from this as follows:
Enter

```
ENCASSUME
HOME
```

The above doesn't apply to axis 4 which has no encoder. If it stalls, restore the robot to HOME, rotate axis 4 ACW/CCW to the stop and enter START

Inverse kinematics values

WARNING – there should be no reason to alter these constants unless some change has been made to the robot.

Z range is limited. All Z values are negative, positive values are not allowed:
Z-MIN -3137 (-313.7mm) (lowest)
Z-MAX -1742 (-174.2mm) (highest)
Minimum distance of slide to motor C-MIN 1110
Maximum X-MAX 2874
MAXC 1048
arm length default 4000 units (400.0mm)

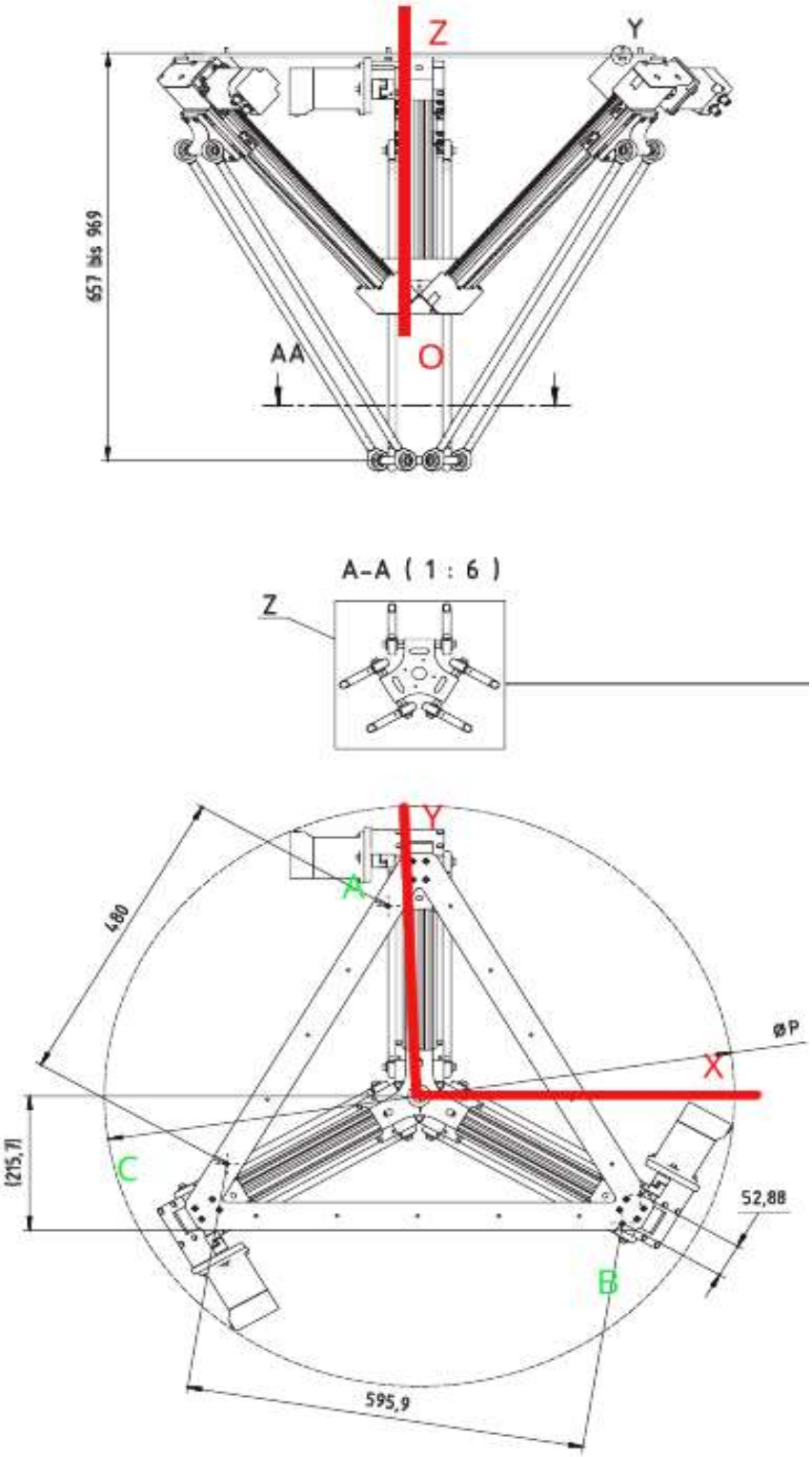
Energizing current

Driver currents are set by choosing resistor values from the following tables.

IDEAL GECKO MOTOR DRIVE CURRENT SETTINGS. STD RESISTOR VALS

AXIS NO.	JOINT NAME	LOGIC CHAN.	AMPS	RESISTOR VALUE	VALUE OF MICROS
1	M1	0	3.0	36k	4
2	M2	1	3	36K	4
3	M3	2	3	36K	4
4	M4 (AXIS 4 ROTATE)	3	1	8.2k	1

10. INVERSE KINEMATICS



The slides are referred to as A, B and C. They are at 45 degrees to vertical.
Motor M1 is C, M2 is B, M3 is A. M3 is in the Y direction. When you move in Y, M3 moves slide A down while slides B and C move up (providing they are not at home position). Movement in X sees B and C move in opposite directions. If X does not appear to be in the correct direction swap both motor and encoder connectors over between B and C.

The co-ordinates of the end-effector are x, y horizontal, z vertical upwards. The co-ordinate origin can be described as the point of intersection of the slides.

The relation between the slides and the co-ordinates is shown in the diagram: y towards A slide, x in the direction C to B. The length of the parallelogram arms is m.

The origin could be described more precisely: x and y are zero on the center axis. Z would be zero where the arms are parallel to the slides at 45° to vertical or equivalently z = - m when the arms are vertical. Since neither of these points can be reached in the actual robot we must define z another way. Such as at (0, 0, -m/2) the arms are 24.3° to vertical.

The positions of the slides are a, b and c positive upwards with zero at the origin.

x, y, z, a, b, c, m are all measured in the units of 0.1mm.

Calculations
The calculations are performed using 24 bit floating point arithmetic (ADL mode) but 16-bit integer values are input and output (fixed point 0.1mm resolution).

The functions provided take values from the stack and leave the results on the stack. They are accessed by loading a code into the A register and jumping to a location depending on the number of input words on the stack: 2000h for 3 words, (2006h for 2 words), 200Ch for one word, (2012h for no words).

Given end-effector x, y, z find slide positions a,b,c:
Put x, y, z on stack and 2 in A register, jump to 2000h
ld a, 2
jp 2000h
CODE XYZ2ABC 3E C, 2 C, C3 C, 2000 ,
stack will be (top first) e z y x

e is an error code on the stack top. 0 is good. 4 means square root of a negative number was attempted. 5 means the result is too big (+ or -) to fit in an integer.

Given slide positions a, b, c find x, y, z:
Put a, b, c on stack and 3 in A register, jump to 2000h
CODE ABC2XYZ 3E C, 3 C, C3 C, 2000 ,
stack will be (top first) e c b a

The arm length has a default value of 4000 (400mm in 0.1 mm units) To change it put a new value on the stack, put 0 in A register and jump to 200ch
CODE SET_ARM_LENGTH 3E C, 0 C, C3 C, 200C ,
Stack should be empty on return.

The above is given for information only. All the required jumps are already part of the RoboForth and all you need to do is enter coordinates.

11. CONNECTIONS

Connections to the rear panel are as follows:-

MOTORS
25-way D-type, female, to M12 connectors on axes 1,2,3 to each axis motor

	25w pin no s	M12 pin no.s
Motor 1 A	1,2	1,2
Motor 1 B	3,4	3,4
Motor 2 A	5,6	1,2
Motor 2 B	7,8	3,4
Motor 3 A	9,10	1,2
Motor 3 B	11,12	3,4
Motor 4 A	14,15	
Motor 4 B	16,17	

ENCODERS
25-way D-type, male, to M12 connectors on axes 1,2,3 to each motor

	25w pin no s	M12 pin no.s
Encoder 1	6,7	3,4
Encoder 2	8,9	3,4
Encoder 3	10,11	3,4
5v supply	20	8
0v	19	5

12. TECHNICAL SUPPORT

95% of all technical support is for software questions. Almost always this is best dealt with by email to support@strobotics.com but you can call if it's urgent.
Email replies are clearer about what to type.
When requesting support if possible quote the serial number of the robot – it is on the back of the robot and you can also get it by typing WRU (who are you).
We can solve your problem given enough information. You can:

1. No need to do a screen shot. Go to the top of RobWin, click comms, save communication. This creates a text file of everything you entered in the command window including what has scrolled off the top. Send that file to support.
2. A project comprises 3 files, filename.run, filename.ed1 and filename.ed2.You can zip these together and send to support.

FCC declaration – please see certificate contained in the transit case.
The equipment conforms to Part 15 sub-part B class A
CE declaration – please see certificate contained in the transit case.
The equipment conforms to:
The Supply of Machinery Regulations 2008
Safety of Machinery - EN 60204-1 2006
Emissions and immunity - EN55022:2010 and
EN55024:2010/A1:2015
– note amendment 1 does not apply.

RISK ASSESSMENT

This form must be completed by a competent Assessor for any procedure using the robot system before an attempt is made at the procedure by any worker or visitor.

For further information on hazards and risks please refer to the section SAFETY IS YOUR RESPONSIBILITY on page 5 of this manual.

Name and Status of the Assessor:	**Date:**
Activity being assessed:	
Known or expected hazards associated with the activity:	
The risk of injury and its severity likely to arise from these hazards:	
Who is at risk?	
Measure to be taken to reduce the level of risk:	
Training prerequisites:	
Level of risk remaining:	
Emergency action:	
References if any:	
Signature of Assessor	**Revision date**