XVIII SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '18

# UNIVERSAL RAILWAY LED MODULE LL-000

Nenad ANTONIĆ [1]
Ivan KOKIĆ [2]
Bojan KOSIĆ [3]
Marko NIKOLIĆ [4]
Željko STOJKOVIĆ [5]

***Abstract*** *– This paper presents the Universal LED module LL-000 - an electronic module with LED light source, intended for the use as a single, coloured light source in railway signals in the relay interlocking system SpDrS-JŽ. LED module is designed as a replacement for dual filament incandescent lightbulbs on main, shunting and limit track signals. Light signals represent one type of an output information from the interlocking and are required to return to the interlocking the information about their operating state. In the SpDrS-JŽ system, this information is obtained from current loop of the signal's light source power supply. LED module is intended for the mounting in the standard signal housings in use on Serbian Railways, instead of a lightbulb support bracket. Mounting of the LED module requires minimal modifications to the housings. Other than that, LED module does not require modifications in the interlocking system, and supports all the operating modes and states that an incandescent lightbulb had – day-time and night-time mode, blinking operation, alarm and error state. Given that the bulk glass lens and the scattering glass of the original optical system are retained, optical characteristics of the signal are at least the same as in the case of a lightbulb. In comparison to lightbulbs, LED technology offers considerably longer lifetime, thus reducing operation costs.*

***Keywords – LED module, relay interlocking, railway signal, incandescent lightbulb***

## 1. INTRODUCTION

Railway interlocking systems were historically primarily based on well-tested and robust electromechanical relay technology, while signalling devices used incandescent lightbulbs as the light sources. One example of such interlocking is SpDrS-64-JŽ, which is in use on Serbian Railways. Regarding the modernization of railway systems, rather than replacing the complete relay interlocking with an electronic one, it is often the case of retrofitting only a part or a subsystem of an existing interlocking system with a modern, electronic equipment.

One of such parts, which are often replaced by a more modern alternative in a railway system, is an incandescent lightbulb used in railway signal lamps. At the time when the development of LL-000 device was initiated, neither of major European manufacturers of railway signalling devices had to offer an electronic module based on LED technology as a replacement for two-filament lightbulbs in SpDrS-64-JŽ which could be used without major modifications in the interlocking system.

## 2. FUNCTIONAL DESCRIPTION

LL-000 ("000" is replaced by the nominal diameter of the specific signal lamp which uses the device, e.g. "136" or "70" on Serbian Railways) is an electronic module with LED light source intended for the use in SpDrS-64-JŽ relay interlocking. The device is designed as a replacement for two-filament incandescent lightbulbs (12 V / 20 W or 30 V / 15 W) on main, shunting and limit-track signals. LL-000 retains the functionality of the lightbulb and supports:

- Day-time and night-time operation
- Blinking operation
- Cold testing of the auxiliary filament
- Alarm state and error state.

[1] Institute „Mihajlo Pupin", Volgina 15, Beograd, nenad.antonic@pupin.rs
[2] Institute „Mihajlo Pupin", Volgina 15, Beograd, ivan.kokic@pupin.rs
[3] Institute „Mihajlo Pupin", Volgina 15, Beograd, bojan.kosic@pupin.rs
[4] Institute „Mihajlo Pupin", Volgina 15, Beograd, marko.nikolic@pupin.rs
[5] Institute „Mihajlo Pupin", Volgina 15, Beograd, zeljko.stojkovic@pupin.rs

LL-000 is designed to be powered by AC voltage, but can also operate on DC voltage when used on some specific signals (e.g. red signals on automatic signalling block (ASB)). LL-000 is connected to the interlocking via 3-wire or 4-wire power cable. 4-wire interface is used on red main signals, since they require auxiliary filament cold testing and the interlocking implements galvanically isolated circuits for each filament. 3-wire interface is used on all other signals, since they have common return line for both filament circuits, while the interlocking automatically breaks auxiliary filament circuit when it detects that main filament is active. Detection of an active filament in SpDrS-64-JŽ interlocking is performed by the current loop in the signal power supply circuit. Functional diagrams of 3-wire and 4-wire interfaces are shown in Fig.1.

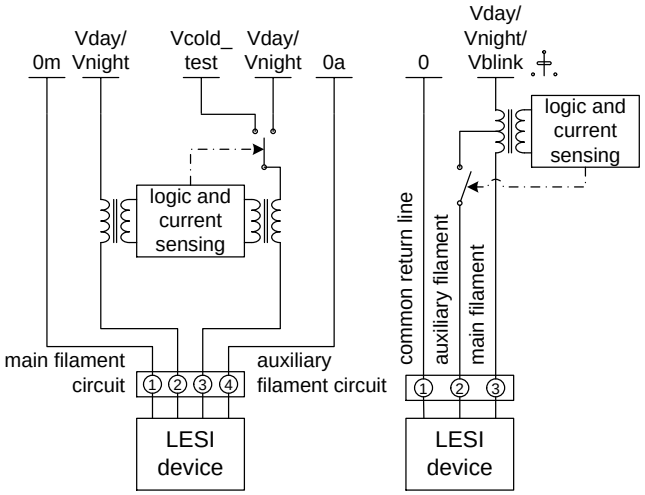


*Fig.1. LL-000 connection in SpDrS-64-JŽ*

A light source of LL-000 device consists of two discrete LEDs, which are controlled separately by the module’s internal logic unit.

The device enters nominal operating mode when a regular input voltage is detected and the light source is fully functional (i.e. both LEDs are operational). The interlocking sets day-time or night-time operation mode by setting the input voltage of the LL-000. In day-time mode, device produces light signal of nominal intensity. In night-time mode, light intensity is reduced to 50% of nominal. LL-000 also supports blinking operation (in both, day-time and night-time mode), with nominal blinking frequency of 1 Hz and 50±5 % light pulse width. One of peculiarities of SpDrS-64-JŽ interlocking is a requirement for the signal lamp to return specific current to the interlocking even during the dark phase in blinking operation when the voltage applied to the lamp is under 2 V. Although incandescent lightbulbs could naturally meet this requirement (since the resistance of a cold filament is very low), system design of LL-000 had been significantly constrained by it.

In the case of a single LED failure, LL-000 enters an alarm state and internally breaks the main filament circuit using a latch relay. This action results in breaking of main filament current loop and is detected by the interlocking which in turn activates auxiliary filament circuit. LL-000 remains in alarm state and operates on the auxiliary filament circuit. In order to maintain signal light intensity, the average drive current of the remaining LED is doubled (which is still less than nominal average drive current for chosen LED’s).

In case of any other irregularity of LL-000 system, or a second LED failure, the device enters an error state in which only a microcontroller remains active. In error state, total current of the device is less than interlocking’s detection threshold and the signal lamp is considered as “burned”.

## 3. DETAILED DESCRIPTION

LL-000 consists of a single printed circuit board and dissipating resistors mounted on the housing lid, and can be divided in three logical units: processing unit, input unit and LED unit, as shown in Fig.2.

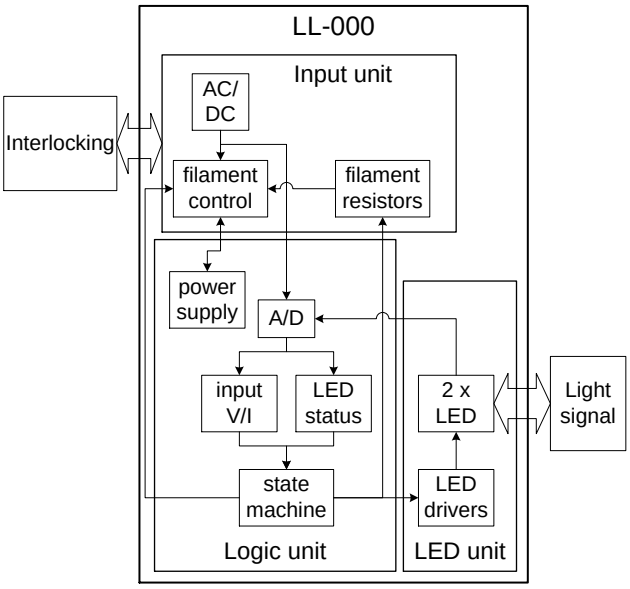


*Fig.2. LL-000 Block Diagram*

Input unit performs simulation of two-filament lightbulb and consists of diode bridge rectifiers (entire LL-000 system is in DC domain and is powered by AC voltage), latch relay for main filament breaking in alarm state and dissipating resistors that simulate filament resistance. Since lightbulb filament is a thermally dependent resistor, at least one discrete resistor is needed to model its resistance for each operating mode – day-time, night-time and cold-testing or dark phase blinking. Since the total power consumption of the rest of LL-000 system is negligible compared to the power dissipated on these resistors, characteristic input impedance of the signal

seen by the interlocking is still predominantly resistive, as in the case of a lightbulb.

Logic unit is organized around safety microcontroller from *Texas Instruments*' *Hercules* family, which implements finite state machine in software, using infinite main loop and timer interrupts. Microcontroller periodically performs A/D conversion of various electrical values in the system and monitors states of each LED. Based on these input parameters, state machine switches operating states which correspond to the device's operating states – day-time, night-time and blinking operation depend on measured input voltages; active filament depend on measured input currents; and alarm or error state depend on the detection of LED or any other failure. For each state, specific set of control signals is generated by the microcontroller, which drive LEDs and appropriate dissipating resistors, and latch relay if needed. All of control signals are dynamic signals – in the form of square wave, in order to ensure an inactive – steady signal state, in case of microcontroller's malfunction or hardware error on the signal path.

LED unit of LL-000 device consists of the light source (two LEDs), their power supply, and constant current drivers (each LED is controlled separately through its designated current driver). LED drivers are driven by the square wave signal of sufficient frequency for the human eye to perceive constant light signal, so that the average luminosity of LEDs is controlled by the control signal's pulse width. LED unit allows a series connection of two LEDs in each controlled branch (four LEDs in total). Two additional LEDs are located on another printed circuit board, which forms a separate light source, controlled by the main module. This configuration is used on limit track signals which originally had two sets of two lightbulbs of the same colour connected in series (two red and two white lights). Control signals for LEDs are multiplexed in time, i.e. only one LED is be driven at any time. This enables the detection of the single LED failure to be performed by measuring total LED current (which detects LED open circuit) and voltage drop on each LED (which detects LED short circuit).

## 4. SPECIFICATIONS

LL-000 device is mounted in the standard signal lamp housings which are in use on Serbian Railways, instead of a lightbulb support bracket. Mounting of the device requires minimal mechanical modifications to the housings to allow for the thermally effective mounting of dissipating resistors on the lid of the housing. These modifications do not interfere with an operation of a lightbulb. Other than that, LL-000 does not require modifications in the interlocking system. One LL-000 module fully installed in the standard housing is shown in Fig.3.

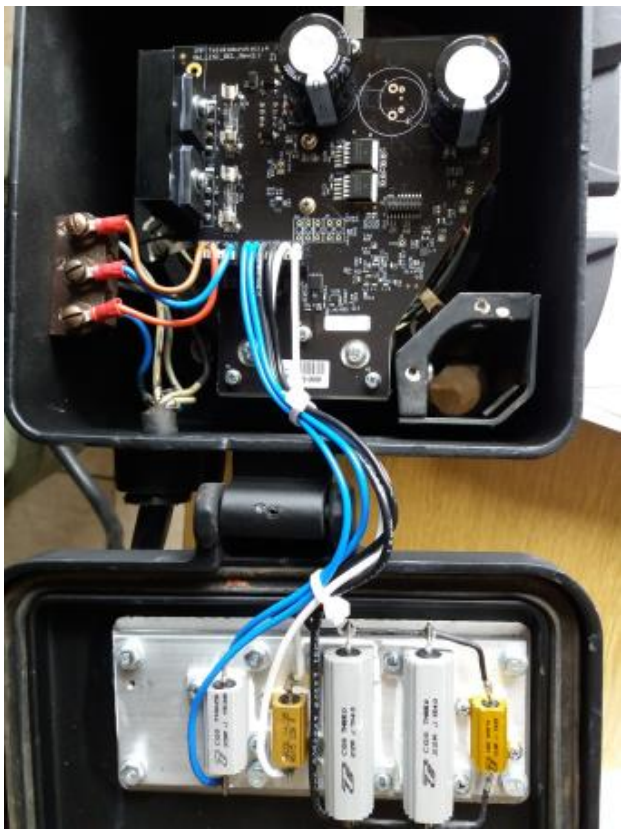

*Fig.3. LL-000 Block Diagram*

LL-000 operates on the AC voltage with nominal frequency of 50 Hz. Absolute maximum operating input voltage is 70 V for main signals and 100 V for shunting and limit track signals. Electrical specifications for LL-000 devices used in SpDrS-64-JŽ interlocking are provided in Tab. 1.

*Tab. 1. Electrical specifications*

| LL-000 type | Day-time | | Night-time | |
|---|---|---|---|---|
| | Voltage [V] | Current [A] | Voltage [V] | Current [A] |
| Red | 14 | 1.3 | 9 | 1.1 |
| Yellow | 20 | 1.3 | 11 | 1.1 |
| Green | 24 | 1.3 | 14 | 1.2 |
| White | 14 | 1.3 | 8 | 1.2 |
| Red/White Shunt | 35 | 0.5 | 24 | 0.42 |
| Red/White Limit track | 60 | 0.5 | 40 | 0.42 |

Original optical elements – bulk glass lens, diverging glass lens and the protective glass – in signal housings are retained when LL-000 is used. Since LL-000 uses coloured LEDs, coloured glass filters are not required and are removed. LL-000 has two, high-brightness LEDs, positioned closely

together. Mounting of the module ensures that the position of LEDs is set so that they occupy the same space as a main filament of the lightbulb did. In this way, light images produced by the LL-000 devices are satisfactorily similar to the original lightbulb images and conform to the requirements in [1]. Colours of LEDs used in LL-000 devices conform to the requirements in [2] and have the following chromatic coordinates:

- Red: x = 0.676, y = 0.320;
- Green: x = 0.198, y = 0.700;
- Yellow: x = 0.572, y = 0.426;
- White: x = 0.295, y = 0.315.

## 5. CONCLUSION

LL-000 railway LED module is designed as a replacement for two-filament incandescent lightbulbs in relay based SpDrS-64-JŽ interlocking system. The module is mounted in existing signal lamp housings with minor mechanical modifications. No other modifications to the interlocking are required. Modified housings retain parts of the original optical system and the placement of the module inside a housing ensures that optical characteristics of the system are maintained. LED module supports all of the operating modes and states required by the interlocking, as well as an operation in the auxiliary filament circuit. The alarm state is entered when a single LED failure occurs while the second LED is still operational. Alarm state is equivalent to the breaking of the main filament circuit. Error state, or breaking of the both filaments, is entered when both LEDs fail, or any other failure is detected by the module’s control logic. LL-000 also supports day-time, night-time and blinking operation as well as a cold filament testing on auxiliary filaments on red lamps on main signals.

## REFERENCES

[1] Interni standard Jugoslovenskih železnica, *JŽS S2.008. "Rasipna stakla za železničke signalne svetiljke - Tehnički uslovi za izradu i isporuku"*, Zajednica Jugoslovenskih železnica, I izdanje 1963.

[2] Interni standard Jugoslovenskih železnica, *JŽS S2.003. "Obojena sočiva i obojena stakla za železničke svetlosne signale i signale na putnim prelazima - Tehnički uslovi za izradu i isporuku"*, Zajednica Jugoslovenskih železnica, I izdanje 1962.