Design of a simple diversion charge controller : Monthly report

WindEmpowerment

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Two months after the beginning of the project, this report relate the project progress. The selection of the technical analogic solution and the design of the analogic circuit have already been done. What is left is the PCB design, the test of the analogic design and the shipping of a prototype to members taking part in the project for testing. The second phase would be to improve the design and also develop a solution using a micro-controller.

1 Selection of the technical solution

The solution we are using is similar in function to the design of the *Tristar*, sold by the *Morningstar Corporation* and the *C40* sold by *Xantrex*. It uses a Pulse Width Modulation (PWM) to regulate the voltage. When the voltage of the DC bus reaches a maximum, some of the energy is transferred to a dump load. The dump load is connected to the battery only during a short period of time at a frequency of 300 Hz. As a result, the wind turbine needs to produce more current and the dump load acts like a brake. The voltage is therefore regulated at a predefined value. On the figure 1, we can see a simulation of the response of the circuit to a voltage higher than the reference. The pink curve is the battery voltage and the blue curve is the output signal which pilot the mosfet transistors. When the voltage is higher than the reference, the duty cycle of the PWM starts growing until it is high enough to stabilize the value of the voltage around the reference voltage.
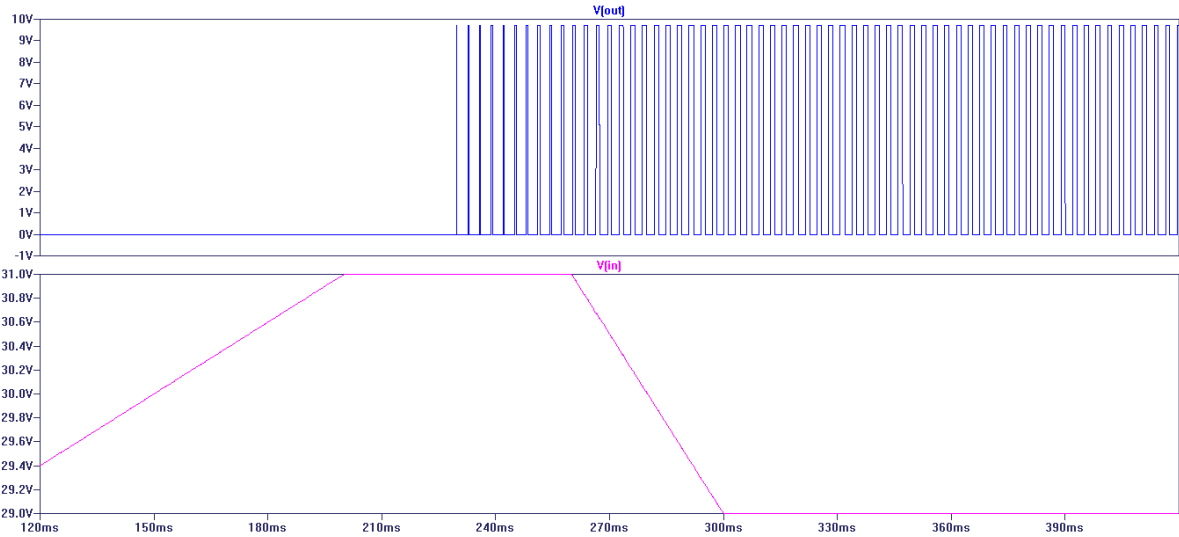
Figure 1: Simulation of the response of the circuit
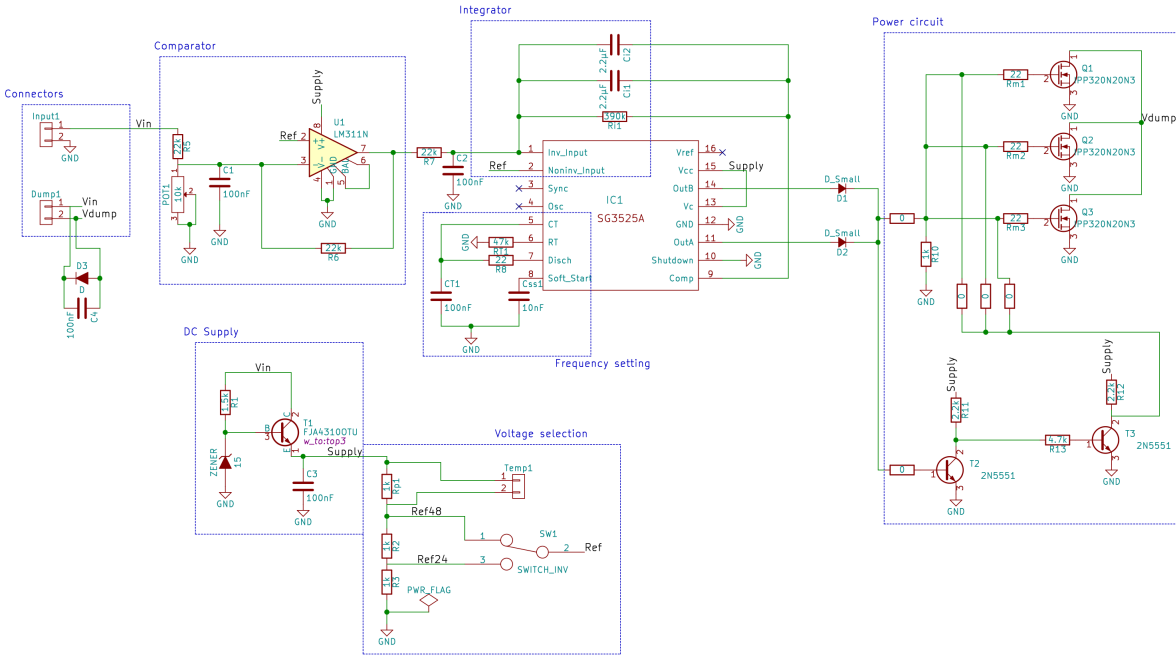
2 Design of the circuit

Figure 2: Detailed schematics of the circuit

The complete circuit is shown in figure 2. It uses a Integrated Circuit

which drive the PWM : the SG3525. It is a wide used integrated circuit, first designed by *Texas Instrument* and now by many other manufacturers. A small documentation on how to use the SG3525 can be found on this blog.
The overall circuit can be divided into 5 parts.
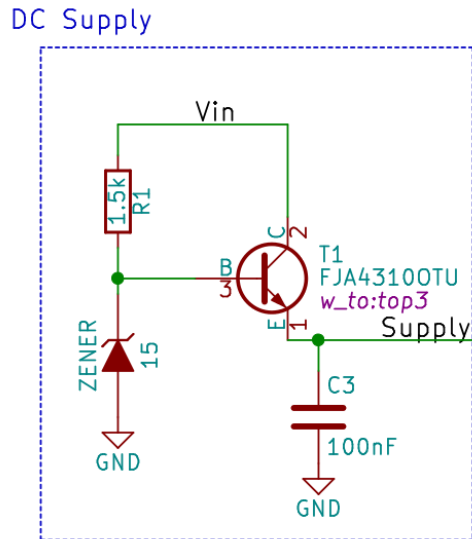
2.1   DC supply

Figure 3: Schematics of the DC supply part

The DC supply is used to power some components such as the Op Amp and the SG3525 and is also used to give a reference for the voltage measurement. The input is the output of the diode bridge on which the wind turbine is directly plugged and the output gives a stabilized voltage of 15 V. It can work with a input from 20 V to 100 V and gives a maximum of 200 mA.

2.2   Voltage selection

The voltage selection module aims to select the voltage reference we are using. The reference is given by a simple voltage divider. It gives a voltage of 10 Volts for the 48 V mode and 5 Volts for the 24 V mode. For now we decided to stick to a regulator which is only working in 24 V and 48 V because the supply we use gives 15 V and therefore cannot be used with a voltage reference of 14.5 V for the battery. However, we will be able to
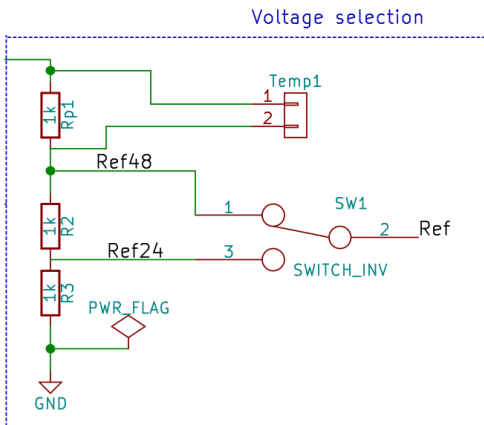
Figure 4: Schematics of the voltage selection part

change the design to work with a 12 V battery secondly.

We added a terminal block in order to add a Platinum sensor probe to adapt the voltage reference to the room temperature. The aim is to change the value of the voltage reference by 3 mV/°C/cell. We have not tested this feature yet but we have good results with the simulation. The user will be able to use the temperature sensor or to keep a fixed reference permanently.
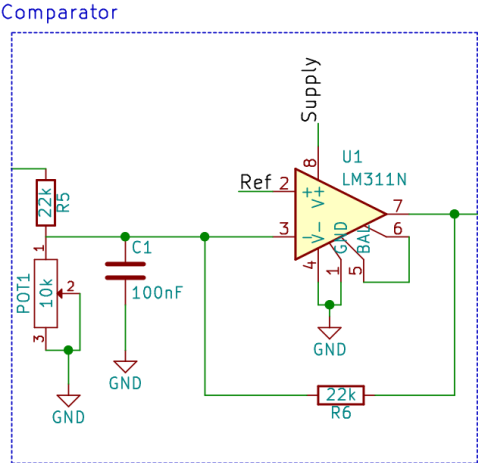
2.3 Comparator

Figure 5: Schematics of the comparator part

The first part of the signal processing is a comparator which uses an

operational amplifier to compare the battery voltage with our reference. A trimmer enable a fine setting of the reference. The output of this stage is a voltage higher than V_{Ref} if the battery voltage is lower than the reference and lower than V_{Ref} if the voltage is higher than the reference as seen on figure 6.
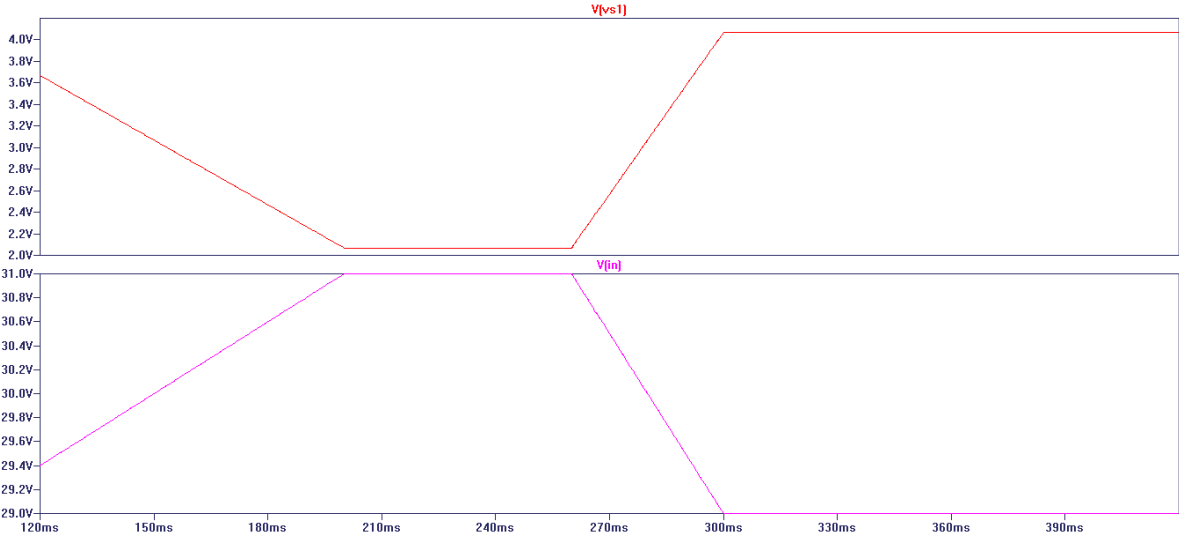

Figure 6: Simulation of the output of the comparator stage (in red) compared to the battery voltage (in pink) for a voltage reference of 29 V and where V_{Ref}=4 V
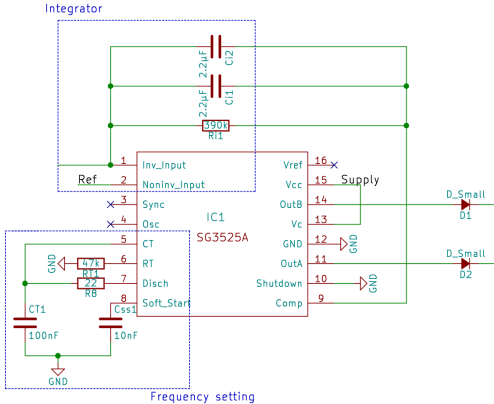
2.4   SG3525 driver

Figure 7: Schematics of the SG3525 driver

We need to integrate the signal in order to keep increasing the duty cycle of the PWM if the voltage stay higher than the reference. Moreover, if the voltage stabilizes at the value of the reference, the duty cycle need to remain constant. We use an inverting integrator with the Op Amp contained in the SG3525 as we can see on figure 8.

An overview of the output of this second stage is shown in figure 9.The
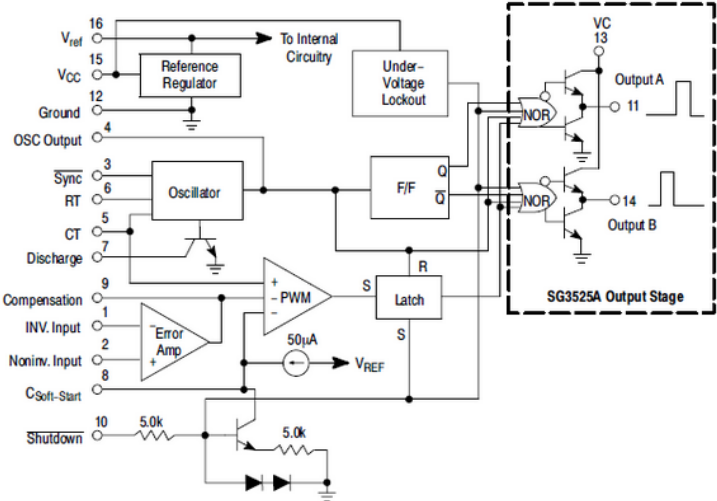

Figure 8: Representative block diagram of the SG3525

blue curve represent the output of this inverting integrator. This output will directly drive the duty cycle of the PWM : a signal of 0 Volts leads to no regulation and a signal greater than 5 Volts correspond to a duty cycle of 100 %. We can see that the value of this signal stabilize in this experiment around 1.7 V when the battery voltage is close to the reference.
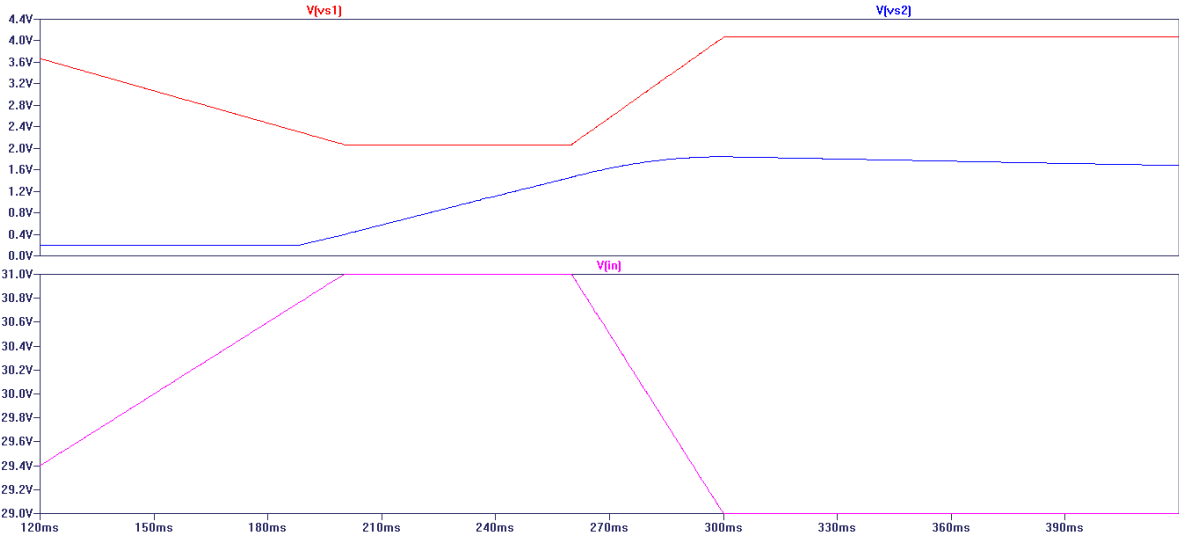
Figure 9: Simulation of the output of the integrator

The setting of the frequency of the PWM is given by :

$$f_{PWM} = \frac{1}{C_T(0.7R_T + 3R_D)}$$

In this case we decided to use a frequency of 300 Hz : the frequency doesn't need to be very high and it correspond to the working frequency of the *Tristar*.

2.5 Power circuit

The power circuit uses a Mosfet transistor that works at 200 V and 34 A. We will put 3 of them in parallel in order to support a maximal current of 100 A, maximal required current being 50 A. for the control of the mosfet, we tried two different and we want to test those two ways of driving the mosfets : either we drive them directly from the output of the SG3525, or we use a gate driver using NPN-transistor to drive them. When assembling the PCB, it is important to chose one way or the other.

3 Results

We had good results with the regulator for now. The regulator has been tested with a DC supply and not with a wind turbine and a battery for the moment. The dump load starts to connect at 28.8 V, and the tension is stabilized between 28.8 and 29.4 Volts, using a 6Ω resistor. The frequency
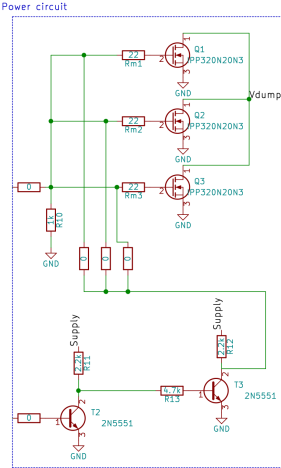
Figure 10: Schematics of the power circuit

of the PWM is around 300 Hz as expected. We had one issue with the circuit, it was tha the voltage on the Mosfets was increasing briefly at high voltage (sometimes greater than 200 V) when the Mosfet was starting to be blocked again. We can see a screen-shot of this issue on the figure 11 which is a measure of the voltage V_{DS} of the mosfet while the circuit is working. We fixed this problem by adding a capacitor and a flyback diode in parallel with the resistor. The solution works better to stabilize and the voltage at a correct level.
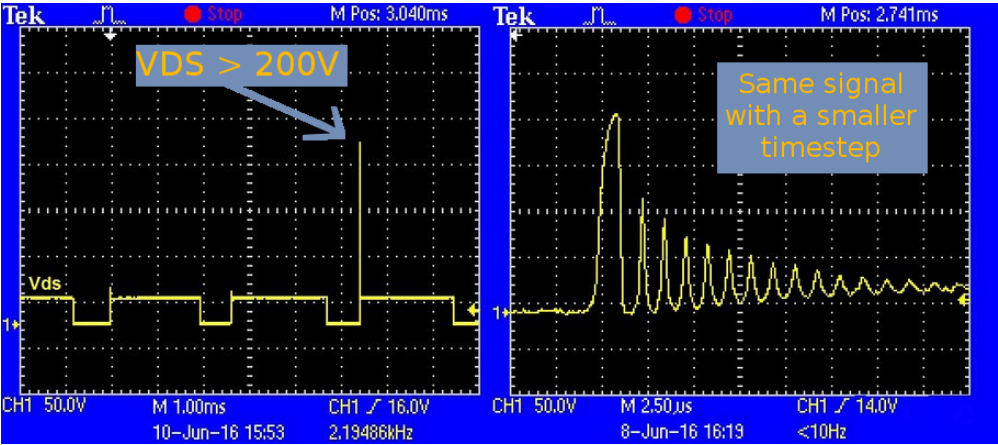

Figure 11: Voltage V_{DS} of the Mosfet versus time

4   Next steps of the project

We already started to design the PCB for the circuit, the next step is to finish this design and then order around ten of them to test them in different situation and ship them to the members of the project. We are respecting the original planning of the project, as the planned date for the order of the PCB is the 18th of july.

If you have any questions or remark regarding the project, please contact me : `clem.gangneux@gmail.com`.