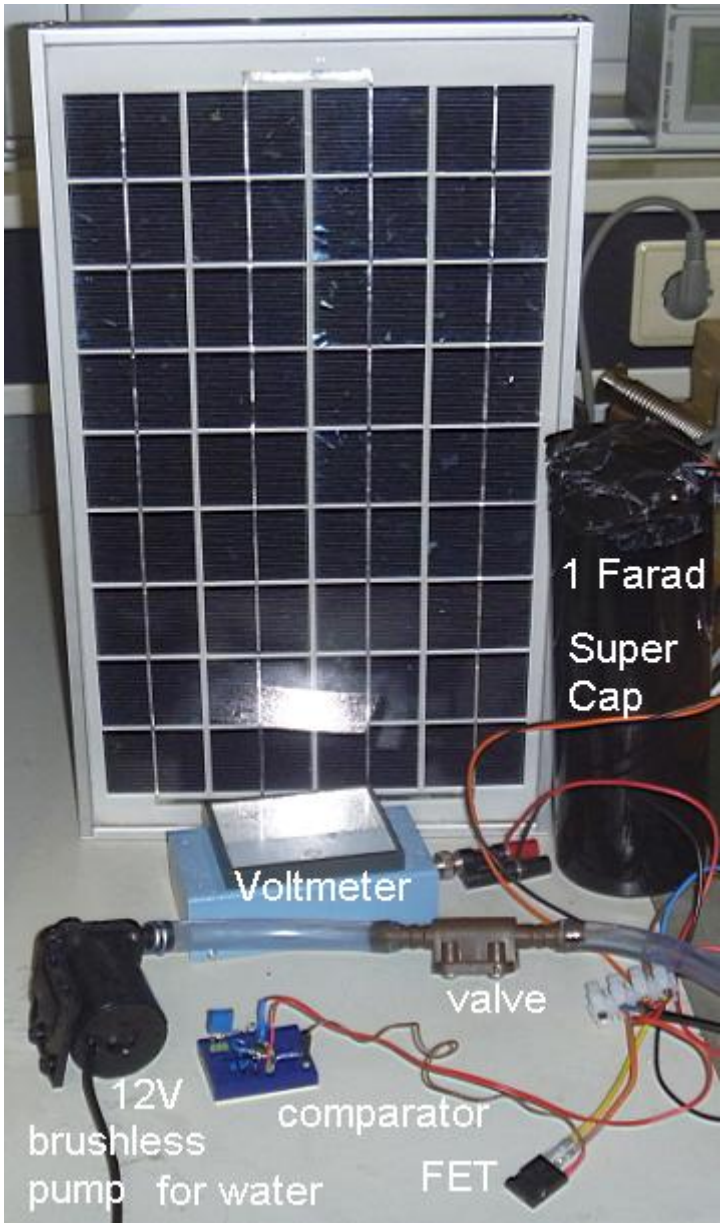
Energy Harvesting for Solar-driven Water Pump

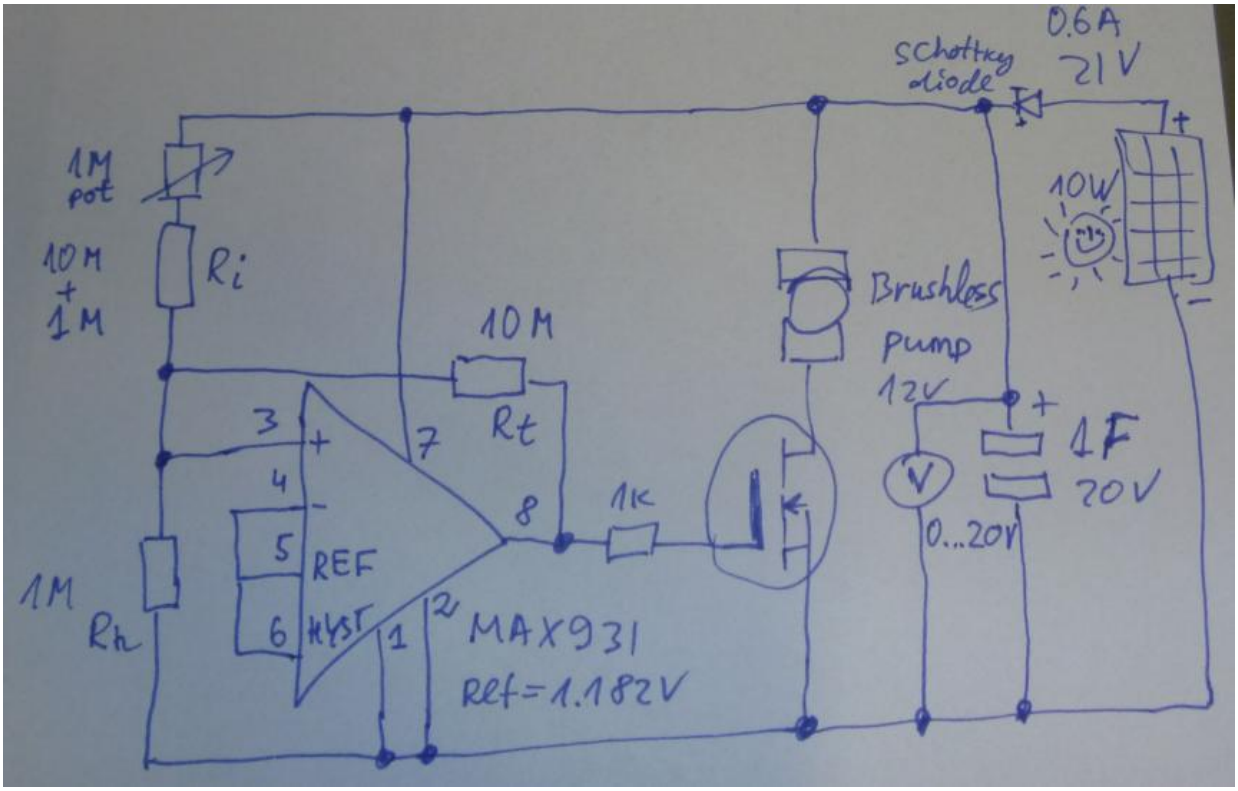


Solar pump can be used to pump water for irrigation of a greenhouse. It happens often that that the day is cloudy and the current from a solar panel drops to ca 10 % of peak, that is no longer enough to drive a motor. Solution would be to have an overdimensioned panel (100 W to drive 10 W pump).

The small current might not be enough to drive motor, but it could be used to charge a large capacitor and then to drive a pump for a short time. Commercial energy harvesting pump with a solenoid piston valve is http://liujia.com/ , can pump 30 m high, but system costs ca 400 EUR. My project was inspired by article "**Economical Energy harvesting**" written by by **Rolf Blijleven** 01-2011 Elektor magazine.

Energy stored in a capacitor increases quadratically with the voltage E=0.5*C*U*U/2. This means that higher voltage is preferable. Due to quadratic dependence one can observe that the voltage increases fast when capacitor is empty and slows down as voltage increases. SuperCap is used because rechargeable battery would be dead after 1000 charging cycles. (However an old car battery could still be attractive to use.)

A comparator circuit is used to switch on the pump motor, when a threshold is reached and to it when the voltage drops below usable level. As motor stops frequently, the water hose should have a flow-back blocking valve. Max931 (thanks to Maxim for free samples) is extremely low consumption comparator posessing an internal reference voltage. Maximal supply voltage of MAX931 is exceeded when using 21 V panel, but the chip has not been damaged. Measured current consumption by the circuit below was 5 uA.



1F 20V Super Cap is from car audio (ca 25 EUR). The cap I have, is having leakage current at voltages above 13V. It might not be to run it in such mode as electrolysis will take place.

At 20 V draws 75 mA
At 17 V draws 7 mA
At 15 V draws 1 mA
At 14 V draws 0.3 mA
At 13 V draws no current

The Solar panel 10W (21V, 0.65A peak) draws current in dark, if connected to an external power supply. Actually try to buy larger panel(s) or briefcase for more fun.

At 20 V draws 80 mA
At 17 V draws 25 mA
At 14 V draws 6 mA
A (Schotky) diode (0.2 V drop voltage) could be put in series with panel to prevent current in the dark.

It is practical to monitor the voltage across the Super capacitor. Galvanometer is preferred to a multimeter as it does not need batteries. Larger galvanometers have better linearity than small ones. From several galvos I was lucky to find one with a large resistance of 3.3 k. A 1M pot in series was adjusted to show full scale at 20 V. Resulting voltmerer resistance was 200 kOhm that is quite small to contribute to discharge.

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Resistor calculations

Simple voltage divider calculation can be used.
When comparator is ON then Rt is in parallel with Ri.
When comparator is OFF then Rt is in parallel with Rh.
Calculations is practical to perform in Excel.

Values used in “Article Economical Energy harvesting” by Rolf Blijleven

5.8	Ri
10	Rt
1	Rh
1.182	V

Mohm		V	
0.909091	0.135501	8.72316	ON
3.670886	0.214092	5.520987	OFF

Below my calculations for 12V pump and 21 V panel. That swiches on at 15 V and off at 7.4 V.

11	Ri
10	Rt
1	Rh
1.182	V ref

Mohm		V	
0.909091	0.076336	15.4842	ON
5.238095	0.160305	7.373429	OFF

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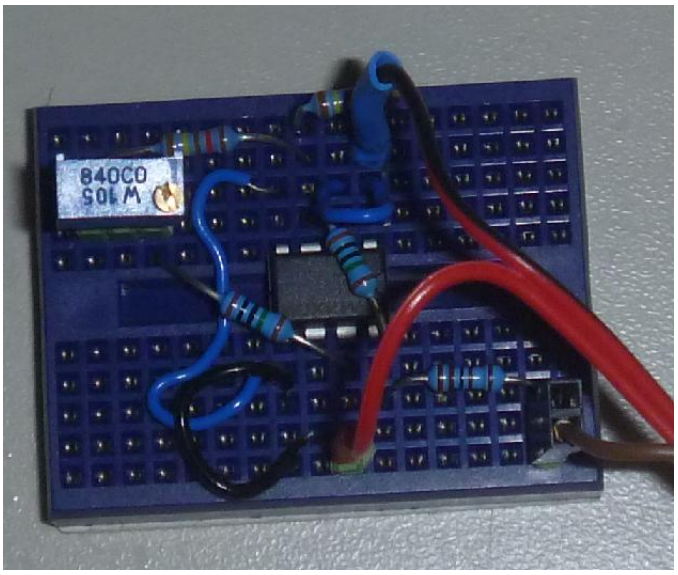
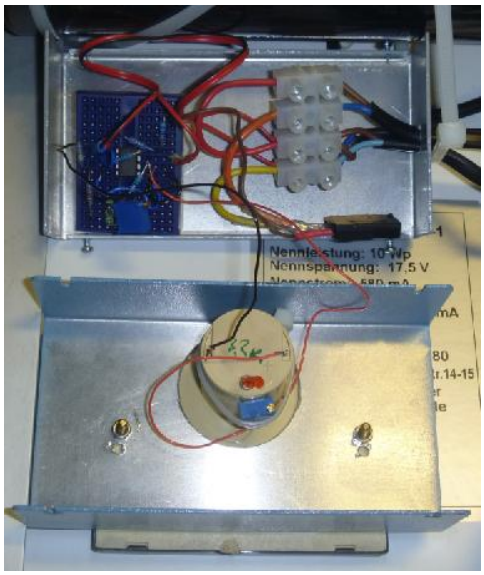
Brushless pump from Ebay. Should last long time as has no mechanic contacts.
Can pump water 2…3 m high.
Rated voltage: DC12V.
Current: 1.05A.
Flow: 550L / h.
Noise: 35dB (0.5 meters).
Fluid temperature range of 0 to 65°C.
Pump motor DC brushless motor, no spark of work.
Pump starting current, high efficiency, stable and reliable operation, low power.
Consumption, energy saving, environmental protection.
Pump motor shaft with high degree of wear-resistant ceramic shaft, continuous service life of 20,000 hours or more. Pumps can be amphibious.
Size:8cm x 6cm Diameter of Outlet:10mm

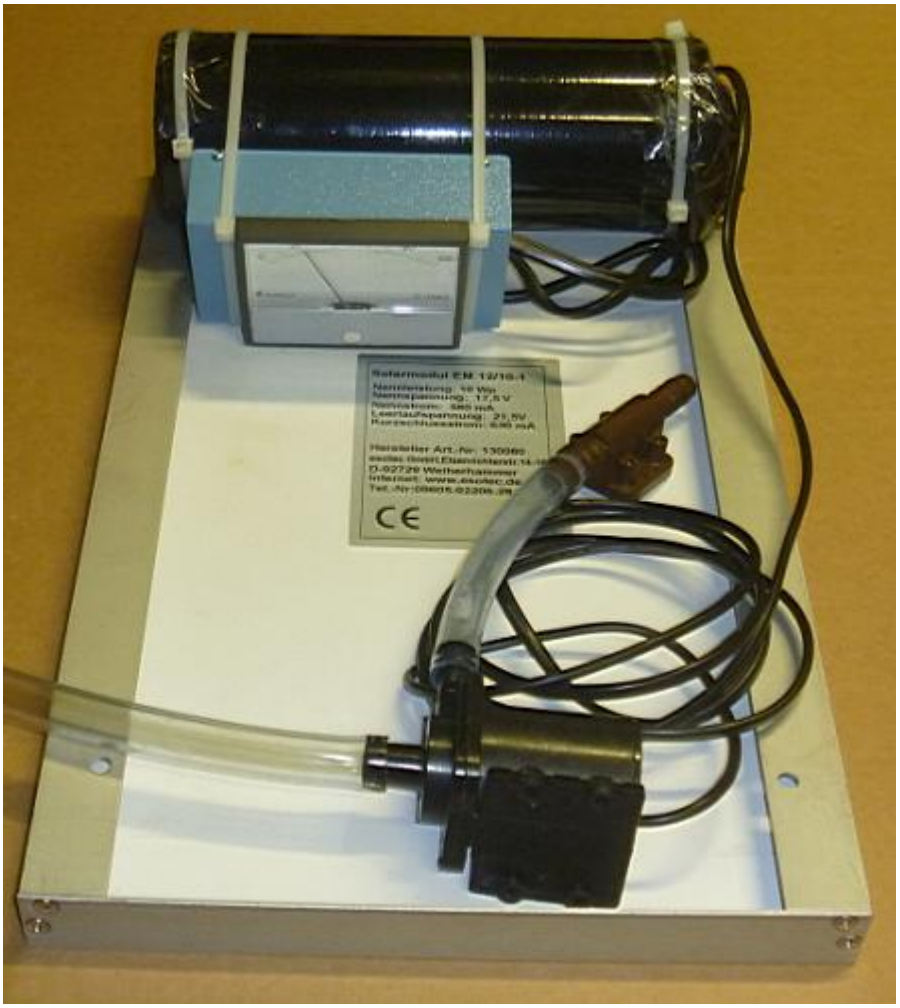
For real life application pump a mesh filter has to be used in front of the pump (sacrifise from your kitchen, pasta water filter). It might be practical to make pump floating by using styropor plate.

Back-flow blocking walve





Test construction was done on a solderless breadboard and later fitted into outdoors-qualified enclosure.



Arduino as a more advanced controller

One might need to implement shutdown function, if the target volume is full, or pump has no water to pump. For that purpose Arduino is more suitable. Analog input can be fed from a 1Meg pot measuring voltage across the super cap. Arduino with a 5 V regulator consumes 20 mA current (with FTDI). This could be reduced to some 5 mA by putting it into sleep mode and without FTDI chip. Together with a display it could allow to count how many seconds pump was running per day or set a time limit per day.

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```
int a; int mot;

void setup() {
pinMode(13, OUTPUT);
//analogReference(INTERNAL);
  Serial.begin(9600);
}

void loop() {
a=analogRead(A0); Serial.println(a);
if (a > 150){Serial.println("ON");  mot=1;}
if (a < 70){Serial.println("OFF");  mot=0;}
Serial.println(mot); digitalWrite(13, mot);   delay(300);
}
```

Atmega169 with Display and Real time clock

Even better solution would be Atmega169 that has a real time clock and display. Demo board AVR “Butterfly” can be bought for 20 USD. (The programming is not so trivial compared to Arduino.) Atmega169 is used in heating thermostats like on picture below and can run from 2 AA batteries for several years.