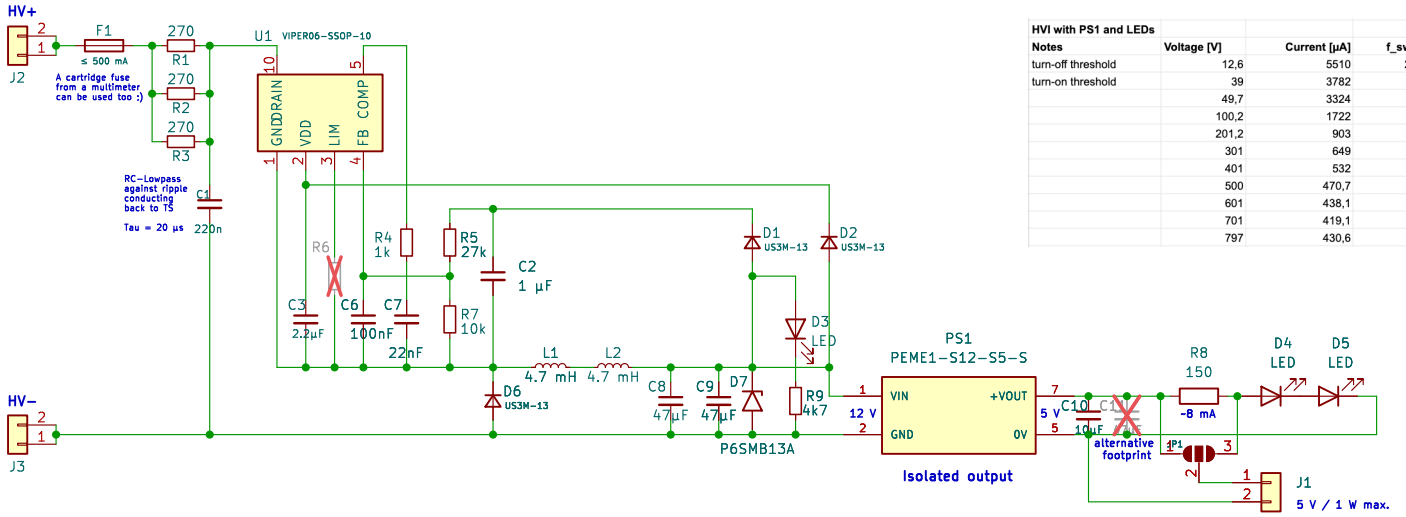
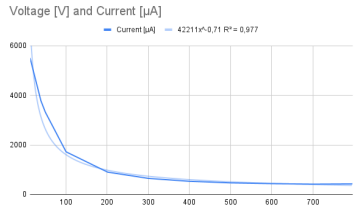
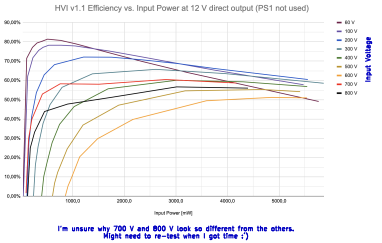
Buck converter using VIPER06
800V -> 5V/12V



HVI with PS1 and LEDs				
Notes	**Voltage [V]**	**Current [µA]**	**f_sw [Hz]**	**P_in [mW]**
turn-off threshold	12,6	5510	29700	69,4
turn-on threshold	39	3782	708	147,5
	49,7	3324	1815	165,2
	100,2	1722	5810	172,5
	201,2	903	6200	181,7
	301	649	5940	195,3
	401	532	5767	213,3
	500	470,7	5733	235,4
	601	438,1	5740	263,3
	701	419,1	5525	293,8
	797	430,6	5229	343,2





I'm unsure why 700 V and 800 V look so different from the others.
Might need to re-test when I got time :)

The HVI (High Voltage Indicator) is used to indicate voltages above 60 V for installation in the TSAC.
The design shown here should comply with FS-Rules, but I'm only sure after it has passed FSG scrutineering :D
Edit: It passed scrut!.

Layout:
The design uses the VIPER06 as a self-oscillating and self-regulating highside-switch, which corresponds to the overall topology of a buck converter.
In order to keep the design compact, the 60 V detection was omitted. This complies with FS-Rules, as the indicator light must light up at 60 V and above, but may also light up at lower voltages. In this case, this is already the case from approx. 40 V.
Galvanic isolation can theoretically be dispensed when mounted with an isolating housing and viewing window.
However, as galvanic isolation is useful in many cases, it was implemented by using an small isolating DC/DC converter (3kV isolation rating).
The back of the circuit board is designed so that the LEDs do not require touch protection, as no dangerous voltage is present (isolated by PCB).
However, all THT components on the back must be covered.
Alternatively, the circuit board can be placed anywhere in the TSAC and an LED can be attached to the housing via the external output (1 W max.).
If the included 1 W DC/DC is not used, approx. 3 W can be drawn directly (unisolated!) at 12 V.

Important: Do not forget to isolate the board with Plastik70 after soldering (necessary due to isolation distances (EV 4.3.6 Table 5 Conformal Coating).

FS-Rules 2024 v1.1 / Source: https://www.formulastudent.de/fsg/rules/

T1.3.1 Direct Connection – two devices or circuits are directly connected if the connection is not routed through any common PCB and does not include any devices or functionality other than overcurrent protection or connectors.

EV 1.2.1 Galvanic isolation – two electric circuits are defined as galvanically isolated if all of the following conditions are true:
- The resistance between both circuits is ≥500 Ω/V, related to the maximum TS voltage of the vehicle, at a test voltage of maximum TS voltage or 250 V, whichever is higher.
- The isolation test voltage RMS, AC for 1 min, between both circuits is higher than three times the maximum TS voltage or 750 V, whichever is higher.
- The working voltage of the isolation barrier, if specified in the datasheet, is higher than the maximum TS voltage.

EV 5.4.8 Each TSAC must have a prominent indicator, a voltmeter, or a red LED visible even in bright sunlight that will illuminate whenever a voltage greater than 60 V DC or half the maximum TS voltage, whichever is lower, is present at the vehicle side of the AIRs.

EV 5.4.9 The indicator must be clearly visible while disconnecting the TSAC from the vehicles. The indicator must be clearly marked with "Voltage Indicator"

EV 5.4.10 The indicator must be hard-wired electronics without software control, directly and only supplied by from the LVS or removed from the vehicle.
the TS from the vehicle side of the AIRs, and always working, even if the accumulator is disconnected

EV 4.3.6 If TS and LVS are on the same PCB, they must be on separate well-defined areas of the board, meeting the spacing requirements in table 5, each area clearly marked with "TS" or "LV".
The outline of the area required for spacing must be marked. "Conformal coating" refers to a coating insulator, solder resist is not a coating.
Table 5: Spacing required between TS and LV -> 300 V DC to 600 V DC: 4.0 mm with conformal coating.

EV 4.3.7 Teams must be prepared to demonstrate spacing on team-built equipment. For inaccessible circuitry, fully assembled spare boards must be available.

Important note: The minimum switch-on time for most VIPER ICs is 400 ns.
If the inductance (L1+L2) is too small, the current rise in these 400 ns will be too high and damage the IC.

L_400ns = (U_in * 400 ns) / L

U_in = 600V
L = 9.4 mH

-> I_400ns = 25.5 mA

The drain current limit for the VIPER06 is 350 mA -> 9.4 mH is OK.

The VIPER06 IC comes in three different switching frequency versions:
VIPER06Xx = 30 kHz
VIPER06Lx = 60 kHz
VIPER06Hx = 115 kHz

I reccommend using the 30 kHz version, since it uses the fewest power and increases overall efficiency.
This version was hardly avialable in the past, but seem to be ok now (2024).
The other versions can be used too, but may cause audible noise in burst mode.
Burst operation also occurs with the 30 kHz version, depending on the load.

Note on capacitors:
Some values appear quite large, but bear in mind that the capacitance of MLCCs is strongly influenced by the applied voltage.
Depending on the manufacturer and series, the capacitance can drop by up to -90%. Check their resources!
(Google the part number of the MLCC manufacturer and go to their website. It often contains nice diagrams :)

Note on the LTSpice simulation:
See "Doc" folder. The VIPER11 is used because I could not find a Viper06 model.
Important: The feedback reference voltage (U_fb) for the VIPER06 is 3.3 V instead of 1.2 V (VIPER11). Adjust accordingly!
The VIPER11 also "features" a max. duty cycle counter protection, which causes a 1 second restart cycle on low input voltages at 12V output, but not with 5V (when used with low precharge current, see LTSpice Notes). Unless tested otherwise.
5V and 12V output should be possible with the VIPER06. Do not forget to choose a Zener Diode approx. 1V above output voltage to avoid output voltage run away in no-load condition. Also choose the DC/DC (PS1) accordingly to you output voltage.

Set output Voltage:
U_out = U_fb * (1 + R5 / R7) - U_D1_forward_voltage

FAQ:

Q: Why are 2x 4.7 mH inductors used instead of a 10 mH inductor?
A: You will rarely find maximum voltage values for SMD inductors, so just an extra precaution.

Q: Why is there no output fuse?
A: The VIPER06 can be short-circuited indefinitely.

Q: I need [insert voltage here], can I do that?
A: You can either change PS1 (12 V to 3.3 V to 24 V converters available)
or (when used directly without PS1) the feedback voltage divider can be altered.
I do not reccomend going above 23.5 V because the IC's VDD voltage will be clamped,
which could lead to high losses or destruction of the IC. Going below 11.5 V
will use the internal high-voltage generator as IC's VDD supply (higher losses).
So ideally, stay between 12 V and 23 V.

Q: Where do I get a cheap high voltage source for testing?
A: I have been using one for 10€ from amazon for many years, which can generate up to
800 V (when both ~+400 V rails are used) from a 8 to 32 V source (15 V delivers most power).
If you want to support me, you can use my affiliate link where I get a small commission
when a purchase is made: https://amzn.to/3TRJJlf
In the docs there is an additional folder 'HV Source' for a 3D-printed case which also
uses a rotary potentiometer instead of the trim pot.

Q: I need more Power!
A: A smaller inductor value could help, but be aware that the minimum on-time is 400 ns.
At high input voltages this could lead to overcurrent when using small inductro values.

Q: Why is the text "Voltage Indicator", "Designed by XXX" and "HVI vX.X" not editable?
A: I like to use a font (Futured) for visuals which is not pre-installed on most systems.
Importing it as a logo is easier to retain it.

Q: This is open source. Can I modify it? Can I sell it?
A: Sure! But please use your own version numbering and change "Designed by Rootthecause"
to "Designed by [Your Name] based on a design by Rootthecause".
As this is licensed under CeRN OHL v2 Weakly Reciprocal, you must disclose the source,
state changes and use the same license if used for non private projects.
Learn more about this here: https://choosealicense.com/licenses/cern-ohl-w-2.0/

Q: I've got a question not listed here, can I contact you?
A: Please use the issues form on GitHub for techical related questions.

Q: Is there a way to support your projects?
A: Yes: https://ko-fi.com/rootthecause

Sheet: /		
File: HVI.kicad_sch		
Title: HVI v1.1 Designed by Rootthecause		
Size: A4	Date: 2024-10-05	**Rev:**
KiCad E.D.A. 8.0.5		Id: 1/1