Addressable LED/ Buzzer structures for signaling/ reflection for urban E-Bikes

Devina Manoeva, Vasil Pichurov
Postgraduate school, Faculty of German Engineering and Economics Education (FDIBA)
Department of Electronics, Faculty of Electronic Engineering and Technologies
Technical University of Sofia
8 Kliment Ohridski blvd., 1000 Sofia, Bulgaria
devina@tu-sofia.bg, vasilpichurov@gmail.com

Abstract – **This paper presents results from a study about an addressable LED wearable indicator system concept increasing visibility and safe interaction between E-bike users and other participants in urban traffic. To this end, we explore existing solutions for small and energy-efficient signaling devices. Exemplar we select one product as basic model, analyze its characteristics and in search of a more suitable functionality for the scientific project for autonomous cargo E-bikes "AuRa", we offer new technical and design requirements. The conducted experimental part is based on investigating safety and ergonomics to QC-test some critical timings of selected LEDs. We want to integrate findings from this and upcoming studies to formulate construction indications for a future control hardware and software design as a proposal for the project "AuRa".**

Keywords – **activity recognition, E-bike, haptic feedback modality, signaling, wearable displays.**

I. Introduction

Nowadays we are experiencing a major upheaval in terms of mobility. The enormously overpopulated cities worldwide quickly need mobility alternatives that are safer, more ecological, and more compact. Autonomous driving as a possible, almost likely future of mobility offers new scenarios to move [1]. In the project "AuRa" scientist of OVGU Magdeburg take the first step to transfer the vision of shared mobility as a service on autonomous driving cargo bikes: users will be able to call a cargo E-bike, which can drive autonomous to the desired starting point users may choose, use it for multiple purposes and release it again for others to use [2]. There, no longer needed, the bike autonomously returns to a waiting point or the next user. This will make real door-to-door mobility possible [3].

Fig.1. Autonomous urban cargo E-Bike "AuRa" prototype, photo: OVGU/ Jana Dünnhaupt

The desired effect of the new mobility offer relates to a wide use by many users. We believe that the increased usage of e-bikes may lead to the need for better and safe visibility and interaction strategies. For both autonomous and manual drive, the interaction via light and sound signaling between the autonomous vehicle/the user and everyone else on the road should be ensured for everyone's safety [4]. The profile of the vehicle is different for both situations: in the autonomous mode we observe the vehicle as a fully autonomous vehicle (human driver excluded), in manual mode we observe it as a conventional vehicle: E-bike with a user (human driver is included).

In this paper, we focus our research on the manual drive. Signaling during a manual ride is especially important so others can see where a cyclist wants to go. Nowadays for communicating intention hand signaling is required for left/right turn or stop-indication. But this type of signaling cannot ensure good safety. To maintain balance, the handlebars need to be griped always with both hands. The user should always be careful when using the arm on the side that controls the rear wheel brake.

Visibility during a manual ride is also especially important so others can see when a cyclist show up. The German law StVZO § 67a [5] define as roadworthy a bike with functioning brakes, pedals, a bell for dispensing acoustic warning, it needs to be lit up from the front and the back as well as have reflectors. But in StVZO there is no law requiring wearing helmets or reflective clothing, which make it much easier for others to see a cyclist. They are not mandatory, but we strongly recommend their usage. Therefore, in our research, we want to contribute to the study about wearable indicator systems for better visibility and safer interaction between E-bike users and other participants in urban traffic. Based on our research, we select a model device as an example of a similar system. To this end, we analyze the device's design and specifications and offer new construction indications for a new addressable wearable LED/Buzzers signaling structure as an optimized proposal. In the experimental part of this paper with QC-Testing we firstly want to test technically how safe the concept of wearing LED-structures can be.

II. Example for a signaling system for E-Bike users, optimizing interaction and visibility

WAYV [6], is a wearable bike safety light system, one that has both front and back turn indicators and remains highly visible in different riding positions, designed by Amit and

978-1-7281-7426-6/20/$31.00 ©2020 IEEE

Dotun (see Fig.2). In the following list we point some main advantages of the system, which argument our choice

Design advantages

- Maximum visibility: It consist of both wearable harness, which can be attached also directly to backpacks and headset, which can be attached to most vented helmets (highest point of visibility positioned).
- Adjustable design: harness and headset are adjustable to fit users with different size and shapes. The “Aura”-bike will be used by different users. Therefore, we consider this point with high priority.
- Compact and light: harness weighs less than 200 grams, helmet gear weighs less than 150 grams. Harness is tough but flexible. It can be stowed in a small bag along with helmet gear.

Technical advantages

- Signaling source: harness has over 200 seamlessly integrated super bright LED's to make cyclist super bright and super visible.
- Signaling art: the indicator LED’s are orange and the backlight ("X") is red. This design is built on the established car lighting and indication paradigms that everybody already understands.
- Wirelessly operation: The harness and helmet indicator lights are controlled simultaneously by a detachable wireless remote on the bike’s handlebars. The remote can be operated without adjusting the grip when turning, the lever is nudged up or down with the thumb to activate the indicators and then nudged again to switch them off.
- Waterproof: all the electronics are sealed and waterproof.

III. Proposal for a Signaling System for “AuRa” E-Bike Users, Optimizing Interaction and Visibility

Trying to make the WAYV system better suitable for the “AuRa”-bike we defined new design requirements for a future concept, we called *“Addressable wearable LED/Buzzers signaling structure”* as an optimized proposal for the “AuRa”-bike. In the following list we point our main design proposals:

- Display system centered around a smartphone: for the hardware controller and powering we will develop a display system centered around a smartphone controller, (see Fig.2), with the power to control the independent functions of the indicator system.

Fig.2. E-Bike- wearable LED indicator system WAVY [6] with new E-Bike – control diagram

- NFC wireless connection: the smartphone controller is connected to the drivers of the LED segment displays by NFC, contactless interface, compatible with ISO / IEC 18000-3 mode 1 (ISO / IEC 15963), which is a standard for wearable electronic circuits. –
- Signaling art: next to stop and turn, we want to add some new use-case scenarios and display additional symbols for “Falling from the E-Bike/Emergency/Danger”, “Losing the E-Bike” etc. This will be another task for the smartphone controller for generating images/signals using the LED segment displays TR1…TR3, TL1…TL3, SH1, SB1, by controlling their brightness, color, and switch between the power states. The challenge of generating images onto LED segment displays is their low resolution to display text. Pictograms are the main carriers of light transmitted information and messages to the other participants in the medium.
- Smart LED drivers: The NFC interface uses Pulse Width Modulation (PWM) at 25kHz to control the brightness of the LEDs with and accuracy of +/-0.1%. This is the first time that LED drivers, which can store the “working hours” for every LED in their internal memory, are used for such a project. This information is used for the automatic CLO system for compensating the bright LEDs which degraded over time. -
- Haptic Feedback to the user: we offer adding haptic signaling for additional use-case scenarios as “Pedestrian crossing Detection”, “Speeding up”, “Brake” as well as “Forward Collision Warning (LDW)” conditions, which activate haptic vibrations in the front of the bicycle helmet to create “Inertia!” feedback loop to gain bicyclist attention and to give preparation time for taking the appropriate position of the body to overcome the moment of inertia. The haptic signaling/feedback to the user can be useful also for indicating other scenarios as of “There is a car behind you”. A light sensor in the back should detect headlights for example and give feedback to the user. -
- Acoustic Signaling: E-vehicles are usually silent. For better safety we offer adding acoustic signaling as a function of the system, which should be able to generate an additional warning sound for pedestrians.

IV. Methodology

In the experimental part of this article, in collaboration with electronics hardware designers, we want to examine safety and LEDs circuit implementation (see Fig.3). as a requirement for ergonomics of a similar LED system, that is so close to the human body. We aim to test behavior under severe conditions. For its end, we choose an experimental equipment and structure (see Fig. 3, 4).

Fig.3. E-Bike - Addressable LED strip

Single full-color LED with driving mechanism used in E-Bike signaling bus is related to US8094102B2 Patent. Accordingly, the invention discloses a package structure of a full-color LED that is equipped with internal driving mechanism. LEDs have an IC built into the LED, which enables communication via a one-wire interface. This means that many LEDs can be controlled using one pin on bl.6 bus driver controller. The LED strips have 3 pins: the power pin, the ground pin, and the data pin (Din and Dout). The power and ground pins are used to apply power to signaling/reflection for urban E-Bikes, while the data pin should be connected to the controller.

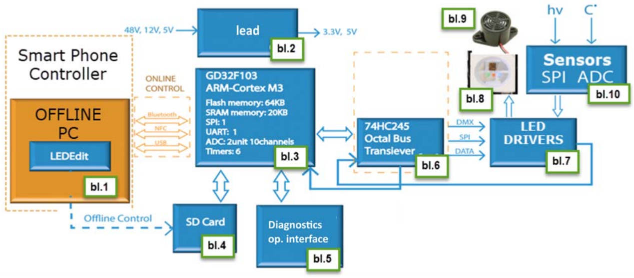
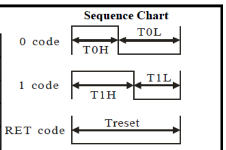


Fig.4. E-Bike - Addressable LED/Buzzers structures

After initial test of the addressable LED/Buzzers structure from Fig.4 we did some QC tests and found that the LEDs were failing in a weird way. Basically 1/10 LEDs had one or more internal diodes failing. Typically, the blue diode, but occasionally red or green and in rare cases multiple or all three diodes failed. The failure seems to be temperature sensitive, and in extreme cases pressure sensitive too. Being temperature sensitive means that from a cold start running full brightness white, in about 30 seconds we will start to see issues, but after it is warmed up (1-5min) those issues will disappear. If poked (pressure) it is very likely we can permanently damage it. The design of wearable displays requires more QC tests for the communication path related with wire length, capacitive loads, trailing/falling edges, and power supply issues. The data transfer protocol uses single NZR communication mode. After the pixel power-on reset, the DIN port receive data from controller, the first pixel collect initial 24bit data then sent to the internal data latch, the other data which reshaping by the internal signal reshaping amplification circuit sent to the next cascade pixel through the DO port. After transmission for each pixel, the signal to reduce 24bit. pixel adopt auto reshaping transmit technology, making the pixel cascade number is not limited the signal transmission, only depend on the speed of signal transmission. RESET time is greater than 280μs, it will not cause wrong reset while interruption, it supports the lower frequency and inexpensive MCU (see Fig. 5).

Data Transfer Time

T0H	0 code, high voltage time	220ns~380ns
T1H	1 code, high voltage time	580ns~1μs
T0L	0 code, low voltage time	580ns~1μs
T1L	1 code, low voltage time	220ns~420ns
RES	Frame unit, low voltage time	>280μs



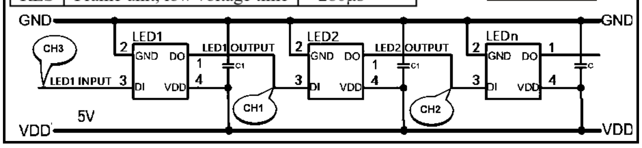


Fig.5. E-Bike- Addressable LED/Buzzers timings

In our test approach, to generate the NRZ bit stream, a timer in PWM mode could be used and generate two different duty cycles for sending a "0" logic or "1" logic. Using integrated PWM's and DMA modules can unload the CPU in the generation of each single bit. The modules in the Cortex MCU can do that in a very effective mode and generate more than 4 addressable LED strip channels simultaneously. NRZ bit stream itself is not a synchronous timing but rather an encoding that can be used in either a synchronous or asynchronous transmission environment, that is, with or without an explicit clock signal involved. Because of this, it is not strictly necessary to discuss how the NRZ bit stream encoding acts "on a trailing clock edge" or "during a clock period", since all transitions happen in the given amount of time representing the actual or implied integral clock cycle. The real question is that of sampling the high or low state will be received correctly provided the transmission line has stabilized for that bit when the physical line level is sampled at the receiving end. NRZ bit stream. To evoke the auto reshaping transmit technology/NRZ decoding and to test the stabilization of the DO-DI transmission line a 3 channel oscilloscopes images were observed.

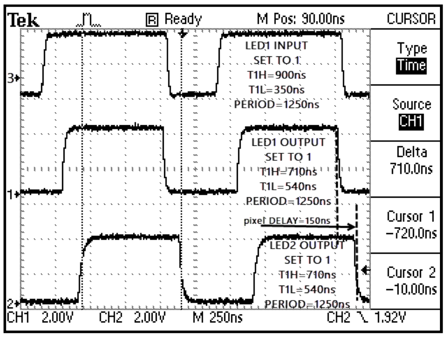


Fig.6. Auto reshaping “SET ALL to 1” for standard clock period

Switching all addressable LEDs in the strip to “pure white” color and “max” brightness in Fig.6 sets the reshaping to T1H=710ns, T1L=540ns and the delay between to pixel is about 150ns. Each pixel draws about 60mA from the power supply. Switching all addressable LEDs in the strip to “pure black” color and “min” brightness in Fig.7 sets the reshaping to T0H=250ns, T0L=1000ns and the delay between to pixel is about 100ns. Each pixel draws about 8mA from the power supply. This condition requires external software on/off control to reduce the power consumption in this case.

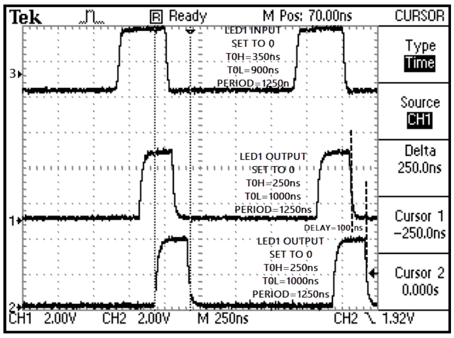


Fig.7. Auto reshaping “SET ALL to 0” for standard clock period

Switching all addressable LEDs in the strip to “pure white” color and “max” brightness in Fig.8 sets the reshaping to T1H=760ns, T1L=2640ns. Each activated pixel draws more than 60mA from the power supply, the voltage level of signal falls under 2V. Some pixels are not lit, and many are active in wrong color and brightness levels. This condition must be avoided because of thermal overheating.

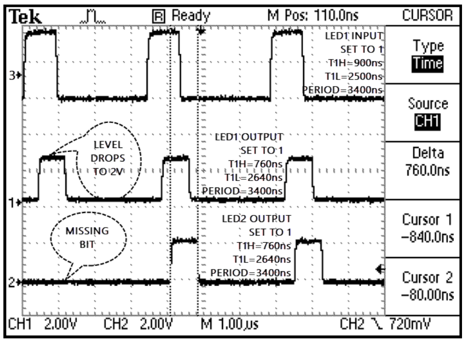


Fig.8. Auto reshaping "SET ALL to 1" for a bit higher than standard clock period.

Switching all addressable LEDs in the strip to "pure black" color and "min" brightness in Fig.9 sets the reshaping to T0H=250ns, T0L=1170ns. Many pixels are active in wrong color and brightness levels. This condition requires external software control to find wrong bytes for light/buzzer signaling.

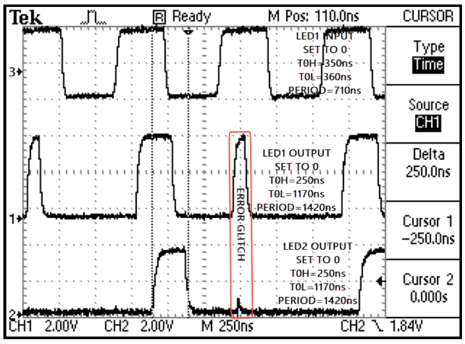


Fig.9 Auto reshaping "SET ALL to 0" for a bit lower than standard clock period.

Switching all addressable LEDs in the strip to "pure black" color and "min" brightness in Fig.7 sets the reshaping to T0H=250ns, T0L=1000ns and the delay between to pixel is about 100ns. Each pixel draws about 8mA from the power supply. This condition requires external software on/off control to reduce the power consumption in this case.

ANALYSYS

The controller schematics Fig.3. was improved with new modules for feedback control path bl.7 to bl.3 to resolve wrong decoded NRZ conditions in addressable LED/Buzzer strip path. New ADC module bl.10 is to be developed to get environment temperature and light level to reduce overheating and to lower and switch-off the power consumption in non-active condition for signaling. The switch-off hardware adds the ability to avoid all signals that are not adequate.

V. CONCLUSION

The chosen hardware for good visibility and prolonged life of the wearable system as well as the controller are a good foundation for experimenting in the field of subsystems for a new and adequate light and acoustic signaling system for autonomous vehicles. A long process of research and analysis will decide which semiconductors like LED pixels, buzzers are most suitable for the selected design, and how new methods incl. the haptic and acoustic feedback will be most effective for the new urban traffic medium, whereby in the future they will be included in the universally defined package for required elements in the exterior design of autonomous vehicles.

ACKNOWLEDGMENT

The paper was created as part of a design and ergonomics research for the project "AuRa" of OVGU Magdeburg. The project is funded by the European Regional Development Fund (ERDF).

REFERENCES

[1] T. Assmann, „Gewerbliche Nutzung von Lastenrädern - Modelle, Verwendung, Vorteile," in ACE Auto Club Europa e.V. (Hrsg.) (Ed.), Mobilität gestalten, Stillstand verhindern (S.60–62). ACE Auto Club Europa e.V, Berlin, pp. 60–62, 2018.

[2] K. Krause, T. Assmann, S. Schmidt, and E. Matthies, "Autonomous driving cargo bikes – Introducing an acceptability-focused approach towards a new mobility offer," in Transportation Research Interdisciplinary Perspectives 6, 100135, 2020.

[3] S. Zug, S. Schmidt, T. Assmann, K. Krause, S. Salzer, M.Seidel and V. Wohlgemuth, „BikeSharing der 5. Generation - Szenarien und Herausforderungen für den Einsatz autonom agirender Fahrräder", in J. Marx Gómez, A. Solsbach, Th. Klenke, Smart Cities/Smart Regions – Technische, wirtschaftliche und gesellschaftliche Innovationen Konferenzband zu den 10. BUIS-Tagen, Springer Vieweg in press, 2019.

[4] D. Manoeva, and S. Draganov, "Lighting utilization as a tool for interaction of small autonomous urban vehicles in mixed traffic environment", in 11th Electrical Engineering Faculty Conference (BulEF), IEEE Library, 2019.

[5] Federal Office of Justice, Germany. Bundesamt für Justiz, Straßenverkehrs-Zulassungs-Ordnung (StVZO) § 67 Lichttechnische Einrichtungen an Fahrrädern, 8 Sept. 2019. [Online] Available: http://www.gesetze-im-internet.de/stvzo_2012/__67.html.

[6] WAYV, 12 July 2019. [Online] Available: https://wayv.uk/pages/about.