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TECHNICAL BACKGROUNDER: CADILLAC'S NIGHT VISION SYSTEM

DETROIT -- In the earliest cars, acetylene lamps were used in an attempt to make driving at night safer. Despite all the technological advances in headlamp technology since then, night time driving remains more dangerous than driving during daylight. On a per-mile basis, driving at night is more than three times as likely to result in a fatality as driving during daylight. While many factors, such as fatigue, contribute to this increase in collisions at night, visibility certainly plays a significant role.

Now Cadillac introduces a technology designed to enhance night time safety, an infrared Night Vision system that helps drivers "see" objects that would otherwise remain in the dark. While Night Vision technology has been used in military and other applications, Cadillac will be the first automaker to offer Night Vision on a production vehicle - the 2000 DeVille. Cadillac is also the first to offer a Night Vision system that :

- Is fully integrated into a production vehicle.
- Offers a head-up display (HUD) to help drivers keep their eyes on the road and hands on the wheel.

Overview

The technology selected for Cadillac's Night Vision program uses infrared imaging with an uncooled focal plane array (UFPA) detector for the sensor and an active matrix liquid crystal display HUD. Raytheon Systems Co. developed the Night Vision sensor, while Delphi-Delco Electronics developed the HUD for the Night Vision system.

The Cadillac Night Vision system is designed to help drivers see beyond the range of the headlamps. The system is not intended to be a drive-by system. A HUD projects a monochrome virtual image near the front bumper of the vehicle. That image is in the driver's peripheral vision. This allows the driver to view the normal road scene unobstructed by the virtual image, yet also look at the virtual image without refocusing or looking away from the road scene.

Having the HUD image projected below the driver's line of sight helps the driver deal with headlamp glare from oncoming vehicles. The sensor is unaffected by ambient light and provides an image that allows you to see beyond the glare of the headlamps. The image location is ideal since the driver tends naturally to look downward to avoid the glare.

The sensor utilizes uncooled infrared technology, which detects the thermal energy of objects that are invisible to the human eye. All objects emit heat, although humans, animals and running vehicles are more visible in the image due to their high thermal contrast with the background. Thermal energy is focused on the detector, using optics designed to pass infrared wavelengths. The energy is absorbed by a grid of detector elements, each of which responds with a change in capacitance. These changes are processed electronically to create a monochrome video image, in which hotter objects in the scene appear white.

This system is only operated at night, when the headlamps are on and the Twilight Sentinel photo cell indicates dark. The Night Vision switch controls image position and intensity. The image position is adjusted by moving the mirror in the HUD, causing the virtual image to move up and down to the driver's desired position. The image intensity control has an "off" detent at the minimum position. The system has a short warm-up time and will display the Night Vision logo until the sensor is ready. The logo is then replaced with the thermal image of the forward road scene.

Motivation for a night vision system

The motivation to develop an automobile Night Vision system is the desire to enhance a driver's field of vision beyond the headlamps. The system is not intended to replace visual information obtained by looking through the windshield, but to provide additional information when it is dark, especially when vision is otherwise obscured. For example, the driver may be temporarily blinded by the glare of oncoming headlamps, or may be unable to distinguish the shape of a deer from the dried brush at the edge of the road. In these and similar situations, Night Vision can help provide information that the driver needs and otherwise would not have.

Infrared: Seeing in the Dark

In 1800, William Herschel, royal astronomer to King George III of England, discovered infrared radiation (IR). While measuring the temperatures of the various colors produced by passing sunlight through a prism, he discovered that heating occurred by rays he could not see. This part of the spectrum is called infrared, because these rays are below (infra) the frequency of red light.

The infrared spectrum begins at a wavelength of approximately 0.75 microns and runs to 1000 microns. Because the IR energy must pass through the atmosphere to get from the source to the detector, infrared imaging uses the ranges of IR energy that travels most easily through the atmosphere. This primarily involves two ranges: 3 to 5 microns, known as medium wave IR (MWIR); and 8 to 14 microns, or long wave IR (LWIR). In these two bands, IR photons are least absorbed by water molecules in the air.

Fortunately, much of the information that drivers need has peak radiation in these ranges. For example, human body temperature is 98.6 F/37 C; the spectral wavelength at which the maximum energy is emitted at this temperature is 9.3 microns.

Every object in the universe emits IR if its temperature is above absolute zero. The amount of radiation depends on two things: the temperature of the object and its emissivity. Objects that are the same temperature can emit IR at different rates. Thermal images are produced by intercepting the radiation from various objects in space and focusing this radiation onto IR detectors. The sensor optics focus the IR energy of a scene onto a 1-inch detector that images heat much like a camcorder images light. The IR energy is focused on a UFPA that is 320 infrared sensing elements wide by 240 infrared sensing elements tall. The elements respond to the thermal energy emitted by objects in the scene. Each element is a temperature-dependent capacitor that changes capacitance depending on how much IR it is receiving. A chopper disc rotates in front of the detector to modulate the scene's energy by allowing the pixels to view the scene and then an absence of scene. It rotates in phase with the detector read-out circuitry timing. The circuit under each element samples capacitance on a regular basis, and these readings are converted into a monochromatic video signal. The video signal is sent to the HUD for display to the customer.

The detector used on Cadillac's Night Vision system is a room temperature, or UFPA, detector, which also has been used for military and commercial applications. The detector temperatures are stabilized with thermoelectric coolers, but there is no attempt to achieve cryogenic temperatures. No mechanical scanner is required to serially trace out object space to produce an image. Instead, each pixel of the UFPA detector "stares" out into space continuously, the scene energy is modulated, and the image is then produced by electronically scanning (reading out) the detector array.

Sensor Installation

Some considerations for installing the sensor on the vehicle are the sensor size, temperature tolerance, mechanical tolerances (e.g., to vibration), dirt tolerance, and vulnerability to stone and weather damage. For the 2000 DeVille, the sensor is placed behind the center of the grille, where it is designed to have an unobstructed view of the road and where it can be kept reasonably clean by car washes, etc. The sensor is temperature-controlled for peak performance. It is equipped with a window to protect the optics as well as give a durable surface to clean. The sensor also incorporates an internal heater to prevent snow and ice build-up on the window.

Optics The lens system uses refractive optics (lenses), similar to those used in visible range cameras that bend (refract) the IR rays from the object to the detector. However, to pass the flux in the IR range of interest, which is 8 to 12 μm , typical optical glasses will not suffice because they act as a filter that ceases to transmit electromagnetic flux at about 1 to 2 μm .

Refractive optics were chosen for the 2000 DeVille because of their smaller package. The optics will be mechanically controlled internally to allow for the system to remain in focus over the automotive temperature range.

Detector Assembly

The UFPA is based on the properties of ferroelectric materials. The ferroelectric material family chosen is barium-strontium-titanate (BST). This material and composition has a phase transition near room temperature where it is most sensitive to temperature differences. An applied field across a capacitor having such properties will respond with a current flow for any change in temperature. This is how the BST detector operates. The detector consists of a BST reticulated structure bonded to a readout integrated circuit. Each reticulated section corresponds to a single detector pixel. The pixels are on 48.5 μm centers and are less than 20 μm thick.

Electronics

The electronics perform all of the video processing, timing and controls. The uncooled detector provides analog single-line video that consists of two interlaced fields, each containing 240 lines. Each line of video contains thermal information for 320 consecutive pixels. The video processing circuitry receives the detector analog video, digitizes and processes it, and converts it back into an analog video signal.

Image Polarity

The Night Vision system presents a "white hot" image, where hotter objects in the scene appear white. Objects the driver cares about most - such as people, animals and running vehicles - stand out from the black background of the night.

The Display

The HUD is integrated into the dash in front of the driver. The HUD projects a virtual image in the driver's peripheral vision near the front edge of the hood. The image has a horizontal field of view of 11 degrees and a vertical field of view of 4 degrees. The objects in the image are the same size as the objects in the road scene, helping the driver relate the image to the road scene. The one-to-one correlation of object size helps the driver judge the distance to an object.

A HUD allows the driver to view the road and the display simultaneously. The HUD has the advantage of providing an image that is at far-field focus and does not require the driver to refocus while glancing at the display. While viewing the display, the driving scene is still in the driver's peripheral view.