Ballast Capacitors for LED SeaLites

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The DSP&L LED SeaLite (LSL) is a 106 W light that can be programmed to flash for short periods. In this way it is hoped that it can be used as a strobe light for underwater macro photography systems such as the Deep-Sea Coral Macro Camera.

The LSL has no on-board energy storage and so it places a high demand on its power supply (a battery for our application) as long as it's on. Each light would draw 4.5 A at 24 V, or a total of about 9 A for two lights. An alternative arrangement would be to add a capacitor bank between the battery and lights. For each flash, the capacitors would be charged by the main battery and then disconnected from the battery. The LSLs would then be flashed, draining the capacitors at a high current. The charging circuit for the capacitors could be current limited to, say, 1 A so the demands on the battery would not be too great.

According to the LSL manual, the lights will operate between 10 and 48 V. However, they'll only operate at 50% brightness below 22 V and 100% brightness above 20 V (there is 2 V of hysteresis). We have a 28 V battery, and want to operate at 100% brightness, so our range is from 28 to 20 V; if the lights automatically switch to 50% brightness between 20 and 10 V then we'll count this light output as extra but won't plan on it.

How big would the capacitors have to be? Since the lights are constant-power devices, they draw more current at lower voltages (see graph on page 9 of LSL manual). It's best to do the calculation based upon the rated 106 W power draw.

Define the 10 ms on time and 106 W power dissipation.

In[75]:=
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onTime = 0.01;
power = 106;
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The energy in W-s (or J) is the power while on times the length of time on.

In[77]:=
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eFlash = power onTime
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Out[77]=
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1.06
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The energy in a capacitor is $\frac{1}{2}$ C V^2, so the energy supplied by the capacitor is the energy at 28 V minus the energy left at 20 V. Rearranging the equation to solve for C

In[78]:=
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Vs = 28;
Vf = 20;
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$$c = \frac{2\,\mathrm{eFlash}}{Vs^2 - Vf^2}$$

Out[80]= 0.00552083

This is 5.5 mfarad, or 5,500 μfarad. These capacitors would have to be rated for at least 35 V (50 V would be better). Note that the size of the capacitor scales linearly with the energy of the flash, so if we wanted a flash twice as long, we'd need a capacitor twice as big.

How long would a capacitor of this size take to charge at 1 A of current, assuming we must charge from 0 to 28 V (i.e. bleeder resistors discharge it between flashes)? We know $I = C\,\frac{dV}{dT}$, so solving for time we have

In[81]:=
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i = 1;
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$$t = c\,\frac{Vs}{i}$$

Out[82]= 0.154583

They would charge in a fraction of a second. The total energy to charge the capacitor with a series-pass current regulator is

In[83]:= $\mathrm{eTotal} = Vs\ i\ t$

Out[83]= 4.32833

The efficiency of this storage is energy out divided by energy in.

In[84]:= $$\mathrm{eff} = \frac{\mathrm{eFlash}}{\mathrm{eTotal}}$$

Out[84]= 0.244898

Only 24% efficient! This much is left in the capacitor below 20 V.

In[85]:= $$\mathrm{eLost} = \frac{1}{2}\,c\,20^2$$

Out[85]= 1.10417

In summary, of the just over 4 W-s used to charge the capacitor, half is lost in the series-pass current regulator, a quarter is used to flash the light, and the last quarter is left in the capacitor. However, this is still only 4 W-s per flash (8 W-s for two lights), and is much less than the 500 W-s used on our larger camera systems.