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12 V, Parking Light Circuit

1. Introduction

1.1. Motivation

His document describes a circuit that powers the bicycle's headlamp and rear light permanently when switched on. The development is based on my first study dated to 2001 and considers further improvements of other guys documented under www.forumslader.de.

The requirement for an uninterrupted power supply makes an accumulator necessary, which bridges the time gap when the electric output from the dynamo is too less. The take over between the power supplied from the accumulator and from the dynamo should happen softly. A permanently running hub dynamo is an ideal basis for such a solution. I use a SON (Schmidt Original Nabendynamo) hub dynamo.

- Switched on, the lights are powered from the accumulator or dynamo dependent on the driving speed.
- Switched off, the dynamo charges the accumulator.
- If necessary the accumulator can be charged by an external power supply.

1.2. General considerations about the design

Headlamp and rear light consist of modern LED lamps, which need DC power. Therefore it is reasonable to operate the whole electrical system of the bicycle with DC. A single point for the AC-DC conversion makes life easier. The most significant factors driving the development are

- A low ESR serial capacitor to achieve a voltage boost at lower speed
- A Schottky diode based AC-DC rectifier
- LiPo cells acting as accumulator
- An intelligent charger

2. Description of the Circuit

2.1. Circuit

The next figure shows the diagram of the parking light circuit. The functionality will be described in detail in the following chapters.

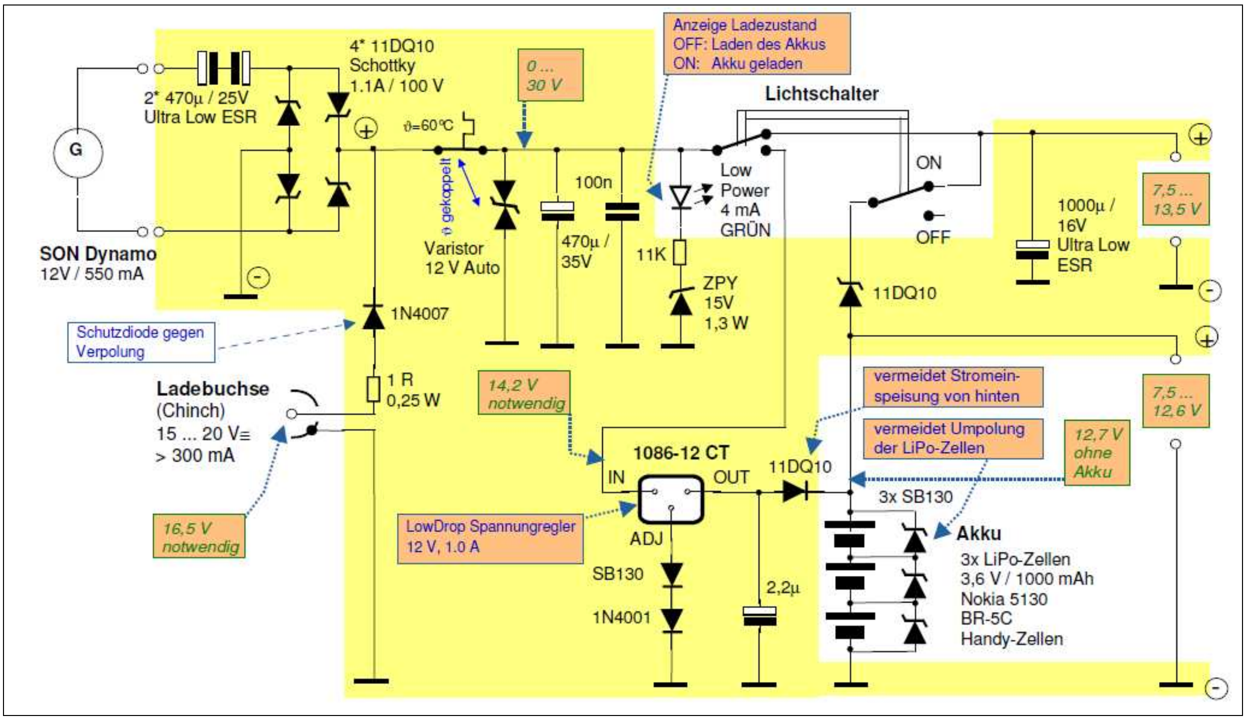


Figure 1: Diagram of the parking light circuit

2.2. Serial Capacitor

The dynamo powers the circuit via two anti-serial connected capacitors of 470 µF / 25 V each. They boost the voltage for a middle driving speed significantly (see Olaf Schulz, Hamburg, Gebetsmühle). Several measurements showed that 1/2 * 470 µF gives the best voltage boost between 18 ... 26 km/h for a consumer resistance of 26 ohms. If the speed is less than 16 km/h the resulting voltage is less than without any capacitor. No matter, the accumulator powers the lights automatically in case of a low dynamo voltage. To keep the circuit simple I abstained from a manually switchable low speed/high speed circuit as described in www.forumslader.de.

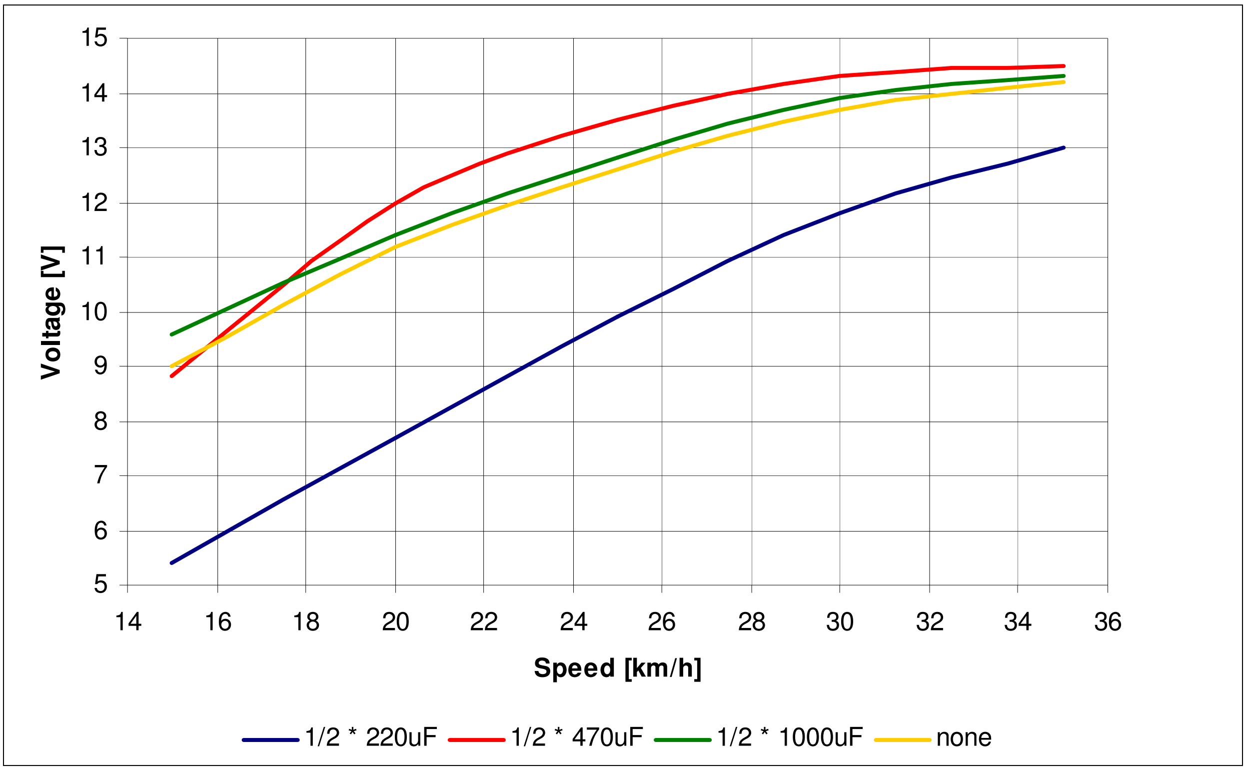


Figure 2: Output voltage of the dynamo for different and none serial capacitor if burdened with 26 ohms

The voltage tolerance of both capacitors is 50 V DC. The varistor (12 V Auto) limits the maximum voltage to 31 V DC. If the thermal switch disconnects the circuit from the dynamo, no current flows, and the whole voltage drops over the Schottky diodes. Thus the voltage tolerance of the capacitors is sufficient.

2.3. Usage of Ultra Low ESR Capacitors

An ultra low ESR capacitor has lower equivalent series resistance (= ESR) than a standard one. Datasheets show, that at 100 Hz an ultra low ESR capacitor of type 470 µF / 25 V has < 0.1 ohms, a standard one > 0.5 ohms. In case of two capacitors an additional resistance of 1 ohm generates a voltage drop of 0.5 V at 500 mA current. Seen as speed, you have to go 1 km/h faster to achieve the same output voltage.

2.4. AC-DC Commutation

All electronic parts need DC. Thus it is reasonable to install a central AC/DC commutation. Compared with silicon diodes Schottky diodes have a less voltage drop. Because the maximum voltage of the dynamo can increase up to 100+ V we must use diodes that can resist such a high voltage. The peak voltage of two serial 11DQ10 (1.1 A / 100 V) of International Rectifier is 200 V, which corresponds to 142 V AC. To reach this voltage the SON dynamo you must go 142 km/h.

In the data sheet of 11DQ10 we find a voltage Drop of 0.5 V at 25°C temperature and a forward current of 0.5 A. That corresponds to a power dissipation of 250 mW or a virtual resistance of 1 ohm. Two serial diodes yield to a voltage drop of 1 V.

Alternatively we might use a power Schottky diode like MBR1060 (max. 10 A, 60 V). This would reduce the forward drop to 0.35 V at 0.5 A for each diode, resulting to a 0.7 V voltage drop for both. You can opt for this solution, but I didn't by reason of volume and price.

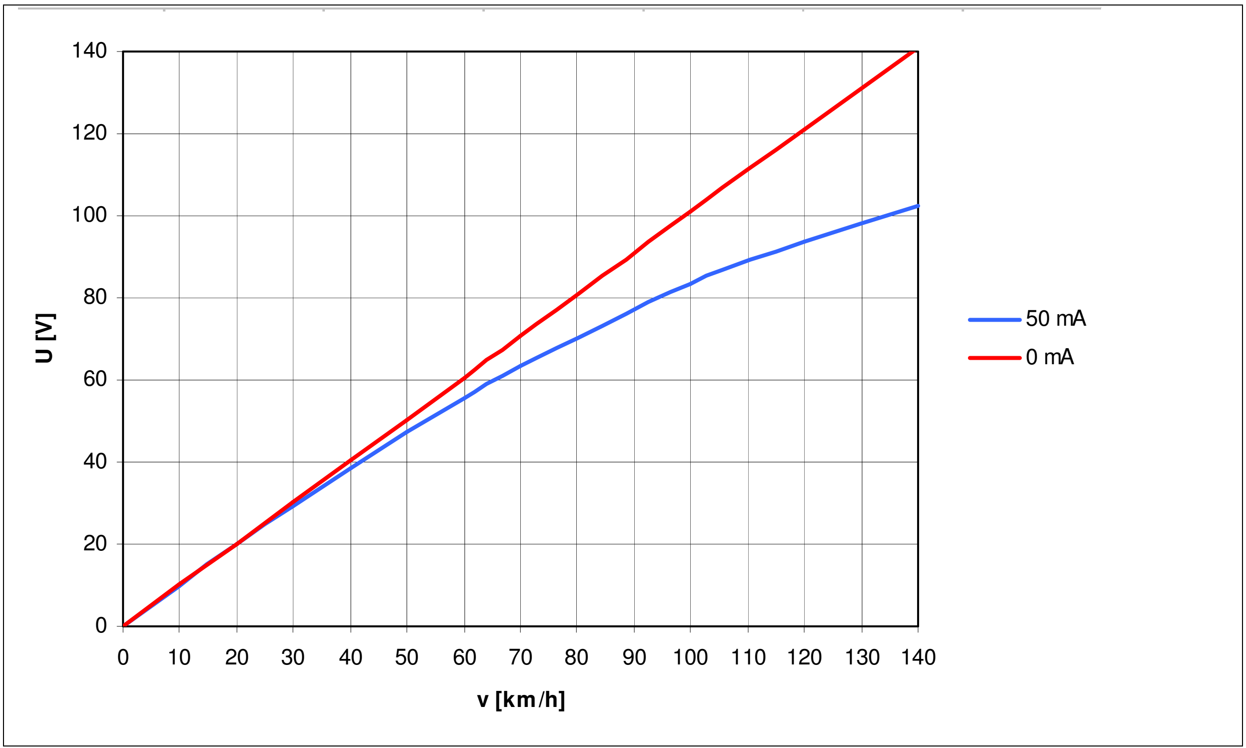


Figure 3: Idle and low burden voltage of the SON dynamo dependent on the velocity (26 inch tire)

2.5. Voltage and temperature control

A metal oxide varistor 12 V "Auto" restrains voltages higher than 31 V DC. This corresponds to 24 V AC. Therewith we are safe from destroying the 1086-12 CT, which tolerates only 40 V.

The next figure shows the power dissipation of the varistor is case of a completely charged accumulator (worst case scenario). The power dissipation is 3 W at 30 km/h and more than 8 W at 40 km/h. We couple the varistor with a 60° thermal switch to separate the circuit from the dynamo is case of higher temperature. The real life showed that this will happen only during long downhill drives.

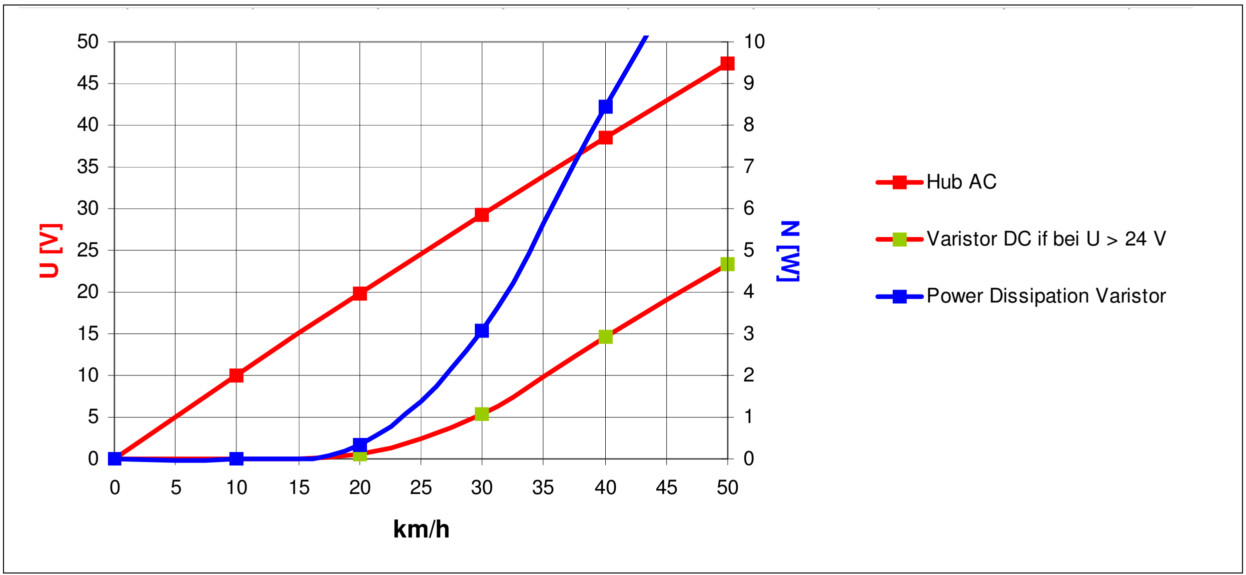


Figure 4: The power dissipation at the varistor increases significantly if the velocity exceeds 30 km/h

2.6. Selection and Number of Accumulator Cells

The LiPo cell Nokia 5130 BL-5C is very suitable for our application. The cell has a capacity of about 0.8 - 1 Ah. The connection pins are located at the front. The cell includes an over- and under-voltage protection. The over-current fuse allows a maximum current of 1 A.

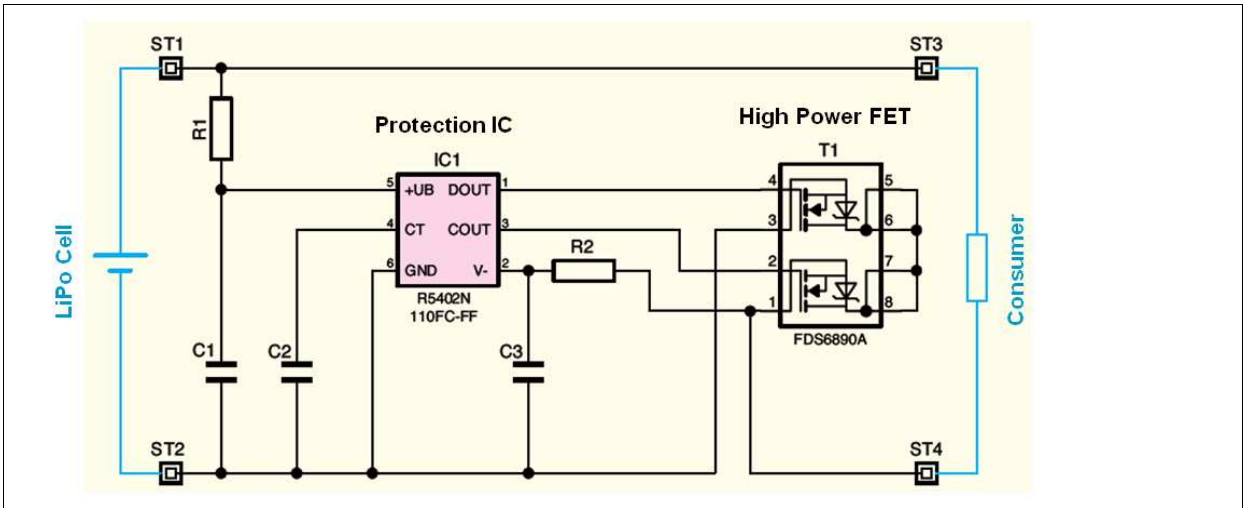


Figure 5: Circuit of a LiPo over- and under-voltage protection (by ELV Elektronik, D-26787 Leer)

Cells for mobile phones are not designed for serial connection. A Schottky diode SB130 must protect the integrated circuit against a reversion of polarity. The diode short-cuts each cell if the cell voltage under-runs 0.5 V.

I decided to use 3 serial cells. This gives the following voltage range:

- Upper Cutoff voltage: 12.7 V (= 3 * 4.235 V)
- Accumulator fully charged: 12.6 V (= 3 * 4.2 V)
- Nominal voltage: 11.1 V (= 3 * 3.7 V)
- Lower Cutoff voltage: 7.5 V (= 3 * 2.5 V)
  (Accumulator fully discharged)

2.7. Charging circuit

We cannot use an intelligent LiPo charger (with a Constant Current / Constant Voltage CC/CV method) because power is not provided continuously. Instead we use a simple Constant Voltage method (CV). It extends the charging time, but has no further disadvantages. A low drop constant voltage circuit for 12 V output regulates the charging voltage exactly. Connection of the ADJ pin via two diodes increases the output voltage to 13.1 V.

In case of low power provision the OUT pin has a higher voltage than the IN pin. A diode keeps reverse current from flowing. This diode lowers the charging voltage to 12.7 V. That's what we require.

To achieve the target voltage of 12.7 V the low drop constant voltage circuit must be fed with an input voltage of 14.2 V.

The next figure allows an assessment how fast you must drive to achieve a given charging current. We see:

- 500 mA charging current cannot be achieved.
- 450 mA charging current needs a speed of 28 km/h
- 20 km/h leads to a charging current of 350 mA
- 15 km/h leads to a charging current of 150 mA

Please notice:

The full charging current is only achieved if the accumulator is fully discharged. The charging current is lower if the accumulator voltage (= charging state) is higher.

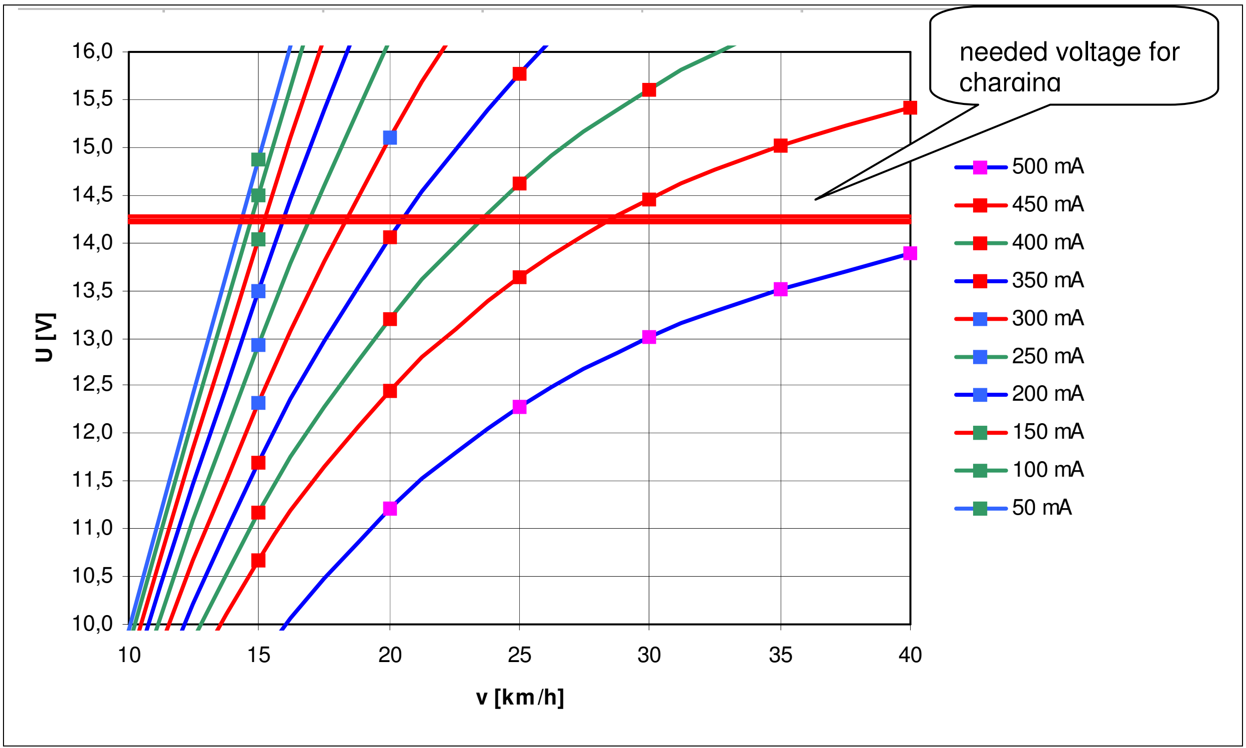


Figure 6: Output voltage of U[V] SON dependent on the driving speed and different currents

2.8. Power change over between accumulator and dynamo

The consumer can be powered by the accumulator, by the dynamo or by both simultaneously. The change over between these conditions runs smoothly. The following figure shows the situation for a 26 ohms consumer.

We consider two extreme situations

- the highest possible accumulator voltage of 12.7 V (e. g. 12.2 V behind the decoupling diode)
- the lowest possible accumulator voltage of 7.5 V (e. g. 7.1 V behind the decoupling diode)

We have the following results:

- speed < 10 km/h: consumer is only powered by the accumulator
- 10 km/h < speed < 15 km/h and lowest possible accumulator voltage: smooth take over from dynamo
- 10 km/h < speed < 25 km/h and highest possible accumulator voltage: smooth take over from dynamo
- speed > 25 km/h: dynamo powers the consumer completly

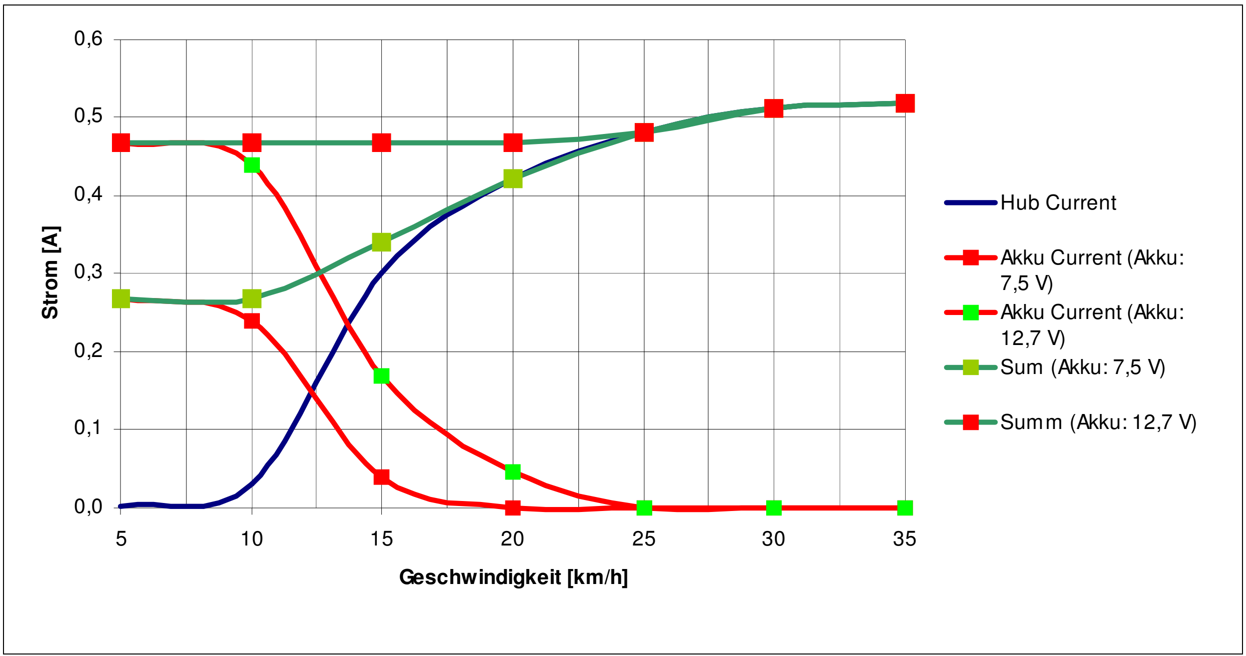
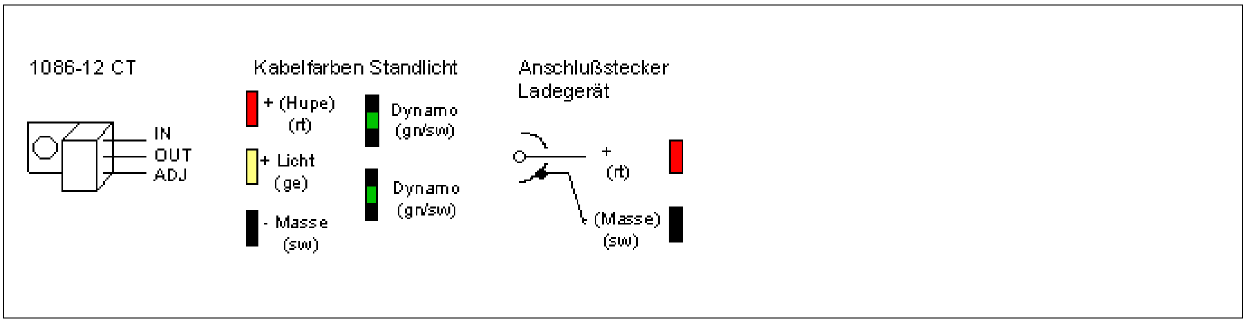


Figure 7: Power distribution between accumulator and dynamo

2.9. Pin Outlet

The whole circuit is designed to fit into the old Union 8520 e housing. This is a benefit in terms of water resistance, shock protection, and mounting. We need 5 connections:

- 2 x dynamo input
- Ground (Minus) output
- Light (switched Plus) output
- Other consumers (permanent Plus) output



3. Weight of the parking light circuit

A Nokia 5130 BL-5C LiPo cell weigh 24 g. Three cells weigh 72 g. In comparison 9 NiMH cells of the type AAA weigh 117 g (9 x13 g). The whole parking light circuit equipped with LiPo cells weigh 170 g.

4. Charging adapter

The parking light circuit is equipped with an additional input plug to charge the accumulator from an external power supply. A diode and a small resistor protect against reverse polarity and raised voltage. Additional charging might be necessary in winter when you bike mostly with the light switched on. The charging plug is connected parallel to the dynamo. Accordingly both kinds of charging are identical.

The charging adapter provides

- Idle: 20 V DC
- with 500 mA Load: 12 V DC

Because the external charging uses the same CV charging method as charging via dynamo, the charging time is relatively long. You need about 8 hours to charge to accumulator completely.

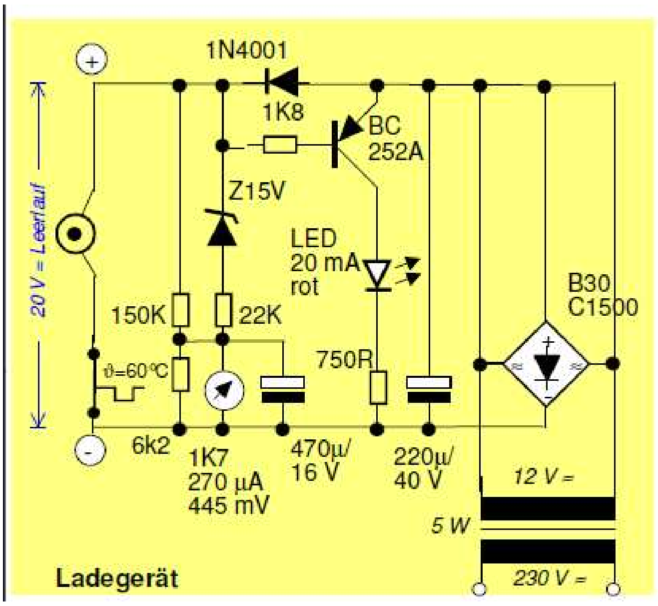


Figure 8: Circuit of the external charging adapter

The charging adapter is protected against short cut and overheating up by a thermal switch.

A red LED indicates the charging process. If charging is finished (or the charging adapter is disconnected from the parking light circuit) the LED stops flashing. An analog meter indicates the charging state. If it shows nearly 0 mA, the accumulator is fully charged.

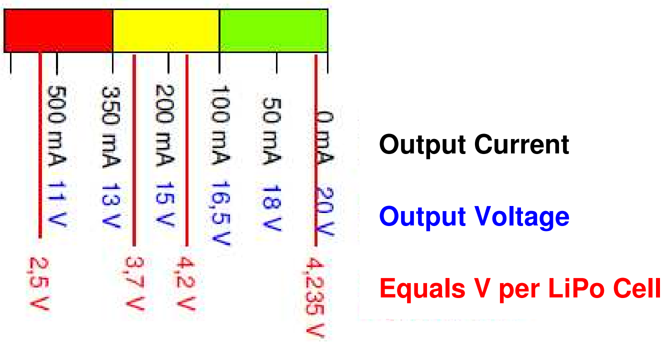


Figure 9: Charging meter

5. Connection to external devices

5.1. Connection of lightening

The (switched Plus) output of the parking light circuit is connected to three lamps

- small green lamp for lightening of the speed indicator
- headlamp build of 4 Cree multi die LEDs (MC-E)
- rear light build of one red Z-LED connected to a constant current control

The rear light is equipped with an additional 1000 µF capacitor. Neglecting the internal resistance of the wire between the parking light circuit and the rear light we get:

1000µF (Parking Light Circuit) + 1000µF (Rear Light) = 2000µF

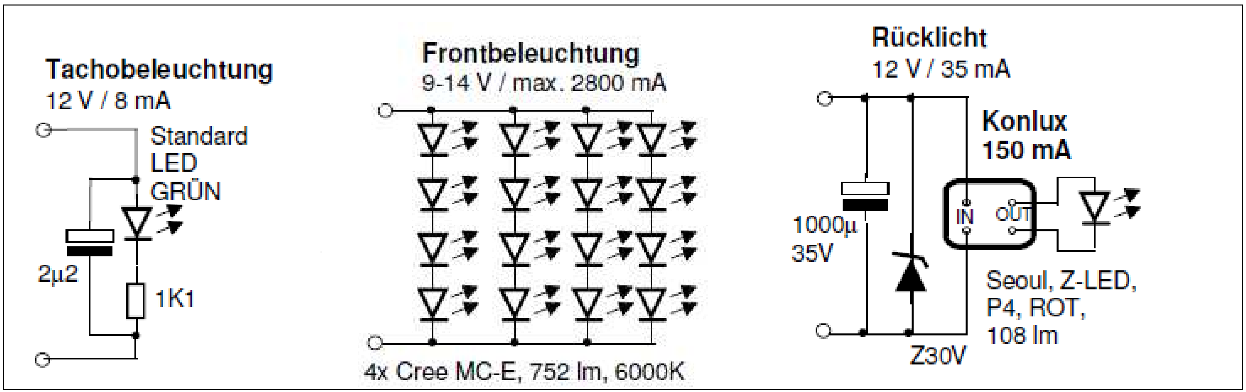


Figure 10: Connection of the head and back lightening to the parking light circuit

5.2. Current consumption @ 12 V

The following table enumerates the power consumption of the different power consumers at 12 V.

Headlamp, 4x Cree MC-E	0 ... 510 mA (max 2800 mA possible)
Rear light (LED with an A1W constant current supply)	35 mA
Speed indicator illumination	3 mA
Electronics own need	0 mA (not charging)

6. Protection of the Switch

The Circuit diagram of the parking light shows that the ingress 470µF capacitor will be discharged over the switch and the 1000µF capacitor when the switch goes from “off” to “on”. The result is a short but high current peak, which might damage the switch. Besides of using a high current switch I developed a relay based alternative. The capacitor will be discharged over a 20 ohms resistor to preserve the switch. This limits the maximum voltage to 10 V, compared to 31 V without this enhancement. A relay changes between the normal operation and the discharge operation.

- If the switch is in the “off” position the relay is activated. Dependent on the used relay a current of 10 mA can be determined. This current is wasted for charging.
- If the switch state changes to “on” the relay keeps a short moment activated, and the 1000µF capacitor is discharged over the resistor. Afterwards the relay drops out and connects the dynamo with the consumer. In this state no additional current is wasted.

Nevertheless I decided for the version without relay, and build in a more robust switch.