



APPLICATION STORY



BMW incorporates thermal imaging cameras in its cars

Lowering the risks of nocturnal driving

Bayerische Motoren Werke, worldwide known as BMW, is one of the most prestigious car brands in the world. It stands for luxury, high-quality, safe and environmental friendly cars, all equipped with the latest technology.

Safety is an issue which is taken very seriously within the BMW Group. New technologies are introduced to avoid accidents and to reduce the number of injuries in case an accident should occur.

Nocturnal driving: twice the risk of an accident as compared to driving during the day.

Accident statistics show that driving at night represents a significant potential danger. In Germany, some 50 per cent of fatal car accidents happen at night, although an average of 75 per cent of all driving is done during the day. This means that the risk of driving at night is twice as high as during the day. A similar situation is to be found in the US. With a 28 per cent share of all driving, 55 per cent of all fatal accidents occur at night.

Accident statistics throughout Europe as a whole also justify intensive consideration of the issue of nocturnal driving. According to estimates, approx. 560,000 people are injured in the dark in Europe and some 23,000 are killed.

The darkly dressed jogger in the half light, the insufficiently lit cyclist at night: the increased risk to pedestrians poses one of the biggest safety problems in the dark. Here again, the Federal Office for Statistics is clear: over 25,000 accidents per year involving pedestrians and cyclists occur during the night in Germany.

The reasons are obvious: poor or significantly limited sight conditions on highways and country roads, obstacles or narrow bends which are recognised too late with the low beam, inappropriate judgement of speed or distance due to a lack of orientation for the eye, driving into the "black hole" of the headlights of oncoming traffic, possibly exacerbated by wet, reflecting road surfaces – just to mention a few examples.



BMW Night Vision module

Our eyes are the first line of defense against these hazards. Unfortunately, eyes are not the best detectors and they can use some assistance when driving at night to avoid accidents.

Making night time driving safer

For years, BMW has developed innovative technologies which provide relief for drivers at night and thus at the same time improve general road safety. Innovations include Xenon lights, which provides significantly increased brilliance and range, "Adaptive Headlights", whose horizontally swiveling headlamps ensure considerably improved illumination of the road ahead and "High Beam Assistant" which turns the headlights automatically on and off, are just a few innovations that can be installed in BMW models and help drivers during night time driving.



BMW Night Vision

Another recent innovation to help drivers see better at night and in the most diverse weather conditions, is the "BMW Night Vision" system.

The core of this system is a FLIR Systems thermal imaging camera. BMW is the first European premium car manufacturer that started to implement this technology in its cars.

"We started to develop the system in 2002," says Mr. Russ, a BMW engineer who helped head the system's design efforts. "At the end of 2005, we started marketing our Night Vision systems as an option on our BMW 7-series models. Today, the Night Vision system can be ordered as an option on our 7-, 6- and 5-series models."

"The first aim of the BMW Night Vision systems is to detect living objects, such as pedestrians and animals, which are not illuminated in total darkness," explains Mr. Russ. "With a thermal imaging camera, people can be detected at a range of about 300m. This is much further than with headlights. Early detection of people means less deadly accidents. But also the early detection of animals, especially in North European countries, is saving the lives of drivers. Hitting e.g. a moose can result in heavy injuries and even death."

Thermal imaging sees more than the naked eye

But a thermal imaging camera can see more than just living objects. By allowing drivers to see thermal images of the road ahead - well beyond what headlights illuminate - drivers are able to detect obstacles, other cars, curves in the road, ... much sooner and have more time to react. Thanks to thermal imaging, drivers can more quickly detect and recognize potential hazards and avoid deadly accidents.

Due to its long range detection capability (up to 300m for a human being, more than 800 m for a 2.3 x 2.3 m object), BMW Night Vision provides a time gain of about 5 seconds at a speed of 100 km/h compared to high beam headlights. This means that drivers have more time to react and can avoid accidents.

A rugged system

"The thermal imaging camera is installed in the front bumper, at the left. Incorporating it into a car is not a big challenge. Only two additional hardware components are needed: the camera and the control unit," continues Mr. Russ. "The camera is well protected against harsh driving conditions. Rain, salt spray, and small rocks hitting the front of the camera are not affecting it."

The camera has a built-in heater to defrost its protective window. This heater is capable of defrosting a 2mm layer of ice frozen to the window within 15 minutes when ambient temperature is -30°C and wind speed against the window is 100 km/hr. The heater is automatically powered when window temperature is less than $+4^{\circ}\text{C}$ and powered down when window temperature is more than $+6^{\circ}\text{C}$. This ensures a clear lens and perfect infrared images displayed on the monitor even in extremely cold environments.

A camera cleaner jet can be activated along with the windshield washer system. It ensures that the lens stays clean at all times. A wiper is not installed and not needed.

Crisp thermal image in the peripheral view of the driver

The BMW Night Vision system is turned on and off using a switch next to the light switch. The 320 x 240 pixels image is displayed on the centrally placed on-board monitor in the dashboard. It is installed in conjunction with the navigation system Professional.

"We decided to show the image of the thermal camera in the centrally located monitor," says Mr. Russ. "It is not in the direct sight of the driver but the human eye can easily and quickly detect moving things in its peripheral view. Once a moving object is detected, the driver can have a quick glance at the screen to see what is happening." The monitor quickly becomes a natural checkpoint for the driver similar to side view or rearview mirrors.



"We deliberately chose not to place the monitor in the direct view of the driver. The distraction would be far too high when something is moving in the image," explains Mr. Russ.

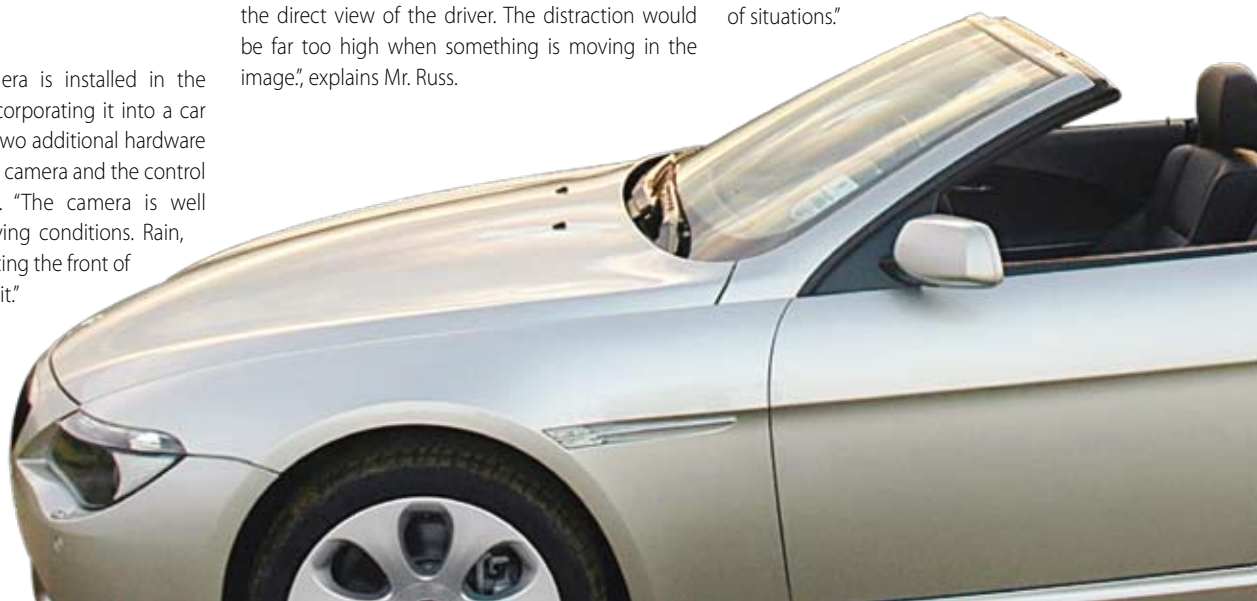
At speeds below 80 km/h, the wide horizontal field of view (36°) of the thermal imaging camera assures that not only the road can be seen but also the areas at the side of the road and surroundings. (bicyclists, pedestrians, children, wild animals, ...) At a high speed the field of view is automatically narrowed to 24° . At the same time, the field of view follows the turning of the road up to 6° left or right. This so called panning movement is controlled by the parameter "steering of the wheels". A digital zoom can be activated which displays objects at further distance in a 1.5:1 enlargement.

Night Vision: two different technologies

There are today two different technologies on the market for night vision systems. Far Infrared (FIR) also called Passive Infrared and Near Infrared (NIR) also called Active Infrared.

The NIR system beams infrared radiation into the area in front of the vehicle. The infrared beamers are often incorporated in the headlights. The infrared radiation is reflected by objects, the road and human beings and converted to an image which can be displayed on a screen. FIR, like used in the BMW Night Vision, registers the differences in heat, or infrared radiation, emitted by objects and human beings. It does not need a separate light source from the vehicle.

"The decision to choose for FIR technology instead of NIR technology needed to be taken at the beginning of the Night Vision project. At that point in time, FIR was to our opinion the best system. For other purposes NIR may be better suited but, to our opinion, not for the use in vehicles to detect people and other objects. Tests showed that we could see much further with FIR and detect pedestrians and obstacles sooner. Furthermore, the distance that you can see with NIR is not only shorter but it is highly dependant on the power of the infrared beamers," explains Mr. Russ. "Today we are convinced that FIR outperforms NIR in a large number of situations."



Not only can FIR detect objects and people at a longer range, it also contains less components so it is less susceptible to breakdowns. Another major advantage is that FIR is not sensitive to the headlights of oncoming traffic, street lights and powerfully reflecting surfaces such as traffic signs. Since NIR systems are using light waves as the basis for their image, especially light intensive objects appear brightly on the screen. This also applies to the infrared beamers of a NIR system when it is detected by another NIR system. This means that the driver can be blinded.

FIR systems, like the BMW Night Vision, are producing a comprehensive image based on the differences in heat radiation of objects and people. Even when these temperature differences are sometimes minimal, a FIR system will detect them and transform them into a crisp image. FIR systems are not affected by light and there is no risk that the driver is blinded by oncoming headlights or other light sources.

A NIR system is giving a complete image of the road, including road marks.

Although at a first glance this may seem an advantage, it delays the detection of people and objects within the image. And although the image generated by an NIR system is initially processed more quickly by users, after a period of familiarization with the FIR system the opposite is true. Many drivers prefer the image generated by a FIR system since they can detect objects, animals and people a lot clearer and faster.

BMW Night Vision is the beginning of a development

As with the introduction of other innovations, there will be several stages of development with BMW Night Vision. "Improvement for the future lies in increasing the image quality," explains Mr. Russ. "Thermal imaging in cars was initially developed for military users where image quality was not that important. Although the camera is already producing a clear,

crisp, detailed image, one of the next steps could be to even further improve the image quality. Another, maybe even more important area for research is the implementation of software that is able to identify pedestrians or critical situations within the general traffic environment."

Initial steps to this so-called object detection have been taken. However, the performance and quality is, not yet, in line with the extremely high demands set by BMW and its customers.



Increasing safety and driving pleasure without taking away responsibility

Just like other safety features in a car, BMW Night Vision was created to increase driver and passenger safety. By presenting the driver with additional and early information, potential danger can be avoided. More information is a bonus in road traffic. Up to 50% of all serious accidents are caused by the fact that the driver did not have the information early enough to avoid the accident.

The BMW Night Vision system also offers the user more driving pleasure. The increased situational awareness provides relief for the driver during a strenuous nocturnal trip.

BMW Night Vision does however not offer total safety. Promising this would be misleading and unjust. It is important that its potential is understood but it is even more important to realize that the driver is the master of his vehicle and that reckless driving will always cause accidents and injuries. No matter how many safety features are implemented in a vehicle.



Visual image



Thermal image



Visual image



Thermal image

More automotive applications for thermal imaging cameras

More and more people are discovering the advantages of thermal imaging cameras for a wide variety of applications. Not only automotive but also security, maritime, firefighting and other sometimes life saving applications are using the power of thermal imaging. Volume production, combined with recent evolutions in detector technology, makes thermal imaging technology much more affordable than before.

FLIR Systems markets the same module as BMW is implementing in its luxury cars, the PathFindIR, for a variety of transportation applications.

Trucks and busses

Professional drivers, have to deal with a lot of stressful and dangerous factors already during daytime such as poor and non-experienced drivers, heavy traffic and long hours behind the wheel. This can put them, their vehicle, goods and passengers in dangerous situations. Driving at night or in poor weather conditions even increases the danger. Thermal imaging can help to protect themselves, their vehicles, loading and passengers.



Trains and metros

Poor visibility during night and in adverse weather conditions causes mishaps not only on roads but on tracks as well. Trains and metros have a huge breaking distance therefore people or objects on the track need to be detected as early as possible to avoid accidents. Thermal imaging can also help train drivers when they go into dark tunnels.



Emergency vehicles

Emergency vehicles need to get to the scene of the accident as fast as possible. Also at night, in all types of adverse weather conditions. The vision of fire truck and ambulance drivers can also be obstructed by smoke when they are called to an accident where a fire is involved. Thermal imaging is able to see through the smoke and ensures that emergency vehicles can reach the accident fast and safe, without causing further accidents.



Military vehicles

See without being seen. This is a major requirement for drivers of military vehicles. Thanks to thermal imaging a military vehicle's head and taillights can be completely covered, still permitting the driver to see through the darkest of nights.



Thermal imaging: how does it work?

Our eyes are detectors that are designed to detect visible light (or visible radiation). There are however other forms of light (or radiation) that we can not see. The human eye can only see a very small part of the electromagnetic spectrum. At one end of the spectrum we can not see ultraviolet light, while at the other end our eyes can not see infrared. Infrared lies between the visible and microwave portions of the electromagnetic spectrum.

The primary source of infrared radiation is heat or thermal radiation. Any object that has a temperature above absolute zero (-273.15 degrees Celcius or 0 degrees Kelvin) emits radiation in the infrared region. Even objects that we think of as being very cold, such as ice cubes, emit infrared radiation. The heat that we feel from sunlight, a fire or a radiator is all infrared. Although our eyes can not see it, our skin can feel it as heat. The warmer the object, the more infrared radiation it emits.

How does a thermal imaging camera work?

Infrared energy coming from an object is focused by the optics onto an infrared detector. The detector sends the information to sensor electronics that translates the data into an image that can be viewed on any standard LCD. Based on the temperature differences of objects, a thermal imaging camera can produce a comprehensive image on which the smallest of temperature differences can be seen.

Contrary to other technologies, such as e.g. light amplification, that need at least small amounts of light to generate an image, thermal imaging needs no light at all.



For more information about thermal imaging cameras or about this application, please contact:

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