SEABOROUGH RESEARCH

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Project 13018
Subject Application Note on enhancements to oneTLed concept
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Summary

This note describes a couple of ideas which can further increase the value of the oneTLed concept or provide more design freedom to Seaborough's licensees: firstly, a method will be described how to make the oneTLed concept also compatible with mains voltage operation (a feature offered by multiple manufacturers for their ranges of LED tubes compatible with electromagnetic ballasts), secondly, adaptations to oneTLed will be described which can reduce power losses with ballasts with permanent electrode preheating , and thirdly, customers who want more freedom to choose the number of LEDS because of visual appearance preferences, will be offered an approach to increase the number of LEDs without changing the overall electrical characteristics of the LED array.

Background on oneTLed

oneTLed is a LED tube concept which is compatible with both electromagnetic (EM) and electronic (HF) ballasts, embedding the following features: (i) the lamp diagnoses whether the lamp is operated at 50/60 or >20,000 Hz and self-adapts the LED array configuration; (ii) in case too high LED tube currents are diagnosed the lamp again self-adapts and takes measures to reduce currents to always safe levels; (iii) measures are taken that more intelligent ballasts which check the performance of the attached lamp do not get erroneous feedback signals. Because of the above, there are obviously constraints to the number of LEDs to be put in series in either EM or HF mode at the wished power selection. OneTLed Gen 1 is not compatible for operation on AC Mains Voltage, because the impedance of the coil of the electromagnetic ballast is an essential part of the oneTLed electronics schematics: see Seaborough's patent application WO2015044311 for more explanation).

AC/Mains Voltage Compatibility

Licensees of Seaborough's intellectual property could upgrade oneTLed Gen 1 to become also an AC/Mains Voltage compatible product by placing an inductor in the lamp as shown in figure 1. The obvious question is: how can we fit the bulky, heavy-weight, typically 600 mH (but ranging from 400 – 1000 mH in certain EM ballast designs) inductor coil of a 58W EM ballast into the limited space inside a T8 lamp of only 1.7 cm diameter? The answer is that LED tubes providing equivalent light output as a conventional fluorescent lamp will be typically at a lamp power between 20 and 25W, iso of the 58W with fluorescent lamps. LED tubes need to handle only ~40% of the power which needed

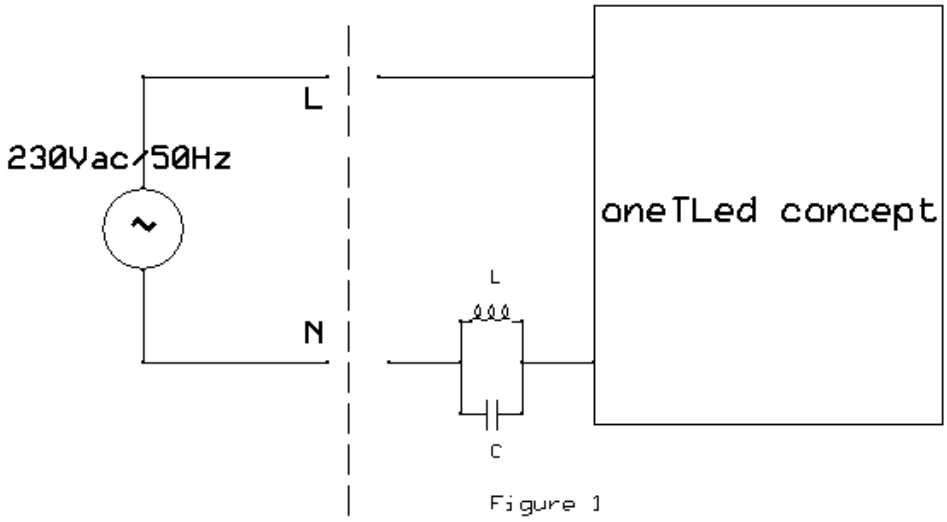

Figure 1: Schematics of AC/Mains Voltage Compatible oneTLed; right from dotted line is the OneTLed lamp.

to be handled with conventional fluorescent lamps, therefore reducing losses by ~40% because of the lower lamp power if the LED tube would run at equal current. Furthermore, oneTLed operates at higher voltage and lower current, therefore substantially reducing resistive losses in EM ballasts. With 58W ballasts resistive losses are typically 11W with conventional fluorescent lamps which are reduced to only ~0.5W with oneTLed. Therefore, substantial miniaturization can be achieved, because of eased thermal conditions. It was verified at Seaborough's laboratories that an inductor choice of some 600 mH (referred to as 'L'' in figure 1) embedded in the oneTLed LED tube the lamp functions well on AC mains as well as when connected to an EM ballast. The presence of the capacitor C along with L, acts as a band pass filter for harmonics close to the line frequency. Seaborough recognizes that such inductors in the right size and aspect ratio are likely not off-the-shelf components, but it does not require rocket-science to make those available when licensees recognize the value of the proposition to make oneTLed also compatible on AC/Mains Voltage.

Reduced Losses with Ballasts with Permanent Electrode Preheating

There is a large variety of electronic ballasts architectures out in the market since 1980, see http://www.seaborough.com/newsroom/seaboroughs-true-plug--play-led-tube-solution-will-accelerate-the-fade-out-of-conventional-fluorescent-lamps-with-massive-energy-saving-opportunities/. Some ballasts feature preheating of fluorescent filaments to increase the number of times a fluorescent lamp can be switched on (any switch-on is a harsh treatment to the tungsten filament and deposited emitter materials to lower the energy required before electrons can leave the tungsten filament). Sophisticated HF ballast designs have preheating for a limited period of time, whereas other designs keep the pre-heating on permanently (such as rapid start ballasts representing 10% of the US installed base) or found with suppliers such as Arlen in Europe.

In order to further optimize ballast efficiency, especially with ballast designs which show low efficiency because of unnecessary permanent preheating, Seaborough proposes to disconnect the filaments (more precisely, replace the filament simulator resistance of typically 8 Ohm by some 22 kilo ohms) after some period of time (30 msec), also reducing the required 'filament simulation resistor count' by a factor or 3 to 4 because the resistance value is significantly increased thereby reducing the power losses on it (for permanent preheating ballasts). As a consequence, resistor temperatures are much lower than when they would be operated permanently. Therefore associated component costs and required PCB surface area can be reduced accordingly. The schematics for such an implementation is given in figure 2. Seaborough has assessed that compatibility is not sacrificed by implementing such 'filament simulation resistor cut-off technology). Obviously, to prevent non-compliancy issues, at the next lamp start-up the filament simulation resistors should be in the circuit again, to prevent erroneous diagnostics by more sophisticated ballasts.

Finally, it should be commented that some HF ballast designs use PTCs for power factor correction. These components typically run at 110 – 120 degree C in fluorescent lamps, not only causing electrical losses but also being a dispute in the lighting industry for decades to avoid these components because of presumed safety issues. When the filament simulation resistors are cut off as advised, also the PTC will be disconnected. In summary, oneTLed cures the shortcomings of less sophisticated ballast designs.

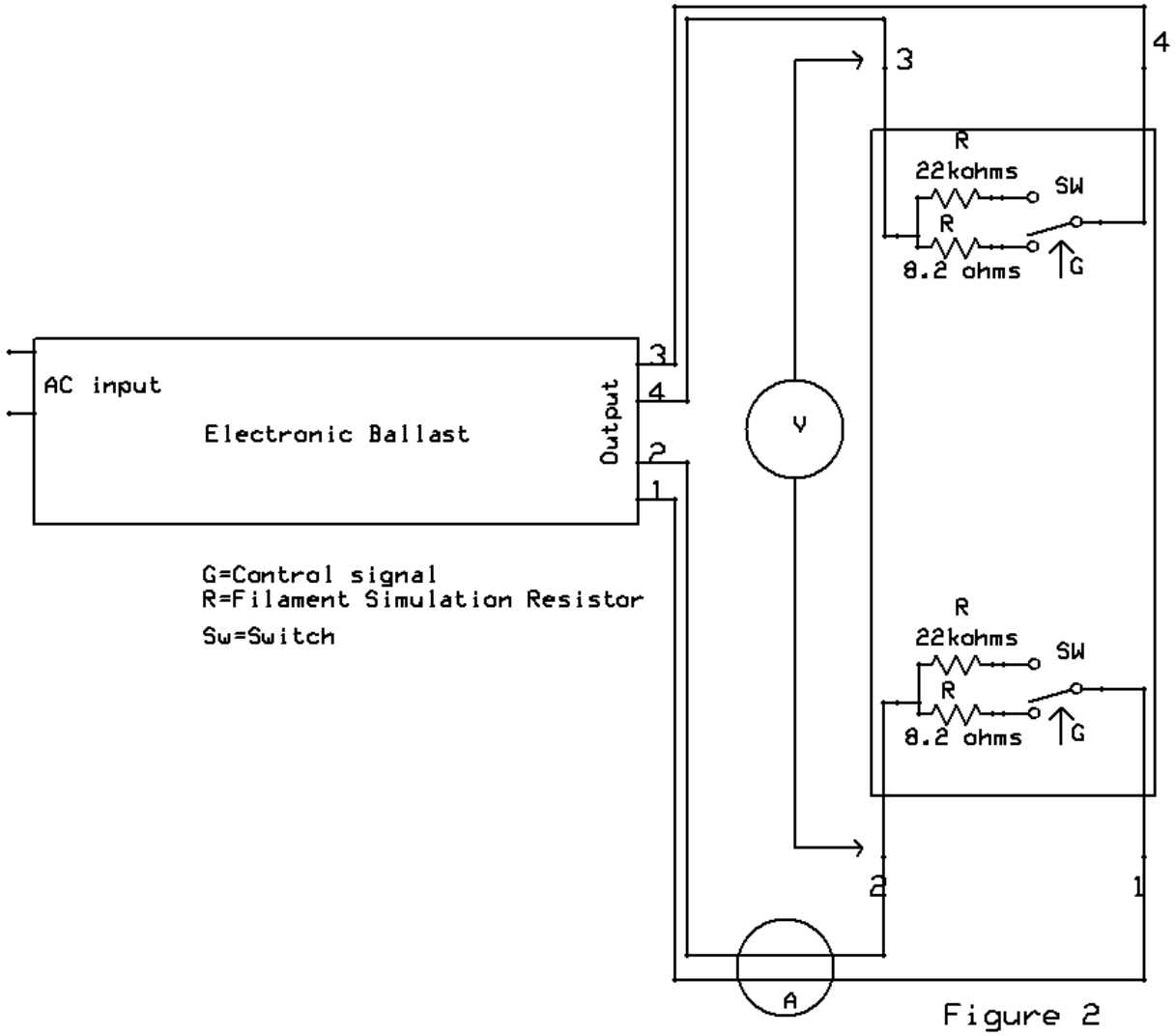

Figure 2

Figure 2: Schematics of filament simulation resistor cut-off technology; after a certain time the switch (30 msec was found to work fine) in series with the filament resistor R opens, and replacement the low resistance of the filament resistors (typically 8 Ohm) by a higher resistance value (advised 22 kilo Ohm).

Creating Additional Freedom to decide on the Number of LEDs in oneTLed

Being compatible with both EM and HF ballasts puts constraints on the electrical LED array configuration. These constraints are defined by the infrastructure of the ballasts in the field. It can well be that LED tube manufacturers want to emphasize visual uniformity performance to their clients and want to deviate from the number of LEDs recommended by Seaborough to achieve ultimate compliancy with the installed base of ballasts. Below a couple of ideas are described how licensees could achieve a higher number of LEDs:

The easiest option to increase the LED count is to apply LEDs of half the current rating and put 2 of them in parallel. In this way the forward voltage of the string does not change, while the required light-generating epi-material is kept the same by using smaller dies. Packaging and pick & place costs will increase though.

Another approach is to use multiple-die packages, widely available in the market recently. 3V, 6V and 9V at multiple current ratings are being offered. An example will clarify the idea proposed: one could design with three 3V (single die LEDs) in series, rated for 120 mA. One could also use four 9V (triple die LEDs) which are rated at 30 mA and placed in parallel. In this way, the forward voltage is still 9V in both cases while the array is able to manage 120 mA, so electrically we are equal, but the 9V route will give licensees the opportunity to increase the number of LEDs by 33%. In this approach the amount of epi is still unaffected, packaging and pick & place costs will be lower than in above example of doubling the amount of LEDs. The above is illustrated in figure 3.

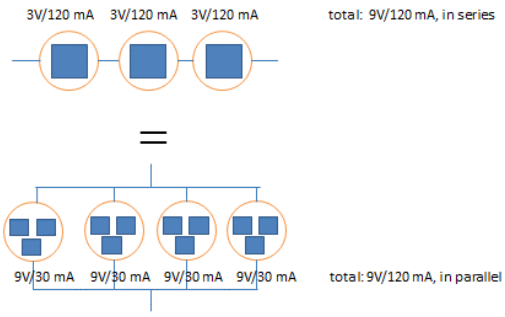

Figure 3: Two manifestations of a 9V/120 mA array using single- and triple-die packages, the second one featuring 4 iso the straightforward 3 LEDs (+33% LEDs).

While the above describes a way to have equal light output per LED, one could also consider to modulate the light output over the LED tube. If per every three 120 mA LEDs in series, one takes out one, and replaces them by two 60 mA LEDs in parallel, the end results is again 9V and 120 mA, but increases the number of LEDs from 3 to 4. In Seaborough's view placing the 60 mA and 120 mA devices alternatingly (smart PCB lay-out) will make such invisible to customers, because of the optical mixing characteristics by the diffuser used

in LED tubes. Also in this case the required epi is similar. Same cost structures as with above 9V approach.

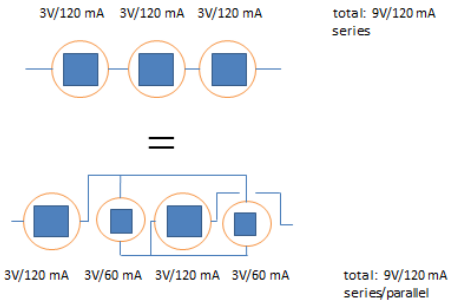

Figure 4 illustrates the above example.

Figure 4: Manifestation of another 9V/120 mA array using alternatingly 60 and 120 mA LEDs.

More options can be created in case manufacturers are less concerned about the most effective epi usage. The above ideas are a starting point to create more design freedom but anyone skilled in the art will be able to come up with variations on the above mentioned themes.