SpareTimeLabs

for PCB revision RC8.1

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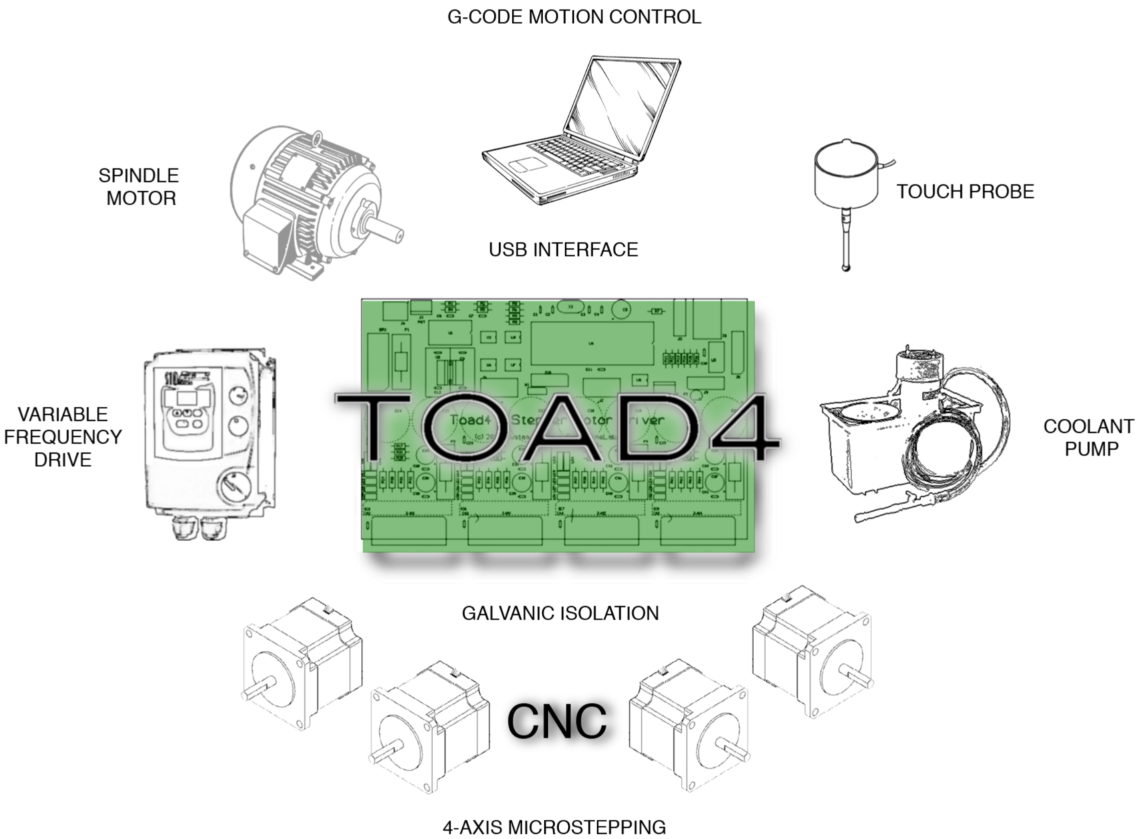
TOAD4 – Manual

revision 2



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Chapter 1

Disclaimer

TOAD4 is a stepper motor controller sold in kit form aimed at CNC machining applications.

Any machine tool is potentially dangerous.

All electrical system have the potential to cause an electric shock or a fire hazard.

Most countries and states have regulations and standards that govern the design, construction, use, deployment and placing on the market of electrical and mechanical equipment.

TOAD4 is sold in kit form with full documentation, including manual, schematics and a pcb-layout detailing its design, construction and intended use.

No safety of design or construction nor warranty is implied, instead *it is your responsibility to ensure that you understand the implications of the design and construction and to comply with any legislation and codes of practice applicable to your country or state.*

If you are in any doubt, you must seek guidance from a professionally qualified expert rather than risk injury or liability to yourself or to others.

SpareTimeLabs or Kustaa Nyholm cannot accept any responsibility resulting from the design, construction or use of TOAD4.

All names of products and trademarks used in this manual are for example purposes only, no endorsement of them by SpareTimeLabs nor endorsement of TOAD4 by their respective owners is implied.

Chapter 2

Introduction

2.1 Introduction

TOAD4 is a self-contained four-axis CNC controller with spindle control and touch probe interface aimed at the hobby market and DIY people. It is built around four Toshiba TB6560 microstepping stepper motor drivers and the Microchip PIC18F4550 USB-enabled microcontroller.

Figure 2.1 gives an overview of the hardware.

If you are not interested in building stepper motor controllers from ground up, i.e. soldering components and tinkering with electronics, then TOAD4 may not be for you. If you just want to control stepper motors from your PC, then you maybe better of with ready-made offerings such as Gecko drives.

On the other hand, if you are interested in tinkering with electronics and/or software, then TOAD4, with its open architecture and documentation, offers an excellent platform for such experimenting at a reasonable cost.

The cost of a four-axis controller based on TOAD4 can be as low $100 if you need to buy just the key components, or $200 if you need to acquire everything. Compare that to a minimum $300 for a four-axis Gecko drive based system which still lacks the power supply integral with TOAD4. Throw in a mini-laptop at $200 and you have the electronics for a four-axis CNC system for less than $400.

This manual deals mainly with the TOAD4 hardware and its capabilities. What the board actual can do depends on the firmware of the board and the application software. TOAD4 is aimed to work with the EazyCNC software, for which firmware is available.

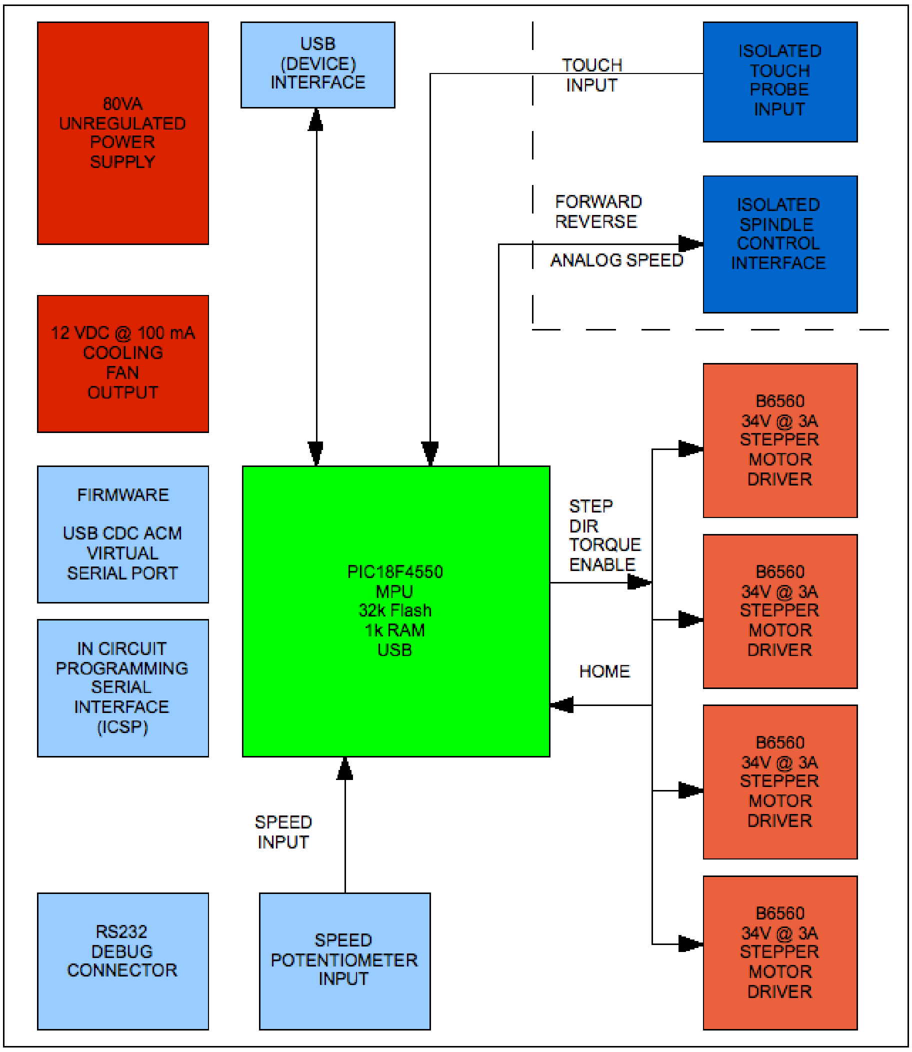


Figure 2.1: TOAD4 block diagram

Chapter 3

TOAD4 Features

3.1 Features in a nutshell

This chapter gives a short walkthrough of what you get with TOAD4.

- Four identical stepper drivers
  - up to 34 VDC drive voltage
  - max 3A / phase drive current
  - software controllable current on/off
  - software selectable high drive / low hold torque
  - resistor 'programmable' max current 0-3 amp
  - four step modes from full step down to micro stepping
  - four different current decay modes
  - over temperature protection
- Four reference/home position switch inputs
  - +12/5 VDC output option for optical gates etc.
- Spindle / Torch control interface
  - optically isolated spindle forward and reverse outputs
  - optically isolated ratiometric spindle speed output
  - compatible with standard variable frequency drives
  - compatible with many plasma torches
- Coolant control output
  - optically isolated output for coolant control
- Touch probe input
  - optional optical isolation
  - optional isolated DC power output for probe

- Speed control input
  - software readable potentiometer input for cutting speed control
- Cooling fan power output
  - 12 V @ 100 mA available for a standard low power cooling fan
- Integral power supply
  - up to 80 VA integral unregulated power supply for motors and electronics
- USB Interface
  - Full Speed / 12 Mb/s interface – no LPT/Parallel port required
  - No drivers needed for host operating system - acts as a virtual COM port
  - Compatible with Windows, Linux and Mac OS X
  - Allows use of mini laptops for CNC applications
- PIC Flash Microcontroller
  - does not depend on host operating system for real time tasks
  - Compiler optimized CPU architecture
  - USB 2.0 / Full Speed / 12 Mb/s interface
  - 1kB RAM memory
  - 32 kB Flash ROM memory
  - Serial port for debugging
  - 10 bit AD converter
  - PWM output
  - Timers
- All Through Hole Construction
  - no hard-to-solder surface mount components used.
- Standard DE9 Connectors
  - all machine internal connections can be done with cheap and cheerful common serial port cables.
- Compact mechanical construction
  - fits in a standard Hammond die cast aluminium enclosure
  - all machine connections easily dis-connectable for service
  - all internal and external connectors on different sides
  - easy mechanical construction
  - optional fan-cooled heatsink can be fitted

3.2 Stepper motor drivers

This is what it is all about: controlling stepper motors!

More specifically: bipolar hybrid stepper motors.

The board contains four identical motor drive electronics based on the Toshiba TB6560AHQ driver chip.

This is a fairly modern chip, supporting up to 16 step micro stepping, that comes in a nice ZIP-25 package that is both easy to mount, solder and cool and requires only minimal external components.

The chip is designed for unregulated 34 VDC operation (i.e. rectified and filtered 24 VAC), which is the main limitation of the driver chip.

The drive voltage limits the amount of current that the driver can deliver to the motor as the step speed goes higher. This depends on the inductance of the motor, but in practice we are talking about NEMA 23-size or smaller motors with 10-15 W power and torque in the 1-2 Nm range.

The chip's voltage supply range is from 6 V up to 40 V, so the board can be used (with some trivial component changes) down at 6 VAC and might be possible to push close to 40 VDC, giving some more drive capability for higher inductance motors, but that will require a better regulated power supply so as not to exceed the 40 V under any circumstances.

The other limiting factor of the chip is its 15 kHz step clock maximum, which limits the step rate to 3750 steps/sec using full step, or 950 steps/sec with micro stepping. With a typical 1.8 step angle or 200 steps per revolution of common hybrid steppers, this translates to about 19 r/sec or 1100 rpm and 4.5 r/sec or 280 rpm, respectively.

In practice, the microcontroller and its firmware can be the limiting factor and it maybe be hard to push the software-generated step clock rate above 5 kHz. Fortunately, most applications are likely to require much slower speeds.

The third limiting factor is the power dissipation or heat the chip can stand. The rated maximum continuous current of the chip is 3 Amps, but this will require substantial cooling arrangements. For this purpose, TOAD4 features a 12 VDC output compatible with standard low cost low power CPU cooling fans.

3.3 Motor current

The motor maximum current is selected by soldering suitable resistors onto the board.

To calculate the resistance value use

R = 0.5 V / Iout

So for the the maximum allowed current of 3 A, use a 170 mOhm resistance value. The bigger the resistance, the smaller the current.

The board has places for two parallel resistors per phase. This allows the selection of two motor currents with just one resistor value by soldering one or two resistors on the board.

With 0.4 Ohm resistors it is possible to get either 1.25 A (one resistor) or 2.5A (two resistors), both of which are what might be considered appropriate and typical values for the applications for which this board is suitable.

Both phases of any one motor should have equal currents and resistances.

It is very important that the resistors are of a low inductance type.

The resistors set the maximum current for any one motor.

In addition to the maximum current set by the resistors, the microcontroller can select a smaller hold current/torque individually for each motor and also turn off the driver for any one motor under software control.

3.4 Optical isolation

The probe input and all of the coolant and spindle outputs are optically isolated.

This isolation is for functional purposes only, in other words the purpose of the isolation is to ensure correct signalling by providing a measure of robustness through eliminating current loops and ground potential differences.

The isolation is NOT FOR ELECTRICAL SAFETY purposes. While the opto-isolators used (4N35) provide 1.5kV or more isolation, the creeping distances on the PCB are not designed to withstand anywhere near that high voltage. Electrical safety MUST NOT DEPEND ON THE OPTICAL ISOLATION.

3.5 USB interface

The PIC18F4550 microcontroller implements a standard USB device interface that requires no external components. The TOAD4 firmware implements a USB CDC ACM, also known as Virtual Serial Port, which makes TOAD4 appear as serial port (COM * or /dev/tty*) on the host computer without any driver installation or creation.

3.6 Spindle / Torch control interface

The spindle control interface consists of two open opto-isolated outputs that are intended to control the spindle forward and reverse signals on a standard variable frequency drive unit.

A spindle speed control voltage is generated using opto-isolated pulse width modulation, and outputs an analog control voltage proportional to a supplied reference voltage.

This type of interface is compatible with common VFDs such as the Commander Technique SE series or Schneider Electric Altivar 11 series (to name a few).

The spindle forward (or reverse) can be used to control a plasma cutter torch such as the Hypertherm Powermax 45.

3.7 Power Supply

The power supply provides the board with 50-100 VA power depending on the transformer used. A 24 VAC 50 VA toroidal transformer fits the Hammond enclosure better depending on the transformer construction, the enclosed types are bigger by a few critical millimeters.

For most applications, 50 VA is plenty as stepper motors bigger than 15 W are rather uncommon and expensive.

The bridge rectifier is a 6 A bridge that has a mounting hole for mounting to the side of the enclosure for cooling. Even though the average current typically will be well below 4 A, the peak current is high and the diodes in the bridge are running hot, so providing some cooling is advised.

The board has room for 8 x 1000 uF 50V capacitors, which provides about 10% voltage ripple at 3 A. Note that this current is NOT the sum of the motor phase currents. Three amps is equivalent to 75 VA of power or 18 W/motor; you are unlikely to need, find or afford stepper motors that large.

Chapter 4

Connectors

4.1 Motor Connectors (J-MX, JM-Y, JM-Z, JM-4)

There are four identical female DE-9 connectors at the bottom of the board, one for each motor, labeled J-MX, JM-Y, JM-Z and JM-4.

The use of DE-9 connectors makes it possible to use ready-made, cheap PC cables for wiring the motors.

A female connector is used as it is less likely to trap swarf that could short circuit and damage the drive chip. It also makes it less likely that the wrong cable is plugged in as the other connectors are male gender.

Each connector has two coil outputs and one reference/home switch input. See Table 4.1 for details.

Table 4.1: Motor Connector Signals (J-MX, JM-Y, JM-Z and JM-4)

DE-9 Pin	Signal
1	Coil A+
2	Coil A-
3	Coil B+
4	Coil B-
5	Not connected
6	+12/+5 VDC optional output for reference switch
7	Reference switch input with 10 kOhm pull up to +12 VDC
8	GND (ground)
9	Not connected

The reference input provides a selectable (with jumper H1) DC voltage output which makes it directly compatible with standard optical gates such as PM-44L as well as traditional microswitches.

Optical gates are easier to adapt mechanically and are generally more reliable than microswitches, but also more expensive at about 10 EUR a piece.

Note that the reference inputs are *not* optically isolated and thus should not be galvanically connected to the metal parts of the machine.

The coil outputs are current limited but are *not short circuit protected* , so take care when making the connections. Never ever disconnect/connect the motor connector while the board is powered and make sure that the connector cannot work loose during machine operation.

Changing the driver chips is painful and may result in irreparable damage to the board.

See Figure 4.1 for a wiring example.

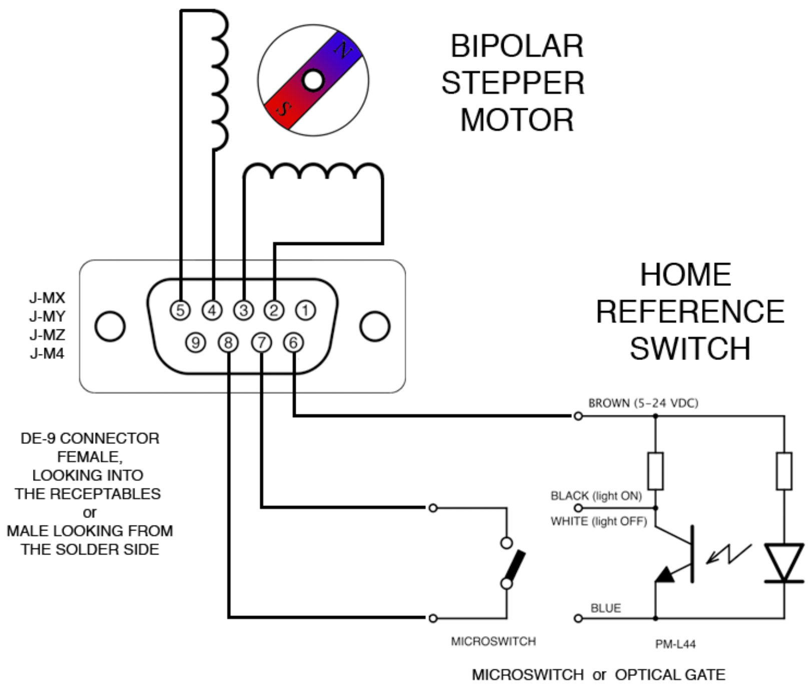


Figure 4.1: Example of motor and home switch wiring

4.2 Spindle/Torch Connector (J8)

The spindle/torch control connector J8 is a 10-pin header to the left of the center of the board.

This header can be mounted to the underside (the solder or non-component side) of the board to make room for the power supply transformer when the Hammond enclosure is used.

The J8 header is connected to the panel-mounted male DE-9 connector using standard AT computer style internal serial port flat cable. If you are ransacking this from an old PC, note that there exists at least one other 'standard' with a different pinout. In the one illustrated here, the ribbon cable wire numbering and DE9 connector pin numbering *don't* match.

Also take care, when inserting the flat cable connector to the header, that you insert it the right way, as it is perfectly possible - but disastrous - to insert it wrong way or at an offset. The pin 1 side of the flat cable is marked on the PCB with a chamfered corner in the top silk, with a triangular mark on the connector and with a different color on the flat cable.

Refer to Figure 4.2 for pin numbering when J8 is mounted on the solder side of the board and Figure 4.3 if it is mounted on the component side.

Table 4.2 also lists the pins and signal for the Spindle/Torch connector, take care to use the correct column depending on which side of the board J8 is mounted on.

Table 4.2: Spindle connector signals (J8)

J8 Pin	J8 comp side DE-9 Pin	J8 solder side DE-9 Pin	Signal
1	1	6	SPINDLE FORWARD+
2	2	7	SPINDLE FORWARD-
3	3	8	SPINDLE REVERSE+
4	4	9	SPINDLE REVERSE-
5	5	-	COOLANT-
6	6	1	0V REF
7	7	2	SPEED OUT
8	8	3	+10V REF IN
9	9	4	COOLANT+
10	-	5	COOLANT-

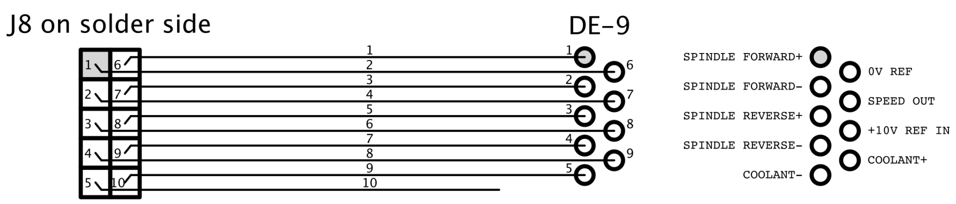


Figure 4.2: Picture of J8 connections when mounted on the solder side

Figure 4.3: Picture of J8 connections when mounted on the component side

Spindle control consists of two optically isolated open emitter transistors that share a common collector connection. These are typically capable of handling 24 V / 20 mA or input impedances of higher than 1.2 kOhms.

These are directly compatible with standard Variable Frequency Drive electronics which typically expect a forward/reverse signal to be pulled up against a voltage supplied by the VFD unit itself. These are also directly compatible with some plasma cutter/torch power supply control signals.

Note that the inputs of some VFD controllers use a common ground instead of a pull up to a common positive voltage. If you are using one of those, you need to leave the SPINDLE REVERSE un-connected and connect the SPINDLE FORWARD signal to the VFD (digital) ground and the SPINDLE COMMON signal to the VFD FORWARD input, which means you cannot use the reverse spindle feature.

The speed control is a separate, optically isolated ratiometric signal generated with pulse width modulation from a reference voltage provided by a typical VFD. Note that while most VFD units *also* accept 20 mA current signal for speed control, the TOAD4 speed output is *not* compatible with that.

Note that a VFD unit has a number of parameters/settings that need to be set correctly for it to operate as desired based on the signals from TOAD4. Refer to the VFD unit manual for details.

Figure 4.4 gives an example of connecting the board to the Control Techniques Commander SE (VFD) variable frequency drive. Note that this assumes *J8 mounted on the solder side.*

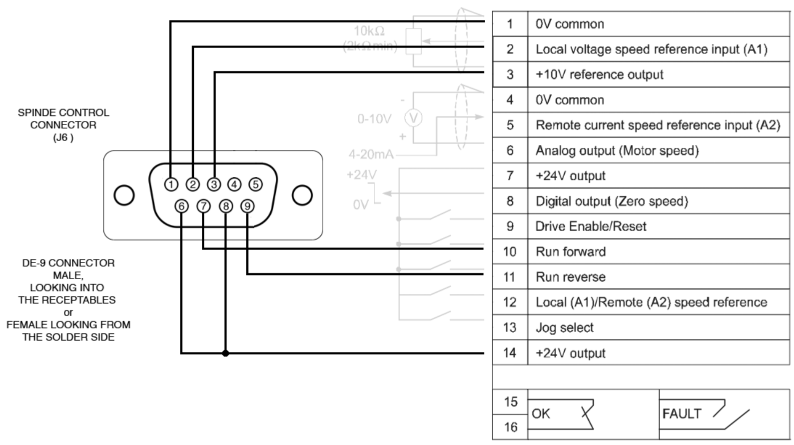


Figure 4.4: Example of VFD based spindle control wiring. .

The coolant control output is yet another optically isolated open collector (Coolant +) / open emitter (Coolant-) transistor, which is typically capable of handling 24 V / 20 mA. Overloading the output may damage the TOAD4 circuitry.

This output needs to be connected via a suitable relay to the coolant pump.

A suitable relay must be able to handle the pump inrush current, provide safe isolation between the low voltage electronics and the pump drive voltage and not over load the TOAD4 coolant output. If the relay coil resistance is smaller than 1 kOhm, you need to use a transistor between the relay and the TOAD4 output.

Also note that the relay needs to have a snubber diode wired across the coil to prevent the inductive kickback of the coil from damaging the TOAD4 output transistor. If a low voltage power supply is used and the same power supply is used to power both the coolant pump and the relay, then that motor needs a snubber diode too.

Don't forget to include a fuse in the circuit!

Figure 4.5 gives of an example of wiring a low voltage coolant pump. Note that this assumes *J8 mounted on the solder side*

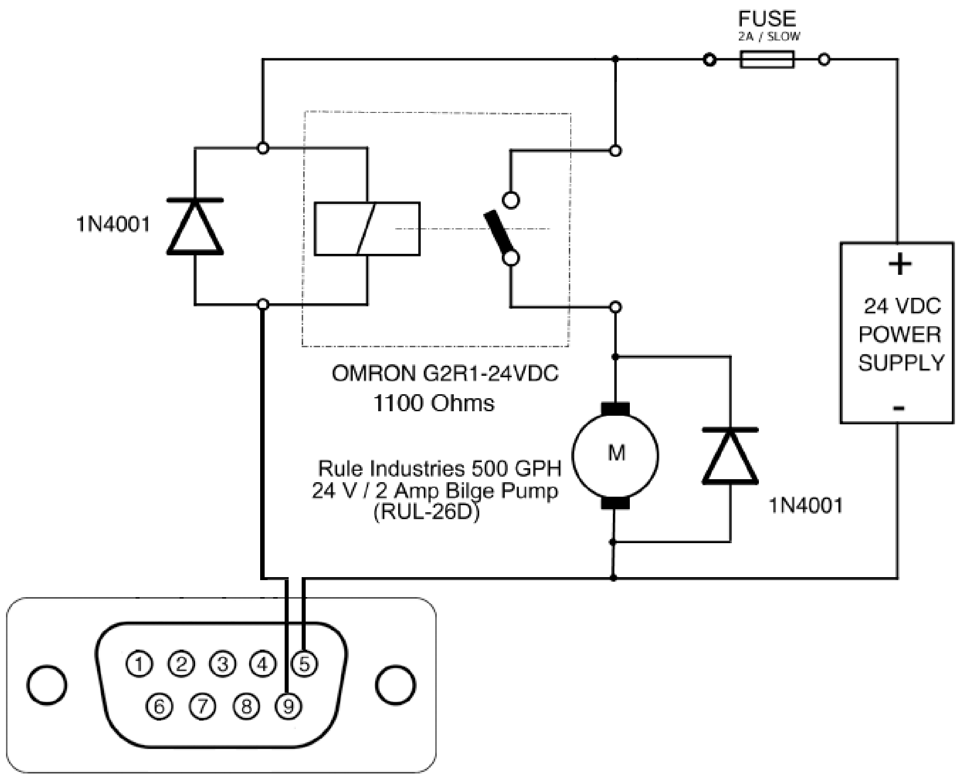


Figure 4.5: Example of bilge pump based cooling system wiring.

4.3 Probe Connector (J9)

The probe input connector J9 is a 10-pin header in the center of the board.

This header can be mounted to the underside (the solder or non-component side) of the board to make room for the power supply transformer when the Hammond enclosure is used.

Like J8, the J9 header is connected to the panel-mounted male DE-9 connector using standard AT computer style internal serial port flat cable.

The probe connector J9 provides an isolated and a non-isolated input for a touch probe.

An isolated input output of +12 VDC 20 mA is available for an electrical/optical touch probe.

The isolated input has a 2.2 kOhm pull up to the isolated +12 V, so pulling it down against the isolated ground is enough to activate the signal.

Likewise the non-isolated input has a 10 kOhm pull to the non-isolated +12V.

Refer to Figure 4.6 for pin numbering when J9 is mounted on the solder side of the board and Figure 4.7 if it is mounted on the component side.

Table 4.3 also lists the pins and signals for the Probe connector. Make sure you use the correct column depending on which side of the board J9 is mounted.

Table 4.3: Probe connector signals (J9)

J9 Pin	J9 comp side DE-9 Pin	J9 solder side DE-9 Pin	Signal
1	1	6	ISOLATED PROBE GND
2	2	7	ISOLATED PROBE INPUT
3	3	8	+12V ISOLATED OUTPUT
4	4	9	AUXIN+R
5	5	-	AUXIN-
6	6	1	AUXIN+
7	7	2	VOUT REF SWITCH
8	8	3	+10V PROBE INPUT
9	9	4	GND
10	-	5	AUXIN-

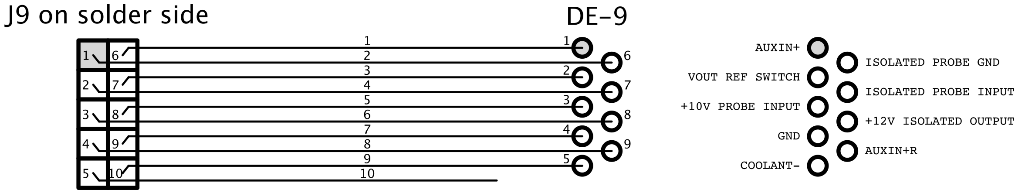


Figure 4.6: Picture of J9 connections when mounted on the solder side

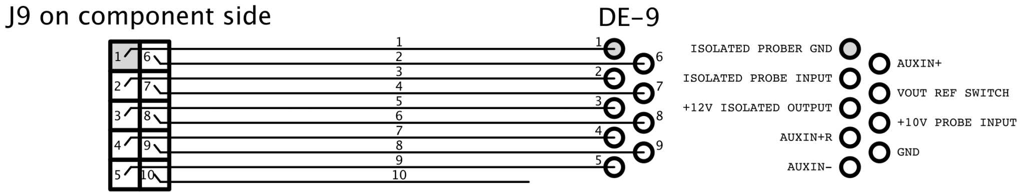


Figure 4.7: Picture of J9 connections when mounted on the component side

4.4 Fan Connector (J10)

A standard PC CPU fan can be connected to the connector J10 to provide forced air cooling for the motor controller chips. This is typically necessary only when running the motors close to the maximum driving capability of the drive chips.

Table 4.4: Fan connector signals (J8)

J10 Pin	Signal
1	Not connected
2	+12 VDC @100mA output for fan
3	GND (ground)

4.5 Speed Potentiometer Connector (J1)

A 10 kOhm potentiometer can be connector to the header J1 as a speed control input device.

Table 4.5: Speed potentiometer connector signals (J1)

J1 Pin	Signal
1	+5 VDC reference output for potentiometer
2	0-5 V input from potentiometer
3	GND (ground)

4.6 Debug Connector (J6)

J6 header provides TTL-level RS232 / serial port for debugging purposes.

To connect it to a standard serial port, some sort of level conversion is necessary.

Table 4.6: Debug connector signals (J6)

J6 Pin	Signal
1	+5 VDC output
2	TX output
3	AUX IN
4	RX input
5	GND (ground)

4.7 USB Connector (J3,J4)

The J4 connector is a USB B (device) connector soldered to the board.

An alternative panel-mounted USB connector can be connected to J3. Panel- mounted USB connectors are not easy to find, but may be harvested from discarded USB connected devices or by cutting away the device connector from a standard USB cable and wiring the cable directly to the J3 holes.

If you use J3, ensure correct wiring / pin layout before connecting.

Table 4.7: USB connector signals (J2,J3)

J3 Pin	J4 Pin	Signal
1	1	VBUS
2	2	D-
3	3	D+
4	4	GND (ground)
5	-	Not connected

4.8 ICSP / PICKit2 Connector (J5)

The ICSP conforms to the Microchip in-circuit serial programming interface (ICSP), which allows firmware programming using the PICKit2 programmer.

Table 4.8: ICSP / PICKit2 connector signals (J5)

J5 Pin	Signal
1	VPP
2	VDD (not connected)
3	GND
4	PGD
5	PGC
6	PGM (not connected)

4.9 Reset / RUN LED Connector (J7)

The J7 header provides connections for a RUN-LED and a reset switch.

The pinout is compatible with a standard AT computer style front panel reset / LED assembly.

Note that if you use both the on-board RUN LED and a front panel mounter RUN LED, then the RUN LED (D1) on the board should be green and the front panel mounted LED should be red because the LEDs are connected in parallel, and with a green and red LED connected in parallel the red (front panel mounted) is guaranteed to work.

Table 4.9: Reset / RUN LED signals (J7)

J7 Pin	Signal
1	LED+
2	LED-
3	Reset switch 1
4	Reset switch 2
5	Not connected

Chapter 5

Jumpper Settings

There are six motor configuration jumpers for selecting the step mode, driver current and current decay mode for each motor individually. To locate the jumpers, refer to Figure 5.1.

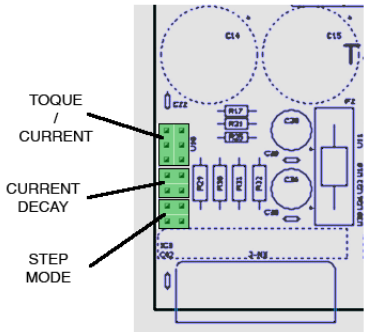


Figure 5.1: Motor configuration jumpers

You don't have to install any of the jumpers, in which case the drivers will default to full step mode with maximum current and normal decay mode, see below for details.

If you are on a shoe string budget, you don't even have to install the headers/pins, but use jumper wires instead, as once the motor current, step mode and decay are selected, they are usually never changed.

In addition to the motor configuration jumper, there is one (H1) for selecting the limit/reference switch supply voltage. With the resistor values given in the schematics, this should always be set in the 12V position, i.e. between H1.1 and H1.2, which is between the two right most pins, as illustrated in Figure 5.2.

The labels and signals for each motor are listed in Table 5.1 for cross reference, but you don't usually need this info, so just skip to the next section to see how to set the jumpers.

For the nitty gritty, refer to the schematics and B6560AHQ driver chip data sheet.

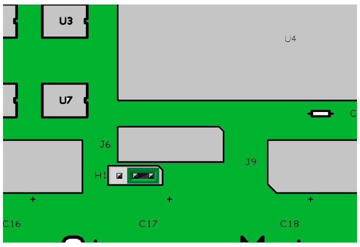


Figure 5.2:

Table 5.1: Motors versus configuration jumpers

Motor	TQ2	TQ1	M2	M1	DCY2	DCY1[1]
X	U9	U10	U29	U25	U21	U17
Y	U11	U12	U30	U26	U22	U18
Z	U13	U14	U31	U27	U23	U19
4	U15	U16	U32	U28	U24	U120

[1] Refers to signals in the B6560 driver chips, see schematic and data sheet for details; see below for how to set them

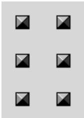
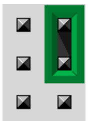
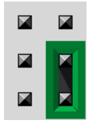
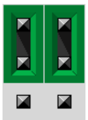
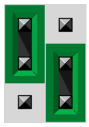
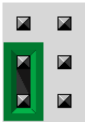
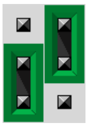
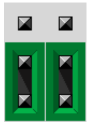
5.1 Drive / Hold Current

For each driver, the motor drive and hold currents can be set with the jumpers as illustrated in Table 5.2.

The currents are defined as a percentage of the maximum current set by the current measurement resistors.

Very often, stepper motors are used at some selected current all the time, regardless of whether they are running or not, but TOAD4 supports the use of a lower holding current when the motor is not running.

Table 5.2: Torque/Current -jumper settings

TORQUE[1]	0	1	TORQUE	0	1	TORQUE	0	1
	100%	100%		100%	75%		75%	75%
	100%	50%		100%	20%		75%	20%
	50%	50%		50%	20%		20%	20%

[1] Refers to signal TORQUE in the schematics. The firmware sets this signal (1) when full torque is required and clears it (0) when only motor hold torque is reguested.

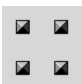
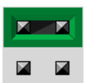
5.2 Step Mode

The driver chip supports four different step modes: full step, half step, fine step and micro step. Fine step provides eight intermediate sinusoidal current values for each full step and micro stepping provides sixteen intermediate current values.

Typically, micro stepping is preferred for its smooth ride, but sometimes speed requirements dictate the use of half or even full step.

The step mode jumper settings are illustrated in Table 5.3

Table 5.3: Step Mode -jumper settings

	Full Step		Fine Step (1/8 Step)
	Half Step		Micro Step (1/16 Step)

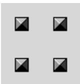
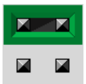
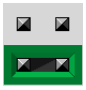
5.3 Decay Mode

The driver chip supports four different current decay modes.

Typically, you'll want to have normal decay mode (no jumpers installed), for details see the Toshiba Application Note *TB6560AHQ Usage Considerations*.

The current decay mode jumper settings are illustrated in Table tab:currentdecay-selection-jumpers

`Table 5.4: Step Mode -jumper settings`

	`Normal decay`		`25% decay`
	`50% decay`		`100% decay`

Chapter 6

Building TOAD4

Building TOAD4 is pretty straightforward if you have ever soldered components to a printed circuit board.

You can find the parts lists, schematics and PCB layout in the appendices, don't forget to read the errata too.

If you have no experience in building electronics, it is well worth the effort to talk to someone more experienced, and the web has a wealth of information on the subject.

Building electronics is mainly a mechanical exercise where spatial relations and constructional soundness dictate order and placement.

Before starting to solder components in place there are a few things to note in the construction and a few decisions to make.

6.1 Mechanical construction

Before soldering the components in place it is good to think about the mechanical construction and enclosure.

The driver chips, rectifier bridge and the voltage regulators all need heat sinking.

One way to do that is to use a metallic enclosure and bolt them to the enclosure. The regulators and bridge have long leads and it is possible to bend the leads so that the components reach out from the board to the enclosure. The driver chips will need to be mounted to a hefty piece of rectangular aluminium bar that then bolts to the bottom of the enclosure.

When planning for the enclosure, note that the motor connectors (possibly the USB connector as well) are soldered onto the board and thus the board needs to be mounted either so that the connectors can be plugged in through the opening in the enclosure or so there is room for the wire connectors inside the enclosure.

See figure 6.1 for a sketch of parts placement and 6.2 for a picture of a completed board mounted into a Hammond enclosure.

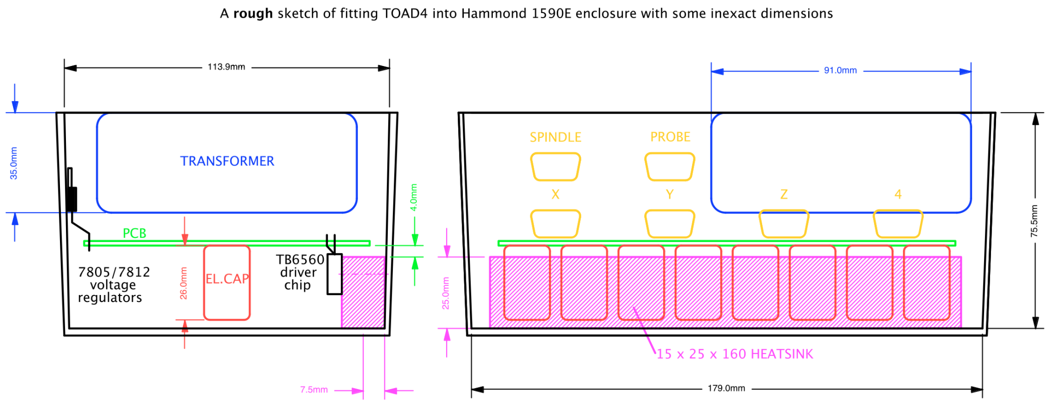


Figure 6.1: Sketch of critical parts placement in a Hammond 1590E enclosure

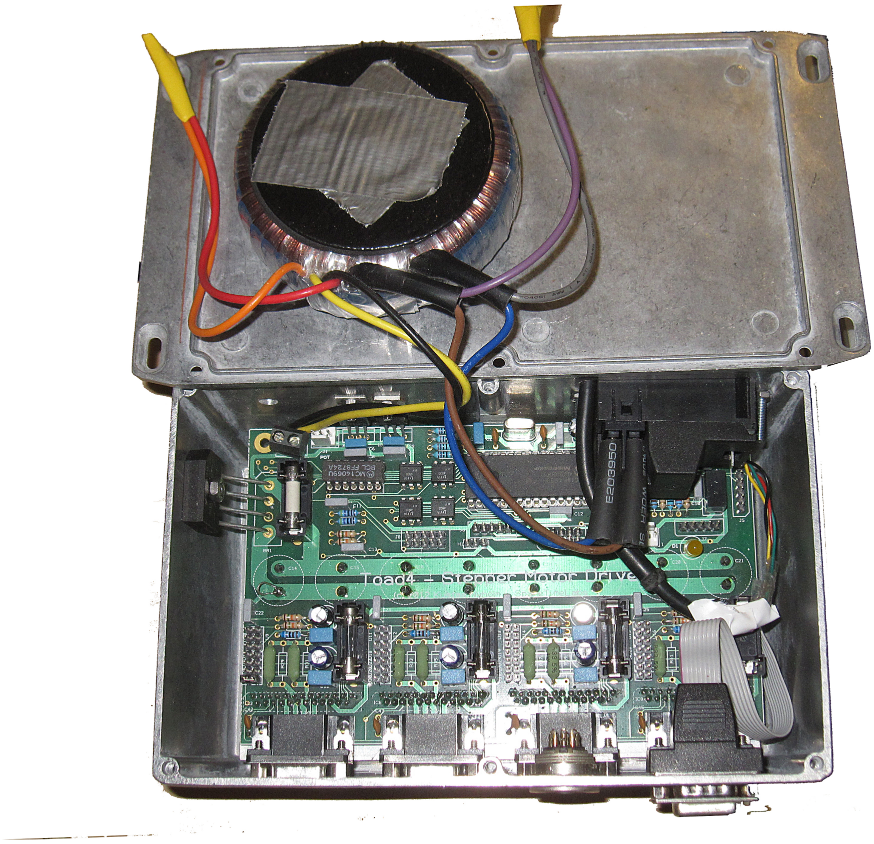


Figure 6.2: A complete 4 axis TOAD4 in a Hammond enclosure

6.2 Motor current selection

Before mounting the current selection resistors you need to decide what is the current required for each motor / axis.

Typically some axes need more current than others.

The motor current is determined by the current measurement resistors on the board.

A pair of resistors set the maximum current for any one motor.

Each motor driver needs two resistors, one for each phase or coil. There is room for two parallel resistors on the board for each phase of each motor. Install either two or four resistors, for example R28 and R30 or R28, R29, R30 and R31.

All the resistors for a given motor driver need to have identical values.

In addition to the maximum current set by the resistors, the micro controller can select a smaller current/torque individually for each motor and also turn off the driver for any one motor under software control.

Note that this is no introduction to stepper motor driving methods, but a few words may come in handy:

Stepper motors are typically driven by current as opposed to voltage, as it is the current in the coil that produces the electromagnetic force that causes torque and makes the axle turn. So although a motor data sheet specifies a voltage for the motor, this is not a relevant parameter as much more than the stated voltage is needed to force the required current to the motor inductance at any appreciable speed.

The stepper motor driver chip controls the current by chopping the voltage; it turns on the voltage and monitors the current until it reaches the desired current, then turns off the voltage. This happens at a chopping frequency of about 100 kHz or more.

To get the desired current, you need to select a stepper motor suitable for your application based on the torque and speed needs and then look up the current from the motor data sheet and 'program' that current to the driver chips.

Programming the motor maximum current is done by soldering suitable resistors onto the board.

To calculate the resistance value, use

R = 0.5 V / Iout

The bigger the resistance, the smaller the current.

So for the maximum allowed current of 3 A that the driver chips can stand, use a 170 mOhm resistance value.

With 0.33 Ohm resistors it is possible to get either 1.5 A (one resistor) or 3.0A (two resistors), both of which are what might be considered appropriate and typical values for the applications for which this board is suitable.

It is very important that the resistors are of the *low inductance type* and they need to withstand up to 1.5W if the maximum current is used.

6.3 Identifying Components/Orientations

Figure 6.5 should help to identify most parts and their orientations.

Integrated circuits typically have their pin 1 marked with a dot near the pin or a notch at the end where the pin 1 is. On the PCB the pin one is marked with a chamfer on the component outline on the silk. All the integrated circuits have are in the same orientation, except the driver chips.

The discrete components, resistors and capacitors, may be more difficult to identify, figure 6.6 together with schematics should help with that.

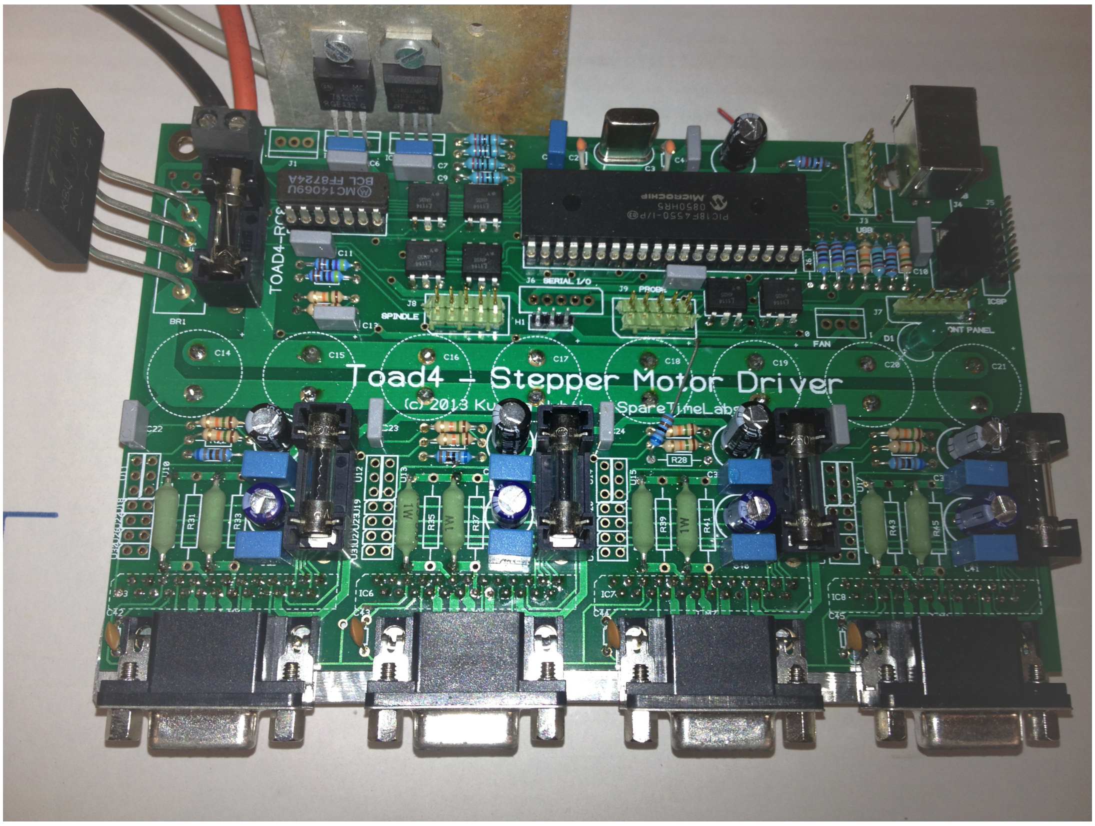


Figure 6.3: A completed board (motor config headers not installed)

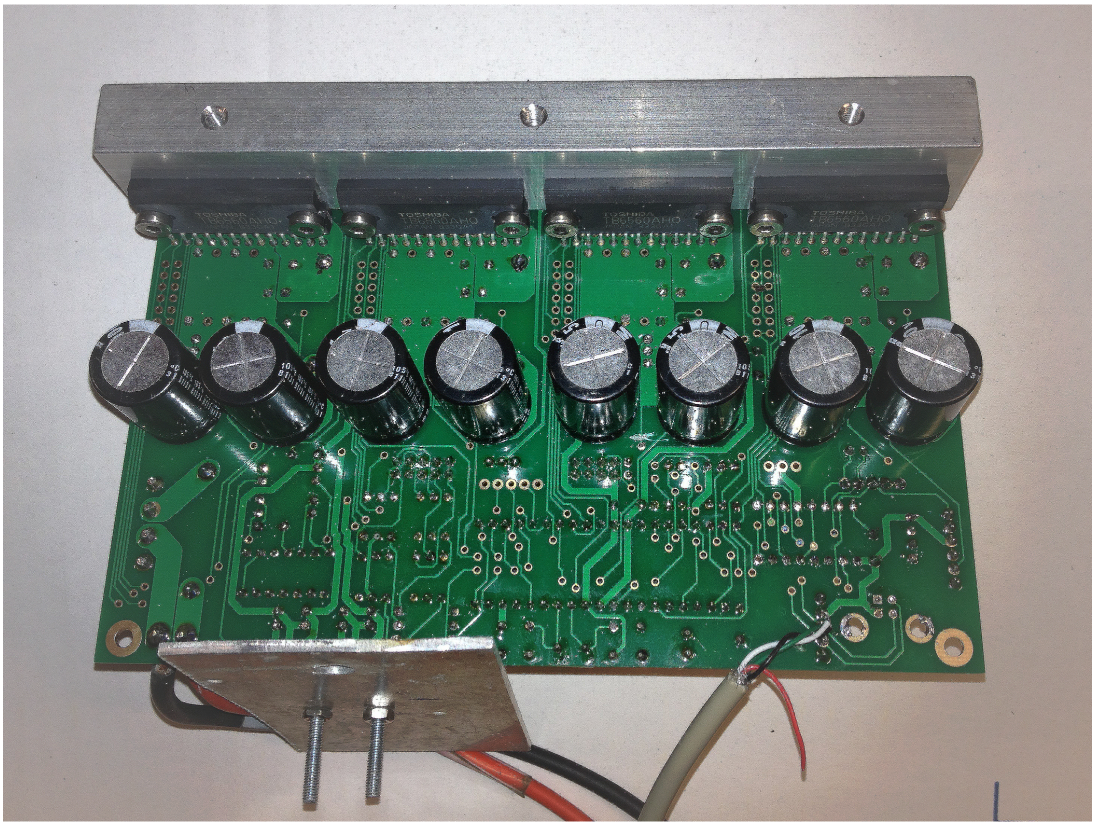


Figure 6.4: Underside of the board showing the driver chips and big filter capacitors

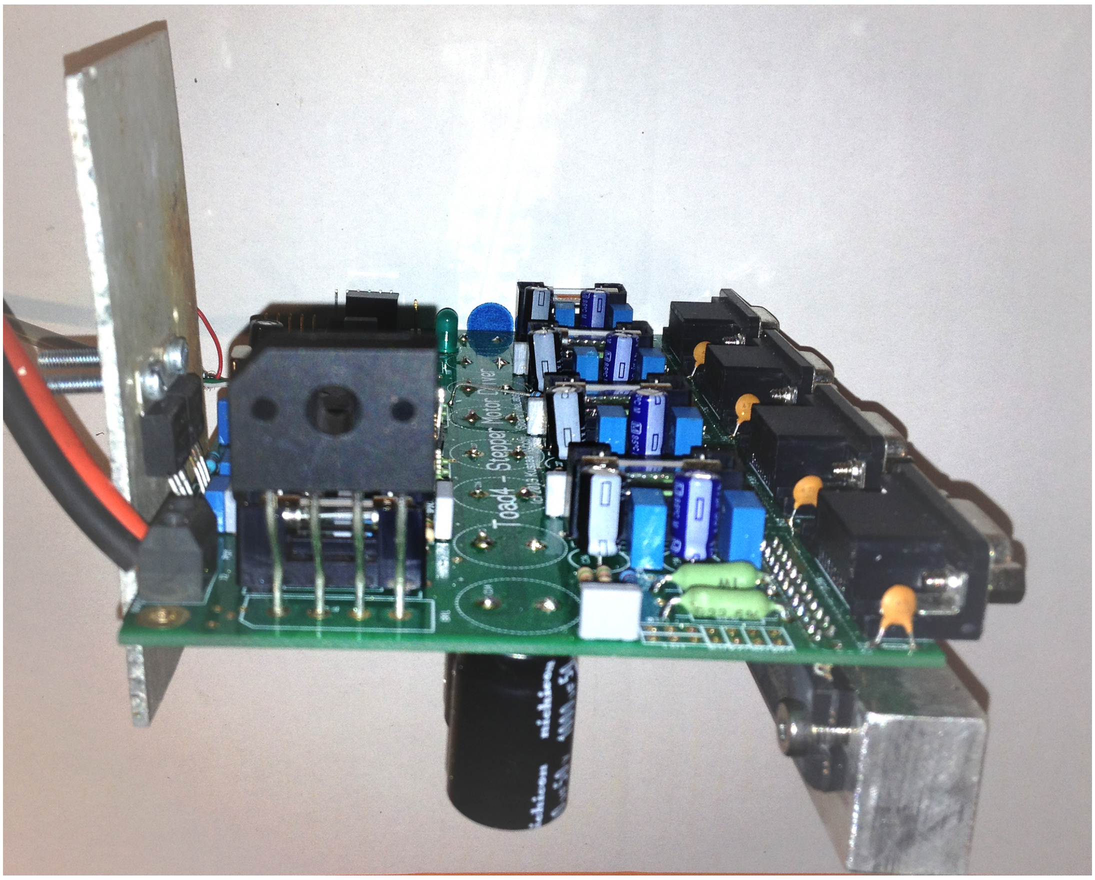


Figure 6.5: Left side view of the board

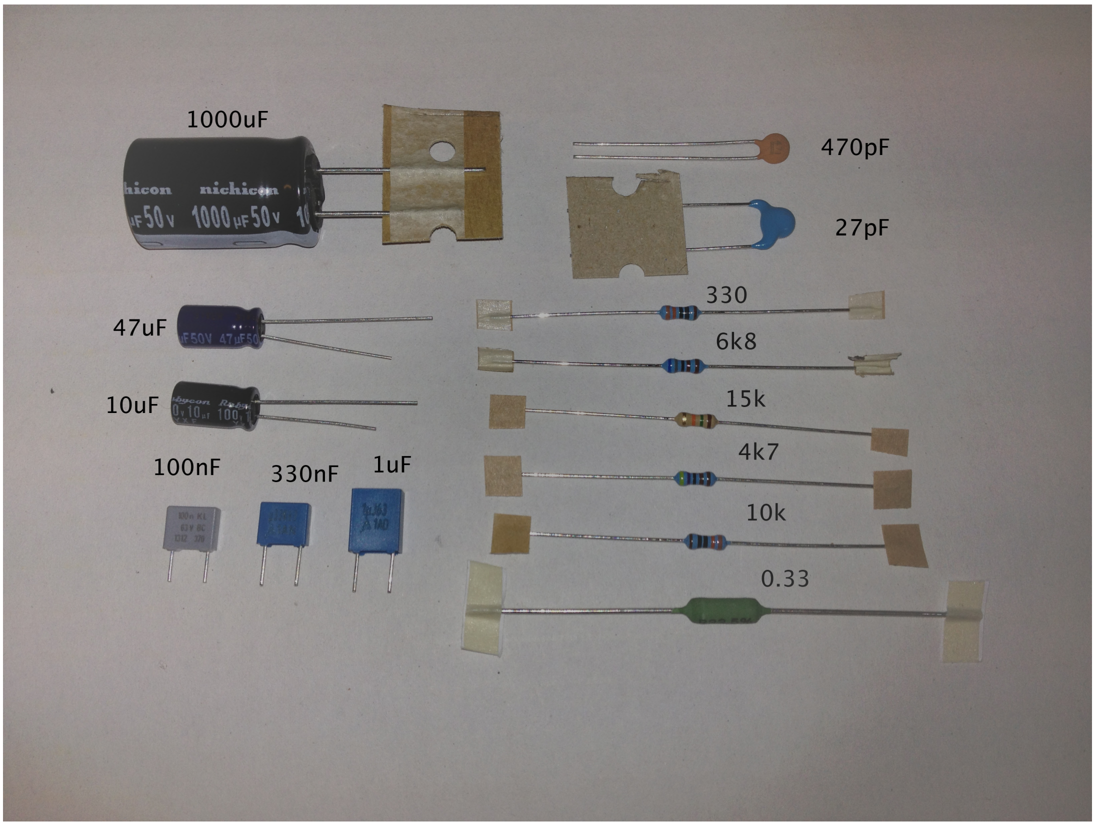


Figure 6.6: Discrete components

6.4 Component Installation

There a lot of tutorials and videos on the web about hand soldering electronic kits, so I won't be doing that here, but some notes may still come in handy.

Take care when installing components, and pay special attention to the orientation, as it is difficult to remove components from the printed circuit board without damaging the board connections.

All components, except resistors, are oriented and need to be installed accordingly.

If a component needs to be removed, it is typically necessary to sacrifice that component by using side cutters to cut the component out leg by leg before removing the component pins, one by one, with soldering iron and a wick or suction tool, taking care not to overheat the board.

If you have not done that before, practice on some old boards first!

When installing components, I find it handy to plug in several components of the same type and size them into the printed circuit board holes, then, with the help of a piece of plywood, turn the board over and solder the leads. This, of course, requires that the components be installed in the order of shortest to tallest.

I would *not* bend the wires to hold them in place, as this makes removal difficult.

When soldering integrated circuits or sockets for them, I solder two opposite corners first and then check that it lies flat against the board, as at that stage it is easy to correct by re-smelting the pin in the opposite corner.

6.5 Components on the 'wrong' side of the board

The following components are designed to be mounted to the 'wrong' side of the PCB, i.e. on the solder or non-component side. The component side of the board is the one with the white silk printing on it. Do *not* mount the following components on that side:

- the eight big 1000uF capacitors (C14-C21)
- the four stepper motor drivers IC3,IC6,IC7,IC8
- headers J8 and J9

The stepper motor drivers need to be mounted on the underside to allow for simple heat sinking of the chips. It is not possible to mount them on the component side, as this will screw up the connections.

The reason for mounting the electrolytic capacitors C14-C21 and headers J8 and J9 on the wrong side is to make room for the toroidal transformer if the Hammond enclosure is used. It is also possible to mount them on the component side of the board.

It is also possible to mount the headers J8 and J9 on the component side, but that will cause re-ordering of signals in the front panel connectors and the wiring needs to be adjusted accordingly.

Note that the example wiring illustrations are shown as if J8 and J9 are mounted on the solder side of the board.

6.6 Order of construction

Typically, the soldering of components proceeds from the shortest to the tallest, starting with the resistors. The order of installation is not critical, apart from the driver chips and the motor connectors, but here is the suggested installation order.

- All resistors, except the current measurement resistors
- Current measurement resistors
- All integrated circuits (except the driver chips) or their sockets
- All small capacitors
- Fuse holders

- Headers
- Small electrolytic capacitors, Xtal
- Driver chips
- Motor connectors
- PSU electrolytic capacitors
- Voltage regulators, Rectifying bridge, the rest

The stepper driver chips should all be first bolted to the heat sink and only then soldered to the printed circuit board, in order not to generate harmful stresses in them when the bolts are tightened.

See figure 6.7 for a picture of drive chips bolted to the heat sink.

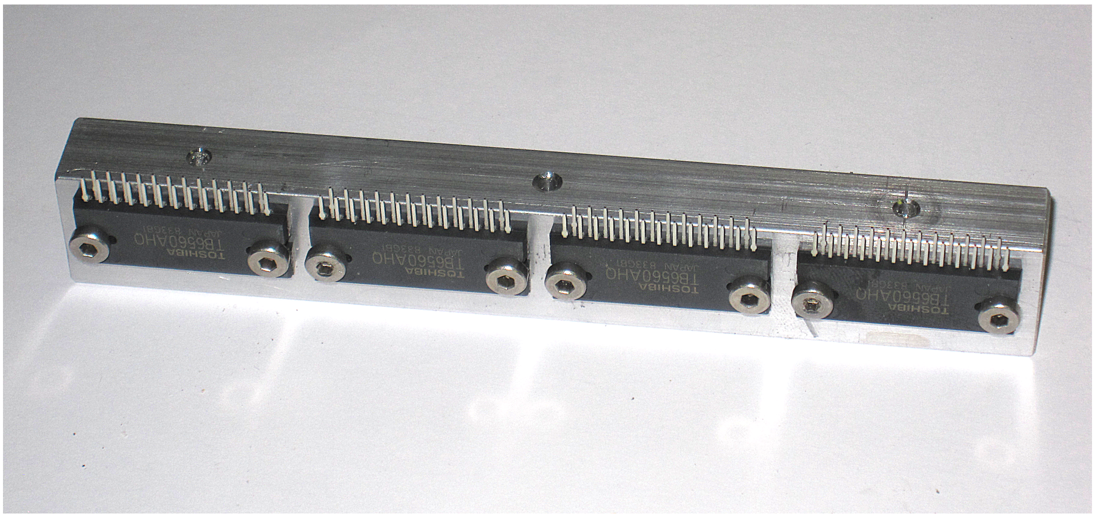


Figure 6.7: A picture of the driver chips mounted to the heat sink
(Note the heat sink in the picture only has three holes versus the four in the drawing)

Performing this might be a bit tricky, so you might first want to just insert the driver chips into the PCB board without soldering, then mount the heat sink to the chips and then proceed with soldering. This may require some ingenuity and dexterity.

The stepper drivers chips (IC3,IC6,IC7,IC8) should be soldered *before* the motor connectors (J-MX,J-MY,J-MZ,J-M1), because soldering the chips is difficult if the connectors are in place.

It is important to ensure that the heat sink will not short circuit the motor connector pins. There should be a gap of about 4 mm between the PCB and the heat sink. To ensure this, put a piece of plastic about 4 mm thick between the heat sink and the PCB and clamp the heat sink to the PCB when soldering the driver chips. At the same time, it is important that the heat sink 'top' surface is 26 mm or more above the PCB so that the electrolytical capacitors will not foul the enclosure when the board is mounted.

After the driver chips have been soldered in place, you need to remove the heat sink temporarily in order to be able to solder the motor connectors.

The rectifying bridge BR1 and voltage regulators IC1 and IC2 should be left with as long leads as possible to allow bending them so that they can be bolted to the enclosure for cooling if the Hammond enclosure is used.

6.7 Wiring

The motors are designed to be wired with standard straight male-male serial cables that are easy and cheap to purchase. The spindle and probe connection can be made with female-female cables. A single ready-made cable of 10 meters cut in the middle will provide the long wiring for two motors.

Some of the ready-made cables are on the thin side, which is good in that they are flexible, which is important in the long run as some of the motor cable are bound to be moving, but this may be a concern as far as current carrying capability is concerned.*

I personally distrust any documentation and my ability to follow them, therefore I check every wire connection with a multimeter equipped with a beeper all the way from an actual component pin to the actual external part, be it a motor coil or spindle controller input.

A wrong connection can cause, in the worst case, hours of damage to expensive or difficult to replace parts, so it is better to be safe than sorry.

If in doubt, ask for clarification or confirmation.

6.8 Fuse and Transform Selection

The transformer and fuse sizes depend on the motor powers, and you should really calculate them according to your installation.

Note that fuses are protection devices, and improper fusing can risk overheating or fire in case of a fault condition, thus you assume the risk of selecting the proper and safe fuse values.

It is difficult to give an exact formula for selecting the transformer and fuses, but here is a ball park method.

6.8.1 Transformer

The transformer nominal output voltage should be between 9 Volts and 24 Volts. Higher than 24 Volts may/will exceed, when rectified, the abs max 40 Volt voltage capability of the driver chips, while smaller than that will not allow regulation for the 12 Volt for the reference switches.

The driver chips can deliver up to 3 Amps of current per phase and 34 Volts. Note that this does *NOT* mean that the board can deliver 3 Amps x 34 Volts or 102 Watts per phase!

It is difficult to find bigger than NEMA 23 motors that can be driven with that current at that voltage. The voltage limits how much current can be forced into the coils given the motor inductance, and 'bigger' motors tend to have bigger inductance. In practice, this means that the motors that you can use with the TOAD4 board are at most in the 10 Watt/coil power region.

So for a four-motor setup, the maximum required transformer size is probably 80 VA.

6.8.2 Primary Fuse

The primary fuse size depends on the total power and line voltage, so at 230 VAC line voltage, the primary fuse size would be 80 Watts / 230 Volts   0.25 A or 350 mA, but the inrush current of the transformer may require that a bigger fuse is used. For 120 VAC line voltage double the fuse size.

6.8.3 Board Main Fuse F1

The main fuse F1 of the board depends on the total power and should be calculated based on the rectified transform output voltage, which is 1.4 x nominal transformer output or 34 Volts for a 24 Volt transform.

In theory, assuming a 24 Volt AC transformer and the aforementioned 60 Watt total power, the main fuse should be 80 W / (24 V x 1.4)   2.3 Amps, but in practice with three 2 Amp motors I've had to use 8 Amp slow fuses as I hate it when the fuse blows in the middle of a plasma cut!

6.8.4 Individual Motor Fuses F2-F5

The individual motor fuses should be calculated on the individual motor power and the rectified transformer output.

In theory, a 10 Watt / coil motor draws on average, given a 24 V transformer, 10 Watt /(1.4 x 24 Volt)   300 mA / coil so a 600 mA fuse should be enough, but in practice I would not use smaller than 1 Amp fuses.

Chapter 7

Testing

Once the PCB has been built it should be tested.

7.1 Preparing

Connect the board to either the 24 VAC transformer or a laboratory power supply, but do not turn on the power yet.

Do not connect motors or USB or any other peripherals to the board.

If you are using a transform remember to use a fuse on the primary side as a problem on the secondary side may not be enough to blow the mains fuse in your house and the transformer may overheat and cause fire hazard.

Insert the main fuse to its holder, but do not insert the individual motor fuses.

The main fuse size depends on the how big motors you expect to drive.

For initial testing a laboratory power supply is preferable as it allows easy monitoring of the current consumption, if that is not available it is recommended to use a current meter in series with the transform, on the safe secondary side.

It is also preferable to test the board on a table top without mounting it into the final enclosure as this allows easy access for trouble shooting and observation.

When the board is used bare without the enclosure the linear voltage regulators should be mounted to small piece of aluminum (5 x 5 cm2) for cooling and the motor current and/or duration of test runs should be kept short and the temperature of the motor heat shank should be monitored. It should not get too hot to touch.

Note that a stepper motor always draws the same amount of current regardless of the speed, so even if they are not running, the motors and the driver chips will heat up if the drivers are turned on.

If you are using the transformer, ensure that the primary side that is will be connected to the live main voltages is properly double insulated and has a fuse on the primary side.

Mains voltage can be lethal and proper insulation is necessary to prevent accidental touching of live parts when the enclosure is open and to ensure that the live wires will not touch the isolated safe voltage side of the circuitry.

7.2 Initial Testing

Once more, before turning on the power, take a final, careful look at the board and connections to ensure that there are no short circuits, stray solder ball or bridges, wire cutting etc.

Turn on the power and observe the current.

The large bank of electrolytic capacitor will draw a large but very short initial rush current which may or may not be observable on the amp meter.

Power on the system.

After the initial rush the amp meter should show about 50 mA.

Now use volt meter to measure that the +5 V and +12 V voltages are within +- 0.2 Volt of the nominal voltage. A convenient place to do that is probe between the ground rail connecting all the big electrolytic capacitors (I always form one of the capacitor leads into a loop for that purpose when a soldering in the components) and the outer most pins of header H1.

You can now let board idle for a minute a so and use your finger to probe that none of the integrated circuits gets warm. About the only thing that should exhibit any warming is the linear regulators. Do take care not to burn your finger in case something empis hot and empdon't touch any dangerous voltages!

Next turn off the power, note that if you are using a transform it will take several minutes for the capacitor bank to discharge.

7.3 Programming the Firmware

To program the firmware into micro controller connect the PICkit 2 or PICkit 3 to the board at header J5 and connect the PICkit to your computers USB port. Take care for the correct orientation, the pin one is marked with a notch on the silk and with a small triangle on the PICkit.

Turn on the power for the board and program the firmware by executing the following command from the command line:

pk2cmd -ftoad4.hex -pPIC18f4550 /m /e /j /r

or using some other software provided with the PICkit.

If that goes without problems, power off the board and disconnect the PICkit.

7.4 Testing the Board

Turn on the power and the D1 LED on the board should turn on and start blinking at about once per second rate.

Next connect the board to a USB port on you computer and after a few seconds the LED should start blinking at double speed to indicate successful USB connection.

7.5 Driver Installation

Next depending on your operating system the driver installation happens.

On Mac OS X and Linux this is transparent and you will not see anything, except perhaps the mouse will freeze for a few seconds.

On Windows you need to point the location of the driver 'eazycnc.inf' file to the operating system.

You maybe better off googling for detailed instructions, but here it is, very briefly, for Windows 7.

Go to the Start -menu and from there select Printers and Devices.

From the window that appears select (somewhere at the bottom) the unknown device that represents the TOAD4 at this stage, right click it, select Properties.

From the dialog that appears select Hardware-tab, then in that tab select from the Device Functions list the driver and click Properties.

From the dialog that appears, select the Driver-tab and from that tab select Update Driver...

From the dialog that appears select 'Browse my computer for driver software', then click the Browse... button and browse to the directory/folder where you have the 'eazycnc.inf' file and click next.

This should install the driver for you.

7.6 Testing the Connection

Now start the EazyCNC program by double clicking its icon.

In EazyCNC press the MACH-button.

You should now see the firmware version in the small one line display below the G-code panel.

If you get this far we know now that micro contoller on the board is working, it has a functional firmware, it is connected successfully via USB to your computer and the EazyCNC program can talk to it.

Now go the Axis-screen in the EazyCNC and ensure that the current selection for all axis is set to 'Low', if not, change it and click the SAVE-button.

Quit the EazyCNC.

7.7 Testing the Motor Drives

Next power off the board and wait for the capacitors to discharge.

Insert the motor fuse F2 for X-axis driver, a 1 A slow blow fuse (marked 1 AT) should be adequate for most motors.

Connect one a motor to the X-axis drive, connector JM-X.

I recommend having an unattached 'test' motor for testing the board, a motor that is not attached to the milling machine or what ever you are going to use the board with.

NOTE! Never connect / disconnect a motor from the board while the board is powered on, that will damage the driver chip! This applies to having poor or intermittent connections as well, so ensure that all the motor connections are secure so that they will not work loose if and when the cables are moved or there is inevitable vibrations.

NOTE! While the motor drives are current limited it is still possible to damage the driver chips by short circuiting the motor leads.

NOTE! Before testing any motors ensure that the current selection jumpers are correctly set for the motor type and the proper current selection resistors are in place.

NOTE! When testing the motors pay attention to the temperate of the motor driver chips, if they get hotter than 80° C you should improve the cooling.

Changing a motor driver chip is possible but painful, even if the driver chip itself is not expensive.

Next power on the board, observe that the LED behaves as described previously, fire up EazyCNC.

Now click the MACH-button, and check that firmware version is displayed confirming a successful and live connection to the board.

At this point you probably will hear a hissing sound from the stepper motor, which is caused by the chopping voltage making the rotor to ever so slightly vibrate.

Now click and hold down the the X- or X+ jog button and verify that the motor moves or tries to move.

If the motor tries to move, but the speed is too fast for the motor to cope, go the Machine Set Up screen and adjust the crawl speed, you may also have to go to the X-axis setup screen and adjust the steps/mm (inch) values. For details see the EazyCNC manual.

If the motor moves, power off the board and repeat above for each motor and axis.

Remember never to connect/disconnect motors while the board is powered up.

Once you know the motors drives are functional you can turn the current setting in EazyCNC to the 'high' or 'auto', but pay attention to the driver chip temperatures.

NOTE Do not allow the driver chips to come hotter than 80° C.

7.8 Testing the Spindle And Coolant Control

Power off the board.

Connect the spindle control outputs to your spindle motor control system (relay or or Variable Frequency Drive) or the torch control input of your plasma cutter.

Make sure that the spindle can cause no harm when it starts to rotate or that the torch will not cause damage when it is started.

It maybe preferable and safer at the point to wire a simple test circuit to test the control outputs, see FIGURE XX, especially when using a plasma torch as without compressed air and proper cutting set up the torch will not fire and thus you cannot observe if the board is functioning properly.

Similarly connect the coolant pump.

See section XX for suggestions on how to connect the control outputs.

When you have double checked your setup, turn on the power for the board and fire up EazyCNC and click the MACH-button to connect to the board.

You can now use the COOLANT button to turn the coolant pump on or off .

You use the Spindle ON button to turn the spindle on and off. If you are using a VFD you can use the + and - buttons to change the speed of the spindle.

Clicking the rotation direction buttons should change the direction of spindle rotation.

NOTE that it may be dangerous to change the direction of rotation while the spindle is running.

7.9 Testing Completed, Now What

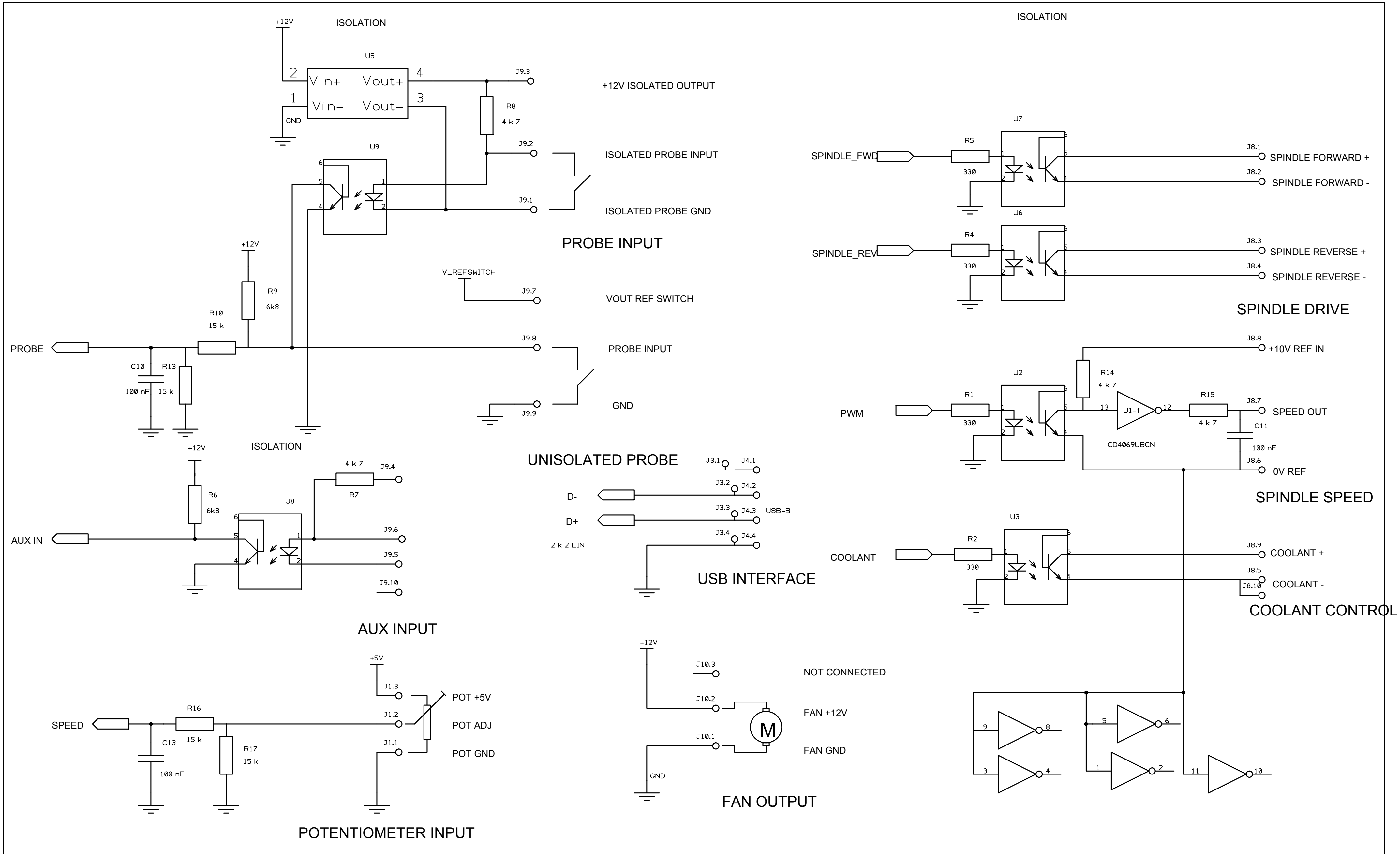
At this point, the board has been tested and you are ready to install it into the enclosure and wire it for the actual machine.

Once that is done, you'll need to configure the EazyCNC software, verify that your setup is safe and works, and you'll be ready to go!

To set up and configure EazyCNC, see the EazyCNC manual.

Appendix A

Schematics



2-May-2013

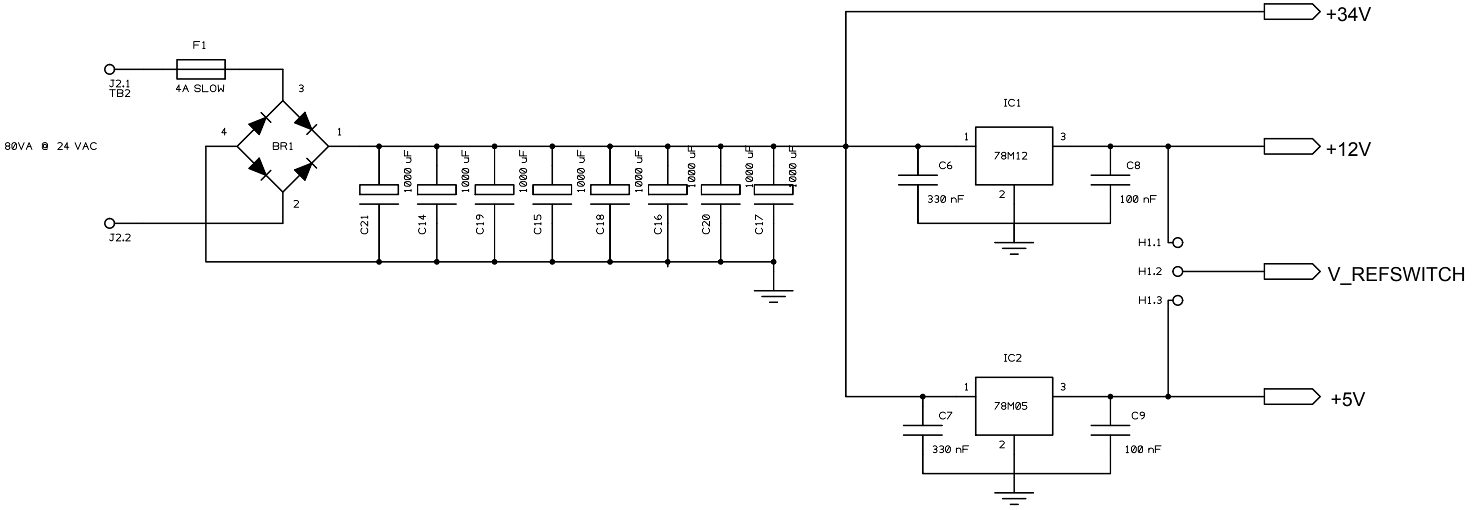
TOAD4

Four Axis Stepper Motor Controller

SpareTimeLabs

Kustaa Nyholm
Laklammenpolku 40
02570 Siuntio
Finland

RC8



2-May-2013

TOAD4

Four Axis Stepper Motor Controller

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Kustaa Nyholm
Laklammenpolku 40
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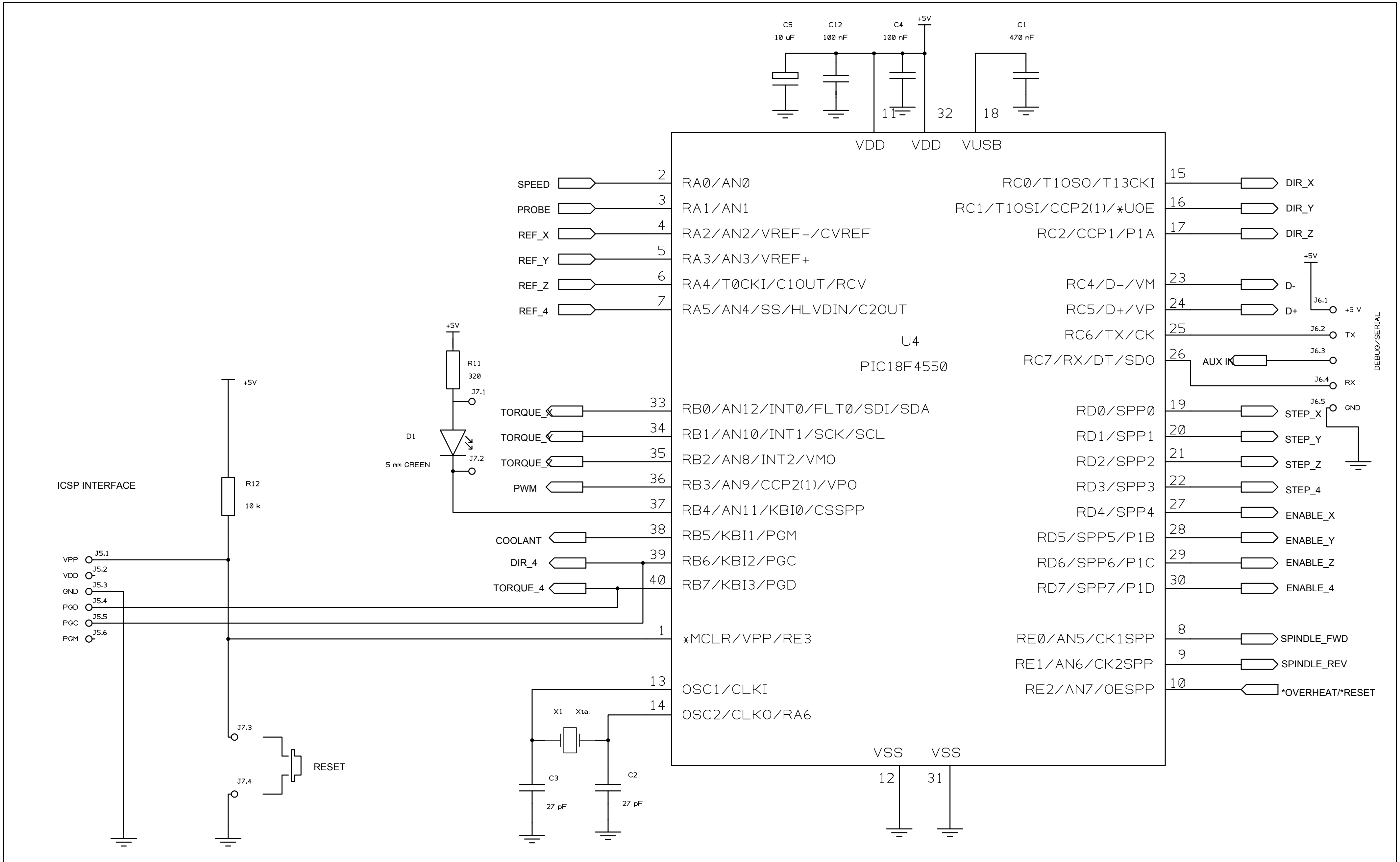
RC8



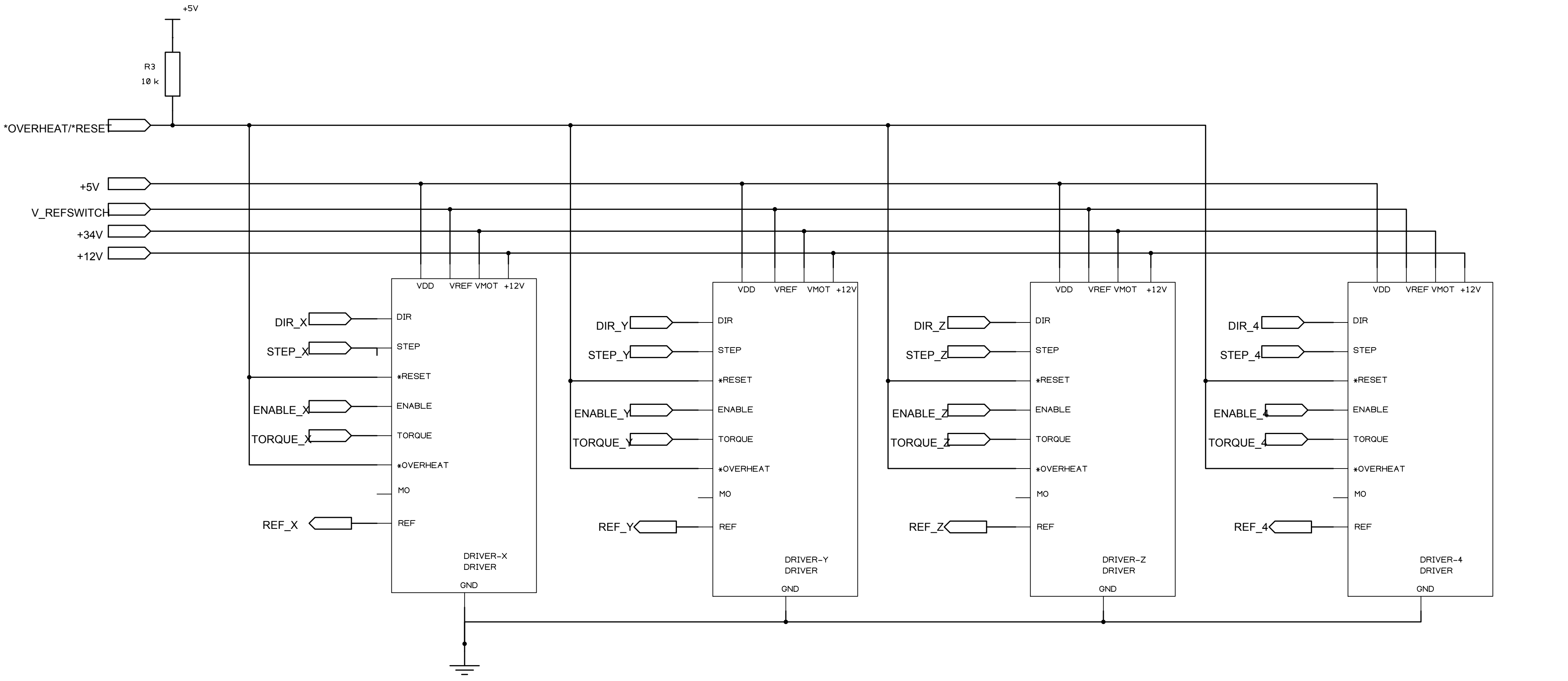
2-May-2013

TOAD4

Four Axis Stepper Motor Controller

SpareTimeLabs
Kustaa Nyholm
Laklammenpolku 40
02570 Siuntio
Finland

RC8



2-May-2013

TOAD4

Four Axis Stepper Motor Controller

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Kustaa Nyholm
Laklammenpolku 40
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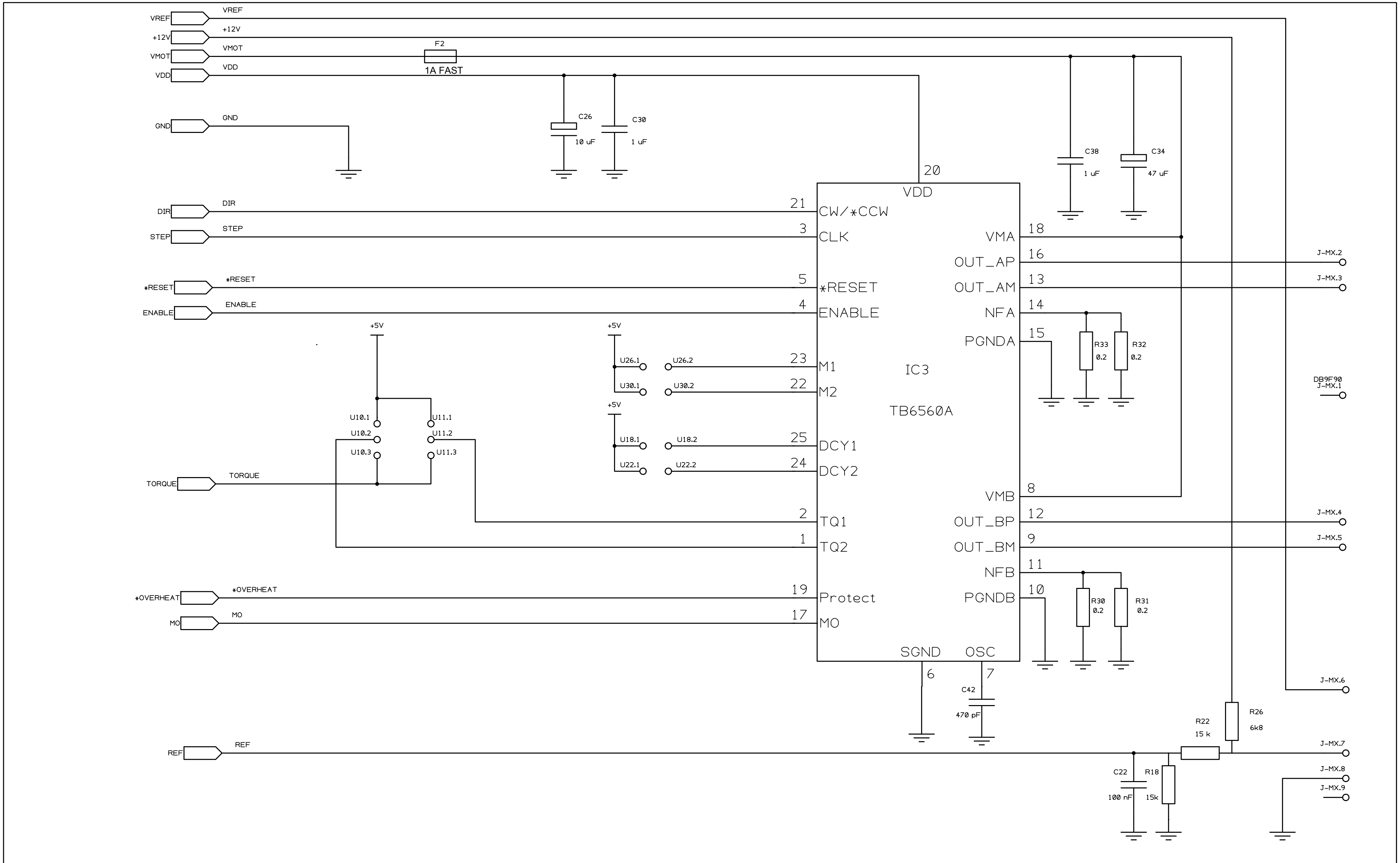
Finland

RC8



TOAD4

Four Axis Stepper Motor Controller

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Kustaa Nyholm
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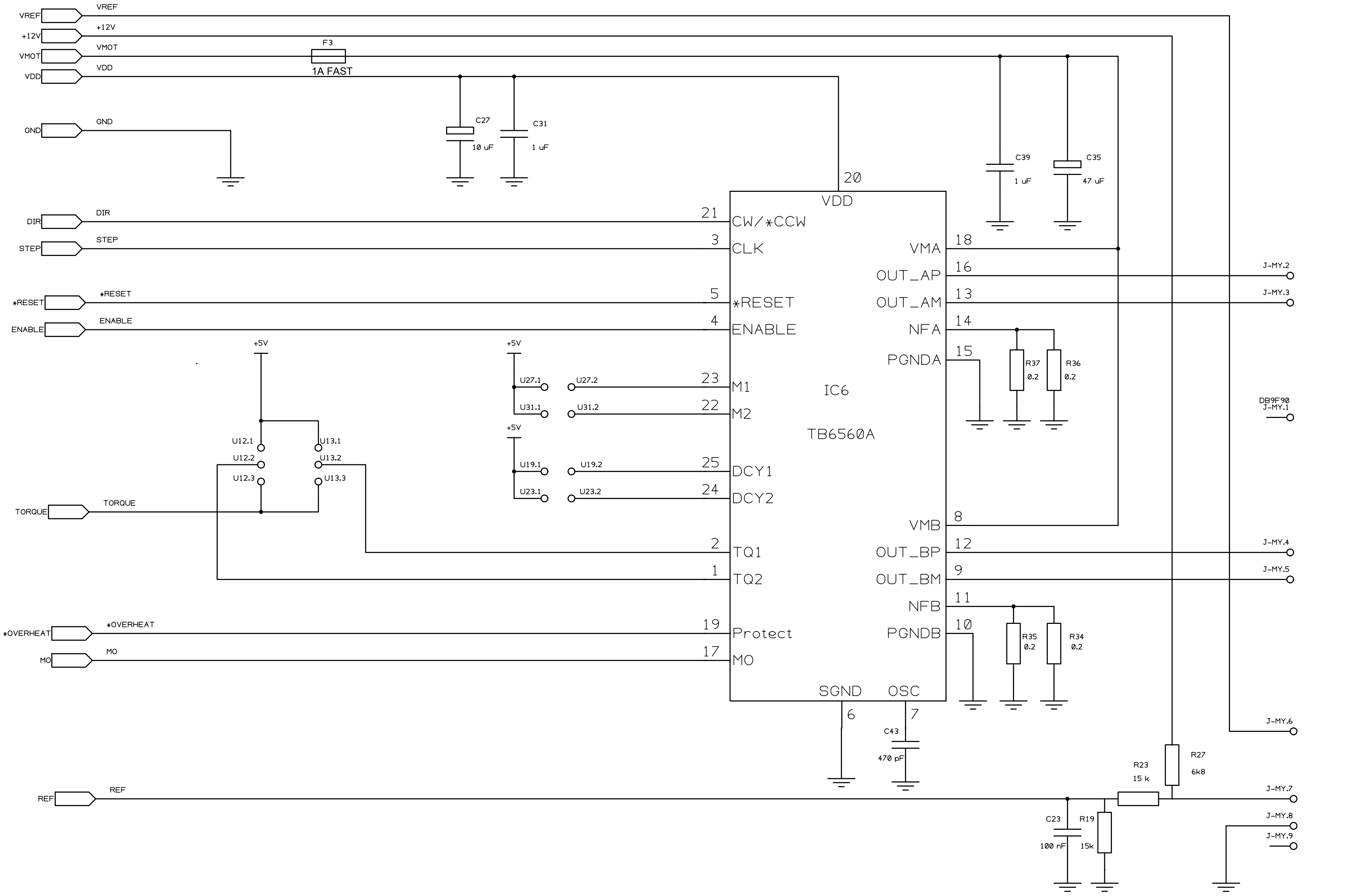
02570 Siuntio
Finland

REV 1



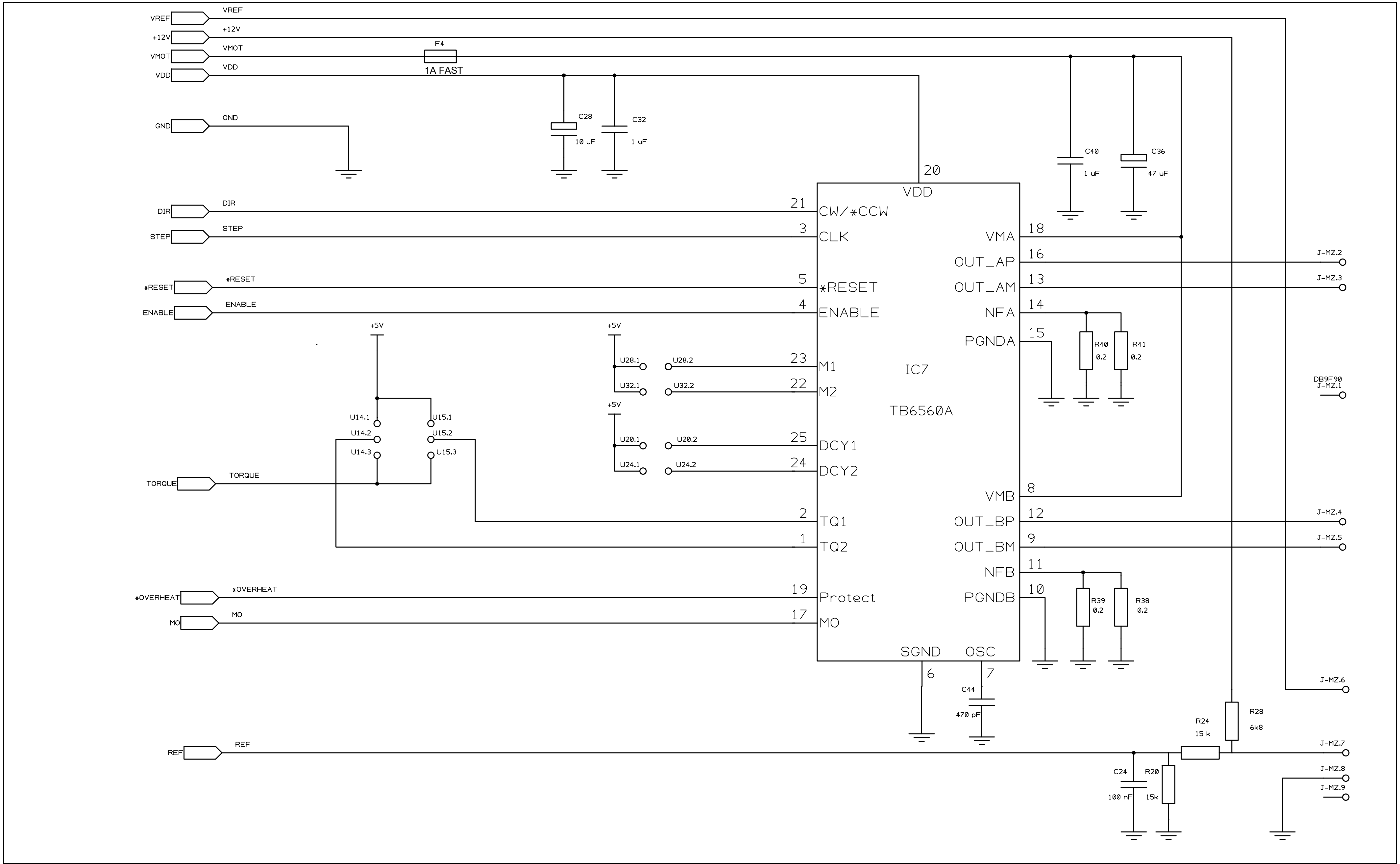
TOAD4

Four Axis Stepper Motor Controller

SpareTimeLabs

Kustaa Nyholm
Laklammenpolku 40
02570 Siuntio
Finland

REV 1



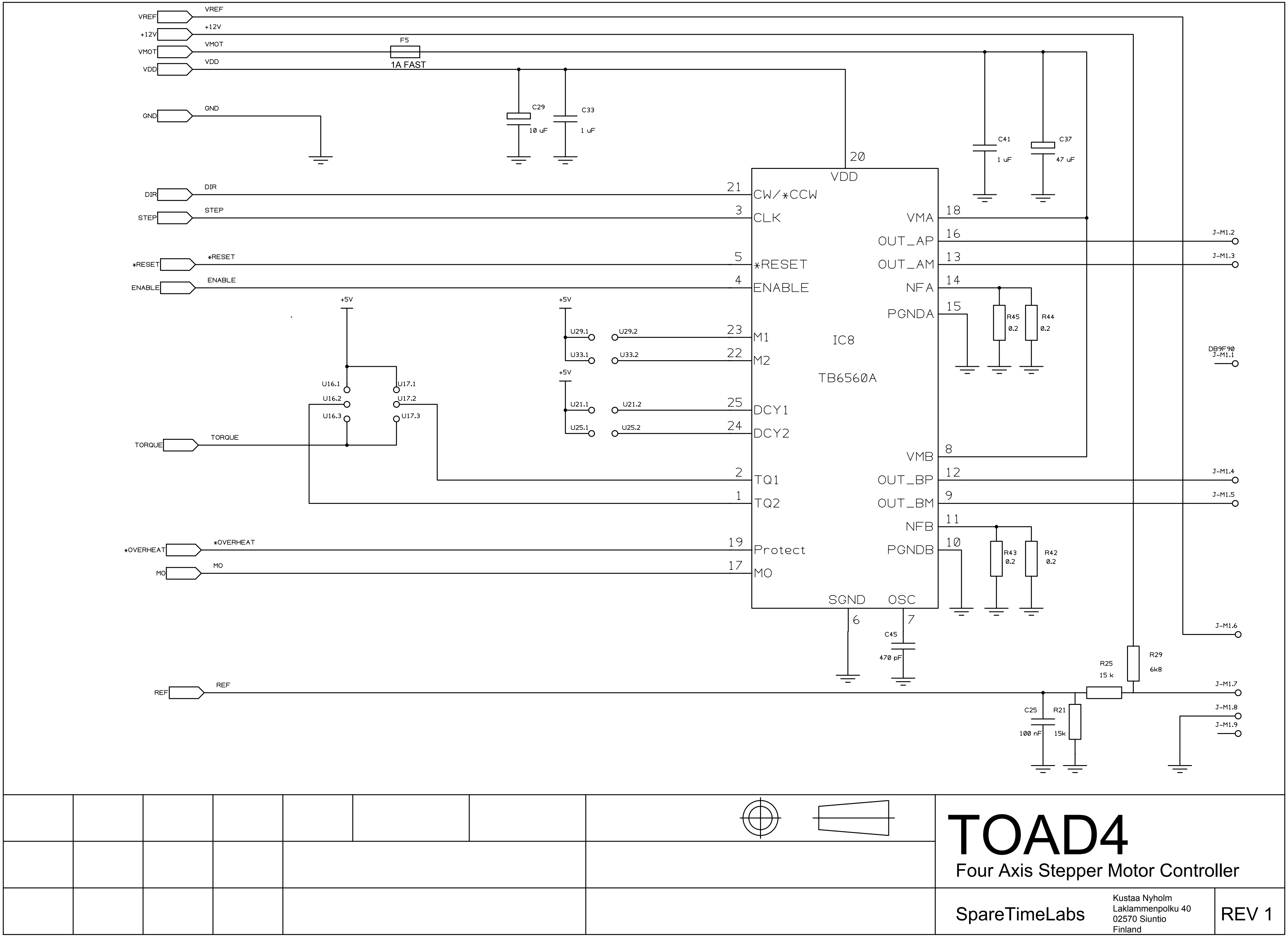
TOAD4

Four Axis Stepper Motor Controller

SpareTimeLabs

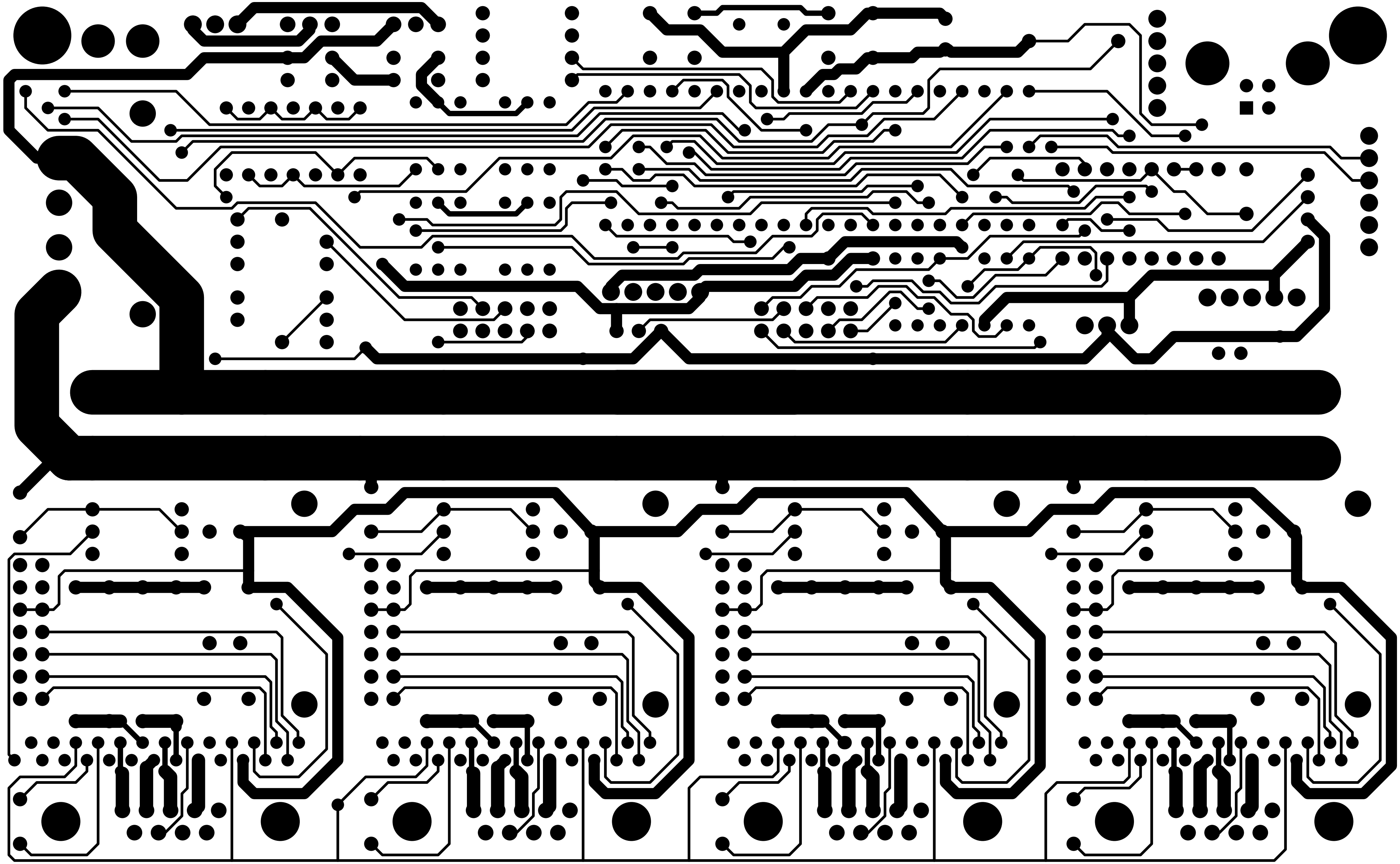
Kustaa Nyholm
Laklammenpolku 40
02570 Siuntio
Finland

REV 1

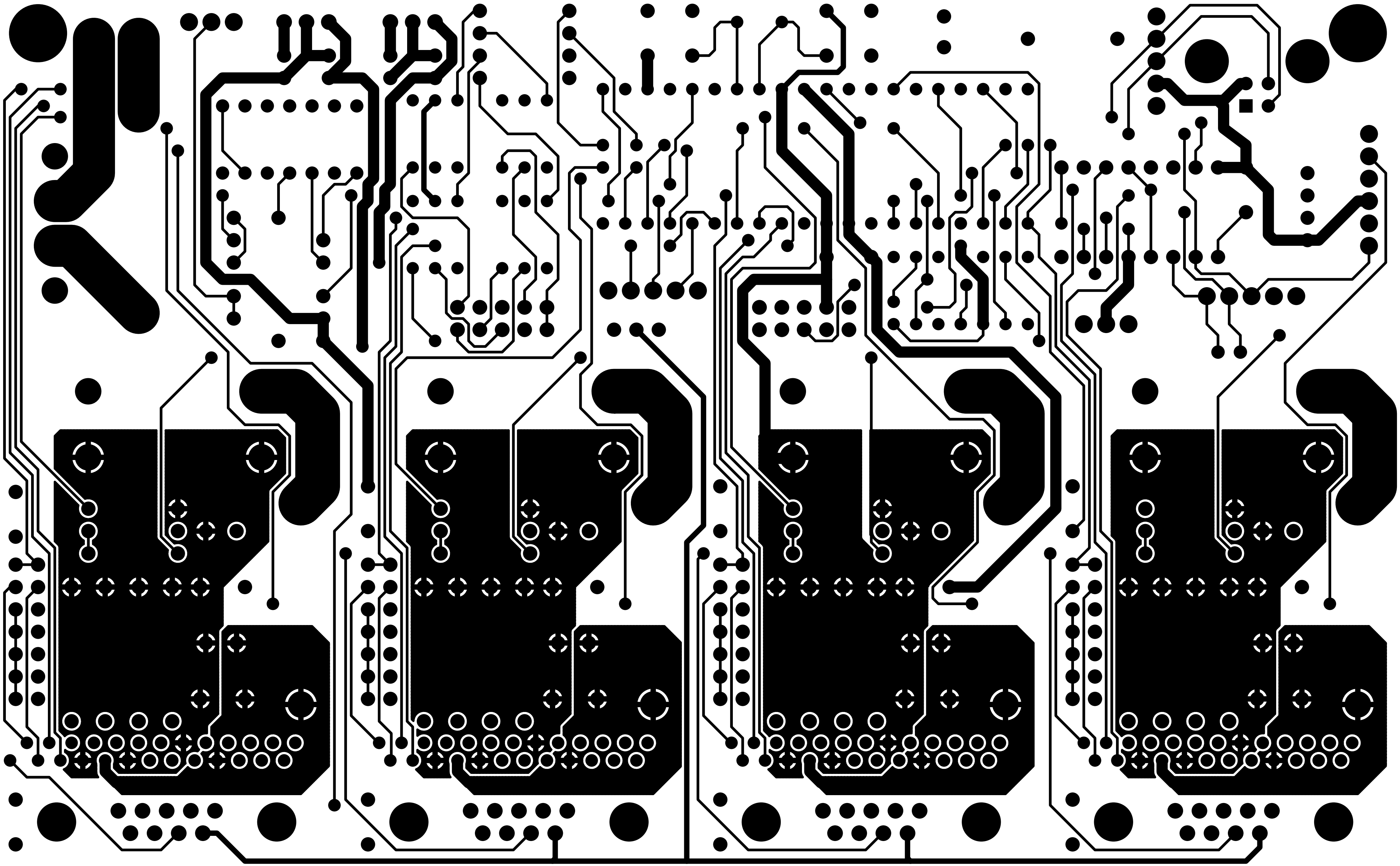

VREF
+12V
VMOT
VDD
GND
F5
1A FAST
C29 10 uF
C33 1 uF
C41 1 uF
C37 47 uF
DIR
STEP
*RESET
ENABLE
+5V
TORQUE
*OVERHEAT
MO
REF
IC8
TB6560A
VDD
CW/*CCW
CLK
*RESET
ENABLE
M1
M2
DCY1
DCY2
TQ1
TQ2
Protect
MO
VMA
OUT_AP
OUT_AM
NFA
PGNDA
VMB
OUT_BP
OUT_BM
NFB
PGNDB
SGND
OSC
R45 0.2
R44 0.2
R43 0.2
R42 0.2
C45 470 pF
R25 15 k
R29 6k8
C25 100 nF
R21 15k
DB9F90
J-M1.1
J-M1.2
J-M1.3
J-M1.4
J-M1.5
J-M1.6
J-M1.7
J-M1.8
J-M1.9
TOAD4
Four Axis Stepper Motor Controller
SpareTimeLabs
Kustaa Nyholm
Laklammenpolku 40
02570 Siuntio
Finland
REV 1

Appendix B

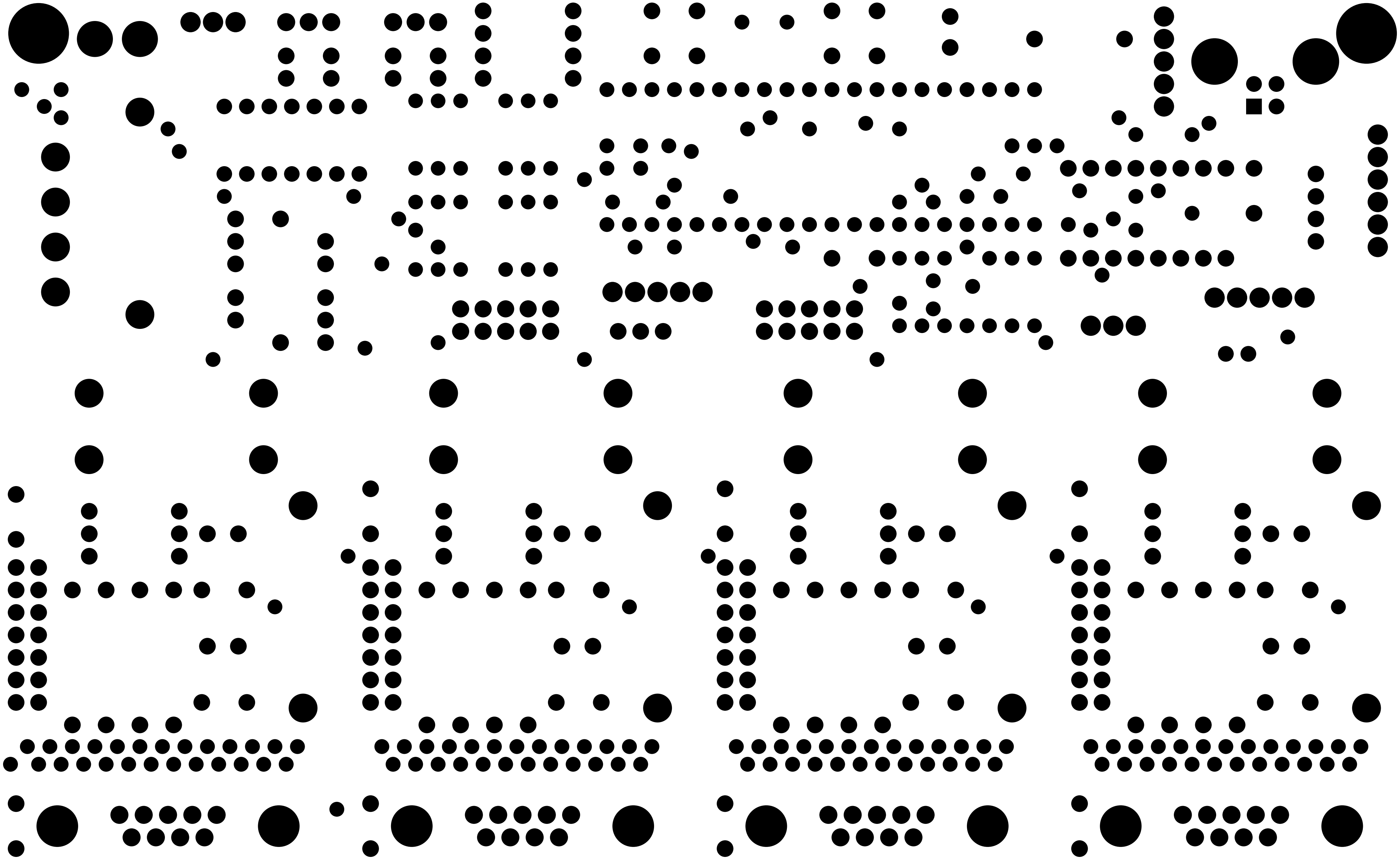
PCB Layout



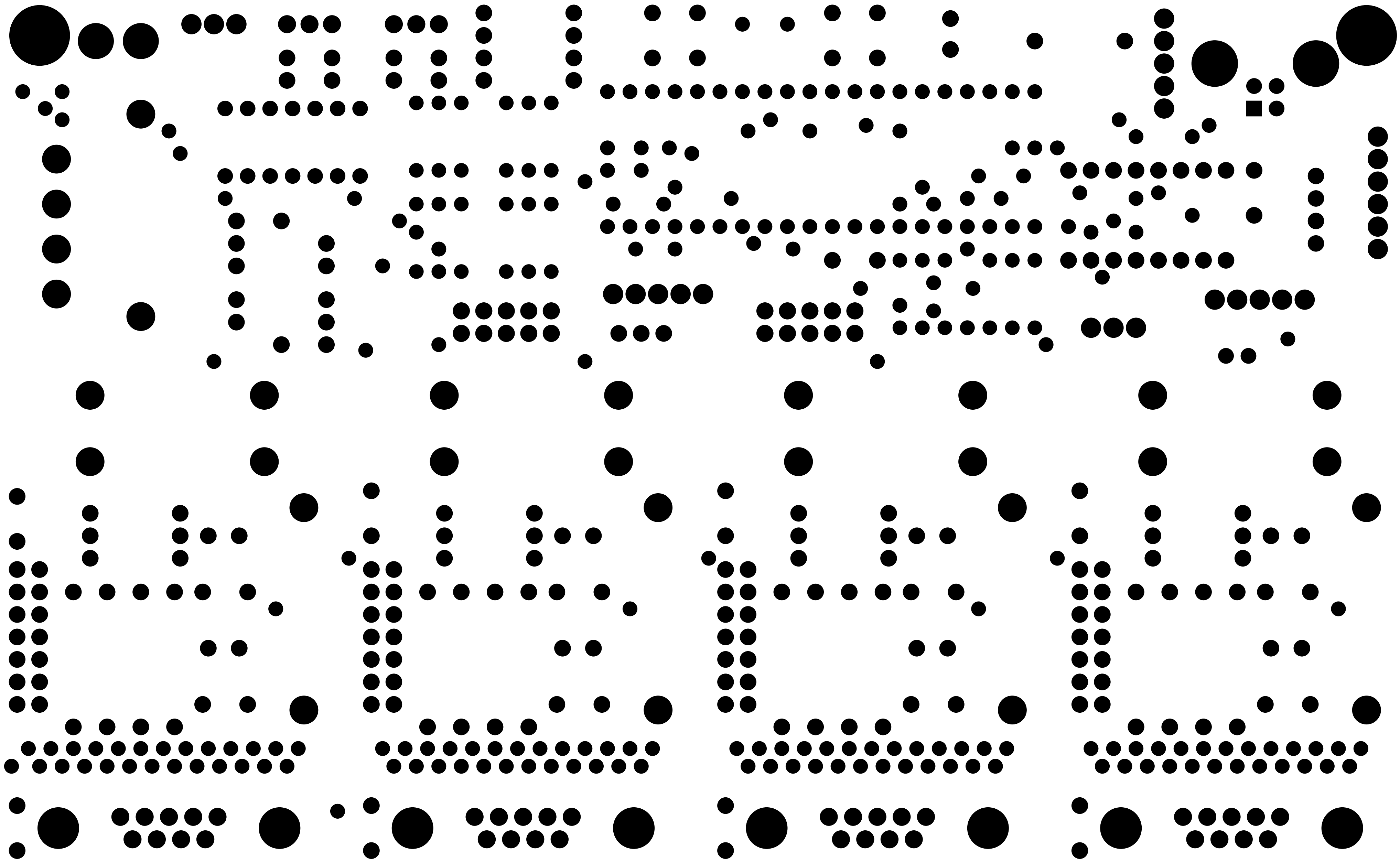
TOP



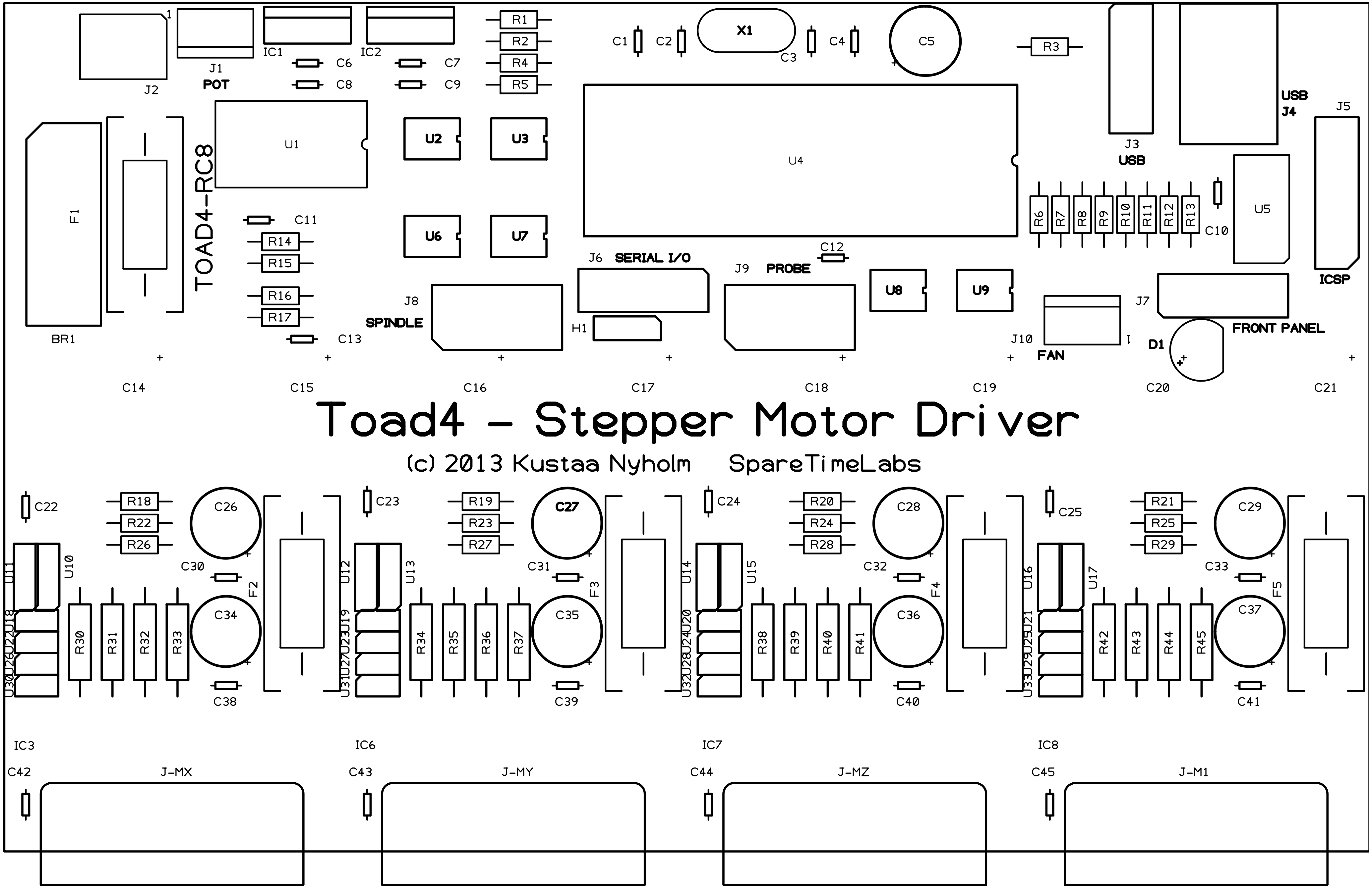
BOTTOM



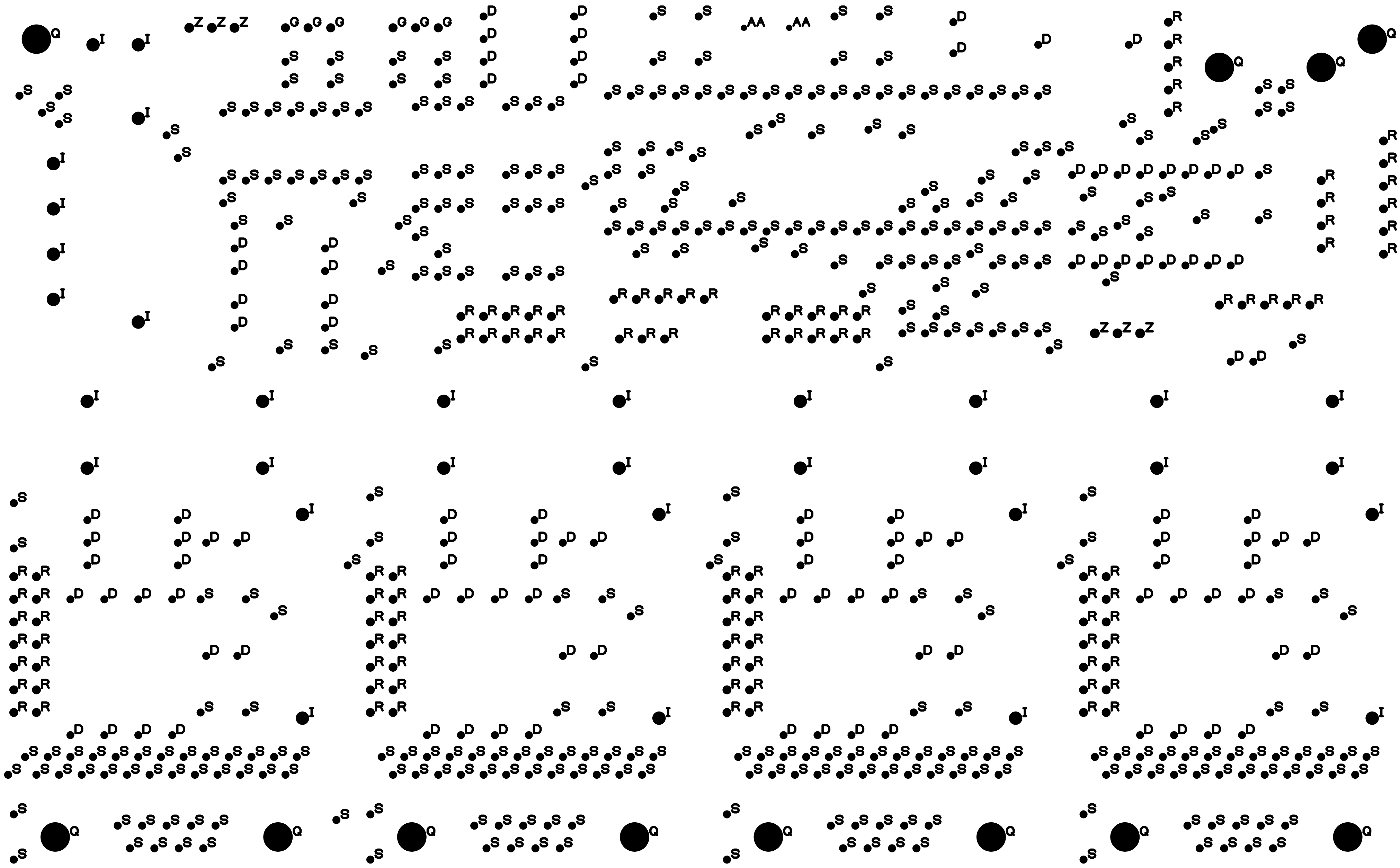
SOLDER MASK TOP



SOLDER MASK BOTTOM



SILK SCREEN TOP



Appendix C

Parts list

1.8.2013/SpareTimeLabs/Kustaa Nyholm

TOAD4-RC8.1 BILL OF MATERIALS v1.1

Component	Type/Value	Note
BR1	BRIDGE 6A	
C1	330 nF	
C4	100 nF	
C9	100 nF	
C10	100 nF	
C11	100 nF	
C12	100 nF	
C13	100 nF	
C22	100 nF	
C23	100 nF	
C24	100 nF	
C25	100 nF	
C5	10 uF	
C26	10 uF	
C27	10 uF	
C28	10 uF	
C29	10 uF	
C8	100 nF	
C2	27 pF	
C3	27 pF	
C6	330 nF	
C7	330 nF	
C14	1000 uF	
C15	1000 uF	
C16	1000 uF	
C17	1000 uF	
C18	1000 uF	
C19	1000 uF	
C20	1000 uF	
C21	1000 uF	
C30	1 uF	
C31	1 uF	
C32	1 uF	
C33	1 uF	
C38	1 uF	
C39	1 uF	
C40	1 uF	
C41	1 uF	
C34	47 uF	
C35	47 uF	
C36	47 uF	
C37	47 uF	
C42	470 pF	
C43	470 pF	
C44	470 pF	
C45	470 pF	
D1	5 mm GREEN	
F1	4A SLOW	
F2	3A FAST	
F3	3A FAST	
F4	3A FAST	
F5	3A FAST	

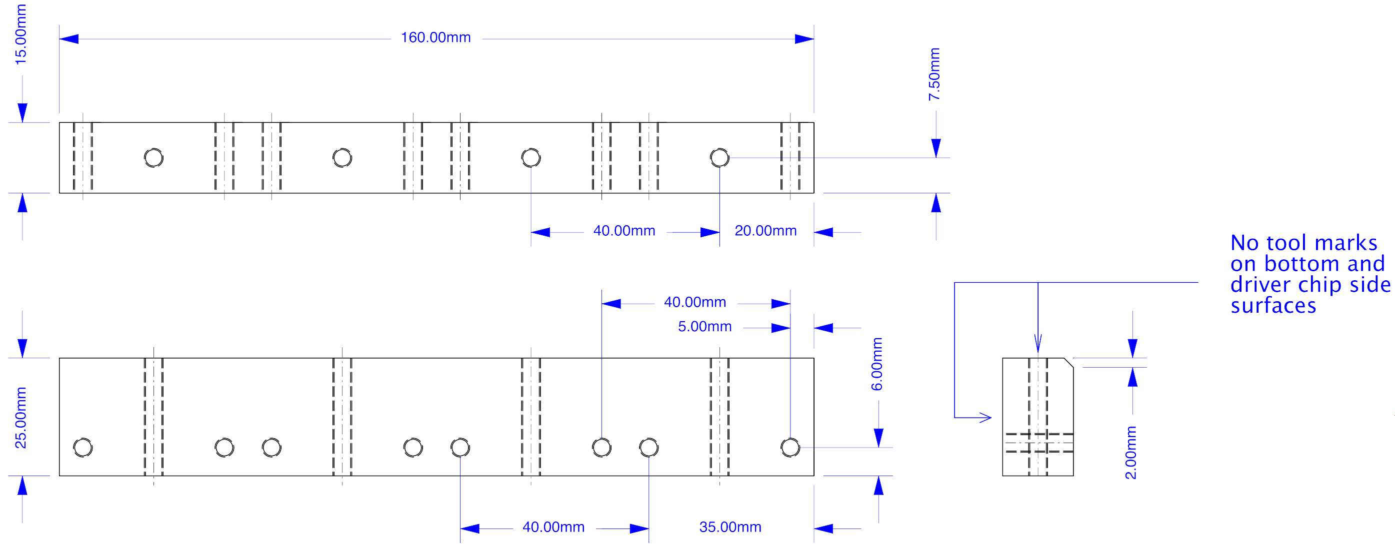
H1	HEADER1x3	
U10	HEADER1x3	MX
U11	HEADER1x3	MX
U12	HEADER1x3	MY
U13	HEADER1x3	MY
U14	HEADER1x3	MZ
U15	HEADER1x3	MZ
U16	HEADER1x3	M4
U17	HEADER1x3	M4
IC1	78M12	
IC2	78M05	
IC3	TB6560A	
IC6	TB6560A	
IC7	TB6560A	
IC8	TB6560A	
J-M1	DB9F90	
J-MX	DB9F90	
J-MY	DB9F90	
J-MZ	DB9F90	
J1	MOLEX3	
J10	MOLEX3	
J2	TB2	
J3	HEADER1x5	
J6	HEADER1x5	
J7	HEADER1x5	
J4	USB-B	
J5	HEADER1x6	
J8	HEADER2x5	
J9	HEADER2x5	
R3	6k8 Ohm	
R12	6k8 Ohm	
R6	6k8 Ohm	
R9	6k8 Ohm	
R26	6k8 Ohm	
R27	6k8 Ohm	
R28	6k8 Ohm	
R29	6k8 Ohm	
R10	15 kOhm	
R13	15 kOhm	
R16	15 kOhm	
R17	15 kOhm	
R22	15 kOhm	
R23	15 kOhm	
R24	15 kOhm	
R25	15 kOhm	
R11	330 Ohm	
R1	330 Ohm	
R2	330 Ohm	
R4	330 Ohm	
R5	330 Ohm	
R7	4.7 kOhm	
R8	4.7 kOhm	
R14	4.7 kOhm	
R15	4.7 kOhm	
R18	15 kOhm	
R19	15 kOhm	

R20	15 kOhm	
R21	15 kOhm	
R30	0.33 Ohm	
R31	0.33 Ohm	
R32	0.33 Ohm	
R33	0.33 Ohm	
R34	0.33 Ohm	
R35	0.33 Ohm	
R36	0.33 Ohm	
R37	0.33 Ohm	
R38	0.33 Ohm	
R39	0.33 Ohm	
R40	0.33 Ohm	
R41	0.33 Ohm	
R42	0.33 Ohm	
R43	0.33 Ohm	
R44	0.33 Ohm	
R45	0.33 Ohm	
U1	CD4069UBCN	
U4	PIC18F4550	
U5	SF_IK	
U2	4N35	
U3	4N35	
U6	4N35	
U7	4N35	
U8	4N35	
U9	4N35	
U18	HEADER1x2	MX
U19	HEADER1x2	MY
U20	HEADER1x2	MZ
U21	HEADER1x2	M4
U22	HEADER1x2	MX
U23	HEADER1x2	MY
U24	HEADER1x2	MZ
U25	HEADER1x2	M4
U26	HEADER1x2	MX
U27	HEADER1x2	MY
U28	HEADER1x2	MZ
U29	HEADER1x2	M4
U30	HEADER1x2	MX
U31	HEADER1x2	MY
U32	HEADER1x2	MZ
U33	HEADER1x2	M4
X1	XTAL 4MHz	

(note) MX,MY,MZ,M installed as four 2x7 blocks

Appendix D

Heat sink



Material 25 mm x 15 mm Al

All holes M3.5 tapped through, de-burred

Tolerances	Scale	Product	Relates To	Name
	1 : 1			TOAD4 HEATSINK
Drw. / Dsgn. / Chk. / Aprv.	Mass kg	SpareTimeLabs		Old - / New - / v1.0

Mark	Change	Date	Changer	Apprv.
-	-	-	-	-

Appendix E

TOAD4RC8 PCB Errata

TOAD4 RC8 board has three errors that need re-working.

E.1 Header J9 pin 10 is not connected

Header J9 pin 10 should have been connected to adjacent J9 pin 5 so that if/when header J9 is mounted on the solder side of the board the AUXIN- signal is connected to the front panel DE9 pin 5.

This can be corrected by bridging pins 10 and 5 of J9 on the PCB with solder.

If J9 is mounted on the component side this fix is unnecessary.

Because this AUX INPUT feature is not currently implemented in software and is thus not used this fix can be left undone.

E.2 Resistor R6 is connected to +12 V

R6 which is the pull up resistor for the optically isolated AUX INPUT should have been connected to +5 V but is wired to +12 V.

This can be corrected by leaving the +12 V end of R6 (6.8 kOhm) not connected and wire it to the nearest +5 V or by using a 15 kOhm resistor for R6 which limits the input current to the PIC input pin to a safe level.

Also because this AUX INPUT feature is not currently implemented in software and is thus not used the R6 can be just left out.

E.3 +12 V is short circuited to GND near R28

Because of PCB layout and design rule check error the PCB trace leading to R28 is short circuited to the ground copper pour on the solder side of the board.

This needs to be corrected by disconnecting the trace from the copper pour.

The easiest way to do this is to cut the trace leading to R28 on the solder side and wire R28 as illustrated below:

Figure E.1:

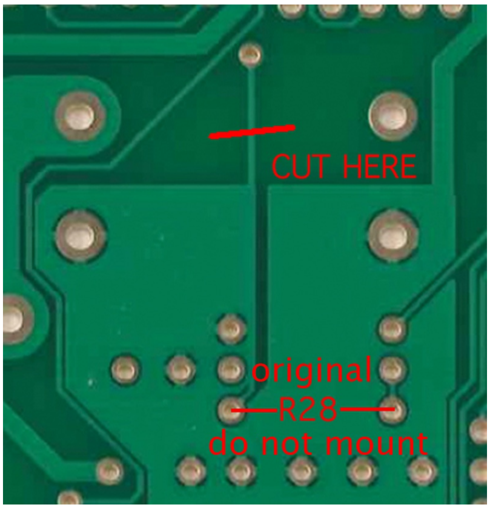


Figure E.2:

E.4 Header labels U10 and U11 are crossed

The header labeled U10 is actually U11 and vice versa.

These headers/jumpers are used to configure the drive current for X-channel motor.

The PCB layout for X-motor is correct so it is only necessary to keep this in mind when inserting/soldering the jumpers and rely on physical layout of the jumpers which is correct and identical in all motor drivers.