UNI PWR module

1.5A Output current, compact size, voltage step UP&DOWN module

1 Features

- 1.6-V to 5.5-V input voltage range
  - Device input voltage > 1.65 V for start-up
- 1.2-V to 5.3-V output voltage range (adjustable with on-board trimmer)
  - Trimmer network can be easily bypassed for external voltage adjustment
- High output current capability, 3-A peak switch current
- High efficiency over the entire load range
  - 8-µA typical quiescent current
- Peak current buck-boost mode architecture
  - Fixed frequency operation with 2-MHz switching
- Compact 28x25 mm size
  - 4x M3 holes for easy attachment
- Screw terminal compatible (5 mm pitch)
- Based on a TPS631000 [4]
  - Overcurrent protection and short-circuit protection
  - Integrated soft start with active ramp adoption
  - Overtemperature protection and overvoltage protection
  - Forward and backward current limit
- Additional high current schottky diode for reverse polarity protection
  - 0.3V drop @ 2A current
  - Can be easily bypassed for lower losses

2 Applications

- Perfect for medium power 5V USB powered applications
- Perfect for battery powered applications
  - 2-3x common AA or AAA cells (Alkaline, Zinc-Carbon)
  - single cell lithium batteries
  - 2-4x Ni-MH accumulators
  - single cell lithium accumulators

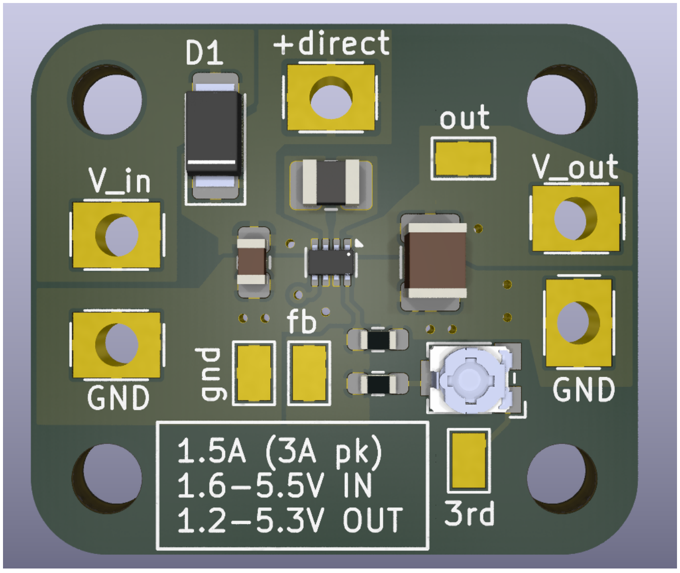

Figure 1: Module render

3 Descriptions

UNI PWR module is quite small, simple and powerful module for low-loss voltage conversion. This module is designed around TPS631000 IC from Texas Instruments and basically adds all the required components to make the IC work properly, resulting in simple and robust circuit. Most of the functionality is derived from the IC itself.

Notable additions are external high power schottkey diode for low-loss reverse polarity protection, protecting the circuit from common mistakes as flipped battery connector, and external resistor feedback network for setting the output voltage with on-board trimmer, requiring only a screwdriver to set the required output voltage.

Primary usecase of this module is to provide constant-specified voltage with the ability to do so for substantial current requirements.

However this does not limit advanced users from tailoring this module to their specific needs. Module has additional solder pads that allow users to bypassing the schottkey diode or the feedback network, allowing users to lower their energy losses or set the output voltage externally.

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4 Why does this need to exist

In this section I'll describe current market gap, which forced me to create this module.

4.1 Headlamp - the perfect problem

Imagine you want to create a simple battery powered torch or headlamp. To make the design simple, you will use widely available AAA batteries as power source. As your light source, you choose a 1W white LED. In theory all you need is a switch and a current limiting resistor to protect your LED. You figure out the required resistor with ease and know you wonder: How valid is this approach? The resistor will be dissipating some power, decreasing your circuit efficiency. And the battery voltage will drop as they discharge.

You try to run some calculations and you are left horrified. Even the simple LED + resistor in series equation is hard to solve. Lambert function? Wtf is that? So you approximate the LED voltage equation with polynomial. Now it works stand-alone, but adding the resistor gives you non-sensible currents. 3h of excel, wolframAlpha and 2 Matlab scripts later you find that you had the current in mA everywhere BUT the resistor voltage term. Now it works. You can now prove what you knew from the beginning but with numbers. You are now TRULY left horrified:

If you used 4 AAA cells in series, you would lose around 40 % of your total battery energy as heat on the resistor. As the batteries discharge, the light output will decrease by 1/3. If you used 3 AAA cells in series, you only lose around 25 % of your total battery energy as heat, but the light output will decrease to 1/6 of nominal. 2 AAA cells barely light the LED at all.

This is no bueno. Not only is this wasteful - wasting precious battery energy as heat, but you would like the light output power to be constant during the whole lifetime of the batteries - informing your adversaries about your headlamp battery life with its low power output is not a good practice.

4.1.1 Note on batteries and LEDs

Most batteries have output voltage dependency on the remaining energy they store. As batteries discharge, their voltage drops. Dependency of voltage on state of charge (SoC) is often non-linear and can depend on discharge current. Example of this dependency is shown in figure 3. [2]

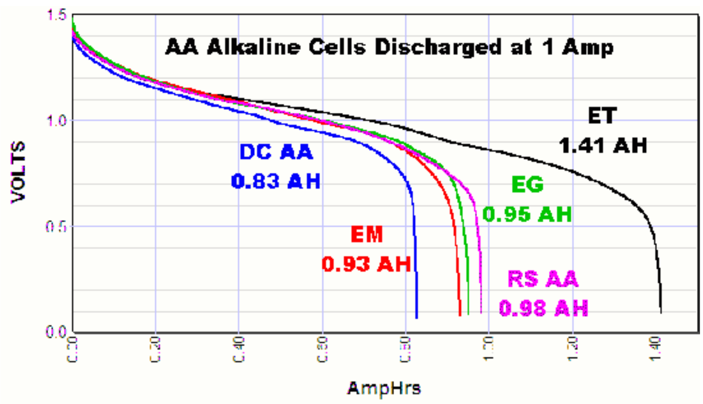

Figure 2: Voltage dependency on SoC of different AA batteries, see [2]

The figure above shows that there can be quite substantial difference in batteries even with the same chemistry. I recommend looking on other plots[2] for different discharge currents to get better understanding about this battery quirk. Some common voltage ranges for batteries are listed in table 1.

Battery type	voltage range [V]
Alkaline	1.6-0.9
Zinc carbon	1.5-0.9
Ni-Cd, Ni-MH	1.3-0.9
Lithium primary bat.	3-2
Lithium accumulator	4.2-2.5

Table 1: Typical battery voltage range from fully charged to fully discharged [1]

This voltage drop is made even more significant when powerful LEDs are in use. LEDs have, same as other diodes, exponential dependency of current on voltage - meaning they are very sensitive to input voltage. Small voltage changes such as 0.2V can be a difference between nominal operation, destruction or significant loss of output power.

For this reason, current limiting resistors are often added in series with the LED. However in battery powered applications, they work against us. At first, they dissipate considerable amount of battery energy. Secondly, they cause a voltage drop, which cannot adopt to decreasing battery voltage, making the LEDs even dimmer as the batteries discharge.

4.2 DCDC converters - the perfect solution

While simplest, resistors are not the only option. If we somehow managed to change the voltage to a stable value, we can power the LED directly without any resistors. There are circuits called switching converters, which can quite efficiently (80-90%) convert from one voltage level to another. The topologies are quite simple, they are available as modules rather cheaply and are often controlled to a specified output voltage. This means they provide specified output voltage independently of the input voltage. Or at least to a point.

The two common topologies are step-up (boost) or step-down (buck) converters. Each topology can **only** increase (boost) or decrease (buck) the voltage. This by itself is a limitation, meaning our desired output voltage cannot intersect the input voltage range at any point (except the edges). There are topologies that can both increase and decrease the voltage such as buck-boost converter topology, but they are quite hard to come-by as a ready made module. Also buck-boost converter has negative output voltage, making it unsuitable for some applications.

Lets now try to design our headlight. We know, that our white LED at full power draws 300 mA and requires 3.4 V. If we were to use step up converter, we can use at maximum 2 AAA cells in series to not intersect input and output voltages. This gives us voltage range of 3-1.8 V. Now we find a problem - none of the commonly available modules can run at only 1.8 V. Most of them require at least 4.5 V and more. (Charge pumps can run from as low as 1V and can step the voltage up, but they cannot handle currents bigger than 100mA usually)

Okay, so lets try the other approach - we will use step down converter. To avoid intersection with input voltage range, we need to use at least 4 AAA cells in series. This gives us voltage range of 6-3.6 V. But we run into the same problem - Most modules require at least 4.5 V to run. If we were to use 5 AAA cells in series, giving us voltage range 7.5-4.5 V, we could make this work. However packing 5 AAA cells into a headlamp is just absurd. Moreover the bigger the voltage difference, the less converters are efficient.

4.3 Conclusion

Wouldn't it be just nice if there were circuits allowing for both step up and down operation, which can work in more battery friendly voltage range? Well, there are ICs such as TPS631000. With its input voltage from 1.65 V, it can run even from 2 discharged AAs (1.8 V). Most lower-power portable applications usually involve MCUs, which often need 3.3, at most 5 V. Even UV LEDs don't need more than 4 V, and small motors can run from 3-5 V. This means that the output voltage limit of 5.3 V is not a problem. Handling 1.5 A of current continuously is more than enough for most applications.

This is why this module needs to exist - be it IoT, be it headlamp, be it a vibrator... simply connect any common battery to the input, set required output voltage, and don't worry about only being able to step the voltage up or down, don't worry about short-circuiting or overheating the module - it will just work.

5 Pinout

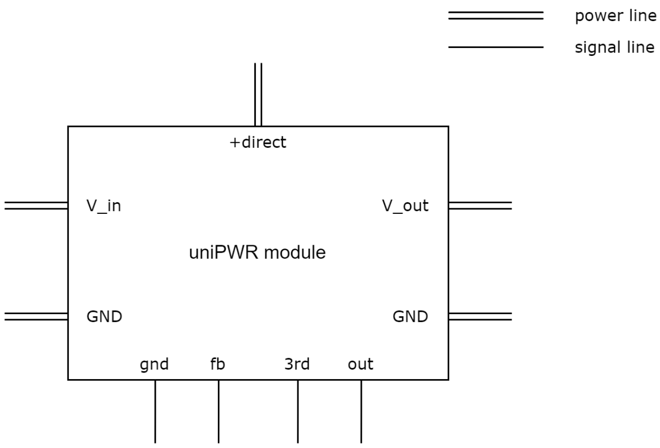

Figure 3: Simplified module pinout

Table 2: Pin functions

Pin name	Function
V_in	Power input, reverse polarity protected
V_out	Power output
GND (both)	Common ground
+direct	Non protected power input, bypasses diode
fb	feedback pin for external feedback network
out	output voltage pin for external feedback network
gnd	ground pin for external feedback network
3rd	unused pin of potentiometer, serves no purpose

6 Specifications

6.1 Absolute maximum ratings

Over operating free-air temperature range (unless otherwise noted)

	MIN	MAX	UNIT
V_in	-30	6	V
+direct	-0.3	6	V
V_out, out, fb (any TPS631000 pin)	-0.3	6	V

6.2 Recommended Operating Conditions

	MIN	TYP	MAX	UNIT
V_in	1.8		5.5	V
+direct	1.65		5.5	V
Continuous output current [1]		1.5	2	A
Inductor current[1]			3	A
Operating junction temperature (TPS631000)	-40		125	°C
Operating inductor temperature	-40		125	°C
Operating capacitor temperature	-40		80	°C

[1] Input or output continuous currents depend on the voltage difference (direction and magnitude). Only current that is truly limited is peak inductor current. Module current throughput won't be higher than the Inductor current limit, but might be lower.

6.3 Thermal Information

Hard to tell, I'd not recommend using the device in environments with elevated temperatures (>60degC) without proper cooling.

Expected temperature rise over the ambient for inductor and capacitors is 10degC under heavy load. Temperature rise of TPS631000 depends on operation mode and is hard to predict.

6.4 Electrical characteristics

	MIN	TYP	MAX	UNIT
V_{FB} - feedback reference voltage	0.495	0.500	0.505	V
Positive-going overvoltage protection threshold voltage. Input and output. Triggers device shutdown, cannot protect from external overvoltage.	5.55	5.75	5.95	V
Positive going undervoltage lockout threshold voltage	1.5	1.55	1.6	V
Negative going undervoltage lockout threshold voltage	1.4	1.45	1.5	V
Switching frequency	1.8	2	2.2	MHz
$R_{FB\text{-}GND}$ - feedback network reistor connecting fb to gnd			100	kΩ

Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.

7 Detailed desribtion

7.1 Overview

This module is a compact size low-loss voltage converter capable of voltage step UP and DOWN for voltages in range of typical battery powered applications. Module is based around TPS631000 IC [4] and derives most of its functionality from this IC. Except for passives required for the IC operation, the module houses custom adjustable feedback network for output voltage selection and diode for reverse polarity protection.

This module features no indication of its operation or error states. This is primarily to minimize power losses for battery powered applications, where power consumption of indicator LEDs can be significant over long term operations. LEDs can be easily added to the board externally by user, for example on the auxiliary pads.

7.2 Schematic

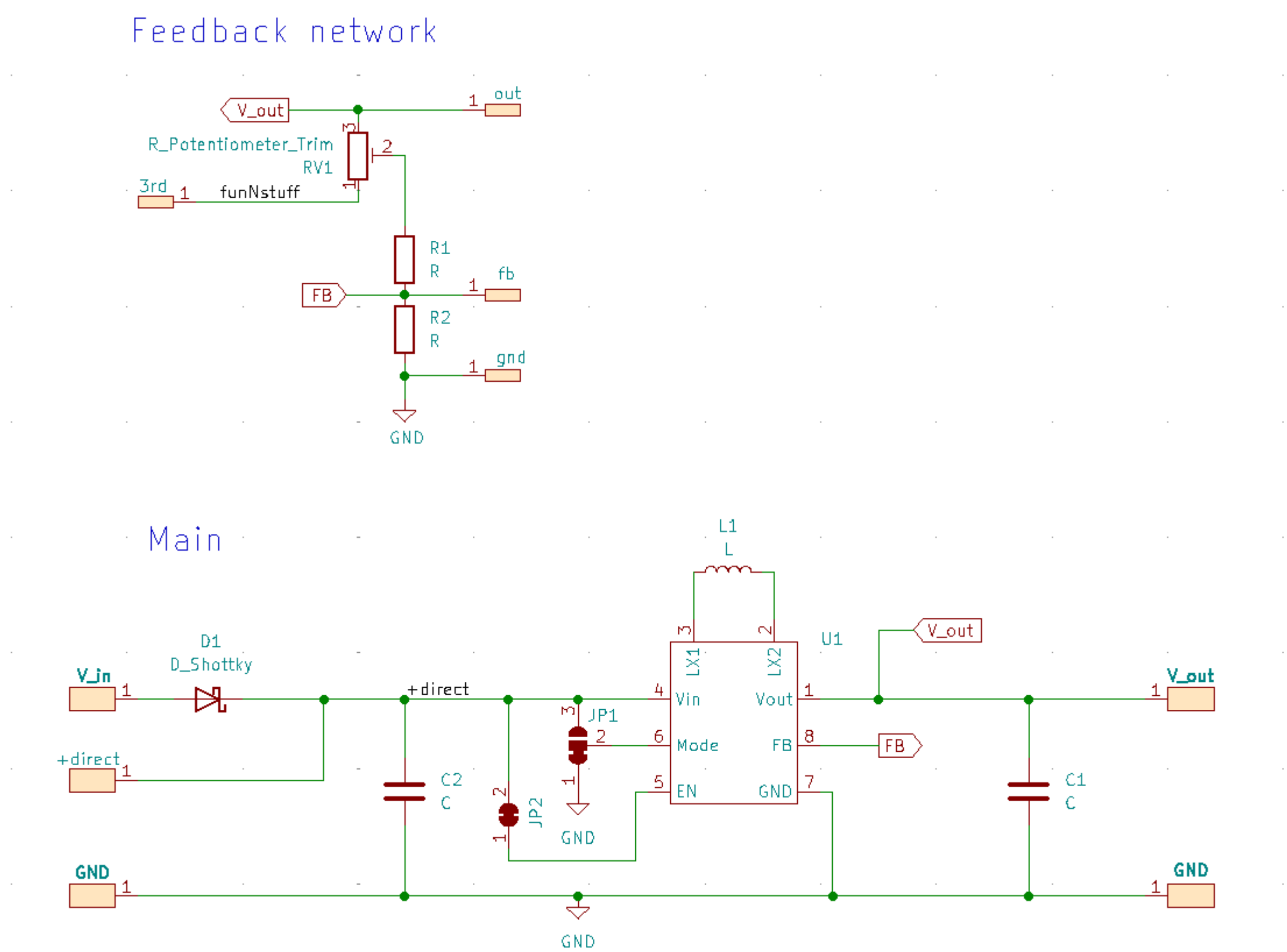

Figure 4: Module electrical schematic

Complete schematic of the module is shown in figure 4. Passives have been chosen in accordance to TPS631000 recommended values specified in datasheet. Great care has been taken to weight both the cost of the components and their quality.

7.2.1 Component list

	Value	Reference
TI, TPS631000DRLR		U1
Murata, GRM32EC81A476KE19L	47 uF	C1
Samsung, CL21A226MPQNNNE	22 uF	C2
Bourns, TC33X-2-504E, Potentiometer	500kΩ	RV1
Stackpole, RMCF0603FT43K0	43 kΩ	R1,R2
Murata, DFE252012F-1R0M=P2	1 uH	L1
Nexperia, PMEG3020EP115, Shottky		D1

7.3 On-board feedback network

To control the output voltage, the TPS631000 requires voltage feedback on its feedback pin. In detail, this voltage is compared with internal reference voltage about 0.5 V. If the feedback pin voltage is higher than the reference voltage, the IC tries to decrease the output voltage and vice versa. This is to say that the feedback network divides the output voltage in a way that it achieves 0.5 V at feedback pin for desired output voltage.

The feedback network has been designed such that it allows the full IC output voltage range despite the 25 % manufacturing tolerance of the potentiometer. For this reason, it is likely that the output voltage range will be mapped to a smaller then full motion range of the potentiometer rotor. This is intentional.

7.4 Protections

The TPS631000 is the most susceptible part to damage in the module. It comes with variety of integrated protections, that make its use more user friendly, but still is not fully protected. As stated before, there is a on-board reverse voltage protection diode. External overvoltage protection was impractical to implement, therefore there is none. Possible implementations are discussed in further section 8.4.

7.4.1 Short circuit protection

The TPS631000 can operate in peak current limit mode, which enables inherent short circuit protection. Simply said, the device allows a maximal inductor current flow of about 3A. In case of output short circuit condition, the current is therefore limited to 3A, without any damage to the device.

7.4.2 Overheat protection

The TPS631000 has internal temperature sensor, that will shut the device down if its temperature reaches a shutdown threshold (exact value is unknown). The device will resume normal operation once it cools down enough, exhibiting hysteresis.

7.4.3 Overvoltage protection

The TPS631000 has integrated overvoltage protection, that shuts the device down, when either input or output reach a overvoltage protection threshold. The device will resume normal operation after the voltage drops bellow another threshold, again exhibiting hysteresis.

It is important to note that this form of protection protects the device only from itself - meaning that even in case of open output, the device won't destroy itself by means of stepping the output voltage up. However this cannot protect the device from external overvoltage, which can damage the device, even when its shut down.

7.4.4 Input reverse polarity protection diode

To protect the TPS631000 from reverse polarity (mistakes such as connecting Vin to 0V and GND to positive voltage: battery reversal), there is external shottky diode, which gets forward biased under normal operation and has the input current flowing through it.

This sadly is not ideal, yet the only practical solution for battery powered applications. Diode is the simplest and very robust way of protecting against reverse polarity. However diodes exhibit a forward voltage drop when current flows through them. This voltage is about 0.7 V for normal diodes and about 0.3 V for shottky diodes.

Since electrical power is linearly dependent on voltage drop (assuming single current path - therefore same current for all power consumers), in battery powered applications, where voltages are low, the diode voltage drop becomes significant loss of power and energy. For example, in case of 3 AA batteries in series, normal diode (0.7 V) will consume 15% of total battery power, assuming the battery voltage does not drop, or about 21% if we assume linear voltage drop of the AA cells. For 2 AA cells this would be 31% assuming linear voltage drop.

Luckily there are shottky diodes, which have lower forward voltage, about 0.2-0.5 V depending on the current. Assuming 0.3 V drop, this leaves us with 9% voltage drop in the 3 AA case and 13% voltage drop in 2 AA case, assuming linear cell voltage drop as they discharge in both cases.

To minimize the energy loss due to protection diode, a rather well performing diode was selected, the PMEG3020EP115 [3]. This diode has very low forward voltages for the current applications the module is expected to handle, see figure 5.

For higher currents, the voltage drop is to be expected around 0.28 V for 1 A of 0.32 V for 2 A, for lower currents the voltage drop will be <0.2 V for current smaller than 100 mA. If higher currents are persistent, the diode will heat up and decrease its voltage drop slightly.

To avoid losses, the diode can be bypassed by powering the device from `+direct` pad. This however means that the TPS631000 is no longer protected against reverse polarity.

7.4.5 Output protections, or rather the lack of them

It is possible to damage the device by connecting wrong voltages to the output as well. The device can handle reverse currents, so it could be operated with output and input side switched, however there is no reverse polarity protection on the output side of the module. This means that applying negative voltage to the output side will likely damage the device. Applying too high of a voltage to the output externally will also damage the device.

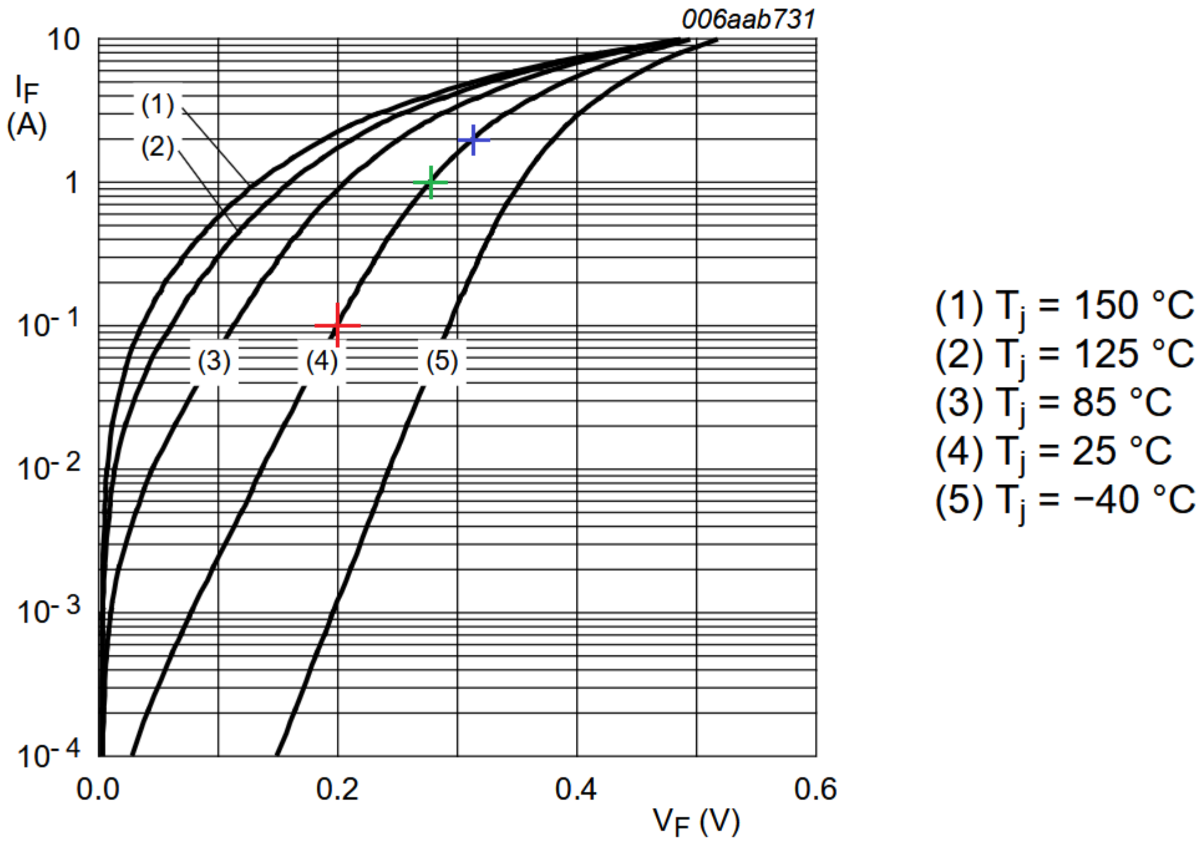

Figure 5: Reverse polarity protection diode forward VI characteristic [3]

7.5 Voltage conversion

From the converter topology point of view, the TPS631000 internally contains H-bridge performing similar task as full active bridge, but only with common ground. This means that the IC can seamlessly switch between operation modes (step up/down) without disturbing the output.

The IC can operate in two switching modes: Pulse Frequency Modulation (PFM) and Pulse Width Modulation (PWM). PFM is more efficient for light loads, where PWM can handle more power and decreases output voltage ripple. Using the IC `mode` pin, one can choose between *auto PFM* and *FPWM* modes.

In *auto PFM* mode, the IC will automatically choose between PFM and PWM switching mode, depending on the current requirements.

In *FPWM* mode, the IC is Forced to operate in PWM mode regardless of current requirements.

UNI PWR module has the *auto PFM* mode enabled by default, as it is more efficient. This choice can be altered by cutting a track and soldering solder jumper on the back side of the device.

7.6 Other features

7.6.1 Undervoltage lockout

The TPS631000 features undervoltage lockout. When input voltage drops bellow undervoltage lockout threshold voltage, the device stops switching, to protect itself from brownout. When input voltage rises above a positive going UVLO threshold, the device resumes normal operation, again exhibiting some hysteresis.

7.6.2 Reverse current operation

The TPS631000 supports reverse current operation - current flow from output to input. Device will automatically do this, when the feedback pin voltage is higher than the reference voltage.

8 Application and implementation

UNI Power module is high-efficiency voltage conversion module well suited for battery powered applications, both low and medium power.

8.1 Typical application

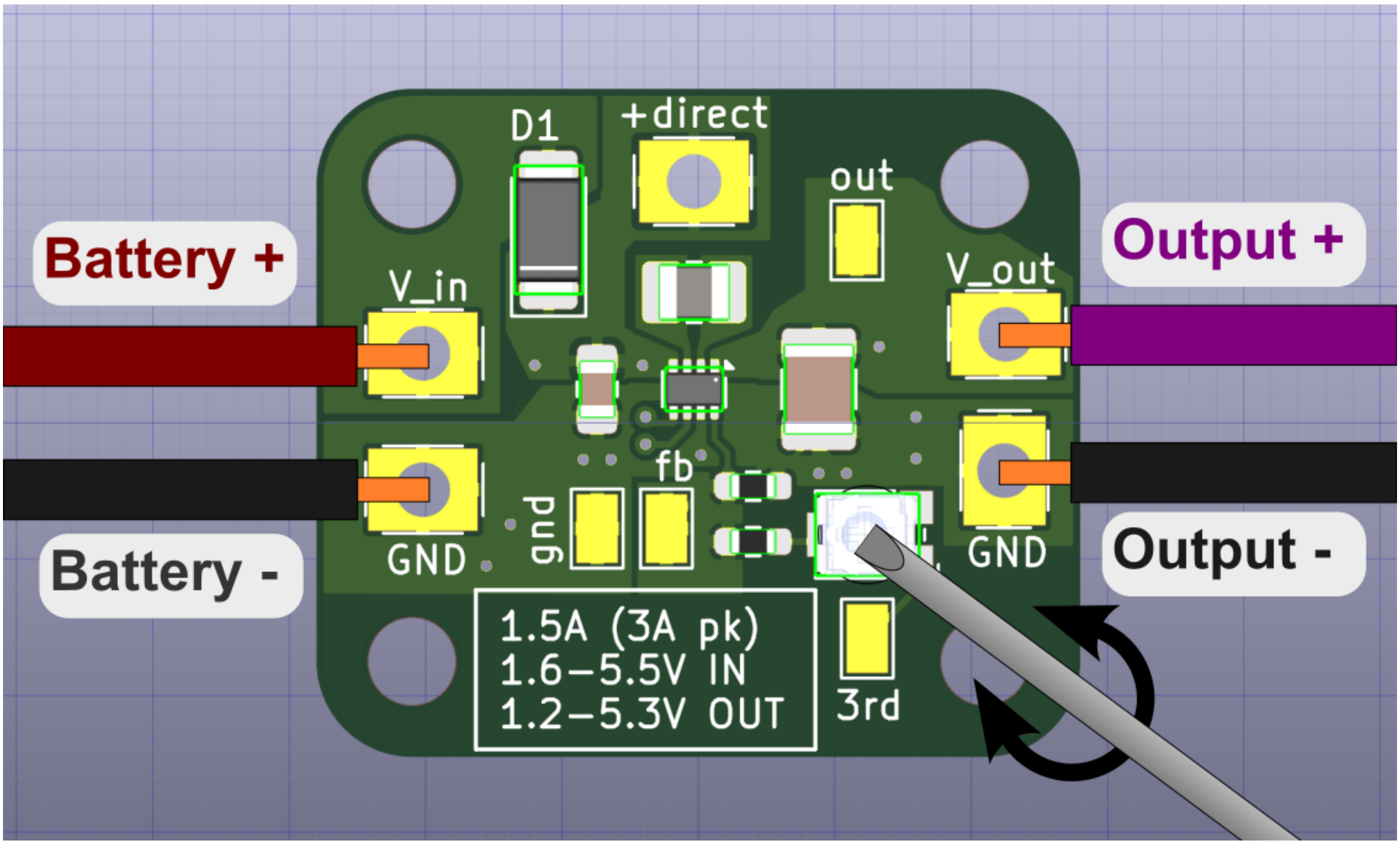

Figure 6: Typical module application

Figure 6 shows typical use of the module - to provide adjustable constant output voltage from compatible battery power source. In this configuration, the module input is protected with reverse polarity diode. Required output voltage is adjusted by turning the potentiometer, as shown in said figure.

To set the required output voltage, do not connect any significant load to the output and measure its voltage with external voltmeter. Turn the potentiometer until desired voltage is set. You can power down the module, the voltage won't change until the potentiometer is turned again.

Take care to not attach output to your load without setting the output voltage first, as it might damage your load.

8.2 Advanced application - external feedback network

Returning to the headlamp application, one might desire a dimmable LED. This can be already achieved by turning the on-board potentiometer, but fesability of this approach shall be disputed, especially in cases where the board is protected in a case.

Solution is an external (off-board) feedback network, where the potentiometer is made accessible in a panel for example, where the module itself is hidden and protected from elements and mice.

The simplest approach is to design resistor divider same way as "Feedback network" shown in figure 4. This network consists of a potentiometer - variable resistance RV1, offset resistor R1 and multiplying resistor R2.

Such feedback network is just a resistive voltage divider, whichs output voltage is guided by formula 1.

$$V_{\mathrm{FB}} = V_{out} \cdot \frac{R_{\mathrm{R2}}}{R_{\mathrm{RV1}} + R_{\mathrm{R1}} + R_{\mathrm{R2}}} = V_{out} \cdot \frac{R_{\mathrm{R2}}}{R_{total}} \tag{1}$$

where V_{FB} = divider output voltage (feedback pin voltage) [V]
V_{out} = divider input voltage (module output voltage) [V]
R_{RV1} = Potentiometer resistance [Ω]
R_{R1} = R1 resistance [Ω]
R_{R2} = R2 resistance [Ω]

We know that the TPS631000 will do everything in its power to keep its feedback pin voltage at $V_{\mathrm{FB}} = 0.5V$. This allows us to rewrite equation 1 such that we solve for output voltage, which however won't help us yet.

8.2.1 Define your design parameters

At this point you need to know what voltages does your load require. In our example we desire range of 2.7 - 3.4 V. Design parameters are shown in table 3.

User defined parameter	value	Circuit characteristics	value
Output voltage low	2.7 V	Feedback voltage	0.5 V
Output voltage high	3.4 V	Maximal R2 value	100 kΩ

Table 3: Design parameters

We now have 2 sets of 2 known values, but the equation 1 still has 3 unknown variables. To make the system solvable, we need to define one more value. I'd recommend defining R2. We can use the R2 already soldered to module, which is $R_{\mathrm{R2}} = 43$ kΩ.

This gives us 2 sets of 3 known values, enough to solve equation with 5 variables.

8.2.2 Calculate required resistances

As said before and visible in eq. 1, output and feedback voltage ratio depends on resistance ratio. Most intuitive approach of calculating the required resistances begins with calculating required divider ratios, as shown in eq. 2

$$\begin{aligned} a_{\mathrm{min}} &= \frac{V_{\mathrm{OVL}}}{V_{\mathrm{FB}}} = \frac{2.7}{0.5} = 5.4 \\ a_{\mathrm{max}} &= \frac{V_{\mathrm{OVH}}}{V_{\mathrm{FB}}} = \frac{3.4}{0.5} = 6.8 \end{aligned} \tag{2}$$

Since we already know R2, we can calculate the required $R_{\mathrm{R1}} + R_{\mathrm{RV1}}$ sum R_T, see eq. 3, 4.

$$\begin{aligned} \frac{V_{out}}{V_{\mathrm{FB}}} = a &= \frac{R_{\mathrm{RV1}} + R_{\mathrm{R1}} + R_{\mathrm{R2}}}{R_{\mathrm{R2}}} \\ aR_{\mathrm{R2}} &= R_{\mathrm{RV1}} + R_{\mathrm{R1}} + R_{\mathrm{R2}} \\ R_{\mathrm{R2}}(a-1) &= R_{\mathrm{RV1}} + R_{\mathrm{R1}} = R_T \end{aligned} \tag{3}$$

$$
\begin{aligned}
R_{T\_\text{min}} &= R_{\text{R2}}(a_{\text{min}} - 1) = 43 \cdot (5.4 - 1) = 189\ \text{k}\Omega \\
R_{T\_\text{max}} &= R_{\text{R2}}(a_{\text{max}} - 1) = 43 \cdot (6.8 - 1) = 249\ \text{k}\Omega
\end{aligned} \tag{4}
$$

We can now get minimal resistance and resistance change, eq. 5. Minimal resistance will be always present in form of offset resistor R1 and resistance change will be accomplished by potentiometer RV1. We assume that minimal resistance of potentiometer is $R_{\text{RV1\_min}} = 0$

$$
\begin{aligned}
\Delta R_T &= R_{T\_\text{max}} - R_{T\_\text{min}} = 249 - 189 = 60\ \text{k}\Omega \\
R_{\text{RV1\_max}} &= \Delta R_T = 60\ \text{k}\Omega \\
R_{\text{R1}} &= R_{T\_\text{min}} = 189\ \text{k}\Omega
\end{aligned} \tag{5}
$$

Resulting values would work, sadly potentiometers only come in few values, so we won't find a 60 kΩ potentiometer. Closest common value is 50 kΩ. We can either live with the fact that we won't get the full output voltage range, or we can recalculate the remaining resistors to get full voltage range with known RV1 instead. We know that $R_{\text{RV1\_max}} = 50\ \text{k}\Omega$, $R_{\text{RV1\_min}} = 0\ \Omega$. See equations 6, 7.

$$
\begin{aligned}
R_{\text{R1}} &= R_{\text{R2}}(a_{\text{min}} - 1) - R_{\text{RV1\_min}} \\
R_{\text{R1}} &= R_{\text{R2}}(a_{\text{max}} - 1) - R_{\text{RV1\_max}} \\
\\
R_{\text{R2}}(a_{\text{min}} - 1) - R_{\text{RV1\_min}} &= R_{\text{R2}}(a_{\text{max}} - 1) - R_{\text{RV1\_max}} \\
(a_{\text{max}} - a_{\text{min}})R_{\text{R2}} &= R_{\text{RV1\_max}} - R_{\text{RV1\_min}} \\
R_{\text{R2}} &= \frac{R_{\text{RV1\_max}} - R_{\text{RV1\_min}}}{a_{\text{max}} - a_{\text{min}}}
\end{aligned} \tag{6}
$$

$$
\begin{aligned}
R_{\text{R2}} &= \frac{R_{\text{RV1\_max}} - R_{\text{RV1\_min}}}{a_{\text{max}} - a_{\text{min}}} = \frac{50}{6.8 - 5.4} = 35.7\ \text{k}\Omega \\
R_{\text{R1}} &= R_{\text{R2}}(a_{\text{min}} - 1) - R_{\text{RV1\_min}} = 35.7 \cdot 4.4 - 0 = 157\ \text{k}\Omega
\end{aligned} \tag{7}
$$

8.2.3 Verify calculated resistances

We can verify the previous results using equation 8. The results match the design parameters well and we've kept the $R_{\text{R2}} \leq 100\ \text{k}\Omega$ Resistors themselves are also made only in common values, so small, but negligible deviation from specified voltage is to be expected. Resistor tolerance should also be considered.

I'm also providing a link for online circuit simulator by Falstad, where the resistance divider can be tested in powering the 1W LED aproximation, see link.

$$
\begin{aligned}
V_{\text{OVL}} &= V_{\text{FB}} \cdot \frac{R_{\text{RV1\_min}} + R_{\text{R1}} + R_{\text{R2}}}{R_{\text{R2}}} = 0.5 \cdot \frac{0 + 157 + 35.7}{35.7} \doteq 2.70\ \text{V} \\
V_{\text{OVH}} &= V_{\text{FB}} \cdot \frac{R_{\text{RV1\_max}} + R_{\text{R1}} + R_{\text{R2}}}{R_{\text{R2}}} = 0.5 \cdot \frac{50 + 157 + 35.7}{35.7} \doteq 3.40\ \text{V}
\end{aligned} \tag{8}
$$

8.2.4 Attaching external feedback network

Module was designed such that the external feedback network can be easily attached. There are smaller "signal" pads exposed for wire connections. Wires can be easily soldered to these pads, allowing for external components to be attached.

It is unlikely that anyone will design the feedback circuit such that it has two dividers in parallel. Therefore, the original on-board network must be disconnected. Easiest way to do so, is to de-solder R1 and R2, leaving the potentiometer untouched but disconnected. This is shown figure 7.

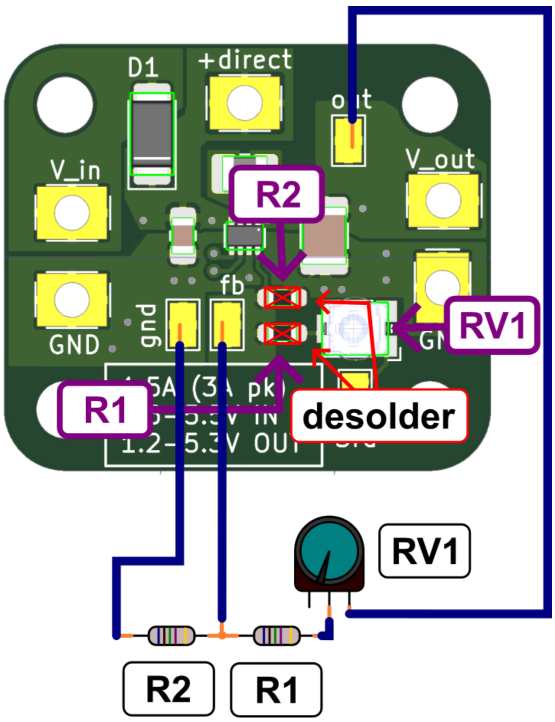

Figure 7: Spektra vibrací na ose X pro oba ventilátory

8.2.5 Control loop stability with external feedback network

Extending the feedback network away from board could in some cases worsen the quality of output voltage control due to parasitic inductance of wires. This would worsen transient response of the voltage control loop and could in extreme cases make the controller unstable. To be explicit, unstable control loop means that the module would not be usable at all.

To prevent control loop instability, additional capacitor between ground and feedback pin (parallel to R2) could be added. This will further worsen the transient response of the loop, making it slower to react to voltage changes, but the output will be stable. Exact required value of the capacitor is hard to estimate. The time constant of the RC circuit created by the capacitor and R1 + RV1 should give a decent hint on how fast will the control loop react.

It is quite that this intervention will not be required and therefore should be only done so after the instability is observed. The TPS631000 has internal protections that should protect the device from destruction in case of instability.

8.3 Combining with lithium accumulators and charge modules

Small and cheap lithium accumulators are quite common, and some, like the ones in single-use e-cigarettes, are basically waste product waiting to be used.

At the same time, Li-acc are very well preforming form of energy source and there are little downsides to their use. If used correctly.

Luckily there exists "Li battery charging modules" such as TP4056 based modules, which allow user to easily charge Li-acc with USB phone chargers, while providing protections against overvoltage and overcurrent. Most of them also provide overdischarge protection and limit the drained current from the batteries, thanks to ICs such as DW01A.

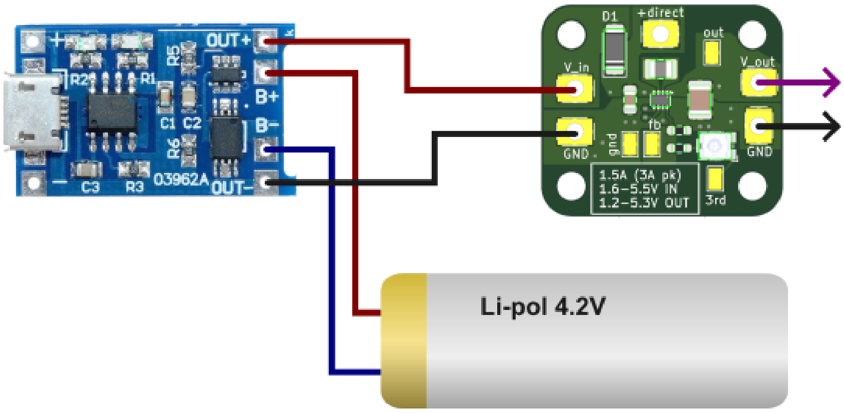

Figure 8: Combining charging module, Li-acc and uniPWR module

Such module can be then very easily connected with both the Li-acc and uniPWR module, as shown in figure 8. This creates a system, that has most of the features Li-acc needs for correct and handy use. Features are listed in table 4. Features might differ between module types. Also it is not really possible to name these cheap modules, thats why I'm not declaring one.

If you are interested in making a power bank with USB output, there might be ready made cheap modules with step-up converters for powering 5V USB. However these can only step the voltage up, and the output voltage is not variable.

Table 4: Features provided by exemplary charge module and uniPWR module

State	Feature	charge module	uniPWR module
Charging	Common power input interface	✓	-
	Li-acc overvoltage protection	✓	-
	Li-acc charge current limit	✓	-
	Li-acc overheat protection	✗	-
Discharging	Short circuit protection	✓	✓
	Li-acc overdischarge protection	✓	✗
	Variable output voltage	✗	✓

8.4 External overvoltage protection

I'm sorry I cant keep wasting time with this datasheet, just figure it out. The polyfuse and thyristor (SRC) approach is a dead-end, as you need to dump a lot of current for the polyfuses to close them (1s closing time @ 8A current). Now at first, the batteries cannot provide 8A. Except maybe for the Li-accs. Short circuit of normal AAs is around 3A, which might just be able to close the polyfuse, but not guaranteed to do so at all. Or you can pick a polyfuse with lesser current rating, but that would limit the capability of the module. Also polyfuses obviously have smaller no-latch currents when heated, so now the circuit might handle even less current when lukewarm.

Even if so, you need a thyristor to crowbar the circuit and latch the polyfuse. Thyristors that can handle 8 amps for a second are big. Like not a cinder block but TO-220. And expensive. For some fucking reason, like cmon its the dumbest of the switching elements.

You could use a single-use burnable fuses, but that's like really annoying, so don't.

The actual valid approach is to get a logic level Pmos or something and disconnect the power input in case of overvoltage. Or there are nice ICs acting as e-fuses which can handle overvoltage protection. But they can be pain in ass to solder.

Anyway if you limit yourself to using the correct amount of batteries or just USB power, you wont overvolt this module.

9 Mechanical

Module dimensions are shown in figure 9. Module has 4 holes in its corners for M3 machine screws (5.5mm head diameter). Additionaly, all power connections have a 2mm hole and have 5mm pitch. 5mm pitch allows you to use common screw terminals. 2mm hole is bit oversized for screw terminals, but makes it easy to attach wires.

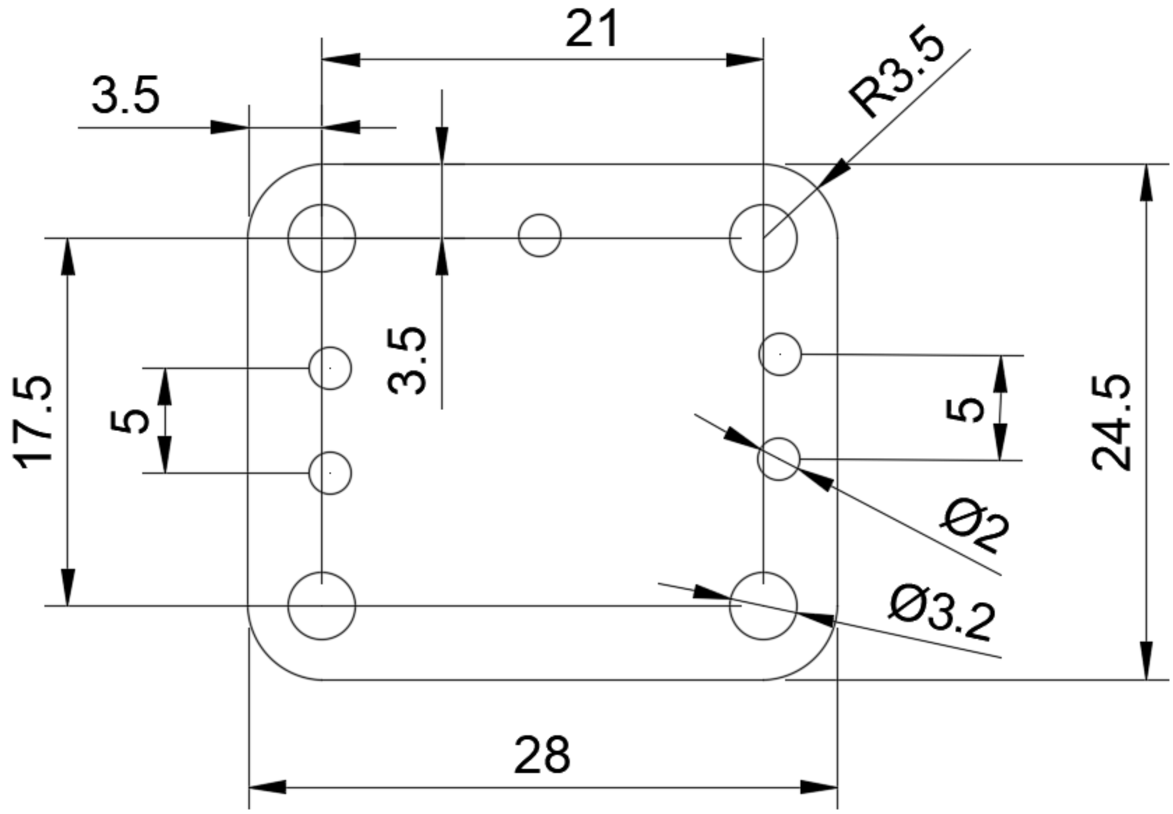

Figure 9: Module drawing

IMPRESSUM

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References

[1] *Comparison of commercial battery types*. Wikipedia. Available from: https://en.wikipedia.org/wiki/Comparison_of_commercial_battery_types

[2] *Discharge tests of AA Batteries, Alkaline and NiMH*. PowerStream, web page, thank good for this man and his webpage, this is so hard to come by. Available from: https://www.powerstream.com/AA-tests.htm

[3] *PMEG3020EP*. Nexperia, datasheet. Available from: https://assets.nexperia.com/documents/data-sheet/PMEG3020EP.pdf

[4] *TPS631000*. Texas Instruments, datasheet. Available from: https://www.ti.com/lit/ds/symlink/tps631000.pdf