The automotive industry is working extremely hard on technologies for autonomous driving. To replace human perception of the environment, the use of driver assistance systems with high-resolution radar and video sensors is essential. Massive quantities of data that need to both be transported via the communication networks as well as processed in real-time are thereby generated. This creates challenges in an unprecedented dimension on recorder solutions as well. When selecting a suitable system, a number of important aspects must therefore be taken into account.

Current radar and video sensors deliver a measurement data volume of approximately 100 MByte/s each. On top of this comes the sensor fusion data from within the ECU for an additional volume of approximately 50 MByte/each. If one assumes, for example, a vehicle that has been equipped with five radar sensors and two video systems, this, together with a number of other measured quantities, results in a data volume of approximately 1 GByte/s that needs to be managed during collection and storing. Thus, a test vehicle generates about 3.6 Terabytes of data per hour and 28.8 Terabytes of data per day (Figure 1).

Multiplied by the number of test vehicles and days of use, this results in massive quantities of data. Furthermore, experience shows that the requirements will grow further as the technology continues to develop.

**Challenges during data recording in detail**

In the first step, the ADAS sensors are to be connected to the recorder. For each sensor to transfer 100 MByte/s, each requires its own Ethernet connection with gigabit bandwidth to the recorder. The same applies for the connection of the ECUs to the recorders.

Planned as memory medium is the use of hard disks, whereby the following requirements are to be satisfied:
- Largest possible disk capacity
- Automotive-suitable temperature range
- Mechanical stability
- High data rate of at least one gigabyte per second
- Low price
Because these partially contradictory requirements cannot be satisfied simultaneously, compromises are unavoidable. Depending on the project, solid state drives (SSDs) or classic hard disks are used. It is not necessary in all cases and for every trip to satisfy requirements such as the automotive-suitable temperature range.

To completely record the data of a test vehicle for autonomous driving for a work day with 1 GByte/s, the storage system requires a capacity of nearly 30 TByte. Such memory sizes and the required transfer rates can only be realized at the present time with RAID systems, i.e., by coupling multiple, large, independent hard disks in a disk network. RAID enables parallel disk access. As a result, the performance of the individual disks can virtually be added and – depending on the RAID level – also optionally offers protection against the failure of individual disks through redundancy.

To fully utilize the resources of the storage hardware, the recorder software, configuration of software and drivers, use of high-performance Ethernet PHYs, setting of the Ethernet message length as well as the choice of the appropriate RAID level play an important role. The CPU of the recorder must be able to reliably handle these large data streams. There must be enough RAM present to buffer an increased data volume in burst phases.

In practice, test drives may vary considerably from one to the next, for example, with respect to test scope and duration. While in one case it is possible to transfer the measurement data to another system after just one day, in another a long-term test might last an entire week. To be clarified here is the question of whether the data can be transferred by swapping disks in the logger or if there is a strategy for quickly reading out the data that does not block the test drive for an excessively long period.

If no provision is made for backing up the data during the day, the user has no alternative other than appropriately dimensioning the disk size.

The question of for whom the measurement data are intended also remains. If one wishes to send a sensor supplier the raw data from his specific sensors, the respective data must be extracted in a separate work step, provided all data are stored in a single measurement file.

The energy management system of the recorder is responsible for keeping the system switched on until powered down, provided no malfunctions occur due to undersupply or voltage drops. During pauses while reading out and transferring measurement data via WLAN, on the other hand, the recorder must not switch to a sleep mode. At the same time, there must always be enough energy in the vehicle battery to be able to reliably restart the car.

Even the best recorder hardware is dependent on optimally functioning recorder software. Its primary task is the receiving and writing of the measurement data on the disk system. In addition, the software provides the developer with services such as the starting and stopping of recordings and allows, trigger conditions to be defined.

The data arrive at the recorder in parallel via multiple Ethernet ports. Typically, these include XCP-on-Ethernet information from ECUs as well as raw data from radar sensors and video cameras that the engineers use for autonomous driving or the ADAS application that is to be tested. An important task of the recorder software prior to the efficient streaming of the data to the hard disk is the time synchronization of the various data sources. Using the CPU resources as optimally as possible, the data are to be prepared in such a way that no further processing is necessary.
Hard disks: Interchangeable RAID system

In addition to being provided with a high-performance RAID controller, there must be a sufficient number of hard disk slots available on the hardware side; these are to be flexibly equipped depending on the project specifications. Important here is that the entire RAID system with all disks either be easy to replace or that a high-performance interface for downloading the data be available.

Recorder software: One instance per data source

The most efficient operation can be achieved by allocating for each data source an independent measurement instance that receives the data and stores it on the disk. In this case, each instance generates a separate measurement file. As a result, the entire measurement is divided into multiple measurement files. The job of the software is to ensure the integrity and time synchronization of the measurement data. Project extensions that arise from an additional source thus only result in another measurement instance.

Recorder hardware: Clones desired

If all hardware resources are exhausted and hard disk slots as well as Ethernet ports are occupied, this problem can be solved through the use of an additional recorder. The time synchronization must not be lost, however. The question of the operating concept also arises: how is the user to start after they are stored. To this end, a measurement data format is required that permits the constant recording of data quantities of any size.

In summary, the following can be postulated: The individual components of the hardware and software are to be selected with great care. A complete solution of hardware and software must be perfectly matched to one another.

Scalable basic concept provides maximum flexibility

With comprehensive scalability over all function units, such as sensor connections, hard disks, software and hardware, all conceivable requirements that may arise during ADAS data recording can best be satisfied.

Ethernet: Classic or Automotive

For the connection of the signal sources, classic Ethernet as well as Automotive Ethernet are equally suitable. The number of required connections may vary greatly from project to project. If the recorder does not have a sufficient number of ports for direct connections, a switch must be connected upstream. The switch then sends the data from the upstream sources together to the recorder via a 10 gigabit Ethernet cable. If necessary, the switch can also assume gateway functionality to physically convert Automotive Ethernet to classic Ethernet. The Ethernet base structure is thereby made scalable, for example, if the number of required ports increases during the course of a project.
and stop measurements at exactly the same time on multiple recorders? Ideally, an additional recorder is added in such a way that, from the perspective of the user, it is fully transparent whether he is solving the measurement task with one or more hardware platforms.

**The completely scalable solution**

The recorder platform from Vector is based on an industrial PC design that is already equipped with a large number of 10-gigabit as well as 1-gigabit Ethernet ports. An expansion unit provides space for up to eight RAID hard disks, which can be completely and very quickly exchanged. There is also space for additional expansions, such as an uninterruptible power supply (UPS). The VX1000 measurement and calibration hardware is used to collect both the raw sensor data and the ECU fusion data and bring them into the PC via Ethernet.

CANape is the recorder software. The new “Distributed High Performance Recording” function included in CANape version 15.0 permits the parallel use of many measurement instances, thereby allowing the multi-core architecture of the computer to be fully utilized (Figure 2). The instances are, thus, not limited to one PC. Rather, the user can easily distribute them over other PCs in the network. The PCs used as part of the recorder solution need only be connected via Ethernet. CANape distributes the measurement tasks over the number of PCs and ensures the time synchronization. With triggered measurements, CANape also provides for precise time control of the processes over all measurement instances (Figure 3). The user needs just one CANape license for the entire setup.

Users benefit from using CANape as logger software in a number of ways. The system can easily be used not only by experts, but by laymen as well. Thus, engineers who work on the further development of their applications have at their disposal the full functionality of the software. To reach the required number of test kilometers, persons without development or tool knowledge can then perform the drives at all hours of the day or night. CANape is able to automatically record the data; no modifications to the vehicle are necessary. Because the system uses the standardized ASAM-MDF-4.1 format to store the data, the measurement data can directly be used by other tools in the evaluation chain.

**Conclusion**

By using recorder solutions with consistently scalable architecture, developers of driver assistance systems obtain very flexible systems that can be expanded to a nearly unlimited extent. The data rates of 500 to 700 MByte/s required in

![Figure 3: Recording of sensor and ECU data, optimization of the algorithm and stimulation of real or virtual ECUs with CANape](image-url)
current autonomous driving projects for the storing of radar, video and ECU data can still be managed at the present time with just a single PC. As requirements increase, investment security is ensured by the VX1000 hardware – which can be used for both ECUs as well as for raw sensor data – and by the scalability of the complete solution.

The complete sensing of the surroundings with all relevant objects that is required for autonomous driving can be realized more quickly and more reliably with a comprehensive solution consisting of software and hardware tools as well as embedded components. During software development with the different types of sensor sources and their fusion, the use of a working prototype is helpful. A combination of the vADAS developer prototyping environment from Vector and the Create algorithm library from Baselabs has proven itself in practical use (Figure 4).

In addition to the validation and testing, Vector also offers project-specific support for the forthcoming requirements with computing-intensive algorithms on multi-core, high-performance platforms, e.g., during the definition phase of ECU architectures with Hypervisor-/POSIX-based concepts. Furthermore, the computers in the vehicle that calculate tactical algorithms for driving maneuvers demand more flexibility from the underlying operating system. Here, the AUTOSAR adaptive platform comes into play. It makes the ECUs fit for future requirements.

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Links
Website Vector: www.vector.com
Product information CANape: www.vector.com/canape
Product information VX1000: www.vector.com/vx1000
General information Vector’s ADAS solution: www.vector.com/adas
Product information BASELABS Create: www.baselabs.de/sensor-fusion-algorithm-development

Figure 4: Visualization in vADAS developer that can be adapted to every application case, both for scenarios with dynamic as well as static objects, such as highway assist, lane-change assistant with blind-spot monitoring or automatic parking.