Configurable Reliability Test System for HB LEDs

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Abstract – **In this paper several techniques for design of reliability test system for high brightness light emitting diodes (HB LEDs) are described. The targeted design would comply with the requirements of various reliability test standards. Possible solutions for LED driving with constant current, LED pulse driving, "question current" method implementation are discussed. The requirements for the digital control system, optional interface to PC and PC application software are explained.**

Keywords –**LED, laser diode, reliability, test**

I. INTRODUCTION

In general the reliability of semiconductor elements can be defined as the ability to operate the device satisfactorily in a defined environment for a specified period of time. In most cases it is tested by putting the devices under test in over stress conditions, compared to their normal work environment. Typically they are put on higher temperature, higher load currents, higher voltage levels, etc… Then their performance characteristics are measured and observed over long time periods.

Especially for the HB LEDs, there are various reliability test standards and methodologies[4][7][8]. The changes in their work conditions generally consist of changing the forward current settings (value and timing characteristics) and changing the working temperature. Typically the diodes are tested with higher or equal to the nominal current value. It can be constant or pulse driven. In the cases of pulse testing the pulse duration, pulse period, turn on and turn off delays are controlled. When the over stress conditions are set, the LED is left to work for some time. Then its characteristics are measured - mainly its volt-ampere curve and the emitted light power dependence on the forward current.

In this article the design considerations of a configurable reliability test system for LED are discussed. In a good test system the overstress conditions can be configured precisely and the output characteristics automatically measured.

II. DESCRIPTION OF VARIOUS BLOCKS IN A LED RELIABILITY TEST SYSTEM

A. Testing high power LED with constant current driving

The main requirements during reliability tests with constant current driving consist of the following:
- precise, accurate and easy current value setting;
- stable output current.

The LEDs can be driven with current or power source. The high power LEDs are driven with switch mode drivers in order to increase the efficiency. Typically voltage source topologies like Buck, Boost, Cuk, Sepic are used with small modifications [3] in order to convert them into current sources. In these solutions exact dependence between the output current, schematic parameters and duty ratio cannot be found. An example circuit of Buck based current source is shown in figure 1a. Typical output current waveform can be seen in figure 1b.

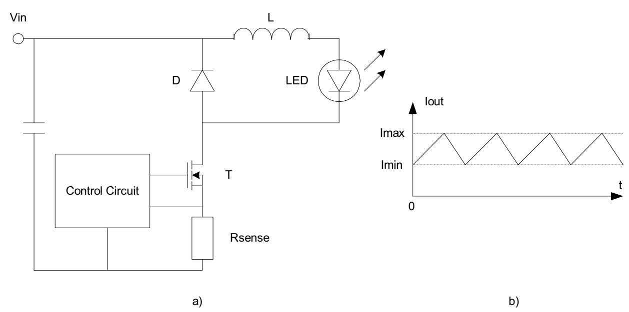

FIGURE 1. BUCK BASED CURRENT SOURCE DRIVER

The widely used control algorithm of such schemes consists of tracking the output current value and detecting the moments when it reaches predefined minimum (I_{MIN}) and maximum (I_{max}). At these moments the switch element state is changed. So the control principle of these current sources relies on output current pulsations of up to 20% of the average current value. Thus they are not applicable as accurate and stable driving sources. Usually the implementation of that algorithm has analog nature. Thus setting of the desired output current value is done through change in the value of analog element/parameter.

Better possibility is to use power source driver, discussed in [1]. An example circuit is shown in figure2.

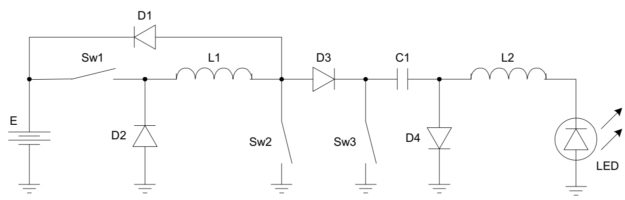

FIGURE 2. POWER SOURCE DRIVER

The operational principle of such circuit is deeply discussed in []. There is an exact dependence between the delivered output power, schematic parameters and duty ratio. It is expressed by the following formula:

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$$I_{OUT} = \frac{2.C.E^2}{U_{OUT}.T}.\frac{d^2}{(1-d)^2}, \qquad (1)$$

where I_{out} is the output current, U_{out} is the output voltage drop, C is the capacitor value, T is control period, E is the value of the DC input voltage source, d is the duty ratio.

So the applicable control principle is not based on pulsation in the output current. By implementing good output filter very stable current value can be achieved.

In [3] there is a described digital control system for such driver. It based on digital control algorithm the can implement proportional (P), proportion – integration (PI) or proportion – integration – derivate (PID) regulation law. That algorithm can be realized with proper microcontroller core. In that case the reference is represented by a variable value writeen in RAM, EEPROM or ROM. So change of the desired output current value can be simply done by a change in a memory cell value.

In fig.3 a variation of the previous discussed circuit is shown [2].

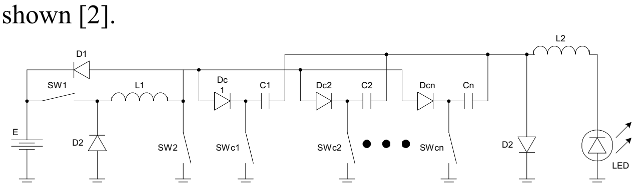

FIGURE 3. POWER SOURCE DRIVER WITH PARALLEL CAPACITORS

The capacitor C1 from the circuit in fig.2 is divided in N parallel connected, separate capacitors in the circuit in fig.3. The capacitors have certain weight ratio and every particular capacitor presence in the capacitance sum is determined by the control circuit. To achieve easier circuit regulation, it's convenient to choose the capacitor values with binary weight ratios: $C_1=C_0.2^0$; $C_2=C_0.2^1$; …$C_n=C_0.2^{n-1}$. If any capacitor C_i, i=1,2,…,n, take part in the capacitance sum forming, then we will consider $k_i=1$ and in the other case $k_i=0$. Then the output current I_{OUT} can be determined by the next formula:

$$I_{OUT} = \left(\sum k_i.2^{i-1}\right).\frac{2.C_0.E^2.d^2}{T.U_{OUT}.(1-d)^2} \qquad (2)$$

So it can be concluded that the reference value for that circuit can be set by controlling N digital signals, which define the state of the switches for the parallel connected capacitors. Then simpler than [3] regulation algorithm can be used – it can have analog nature[1].

As conclusion it can be said that for constant current LED driving for reliability test purposes power source based drivers should be used. This way stable output current can be achieved. The current value setting can be done easily digitally – either by writing reference value at specific memory cell (the circuit in fig.2) or by N digital signals (the sircuit in fig.3).

B. Testing high power LED with pulse current driving

There are several possible approaches for pulse LED driving using as a base a constant current driver.

A switch mode regulator for high power LEDs consist of the following blocks: output filter switching block, control system and energy source. The control system defines such duty ratio for the switching block that the desired level of energy is fed from the input source to the output. This is represented in figure 4.

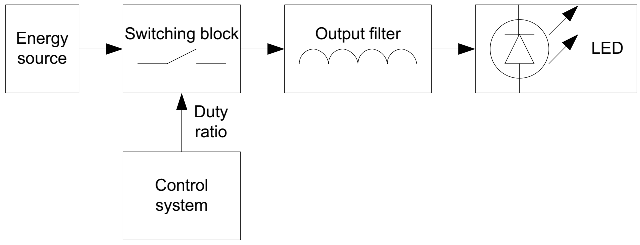

FIGURE 4. BLOCK DIAGRAM OF A SWITCH MODE LED DRIVER

The first approach for pulse driving consists of forcing the duty ratio to zero [9]. In this way the processes in the whole (or part of the) switching block are stopped, as no more energy is delivered to the output filter. In the case of ideal switching block that can be started or stopped at a moment, the driver turn on/off times are defined by the output filter. In most of the used switch mode topologies (Buck, Boost, Cuk, Sepic) the output filter consist of an inductor. Then for the minimum driver turn on/off time can be written:

$$T_{transient} = L.\frac{I_{OUT}}{U_{out}}, \qquad (3)$$

where: I_{out}, U_{out} are the output current and voltage, L is the value of the filter inductance and $T_{transient}$ is the calculated turn on/off time.

It can be seen that for typical application with I_{OUT}=1A, U_{OUT}=2V, L=200uH, the transient time would be 100us. With such approach it would be very difficult to go below microsecond or tens of microseconds transient time.

Advantage of the discussed method is that ideally the power consumption in turn off state is zero.

In the second approach for pulse driving a switching circuit is placed between the driver and the high power LED [4]. An example schematic is represented in figure 5.

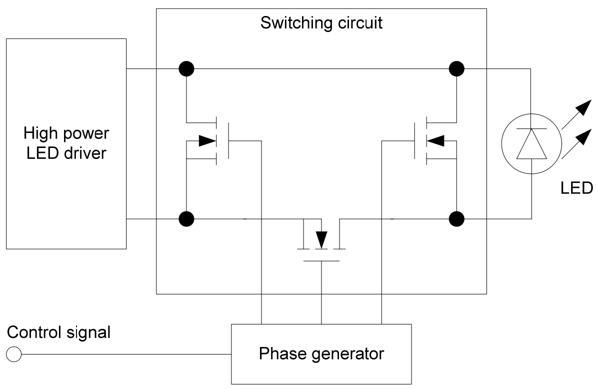

FIGURE 5. PULSE DRIVING WITH SWITCHING CIRCUIT

The switching circuit consists of several switching elements, which are connected in parallel or serially. The switching elements are driven by the input control signal after additional phase shifting. This way proper consequence of the transients can be insured.

The purpose of the switching circuit is to shunt the power LED during the pulse off time. During the pulse on time the switching circuit should not influence the normal system work. During pulse off time the driver output current should flow through the switching circuit, but not through the LED. The voltage drop over the switching elements must be equal to the one over the LED during the pulse on time. This way the driver would not see any change in the output load.

Using fast switching devices the transient time can go down to nanoseconds.

Disadvantage of the discussed method is that the power consumption is constant – in turn off state it is the same as in the turn on-state, as the same current is flowing and the processes in the driver are not stopped.

Another disadvantage of the discussed method is that practically the voltage drop over the switching circuit would be different from the voltage drop over the LED. Some control systems rely on constant output voltage, thus the turn-on time can be increased due to their response delay.

As a conclusion it can be said that for the purposes of reliability tests the second approach for pulse driving – using output switching circuit, is preferred. In this case the power consumption is not important.

C. Testing high power LED with the "question current" method.

Typical method for reliability LED tests is the "question current". It is illustrated in figure 6.

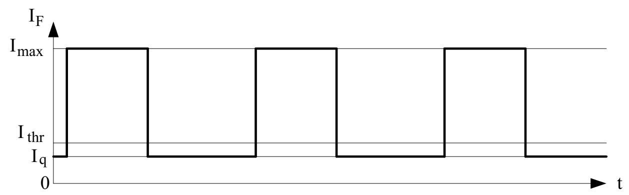

FIGURE 6. OUTPUT CURRENT WAVEFORM IN "QUESTION CURRENT" METHOD

The "question current" method is sub-method of the pulse LED testing. In this method during the pulse off time the output current is bigger than zero. It is still below the threshold value, so the diode is not emitting light. This "question" current value is chosen in such way that measurement of the LED forward voltage drop can give information about the temperature performance of the DUT.

As the "question current" value is comparatively pretty lower, it is not reasonable to be produced by the high-power driver used for the primary pulse. It can be produced by another, secondary LED driver circuit. The requirements for this secondary driver are much lower. Its output current value still must be stable, accurate and easy to set. But it must have much lower amplitude. Thus even linear current source can be used or if the amplitude is still high enough it could be a standard Buck based switch mode current source with analog control.

Both, the primary and the secondary current sources must be synchronized by common control system.

D. Measurement units in high power LED reliability test systems.

During a high power LED reliability tests, the output light power and the diode forward voltage must be measured.

Output light power meters usually are based on photodiodes and proper optical system design must be taken into account. The measurement of a forward diode voltage, which usually is in the range 0.5V to 3-5V, can be done with any of the standard voltage measurement methods.

These measurements must be done in both driving modes: with constant current drive and with pulse current drive. In the case of pulse driving several challenges appear. The measurements must be synchronized with the pulse driver. Also they must be done in very short time period – the pulse on time period. Another possibility is to average the measurement result over long time, but it needs additional data processing.

III. A COMPLETE TEST SYSTEM

A. Block diagram.

Typical block diagram of a complete system for LED reliability tests is shown in figure 7.

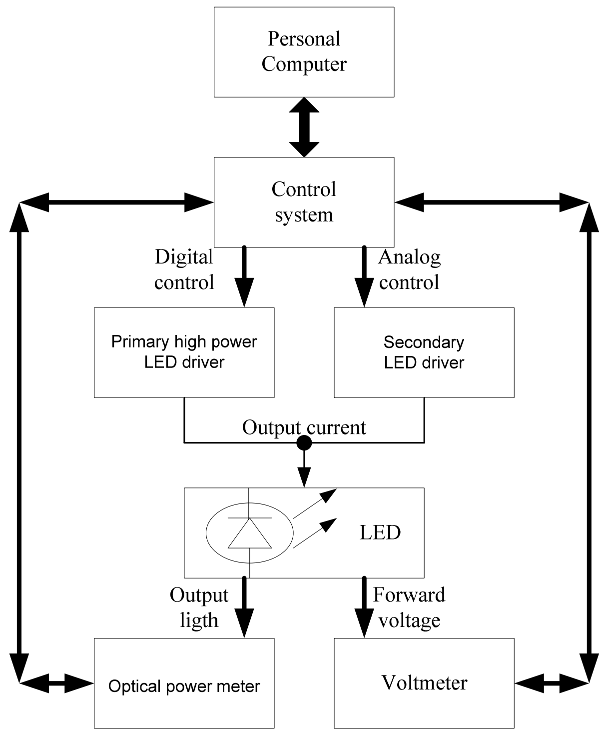

FIGURE 7. BLOCK DIAGRAM OF A COMPLETE LED RELIABILITY TEST SYSTEM

As it can be seen, a complete reliability test system includes the blocks described above, control system and a PC.

In a complete system the primary LED driver is a high-power one that can be used in constant current or pulse current driving modes. The secondary LED driver is a low-power one that can be driven only in constant current mode and usually is used in "question current" tests. Then the LED forward current is a sum of the currents delivered by the primary and secondary sources.

The control system defines all input signals to the primary and secondary diode drivers in order to determine the output current value and timings as pulse period, duty cycle, etc… The control system also defines the settings for the measurement units, such as measurement range, synchronization pulses, etc … It also reads the measurement results. The control system can be connected to PC allowing application software to reconfigure the test system in order to comply with the various test standards.

B. Requirements for the control system and the application software.

As described above the control system must do a lot of digital processing. So it must consist of at least one microcontroller. But it is better to use two microcontroller cores: for lower and higher levels of processing.

The microcontroller core responsible for the lower level processing would be focused on the digital control of the primary driving source, implementing the algorithm described in []. It also will produce synchronization signals for the rest of the test system.

The microcontroller core responsible for the higher level processing would communicate with the external PC. It also would set the reference values for both driving circuits and the proper ranges for the measurement units. If any post-processing of the measurement results is needed, it would be done by the "higher-level" core.

The PC application software must be able to put the whole test system in various conditions, required by different test standards. The PC application software must give to the used the following options to configure the test system:

- to chose constant or pulse driving mode for the primary LED driver;
- in the case of constant LED driving to chose desired current value;
- in the case of pulse LED driving to chose the pulse period, pulse on time, current value during the pulse on time;
- to chose whether secondary LED driver to be used;
- to chose current value for the secondary LED driver;
- to chose test duration time.

All these settings should be accessible by the used in user-friendly way.

The PC application software must be able to read, store and represent the measurement results. The speed of the interface to the test control system must be properly chosen. If many fast measurements are to be done, it must be high enough. The measurement results must be saved in a format that allows further data processing. Possible format is the comma separated file, which can be processed by many excel programs. The representation of the measurement result must be clear and easily understandable by the user. Text and graphical, summary and full data forms should be available.

IV. Conclusion

In this paper design solutions for configurable HB LED reliability test system were described. All basic system blocks and the complete system as a whole were analyzed.

It was concluded that power source driver must be used in order to achieve stable output current. The proposed schematic solution can by digitally controlled.

In the case of pulse LED tests proper output switching circuit was proposed to be used. It assures fast transients – low turn on/off times. The higher power consumption can be neglected.

Two level control system was proposed. The lower level implements the regulation algorithm and synchronization and the higher level handles the interface with PC.

The requirements for the PC application software were explained. It should be user-friendly, able to set the test system in the desired condition and able to read, store and represent the measurement data.

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