Feature Highlights

- Powerful switch module for any type of DC loads
- Replaces Relays and SSRs
- Two channels
- High-power MOSFETs with very low Rds(On) of just 1.4mΩ
- Opto-isolated power and control circuits
- Up to **55A** per board without fan
- Control voltage: 3.3-16V, logic-level compatible
- Load voltage: 12-24V
- Protection diodes for driving inductive loads
- Channels can be combined together to deliver the maximum power to heavy load
- Ability to control channels both from power outputs where low-side switching is used and from signal outputs of any 3D-printer control board
- “Channel-ON” and “Power-ON” LEDs
- Tiny size: just 50x68 mm
- 2 additional power connectors
- Open-Source and Open-Hardware
- Developed and made in Russia

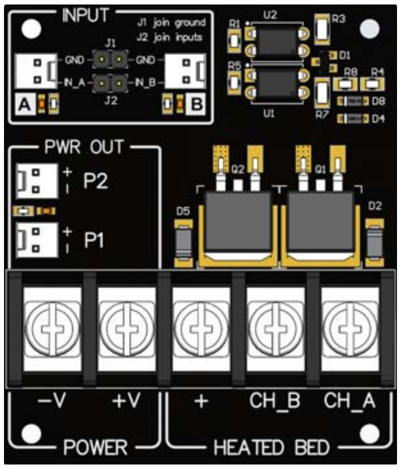


Fig. 1. Board top view

Differences from the previous version 1.0:

- Fully isolated from each other inputs. Now you can control both channels from power outputs of all popular 3D printers mainboards.
- New more intuitive connectors and jumpers layout.
- Power terminal block replaced from 9.5mm pitch to 11mm.

1 Overview

Cheap3D MOSFET Switch Board is a tiny yet very powerful module designed to drive high-current **DC loads** such as 3D printer **heated beds**, extruder **heaters**, **LED lighting** stripes, **motors**, etc. There are two power channels, which can be controlled independently or can be combined to drive one much higher load.

The board is intended to replace weak MOSFETs found on cheaper RepRap boards such as RAMPS, RAMBO, RUMBA, MKS Gen, MKS Base, Anet etc. It is also an ideal solution for driving high-power loads instead of regular Relays, or Solid-State Relays (SSRs) which build up a lot of heat and frequently require massive heatsinks.

Both channels are opto-isolated so no current flows between input (“Logic”) side and output (“Power”) side, which allows usage of different PSUs for control board and the load.

MOSFETs used have extremely low Rds(ON) resistance of just **1.4mΩ** (reduced to overall **0.7mΩ** with channels combined) so the voltage drop on board is lowest possible (much lower than SSRs), and for most loads this board requires **no fan or heatsink** at all.

Powerside has built-in **reverse protection diodes** which protect MOSFETs from voltage spikes when used with inductive loads.

The control side is fully compatible with virtually any MCU board (Arduino included) that can supply 3.3V (up to **16V**) logic level signals. Low-frequency PWM operation is also supported.

The board utilizes two convenient standard 2.54mm pitch output power connectors that can be used to drive fans, backlight, etc up to 500mA per each connector.

Technical data

Table 1. Electrical characteristics

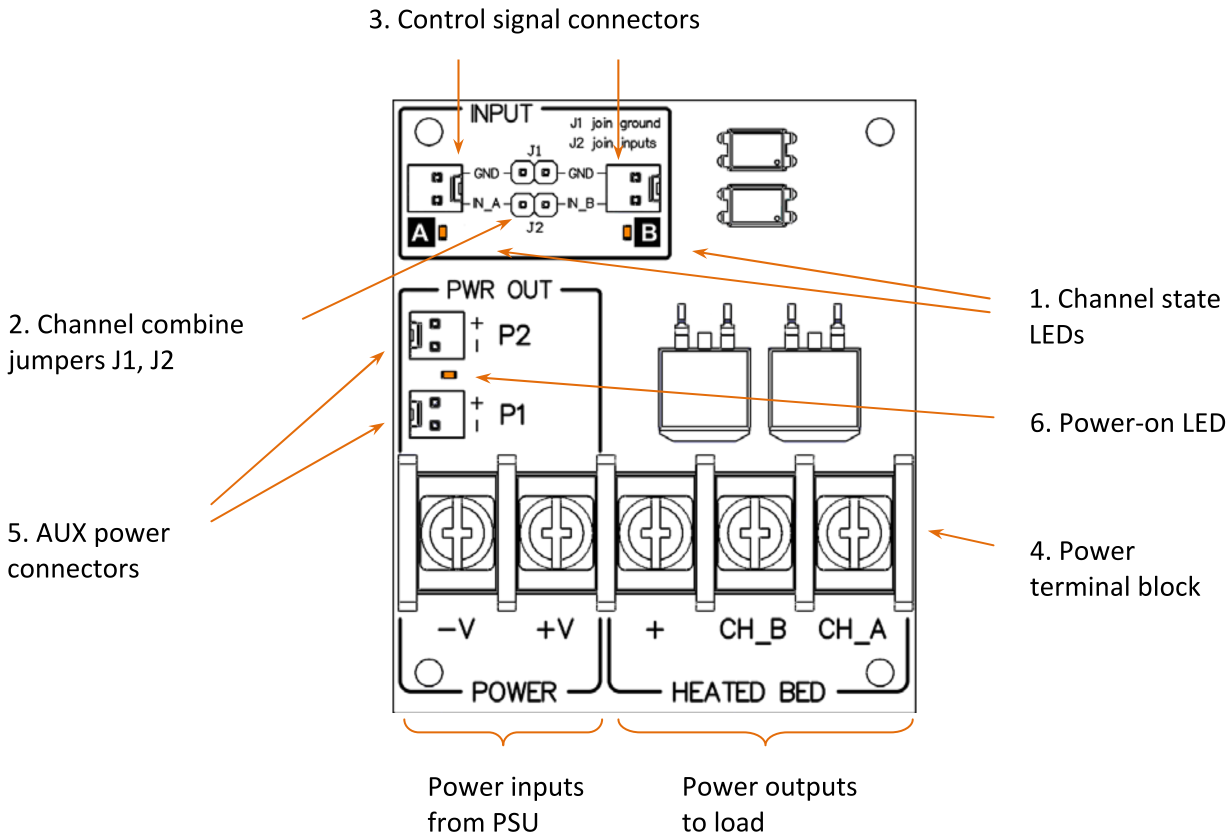
Parameter	**Rating**		**Units**
V+ to V- (Load voltage)	**12…24**		**V**
Maximum load current (two channels active or combined)	**55** (27.5 per channel)	without fan	**A**
	80 (40 per channel)	with fan	**A**
Maximum load current /single channel only (other channel not active)	**35**	without fan	**A**
	50	with fan	**A**
Maximum pulsed current (single channel)	**100 A for 6 sec**		
IN_A/IN_B inputs to logic GND	**3.3…16***		**V**
IN_A/IN_B inputs sink current	**2.8…20**	single channel	**mA**
	5.6…40	combined mode	**mA**
Ambient temperature	**-40 to 85****		**°C**
Maximum MOSFET case temperature	**130 °C**		**°C**
Maximum PWM Frequency***	**4000**		**Hz**

*For control voltages higher 16 V increase values of resistors: R1 for IN_A, R5 for IN_B. The current through each resistor should not exceed 20 mA. For 24 V replace resistors to 2.4 kOhm 0805.

**All parameters are tested at the 25 °C ambient temperature. For higher ambient temperatures maximum current, maximum PWM frequency and other parameters may degrade.

***PWM frequencies higher 4000 Hz can be supported, but not tested.

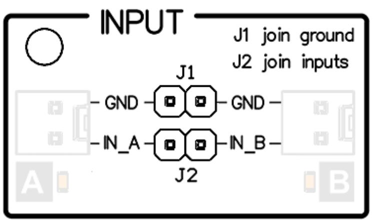
2 Board layout



1. Channel state LEDs

These LEDs light up when the corresponding channel is turned ON.

2. Channel combine jumpers J1, J2



With combination of these jumpers J1, J2 you could perform all possible wiring diagrams:

Common ground: connection to Arduino and other boards signal outputs.

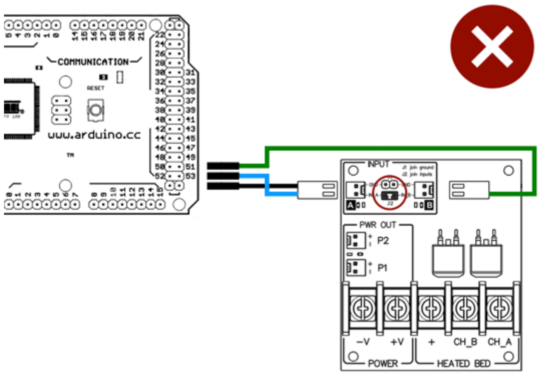
Common VCC: to connect to power outputs of RAMPS, MKS Gen, MKS Base, Anet, RUMBO, RAMBO and all other boards, which have low-side switching outputs.

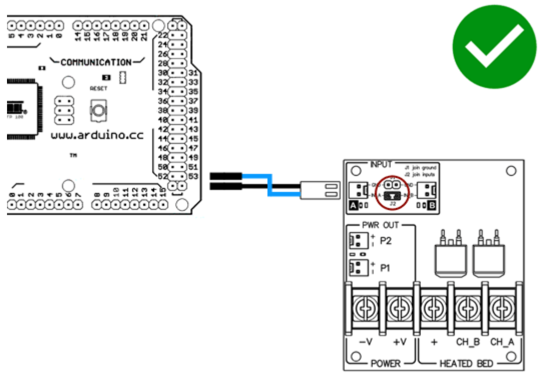
Channel combining: suitable if you want to control both channels by one Arduino pin or want to combine output channels.

Galvanic isolated inputs (completely isolated from each other channels inputs): useful to control channels by individual boards with different ground level or when one channel is controlled by signal output and the other by power. This diagram can be used to control channels by power outputs of your mainboard as well as “Common VCC”.

Jumper J1 combines GND inputs. Jumper J2 combines control inputs

When jumper J2 in place, **be sure that only one wire comes** from IN_A/IN_B inputs (in fact, there should be one "signal" wire and one "Ground" wire, but not all three!) to your mainboard. As this jumper just shorts IN_A and IN_B together, when your Arduino sets "High" on CH_A and "Low" on CH_B, these Arduino ports would be shorted, draw too much current from one to another, and this may permanently damage your MCU board!





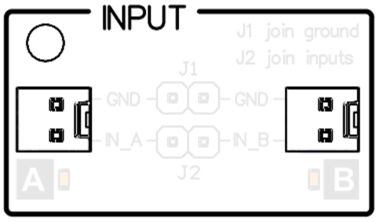
J1 J2	J1 in place, J2 open	*Common GND* Normal connection to signal outputs of your control board (signal inputs of Arduino, RAMPS or Raspberry Pi). Channels working independently, GND inputs are combined. Three wires needed: common GND and two channels inputs: IN_A, IN_B.
J1 J2	J1 in place, J2 in place	*Common GND & common control inputs* Fully combined channels inputs.* Two loads are controlled by one pair of wires, connected to any control connector: GND / IN_A or GND / IN_B. **
J1 J2	J1 open, J2 in place	*Common VCC, separated GND* Channels working independently. Positive inputs are combined, while the negative are driven independently. Used when you want to drive two loads from two N-channel power outputs. Three wires needed: common VCC / IN_A and GND_A, GND_B.
J1 J2	J1 open, J2 open	*Completely isolated from each other channels inputs* Galvanic isolated inputs. Channels working independently. This diagram could be used to independently drive two different loads, for example, heated bed and extruder heater, from two power outputs of your mainboard (RAMPS, Anet, MKS, etc). Each channel controlled by two wires: GND / IN_A and GND / IN_B***.

*When channels are combined, the current drawn from your mainboard to input pins doubles.

****Warning: when the jumper J2 is in place, it just shorts IN_A and IN_B. Don't connect IN_A and IN_B to your mainboard simultaneously, only one wire: IN_A or IN_B. When both IN_A and IN_B are connected to the mainboard and the J2 is in place, your mainboard may burn!**

*****This wiring diagram is also suitable for driving one channel from signal output and second from power output, or to drive channels from two mainboards with different ground level.**

3. Control signal connectors



This is the input you use to connect this MOSFET board to your mainboard (e.g. RAMPS, Arduino, etc).

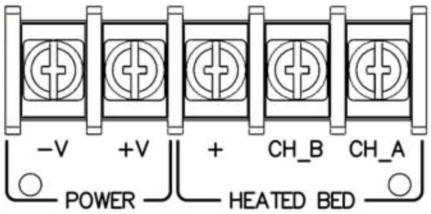
Input pins accept any signal from 3.3V to **16V** and draws 2.8mA (at 3.3V) to 20 mA (at 16V).

The board can accept higher input signal levels, but resistor values (R1 for CH_A and R5 for CH_B) should be increased. Pick up the resistance value so that the current through each resistor will not exceed 20 mA when high input signal level applied.

The inputs are designed to be wired directly to any 3.3V-16V motherboard pins (e.g. any Arduino, Raspberry Pi, ESP8266 port, or virtually any prototype board in the world).

Connect GND pin to your motherboard Ground(GND), and CH_A/CH_B to motherboard pins you wish to use as control pins.

4. Power terminal block



Used to connect your power supply and the loads. This is a standard 11mm-pitch screw terminal.

<u>POWER part:</u>

Connect your PSU to **V+** and **V-** terminals: V+ to PSU "+" (e.g. +12V), and V- to PSU "-" or GND.

<u>HEATED BED part:</u>

This is where your load (e.g. heated bed) comes. Connect the load wires to "+" and CH_A/CH_B.

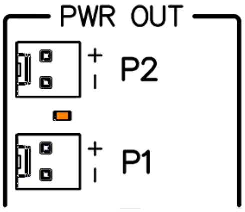
If you use two separate loads (e.g. heated bed and a heavy LED backlight), connect one side of both loads to "+" terminal on MOSFET board, and the other side of every load to CH_A and CH_B, respectively.

To combine both channels for delivering bigger currents to a single heavy load, connect one side of the load to "+" terminal and the other side of the load to any of CH_A or CH_B channels. **Put a thick wire strip between CH_A and CH_B.** (see "Board Connection" section below)

Note: The MOSFET board is "Low-Side" (N-channel) switch by design, so one end of your loads would be permanently wired to "V+" (e.g. 12V), and the other end of your load will be switched to "Ground".

The maximum allowable current through the whole terminal block is **55A** (**80A** with fan).

5. AUX power connectors



For your convenience, we included two standard 0.1" (2.54mm)-pitch auxiliary power connectors that are wired internally to Power **V+** and **V-**. You can use these to power small loads such as fans, lighting, or even a fan to cool down the board itself. The voltage there is the same as your "Power" PSU. Allowed current per connector: **500 mA**. These connectors have nothing to do with "logic/input" side and are permanent-ON, not controllable by your MCU.

Note: As one of the benefits of this board is opto-isolation between "logic" and "power" parts, it is generally a good idea not to use these AUX connectors to power up any devices wired to your MCU. If for some reason you still want to do this, beware that opto-isolation would no longer be provided, and pretty high currents or spikes can flow between power load and your motherboard.

6. Power-on LED

The PWR LED lights up when "Power" side PSU is connected to **V+**/**V-**.

3 PWM operation

The input signal can be Pulse-Width modulated (PWM). It is a common way to reduce power delivered to a load, and frequently used in various motherboards. The board natively support PWM signals that most of 3D Printer boards can provide.

Arduino + RAMPS hardware (and all clones/derivatives) with popular Marlin firmware support PWMing extruder heaters/heated beds. Table below shows the available PWM modes:

PWM Mode	Frequency	Mode supported
Super Slow	0.8 Hz	Full
Slow	8 Hz	Full
Fast	500 Hz to 1000 Hz	Partial, load current limiting required

Usual Arduino frequencies of 500Hz and 1000Hz are supported, but due to excess heat generated, the current should be limited. Restrictions for single channel operation:

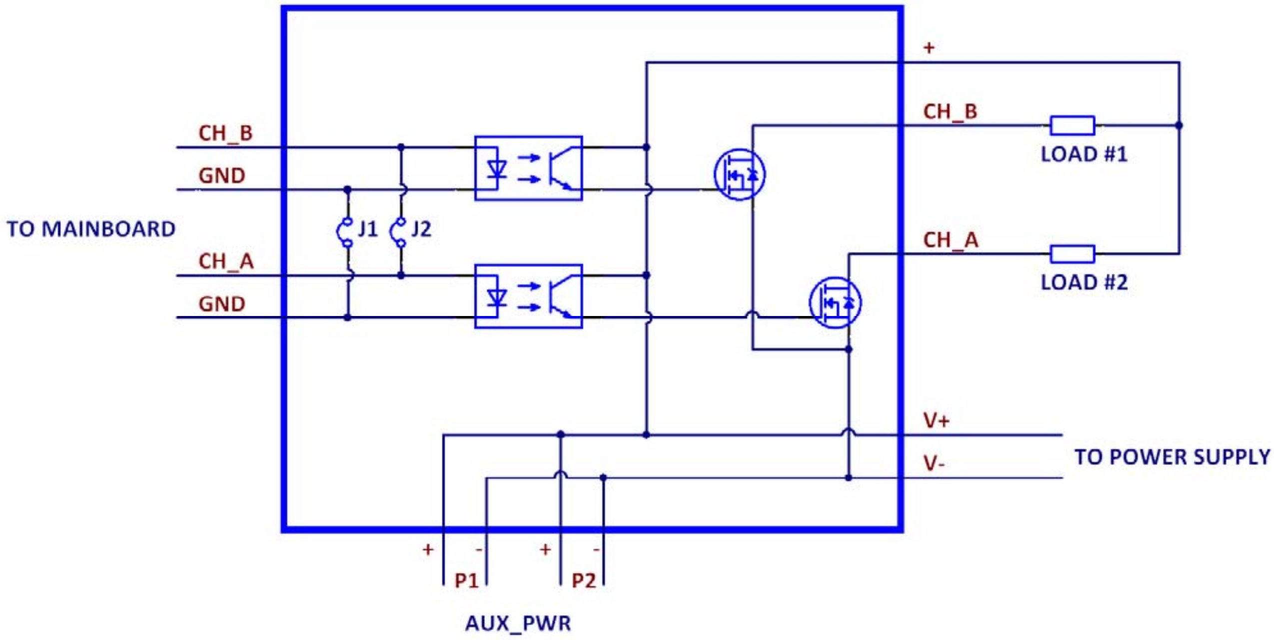
Frequency	Maximum load current with single channel active	
	No fan	With fan
10 Hz	38 A	50 A
500 Hz	33 A	38 A
1000 Hz	29 A	35 A

Note: To keep the board price lowest possible, we did not integrate proper (and expensive) MOSFET gate drivers, so this board does not work very well with higher PWM frequencies and would tend to overheat. As a rule of thumb, keeping the PWM frequency below 10 Hz would work well. For more information on "Load vs. Maximum frequency" curve, Refer to diagram at Fig.5.

For those geeks who want to build their own curves or drive something very specific, MOSFET open/close waveforms are provided at Fig. 7.

4 Board connection

Simplified connection diagram



Below are some examples of board connection for most cases.

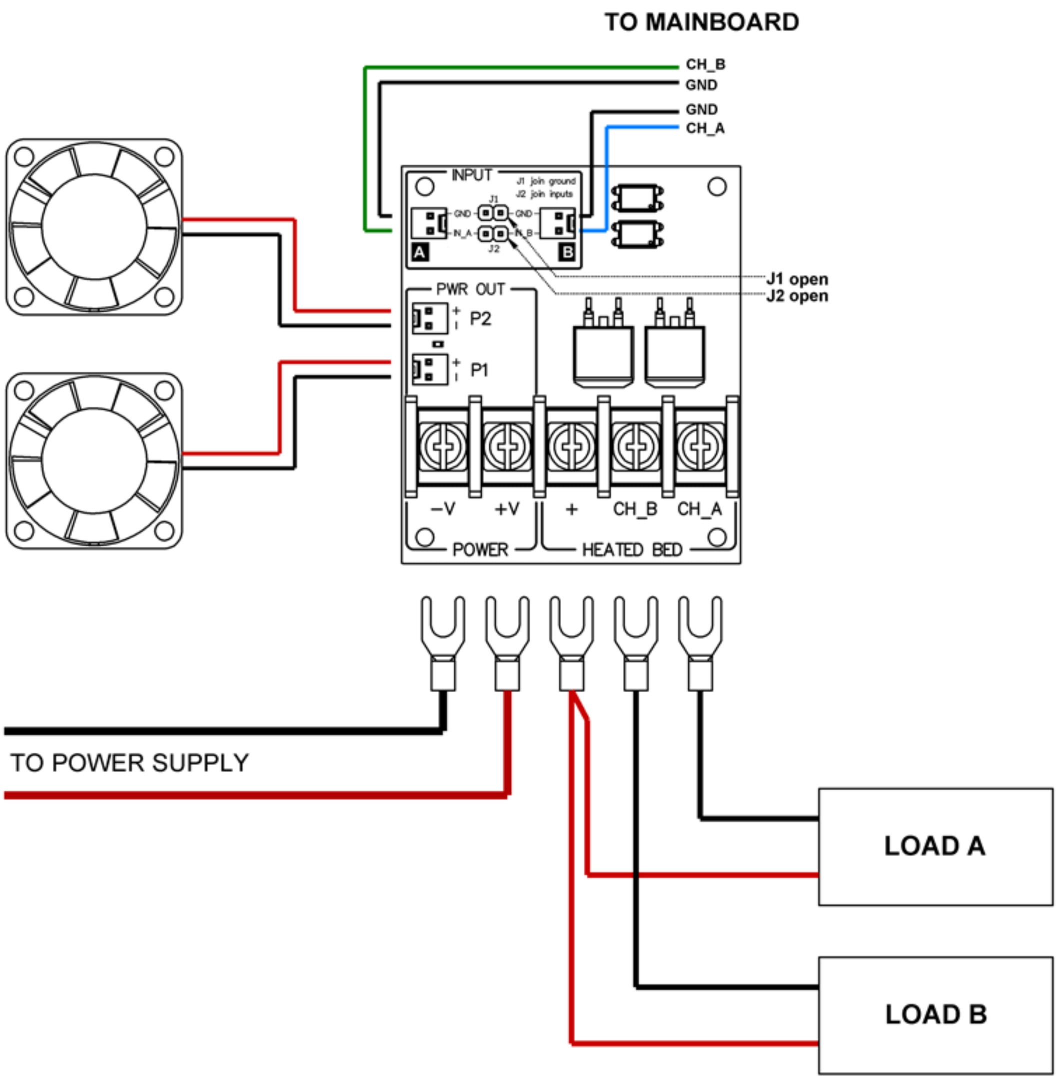
4.1. General connection diagram: two independently switched loads.
This the most universal connection diagram is used when you need to control channels by **signal** outputs of your mainboard or from **power** outputs of RAMPS, RAMBO, RUMBA, MKS Gen, MKS Base, Anet and any board which have low-side switching outputs.

Signal outputs could be in 3 states: high level, low level, and high-impedance. Power outputs with low-side N-channel MOSFET could be only in 2 states: low level and high-impedance.

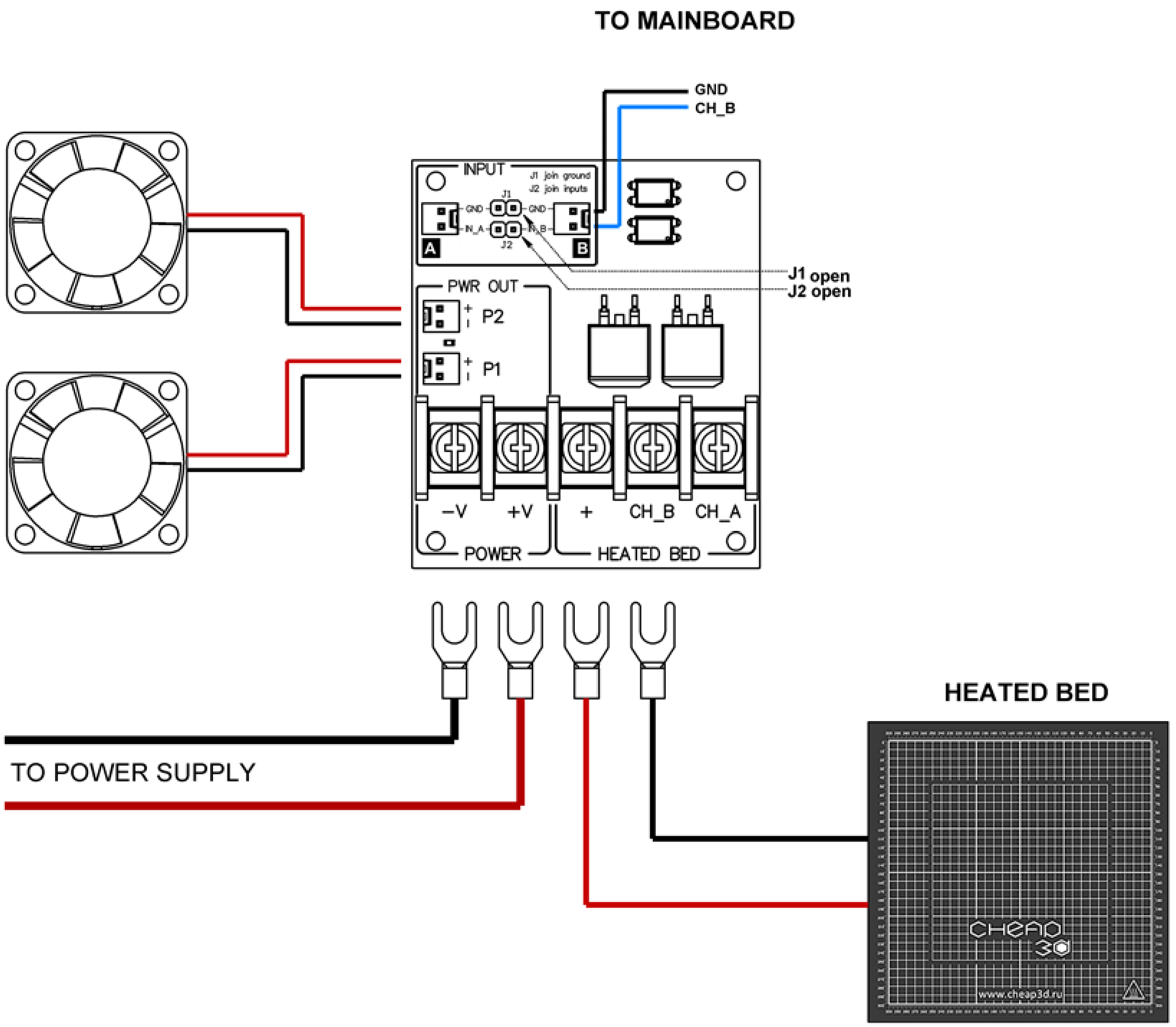
Signal output is connected to IN_A or IN_B and corresponding GND line to the ground line of your mainboard.

Power output, on the contrary, is connected to GND and the corresponding IN_A or IN_B is connected to positive of your mainboard or PSU. When connecting positive to PSU, remember that **maximum input voltage** from GND to IN_A / IN_B is **16 V**!

With this connection diagram channel inputs are isolated from each other and each channel is controlled by two wires: IN_A / GND and IN_B / GND. This makes it possible to control one channel from power output, and the other from signal output.

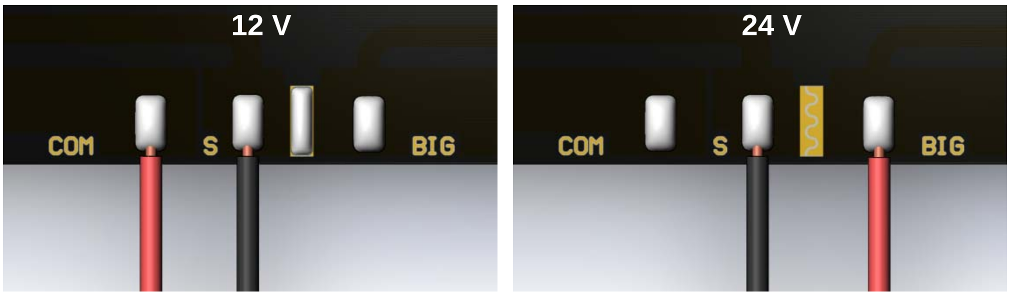


4.2. Cheap3D heated bed 1-zone mode connection. Channel combining is not used.



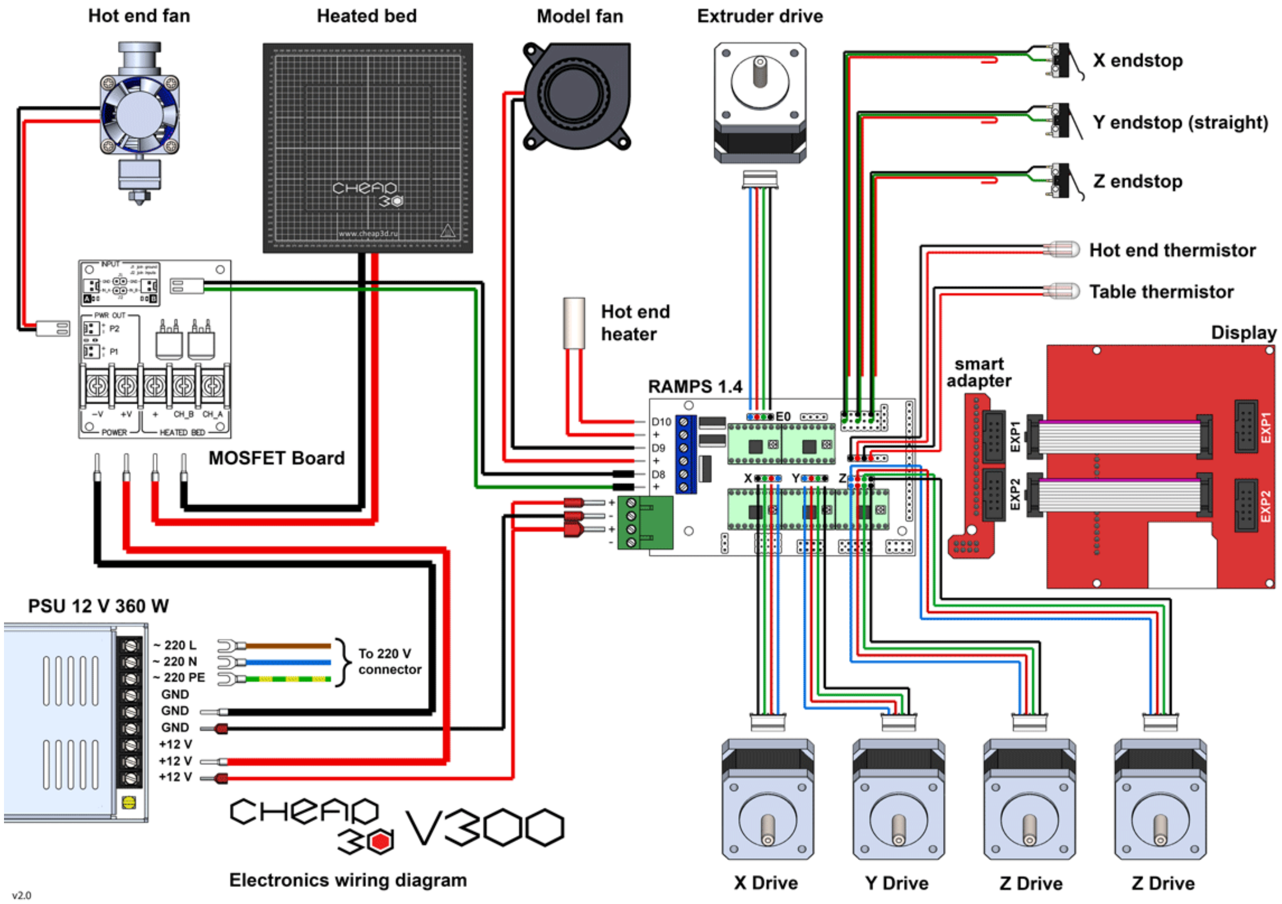
Cheap3D heated bed could be powered from 12V or from 24V. Depending on the voltage value, use one of the connection diagrams below:

12V: VCC (+) to pad «COM», GND (-) to pad «S», the jumper between «S» and «BIG» soldered.
24V: VCC (+) to pad «S», GND (-) to pad «BIG», jumper between «S» and «BIG» opened.

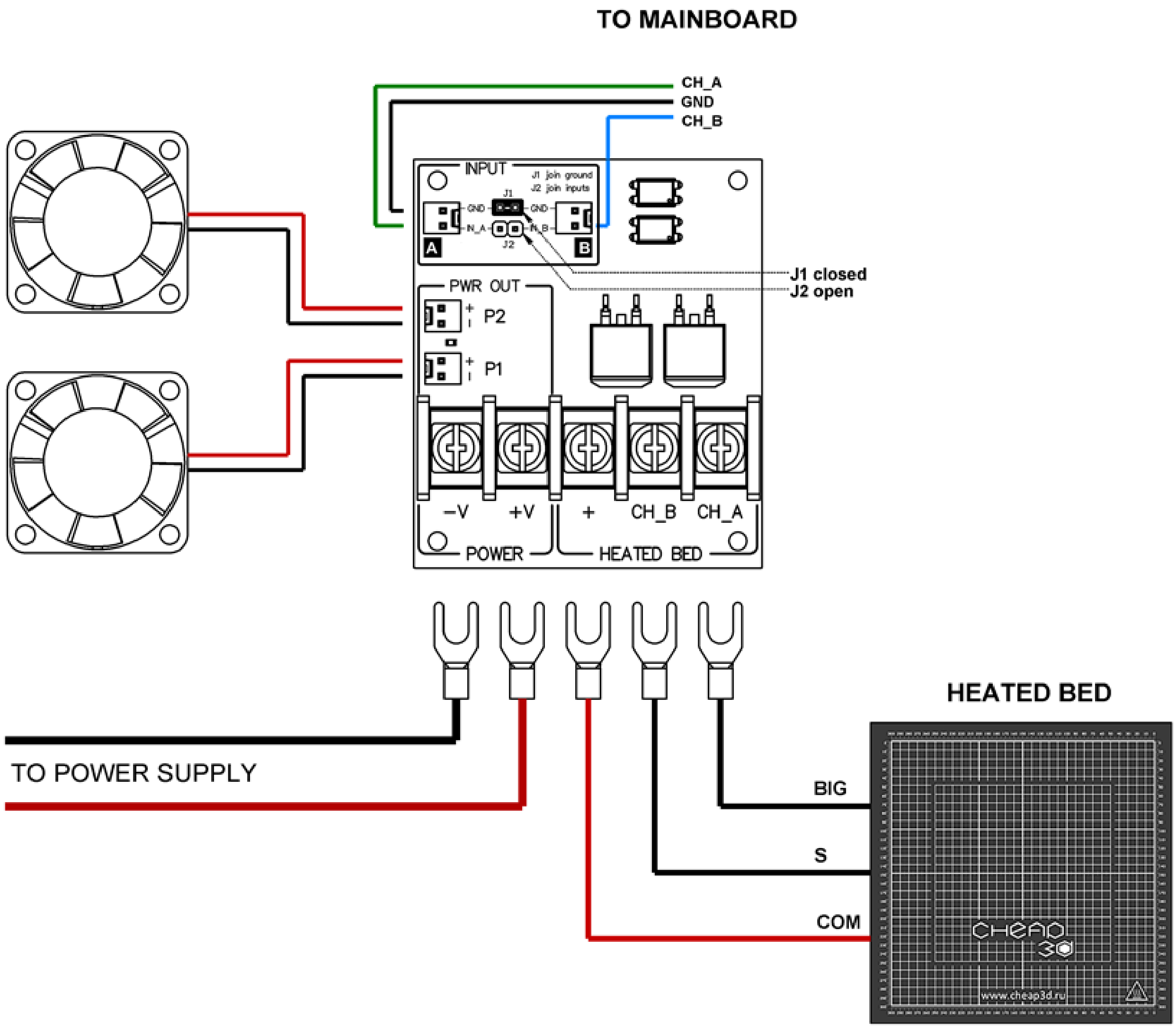


4.3 Replacing standard relay board to MOSFET board in Cheap3D V300

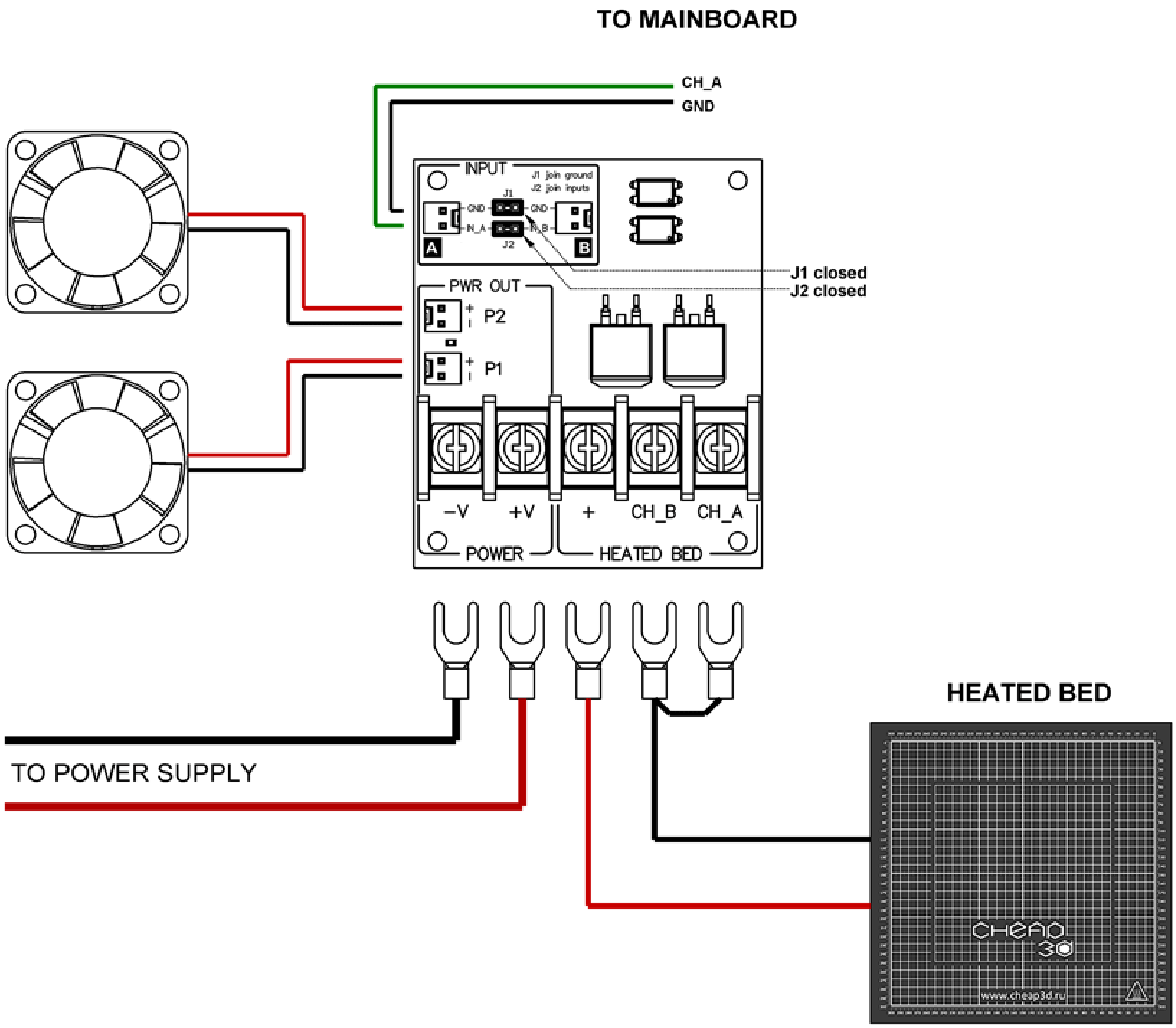
As this MOSFET board allows you to enable PWMing for heated bed, we recommend enabling the PID in your firmware. This allows more precise temperature regulation, and prevents heated bed (and print surface) warping during the print. For a pre-compiled firmware, contact Cheap3D team at cheap3d@cheap3d.ru



4.4. Cheap3D Double-zone heated bed with independently controlled zones.

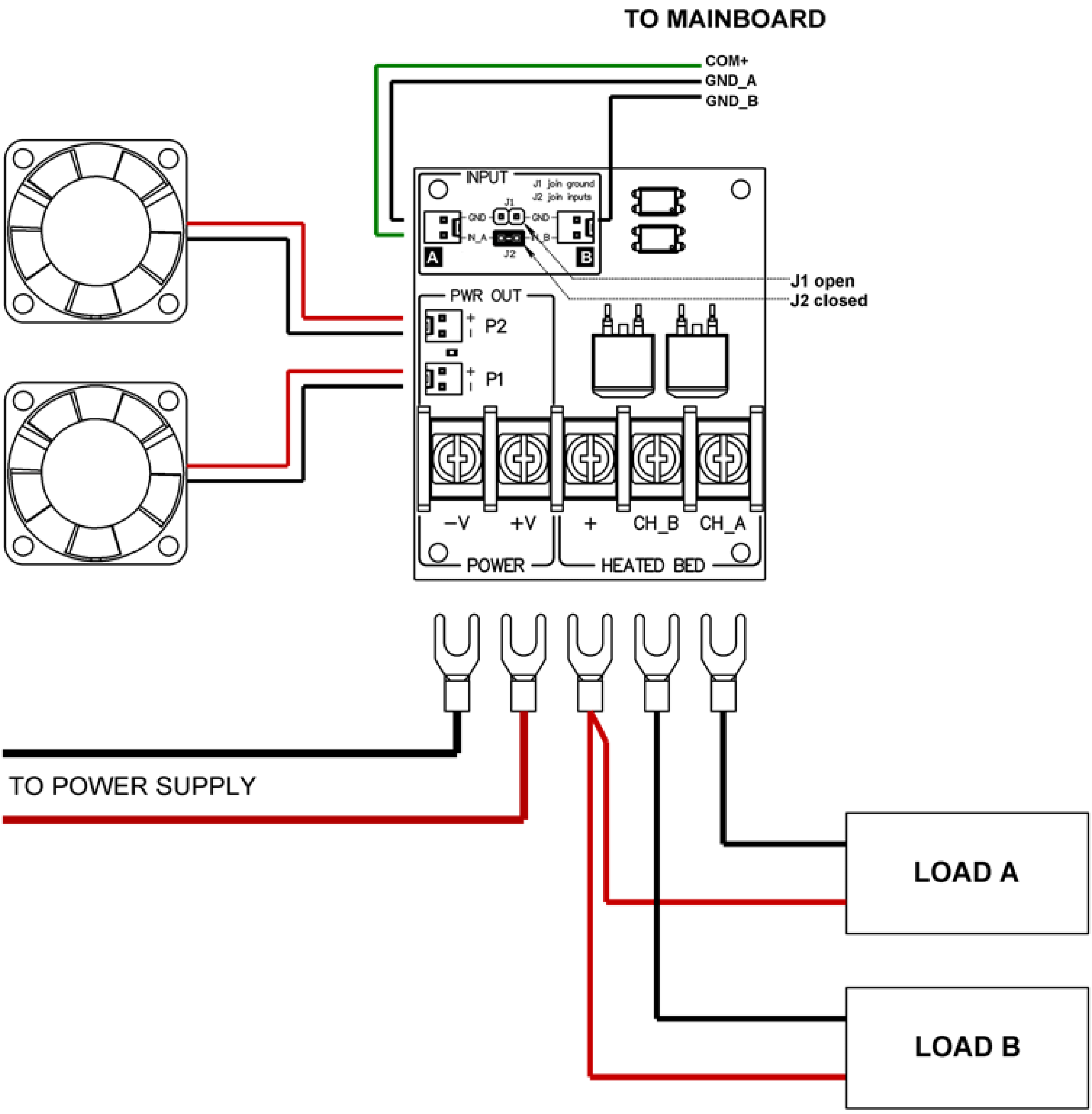


4.5 Connection of one high-power load.
Channel inputs are combined and outputs are combined.



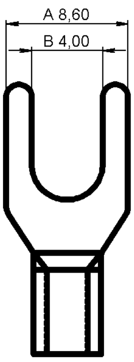
4.6. Connection to power outputs with low-side switching.

In this case the channel positive inputs IN_A and IN_B are combined and the control is provided by switching the GND inputs. This diagram is used quite rarely in case of controlling the channels independently by three wires from mainboard outputs with N-channel switches.



5 Power wire gauge and connection guidelines

High power this board delivers requires good current transfer solutions. For currents of **15A** and above we highly recommend using of **crimped** insulated or non-insulated U-terminals. Ensure that your terminals have dimension “A” less and dimension “B” more than specified in drawing below.



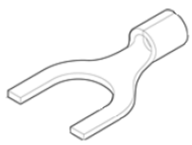
A: Should be equal or less than 8.60mm

B: Should be equal or more than 4.00mm

To select the terminals depending on the wire cross-sectional area, use the following tables.

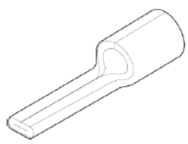
U-terminals:

Section area, mm^2	AWG	Part number
0.5-1.5	22-16	SNBS1.25-4, SNBM1.25-4, SNBL1.25-4, SNBS1.25-5, SNBM1.25-5
1.5-2.5	16-14	SNBS2-4, SNBM2-4, SNBL2-4, SNBS2-5
2.5-4	14-12	SNB3.5-4, SNB3.5-5
4-6	12-10	SNBS5.5-4



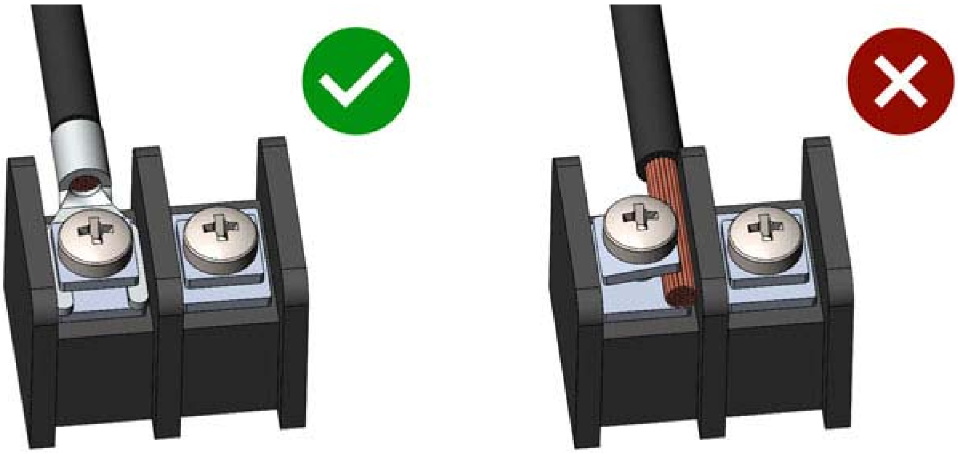
I-terminals

Section area, mm^2	AWG	Part number
0.5-1.5	22-16	PTN1.25-18
1.5-2.5	16-14	PTN2-18
4-6	12-10	PTN5.5-18*

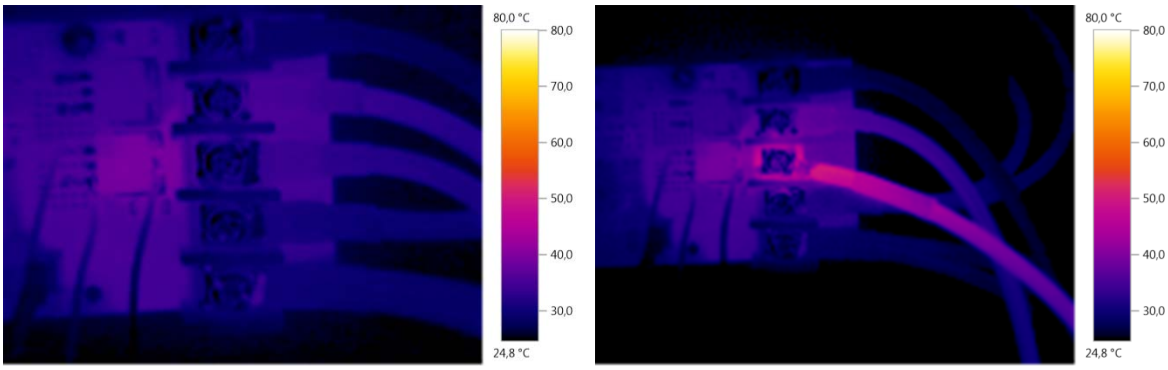


* may need to be finalized (squeeze by pliers)

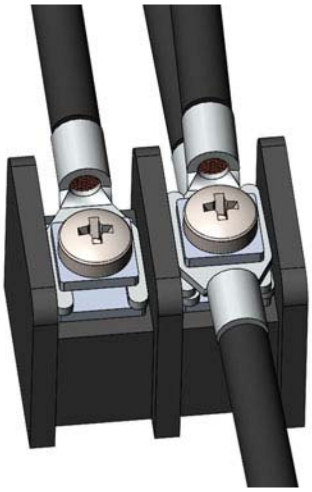
Terminals provide good, stable and uniform contact compared to bare wire:



You can see the difference at the thermograms below. The left thermogram shows heating of wire with crimped u-terminal. On the right side – bare wire.



Also, with u-terminals you can easily connect 2-3 wires to one screw:



While it is generally ok (and frequently used by hobbyists) to use bare wire for small loads (**under 15A**), we highly **do not recommend** screwing in a bare wire instead of crimped one. Such a connection would generate much higher heat that can lead to melting of terminal block or **cause fire** under heavy loads. Also, bare wire would require frequent tightening of screw terminals overtime.

To select the proper wire gauge, use the table below.

Current, A	**Area, mm^2**	**AWG**
10	1.5	15
20	2.5	13
30	3.0	12
40	5.2	10
50	8.4	8
60	13.3	6

Note: It is generally ok to substitute one bigger gauge wire to two smaller wires, if sum of their cross-section area is not less than the area of this bigger wire (e.g. instead of one 10 AWG wire you can use two 12 AWG wires)

6 Nerd zone: Testing results and Graphs

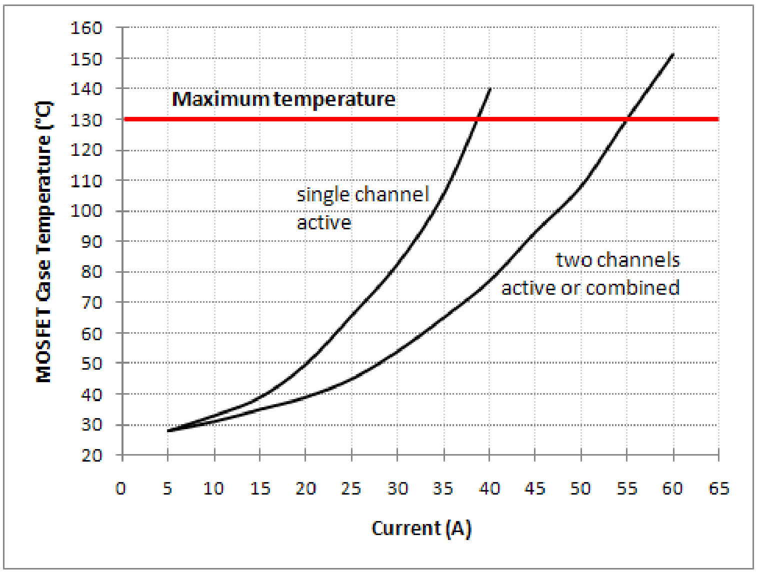


Fig. 2. Board Temperature vs. Load Current, without fan

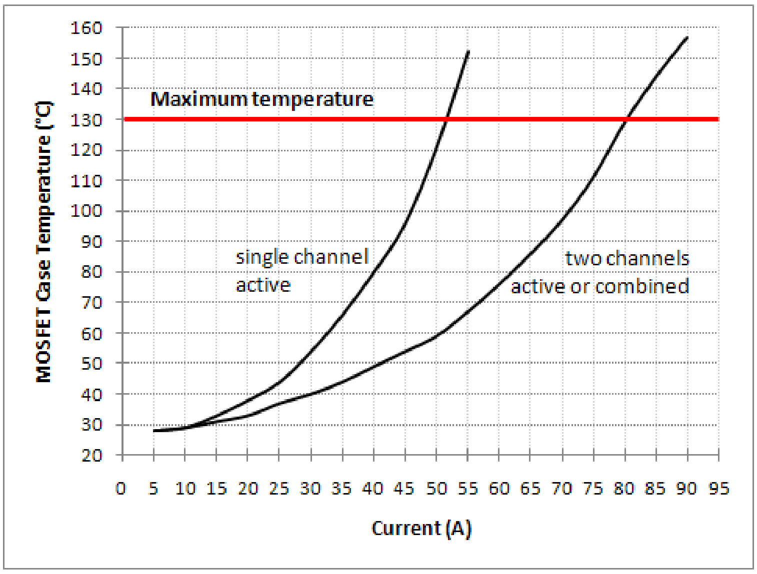


Fig. 3. Board Temperature vs. Load Current with fan

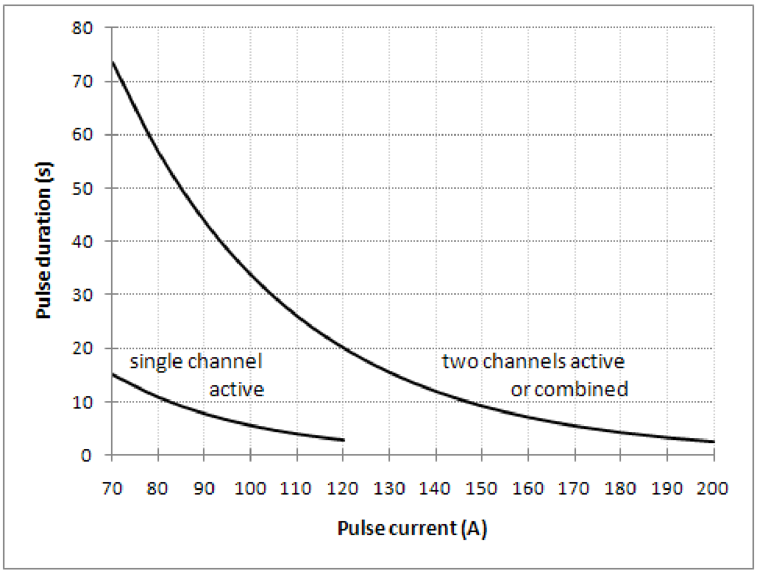


Fig. 4. Pulsed current duration

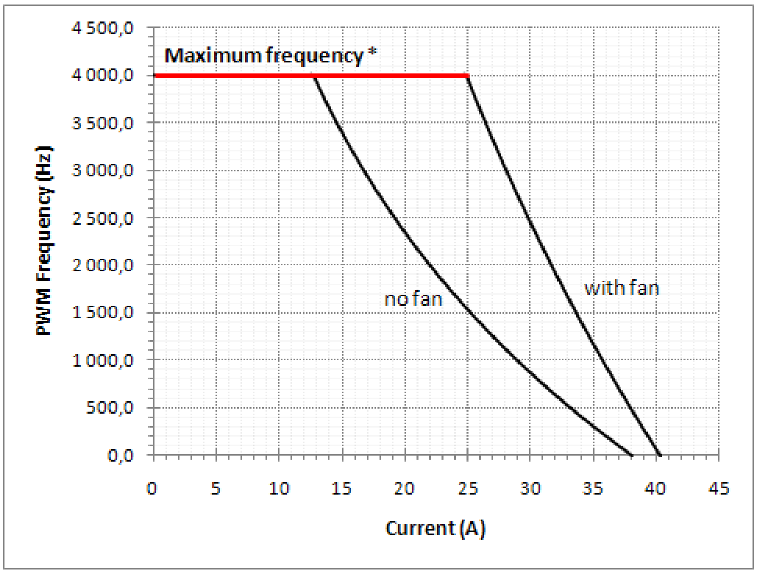


Fig. 5. Maximum PWM Frequency vs Current, single channel active

*The frequencies above 4000 Hz are not tested.

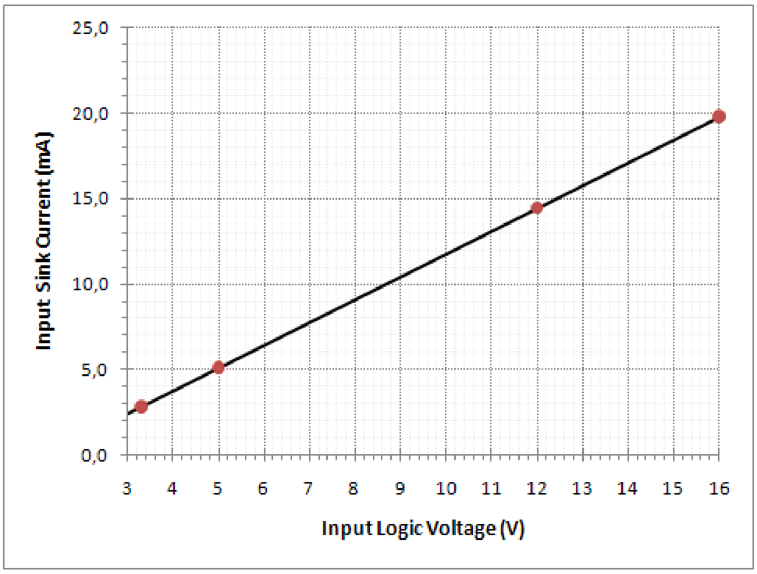


Fig. 6. Input Sink Current vs Input Logic Voltage

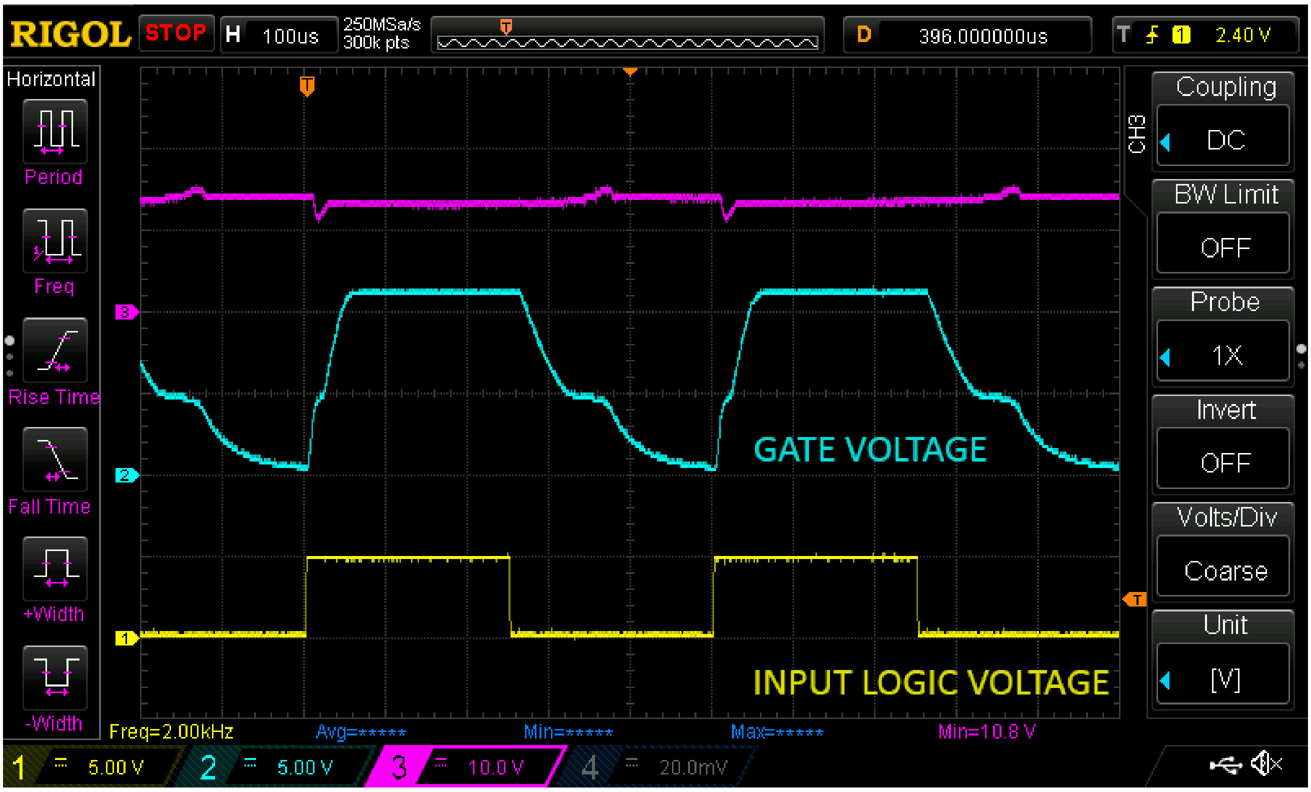


Fig. 7. MOSFET Switching waveforms

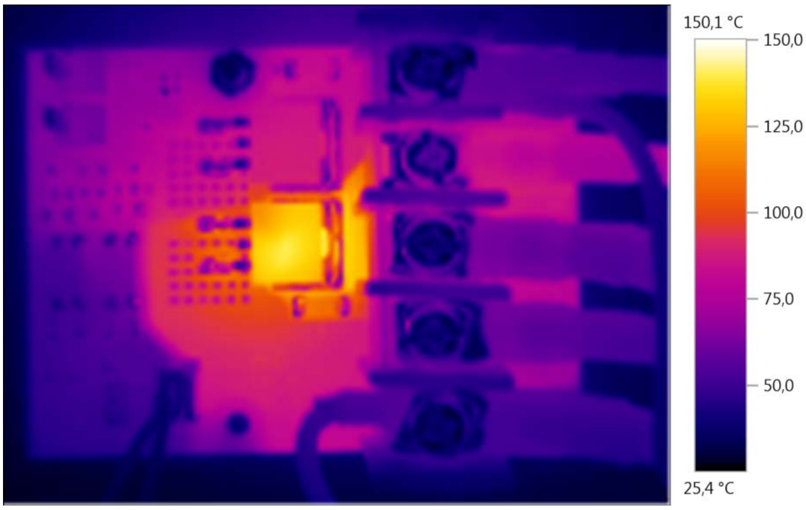


Fig. 8. Thermogram, single channel active, maximum MOSFET case temperature, current 35 A

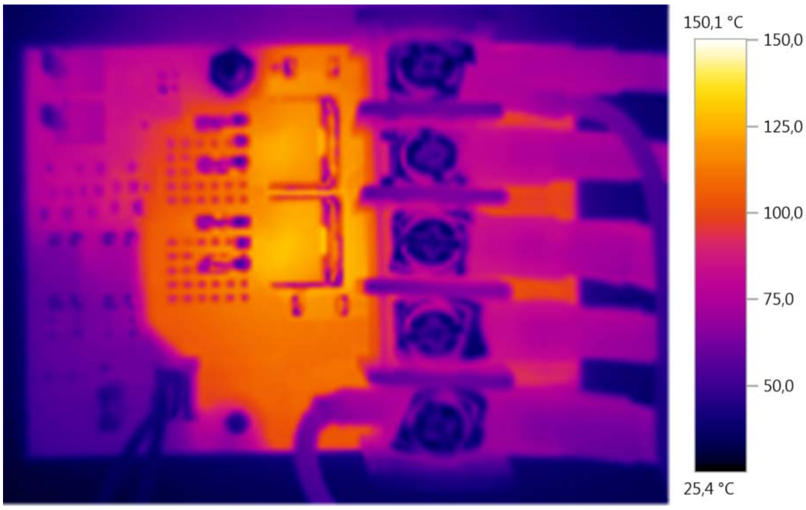
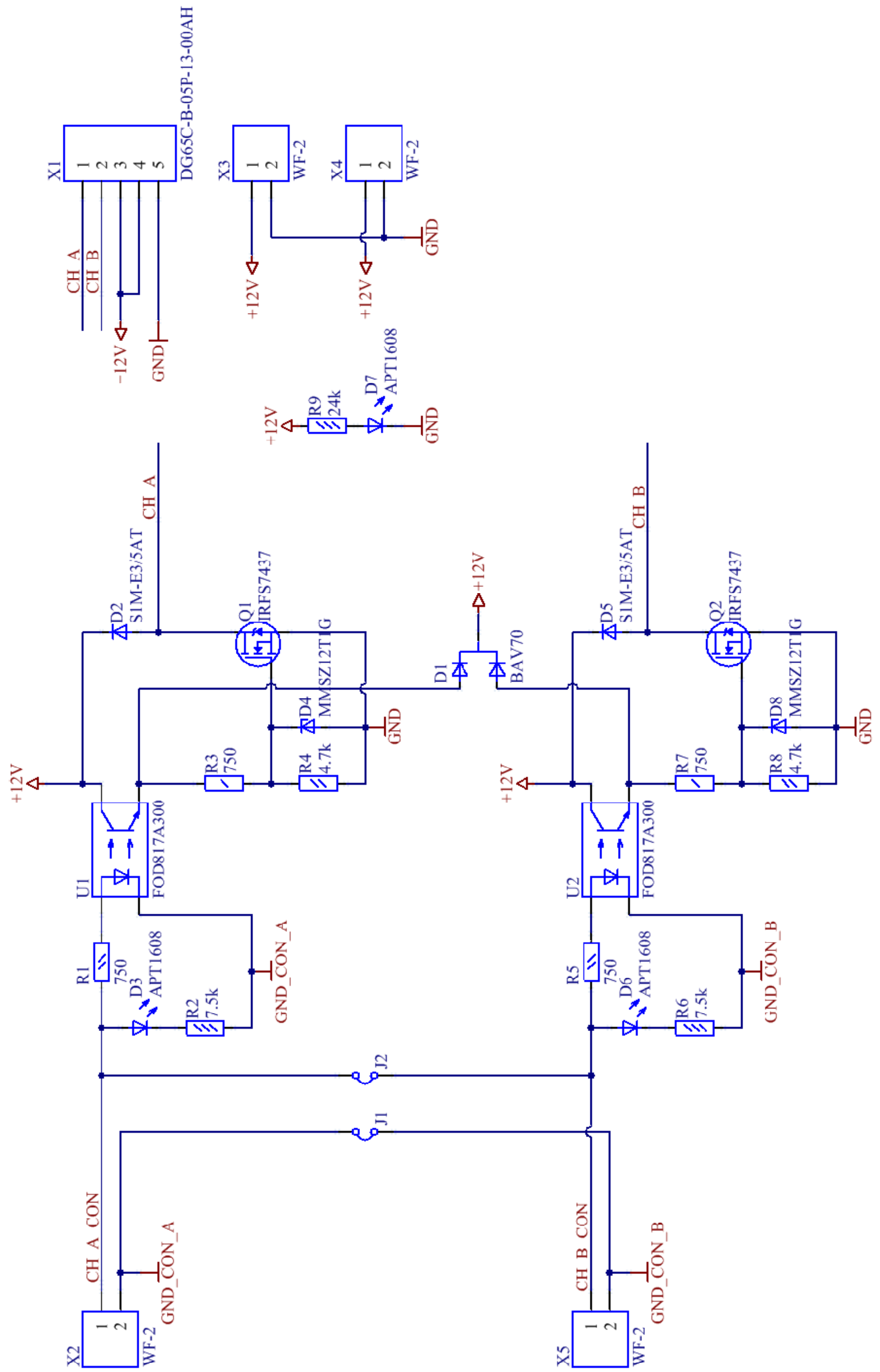
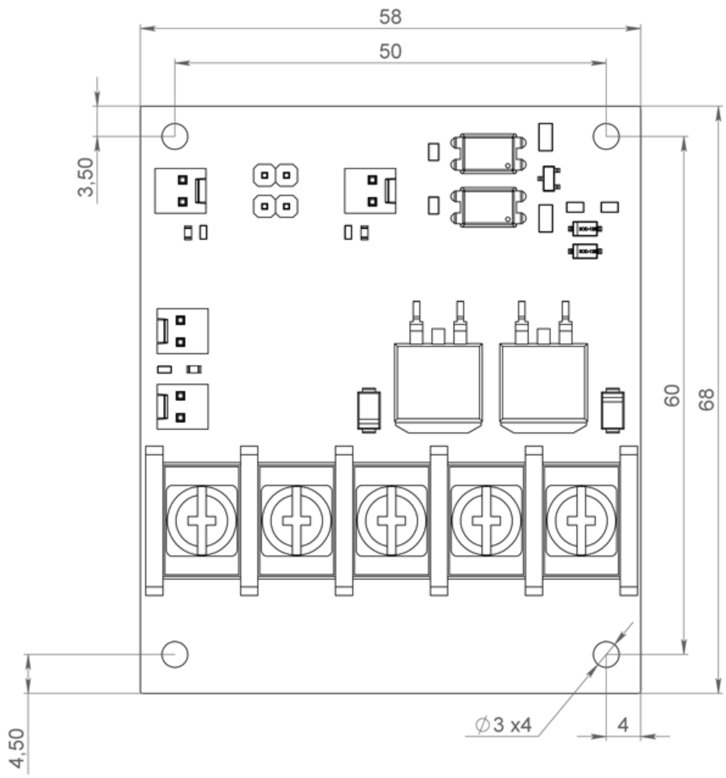


Fig. 9. Thermogram, two channels active, maximum MOSFET case temperature, total current 55 A

7 Board schematic



8 Board dimensions (all units in mm)



9 Errata

There is no known errata for this board.

10 Revision History

Version	Date	Changes
rev. 2.0	2017-05-16	Initial release