

General power/wiring concept, consumptions and temperatures

Notes about Trikarus wiring

- PSU
 - The switching power supply can be switched on and off via a relay. This saves power consumption, the life time can be improved, there is less audio noise and the safety of the machine is better. The PSU relay is switched **on by default**. It has to be switched off explicitly via GPIO. This prevents losing power while printing due to GPIO problems
- The [emergency stop switch](#) turns off the power supply, but not the UPS. Why? The UPS only supplies server services. The power supply is solely responsible for supplying critical actuators (extruders, motors). The emergency halt physically also kills the Smart Steppers so they cannot be accessed from Duet and not from Raspberry. So they are secure to be not abused by any USB serial script or enable/step signal.
- [Shangjiu Mini UPS FX5-48 / Vultec Continuity UPS30PW-DC](#) (Uninterruptible power supply (UPS))
 - is necessary because the electricity in the industrial museum is possibly switched off at night. However, server services should be able to save status values cleanly and independently, so that prints can be continued later. Both Duet Web Control and Repetier Server can be used for this (print recovery)
 - is required to power Freifunk router and Raspberry Pi + connected devices. This allows ...
 - running a management network with network access over SSH
 - flashing of Duet firmware
 - flashing of Smart Stepper firmware
 - clean start and shutdown of Raspberry Pi and running services like Repetier Server
 - collecting and sending metrics for monitoring the allover system stability
 - A UPS for motors is explicitly not wanted. That would come with a strong increase in weight of the device
 - the UPS charges as long as mains voltage is present and it also charges when the [emergency stop switch](#) has been actuated

- Smart Steppers
 - The [4 Port USB Hub GL850G Genesys Logic + 24V DC/DC Converter Traco Power TMA 2405S](#) for the [Smart Stepper rev 1/20/2019 by MisfitTech](#) is externally supplied with 5V. In order not to unnecessarily burden the Raspberry Pi, the voltage comes directly from the power supply via DC / DC converter which is attached to the PSU. The USB hub originally had a backfeeding effect on the Raspberry Pi. The 5V lead in the cable was then cut to disable this volatile (unstable) transition state. So Smart Steppers are powered by 4 port USB hub and/or 24 V PSU voltage. In case the control relay turns off, the PSU or the main power cord is plugged off, all Smart Steppers will go offline. If PSU is off *lsusb* command will return no Smart Steppers
 - The [Duet 2 Ethernet v1.04](#) is supplied via USB (5 V) and via 24 V power supply.

Raspberry Pi powering

While building Trikarus a lot of lessons were learned regarding power supplying. If the used power chords are too thin and/or too long the Raspberry Pi gets problems with undervoltage occurrence (cheap wiring). This leads to failing USB device addressing while boot procedure (*dmesg*) and randomly losing devices from device tree (*lsusb*). So you can see things happen like unavailable webcam, flickering Smart Stepper displays and so on. Additionally USB backfeeding occurred when using cheap USB hub with external voltage supply. This back-powered Raspberry Pi. In case the PSU was offline this meant that the hub was not powered externally but Raspberry Pi tried to power the power source of the hub. This led to useless large voltage drops.

The official Raspberry Pi power supply is rated at 5.1 V. The final way to fix powering issues using the given UPS was to use really short powering (explicitly "charging") cables (25cm). Even with short cables we did not get fully rid of undervoltage warning because UPS does not deliver 5.1 V and it's hard to find short USB cables. Ideally choose AWG24 cables (often labeled as "2.0 A" cables). A good chord has ~5 mm diameter (regular cables often have only 2 - 3 mm). Some users reported that's its even better to use AWG20 USB cables and solid power supplies with 3.0 A.

Running at the exhibition

Due the fact that Trikarus runs at a location where security matters, the power might go offline from late afternoon till early morning. In this time the system may be inaccessible and the printer cannot print. To allow large prints over many days it's required to save the XYZ position of the effector to continue the print from day to day even if power was lost.

Power loss can happen

- spontaneously
- by hitting the emergency halt button (cuts PSU input so Duet and Smart Steppers go offline)
- by planned daily shutdown (staff/personnel)

In an ideal world we would use a brake system

Letting continue Hangprinter to print it's previous job it's a must to quickly react on power loss. All the time a power loss happens Hangprinter needs to store it's XYZ position and to stop the effector at a known position by triggering brakes at the drives without losing any steps. Otherwise the position will be not accurate and a continue of the print is hard (but not impossible). A separate, second UPS could be installed to safely power Duet and Smart Steppers until the effector parked into a known position. However it's not yet possible to do this the desired way because it requires much more electronics which would raise the weight of the ceiling module heavily. It's also expensive and needs additional control by GPIO. There are different working principles for brakes and it's a question of general concept. In theory there exist brakes which trigger if power is lost while there also exist brakes which trigger if power is available only. For Hangprinter it makes sense to have brakes which trigger in case no power is available. This will ensure that the effector cannot lower down unexpectedly. More details about future ideas can be found at [Drive motor brakes](#). **At the moment Trikarus has no brake system.**

Cable supply from ceiling module to effector

The power and data supply between ceiling module and effector is done by a major [chainflex CF2.02.24 cable by igus](#) and a separate wire for heater cartridge power. General Ohm's law in electronics says: the longer the wires or the smaller the wire section get, the larger the resistance gets. The cable length between top and effector is roughly about 3.5 meters (includes about 0.5 meters of dangling buffer cable length to extend the print size in height or diameter for example). So the voltage will drop noticeably and the wires require good dimensioning to prevent overheating or doing "russian style" wiring. They need good flexibility and high amount life cycle, but low weight. Trikarus uses a professional cable from igus. It's not that light weight sadly but it's more stable and less cable salad than other Hangprinters are used to have. It needs to support the cable to prevent collisions between printed objects on the platform and the cable. The used cable is also well isolated for wiring the I2C IMU sensor which is installed at the effector. Furthermore the thick cable acts as some simulation for Hangprinters which would have more than one extruder or contain more advanced tools. A regular Hangprinter with, let's say 4 extruders, could not be wired up by a bunch of flat ribbon cables.

Cable Nr.	Wire Nr.	Actuator/Sensor	Values	Required / optimal section	Available section	Pin
1	1	actuator - heater cartridge 80W/24W	80 W/24 V → 3.3 A	1 mm ²	1.5 mm ²	+ 24 V
1	2	actuator - heater cartridge 80W/24W	80 W/24 V → 3.3 A	1 mm ²	1.5 mm ²	-
2	Bundle 1 - 1 - white	actuator - stepper motor	~5 Watt per phase (measurements by equally stepper motors from other 3d printers) → Σ ~10 W	0.25 mm ²	0.25 mm ²	A1
2	Bundle 1 - 2 - brown	actuator - stepper motor	~5 Watt per phase (measurements by equally stepper motors from other 3d printers) → Σ ~10 W	0.25 mm ²	0.25 mm ²	A2
2	Bundle 1 - 3 - green	actuator - stepper motor	~5 Watt per phase (measurements by equally stepper motors from other 3d printers) → Σ ~10 W	0.25 mm ²	0.25 mm ²	B1

Cable Nr.	Wire Nr.	Actuator/Sensor	Values	Required / optimal section	Available section	Pin
2	Bundle 1 - 4 - yellow	actuator - stepper motor	~5 Watt per phase (measurements by equally stepper motors from other 3d printers) → Σ ~10 W	0.25 mm ²	0.25 mm ²	B2
2	Bundle 2 - 5 - grey	actuator - blower fan 50x5015 - Nr. 1	2.88 W / 24 V → 0.12 A (measured)		0.25 mm ²	+ 24 V
2	Bundle 2 - 6 - pink	actuator - blower fan 50x5015 - Nr. 1	2.88 W / 24 V → 0.12 A (measured)		0.25 mm ²	GND
2	Bundle 2 - 7 - blue	actuator - hotend fan 40x40x10	1.44 W / 24 V → 0.06 A		0.25 mm ²	GND
2	Bundle 2 - 8 - red	actuator - hotend fan 40x40x10	1.44 W / 24 V → 0.06 A		0.25 mm ²	+ 24 V
2	Bundle 3 - 9 - violet	Sensor - GY-521 MPU6050			0.25 mm ²	VCC 3,3 V
2	Bundle 3 - 10 - black	Sensor - GY-521 MPU6050			0.25 mm ²	GND
2	Bundle 3 - 11 - grey-pink	Sensor - GY-521 MPU6050			0.25 mm ²	SCL
2	Bundle 3 - 12 - red-blue	Sensor - GY-521 MPU6050			0.25 mm ²	SDA

Cable Nr.	Wire Nr.	Actuator/Sensor	Values	Required / optimal section	Available section	Pin
2	Bundle 4 - 13 - white-green	Sensor - Duet PT100 RTD Board 1.1a	mA range		0.25 mm ²	PIN
2	Bundle 4 - 14 - brown-green	Sensor - Duet PT100 RTD Board 1.1a	mA range		0.25 mm ²	PIN
2	Bundle 5 - 19 - white-pink	Sensor - Duet IR probe	0,1W / 5V → 20mA 0.04 W / 3.3 V → 12mA		0.25 mm ²	GND
2	Bundle 4 - 15 - white-yellow	Sensor - Duet IR probe	0,1W / 5V → 20mA 0.04 W / 3.3 V → 12mA		0.25 mm ²	SIGNAL
2	Bundle 4 - 16 - yellow-brown	Sensor - Duet IR probe	0,1W / 5V → 20mA 0.04 W / 3.3 V → 12mA		0.25 mm ²	VIN 3,3 V
2	Bundle 5 - 17 - white-grey	actuator - LED stripe ~120 LEDs SMD 3528	8.64 W / 24 V → 0.36 A (measured)	0.25 mm ²	0.25 mm ²	+ 24 V
2	Bundle 5 - 18 - grey brown	actuator - LED stripe ~120 LEDs SMD 3528	8.64 W / 24 V → 0.36 A (measured)	0.25 mm ²	0.25 mm ²	GND
2	Bundle 5 - 20 - pink-brown	Encoder Keyes KY040			0.25 mm ²	CLK
2	Bundle 6 - 21 - white-blue	Encoder Keyes KY040			0.25 mm ²	DT
2	Bundle 6 - 22 - brown-blue	Encoder Keyes KY040			0.25 mm ²	SW

Cable Nr.	Wire Nr.	Actuator/Sensor	Values	Required / optimal section	Available section	Pin
2	Bundle 6 - 23 - white-red	Encoder Keyes KY040			0.25 mm ²	+
2	Bundle 6 - 24 - brown-red	Encoder Keyes KY040			0.25 mm ²	GND

Power consumptions and temperatures - Overview by combination and running modes (idling, usual operation, boot, ...)

Power complex (separate power sources)	Device	Running mode	Consumption	Max. available power	Hints for measurements
1 (Power Supply Unit PSU)	Switching Power Supply MW RSP-320-24	default	6.7 W	320 W	temperature at 24 °C room temperature is about 30 °C

Power complex (separate power sources)	Device	Running mode	Consumption	Max. available power	Hints for measurements
1 (Power Supply Unit PSU)	Stepper Motors MT-1705HS200AE by Motech Motors & Stepper Motor MT-1703HSM168RE by Motech Motors	default	4.25 W	-	• consumption is not total, it is per stepper motor • temperature at 24 °C room temperature is about 30 °C (torque mode) • temperature after 4 hours print at 25 °C room temperature approx. 60 ~ 70 °C (maximum of 80 °C allowed - otherwise

Power complex (separate power sources)	Device	Running mode	Consumption	Max. available power	Hints for measurements
-	Shanqiu Mini UPS FX5-48 / Vultec Continuity UPS30PW-DC	fully charged, Raspberry Pi and router are attached and running	-	30 W	temperature at 24 °C room temperature is about 30 °C
1 (Power Supply Unit PSU)	Shanqiu Mini UPS FX5-48 / Vultec Continuity UPS30PW-DC	charging	?	-	
2 (USV)	Raspberry Pi 3 B	boot	4.35 W	-	without any other connected devices
2 (USV)	Raspberry Pi 3 B	idle	2.50 W	-	without any other connected devices; Bluetooth, SMD LEDs, WLAN, HDMI deactivated

Power complex (separate power sources)	Device	Running mode	Consumption	Max. available power	Hints for measurements
2 (USV)	Raspberry Pi 3 B	default	?		• bash output: "CPU temperature: 41.318°C" (after 15 hours of uptime and with all devices connected) • around 78 °C at maximum stresses • for Raspberry Pi 3 B a PSU with minimum 10 W (2 A, 5 V) is required

Power complex (separate power sources)	Device	Running mode	Consumption	Max. available power	Hints for measurements
2 (USV)	Router TL-WR842N by TP-Link	default	1.60 to 2.60 W	-	
2 (USV)	USB Port: USB-Stick USB 3.1 32 GB - SANDISK Ultra Luxe		0.27 W (~55 mA)	-	
2 (USV)	USB Port: Webcam C920 by Logitech		0.83 W (~170 mA)	-	
1 (Power Supply UnitPSU) + 2 (USV)	USB Port: 4 Port USB Hub GL850G Genesys Logic + 24V DC/DC Converter Traco Power TMA 2405S		0.39 W (~ 80 mA)	-	

Power complex (separate power sources)	Device	Running mode	Consumption	Max. available power	Hints for measurements
1 (Power Supply UnitPSU) + 2 (USV)	USB Port: Duet 2 Ethernet v1.04		1.05 to 1.20 W (~ 250 mA)	-	MCU temperature (see Duet Web Control) approx. 35-45 °C at ~ 25 °C room temperature
1 (Power Supply UnitPSU)	COB LED Spot 6000-6500K 260mA 10V 2x spot connected in series. Therefore double the voltage!		- measured 0.03 A @17 V = 0,51 A - final configuration at 260 mA @ 19 V = 0.5 A		

Power complex (separate power sources)	Device	Running mode	Consumption	Max. available power	Hints for measurements
1 (Power Supply Unit PSU)	LED stripe 24V - ceiling module • ~522 LEDs SMD 3528) • length 3x 27.5 cm + 3x 62.5 cm = 435 cm		37,6 W / 24 V = 1.57 A		approx. 32 ° C temperature after 30-60 minutes at ~ 13 ° C "room" temperature
1 (Power Supply Unit PSU)	LED stripe 24V - effector • ~120 LEDs SMD 3528 • length 100 cm		8,64 W / 24 V → 0.36 A		approx. 28 ° C temperature after 30-60 minutes at ~ 13 ° C "room" temperature

Power complex (separate power sources)	Device	Running mode	Consumption	Max. available power	Hints for measurements
1 (Power Supply Unit PSU)	Aero Titan Extruder and SuperVolcano Hotend by E3D				- PETG fan shroud keeps at room temperature of ~ 18 °C when extruder reached temperature 250° C for ~1 hour - the surrounding metal bracket gets a temperature of ~ 30 - 50 °C

230V Source Power

Trikarus now has a fuse in the fuse box with the number **UV 1_F6**, as well as an FI circuit breaker (above on the cable route). This is new due to the movement to the permanent exhibition in 2022.

Total power consumption - sum up of power modes

1. PSU is on and Smart Steppers are idling around (enabled) → 47 Watts
2. PSU is on and Smart Steppers are idling around (enabled) + LED stripes on spot are switched on → 90 Watts
3. PSU is on and Smart Steppers are idling around (enabled) + LED stripes on spot are switched on + active hotend (heating up + active fan) → 182 Watts
4. PSU is on and Smart Steppers are idling around (enabled) + LED stripes on spot are switched on + active hotend (heating up + active fan) + active filament blower fan → 185 Watts
5. PSU is on and Smart Steppers are idling around (enabled) + LED stripes on spot are switched on + active hotend (target temperature reached + active fan) + active filament blower fan → 95 Watts
6. PSU is on and all Smart Steppers are moving + LED Stripes on Spot are switched on + active hotend (target temperature reached + active fan) + active filament blower fan → 109 Watts

Wiring overview

- [Duet to effector wiring](#)
- [Main wiring \(ceiling module\)](#)

Version #2

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