

Human-machine interface

Head-up displays for greater safety when driving trams



*Illustration 1:
Example of a Combiner
head-up display for
driver assistance with
selected information,
navigation instruction
and warning signal*

Dr. rer. nat. Christian Trapp, Senior Manager Interior Electronic Functions/Instrumentation & Displays, Continental Engineering Services

Important driving information at a glance – without taking your eyes off the traffic: That is the strength of a head-up display. Continental is currently putting a solution into series production that is optimised for original equipment and retrofitting of trams.



Source: Continental

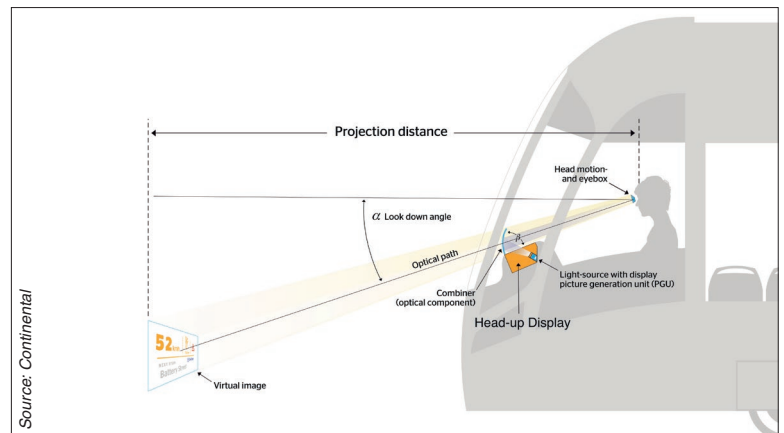
Trams are experiencing an upswing due to the growing importance of local public transport (LPT) and its high environmental compatibility compared to private transport. Rail enjoys a high level of acceptance – also and especially in inner-city areas. This can be seen from the growing number of tramway operations in Germany over the years.

At the same time, this trend brings challenges, because trams on level tracks move right through the middle of dense public traffic. For drivers, it is a great challenge to keep an eye on cars, cyclists and pedestrians as well as important driving data, traffic signs and navigation instructions. In a situation in which it is already difficult for tramway operators to find young talent for the driver's cab – and to retain them in the long term – the so-called head-up display (HUD) can make a substantial contribution to the road safety of trams and to reducing the workload of the driving personnel.

“Head up” in the driver’s cab

Originally, the technology of the head-up display originated in military applications in fighter aircraft, where it was used to prevent other flying objects from being lost from sight due to instrument readings or similar. In cars, the HUD is now in series production in many cases as a contribution to safety and ergonomics.

A HUD is much more than just an additional display in the driver's lower field of vision (Illustration 1). This is due to the optical peculiarities of a real HUD – for example, in contrast to a transparent display on the windscreen or in a separate component. One of the main advantages of HUD is the length of its beam path (Illustration 2). Unlike conventional displays in the dashboard, where the viewing distance is around 60 centimetres, for example, the display of a HUD



*Illustration 2:
Beam path in
the Combiner
head-up display*

appears in the distance range of several metres in front of the driver, depending on the design.

This makes a huge difference in the driver's workplace: You can read a HUD while continuing to observe the traffic situation. This is possible because the focus planes of the traffic and the HUD are very close to each other for the eyes. It is quite different with conventional displays or transparent displays on the windscreen: Here, the eyes have to work to adjust to the changing viewing distance. This accommodation work is tiring in the long run, and it takes time. In the brief moment of looking back and forth, the person in the driver's seat can no longer perceive the surroundings.

Illustration 3 shows how blurred the environment in the periphery of the field of view becomes when the driver looks downward at one of the displays in the instrument panel (right half of the image). The HUD content and cyclists, on the other hand, are equally visible to the eye (left half of the image).



*Illustration 3:
Effect of a Combiner
head-up display:
The focus planes of
the display and traffic
situation are close
together (left half of
the image), unlike
with the conventional
instrument (right half
of the image)*

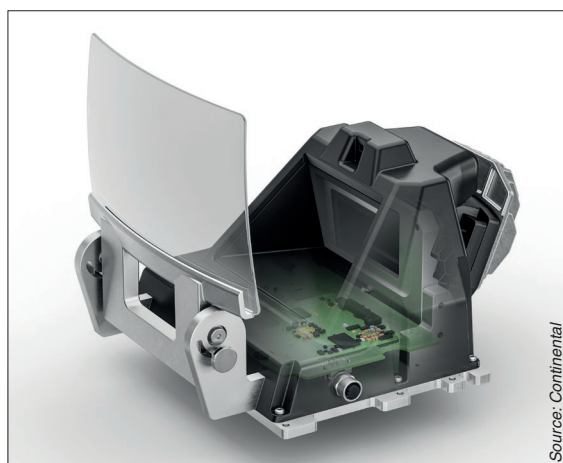
Since tram drivers have to constantly manage a changing viewing distance on some sections of the route due to the complexity of the environment, the HUD makes the driver's workplace much more ergonomic. The second main advantage of a HUD is its effect as an information filter. A HUD offers selected and, depending on the situation, important information for the driving task in a pre-selected manner. If the driver wanted to read this information in a conventional driver's cab without HUD support, several instruments would have to be read at the same time, which would increase the time spent looking away from the surroundings.

In this way, the HUD acts as a system that focuses the driver's attention on the essentials and keeps the eyes where they belong: on the traffic situation. In addition, a true HUD has a very powerful light source that produces a readable display under all prevailing ambient light conditions. Automatic brightness tracking always ensures the right luminosity and a high-contrast image. In addition, it is now standard for the HUD to have a full-colour display. This also serves to promote ergonomics and safety, because effective signal colours or colour changes intuitively direct the driver's attention to the right place.

Technical implementation

The Combiner HUD, developed by Continental Engineering Services as an option for retrofitting and original equipment of trams, is based on series production experience in automotive applications, where Continental is a pioneer with this technology. In principle, HUDs can be designed in two versions: Either the display is mirrored directly into the windscreen and uses its reflective behaviour. This windscreen HUD is only suitable for original equipment and must be extensively adapted to the respective vehicle model, among other things because the shape, appearance, and inclination of the windscreen require a relatively large development effort.

*Illustration 4:
The compact Combiner
head-up display for trams
is a ready-to-install
module*



For this reason, a second technology has been established with the Combiner HUD, in which the display is mirrored into a small transparent synthetic glass pane (= Combiner) with excellent optical properties, which is part of the optical system. This Combiner HUD is much more economical to implement because the beam path is easier to control as all components are integrated into one module.

Given these advantages, the near-production tram HUD presented here is based on Combiner technology and has up to 800*480 pixel resolution. Illustration 4 shows the complete module. It integrates the electronic control, the actual display, the light source and the Combiner in one compact unit. In addition, there is a cover that prevents irritating reflections. In view of the typical small series requirements for trams, this rail solution is consistently designed to be modular and scalable. Depending on the display size required in the individual case, the individual components can be adapted with minimal effort thanks to defined interfaces and options.

The tram HUD can be connected to the on-board electronics either via a CAN port or via an Ethernet port. The HUD can either be designed as an intelligent solution that generates symbols and displays using its own electronics on the basis of data, or the HUD can be designed with low computer capacity and in this case only feeds supplied symbols and content through to the display.

One of the technical strengths of the rail solution is the proven HUD light source, which must be able to cope with a tremendous ambient light dynamic – from darkness to bright sunlight – to keep the display constantly readable. This light source in the tram HUD is a proprietary development that has already proven itself hundreds of thousands of times in cars and generates a virtual image with a maximum luminance of more than 10000 cd/m² (candela/m²).

Due to its modular design and adaptability, the tram HUD can also be retrofitted into driver's cabs. Its small dimensions enable integration without violating valid regulations for the driver's field of vision.

The HUD as the basis for additional safety functions

The HUD helps drivers to keep a close eye on the traffic at all times. Especially on inner-city sections, where pedestrians and cyclists frequently cross the tracks – in order to reach or pass the tram – and where car drivers easily misjudge whether they can still pull in front of a tram, a lot depends on the tram driver's presence of mind.

By now, driver assistance systems serve to better meet this challenge. The HUD also offers a central advantage for such systems: As a dynamic information filter



*Illustration 5:
Monitoring of the driving
environment to the side
and ahead*

at the ergonomically best possible location, it makes warning signals for drivers visible in their line of vision. But that's just the beginning: When a HUD is available in the tram, it can serve as a platform for networking with other safety functions. One example is a camera directed at the driver, which can detect diversion of gaze due to distraction. Appropriate warning signals to the driver serve to draw his attention back to the traffic situation. The HUD provides an ergonomically favourable human-machine interface in such moments of shock to direct the driver's attention.

This has great potential, because even surveillance that covers the areas to the left and right of the lane requires a warning strategy for detected objects with a potential accident risk, which signals to drivers where their attention is required. This is also a conceivable combination with the HUD as the first port of call for visual cues (Illustration 5). All this does not merely serve to initiate necessary emergency braking in good time. Ideally, by supporting the drivers, it is even possible to reduce the number of emergency braking manoeuvres, as these can always be associated with a risk for standing passengers.

This is possible because the HUD, in an intelligent combination with advanced driver assistance systems, can contribute to extending the time available between the detection of a danger, the perception and correct interpretation of the situation by the driver and the adequate response. This goal should be pursued already given the long stopping distance of a tram. This in turn also serves to reduce the number of accidents that are emotionally stressful for drivers.

As it can be observed that many urban pedestrians are paying more attention to their smartphones than to the traffic around them, the responsibility of drivers for the protection of vulnerable road users has become far more important. The HUD is a valuable component that provides the best possible technical support for drivers in this situation.

Outlook

On the one hand, the HUD makes the workplace in the driver's cab of a tram more attractive; on the other hand, this form of selective display increases safety in public transport. With an economical Combiner HUD solution that has been specifically optimised for use in trams on the technical basis of proven series products for cars, a new visual interface is available that lends itself as a component for intelligent and ergonomically favourable networking with driver assistance systems. ■

This article has been first published in German in *Deine Bahn* – Trade magazine for rail technology, railway operations, education and training, Issue June 2022.

Published by Bahn Fachverlag Ltd.,
Berlin, Germany
www.system-bahn.net
www.bahn-fachverlag.de