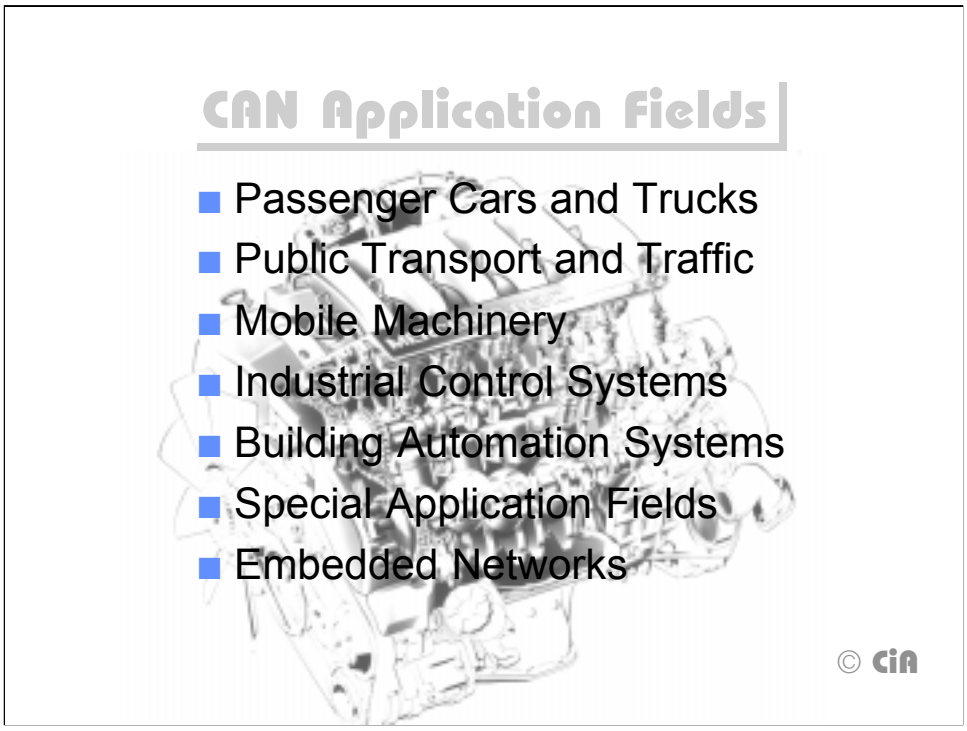


Controller Area Network (CAN) serial bus system was originally developed for in-car use. Today most of the European passenger car manufacturers have already designed powerengine systems as well as multiplex systems based on CAN networks. But CAN networks are also installed by several other industries. The main application fields are industrial control systems and embedded networks.

In general, CAN is suitable for all applications, where several microcontroller-based sub-systems or devices have to communicate. CAN provides multi-master functionality and real-time capability. Unique features are the implemented error detection methods and the fault confinement, which meet the reliability requirements of medical equipment, elevators, and other human-related applications. The enhanced features of CAN protocol will make CAN-based networks suitable for safety-critical applications even for control-by-wire.

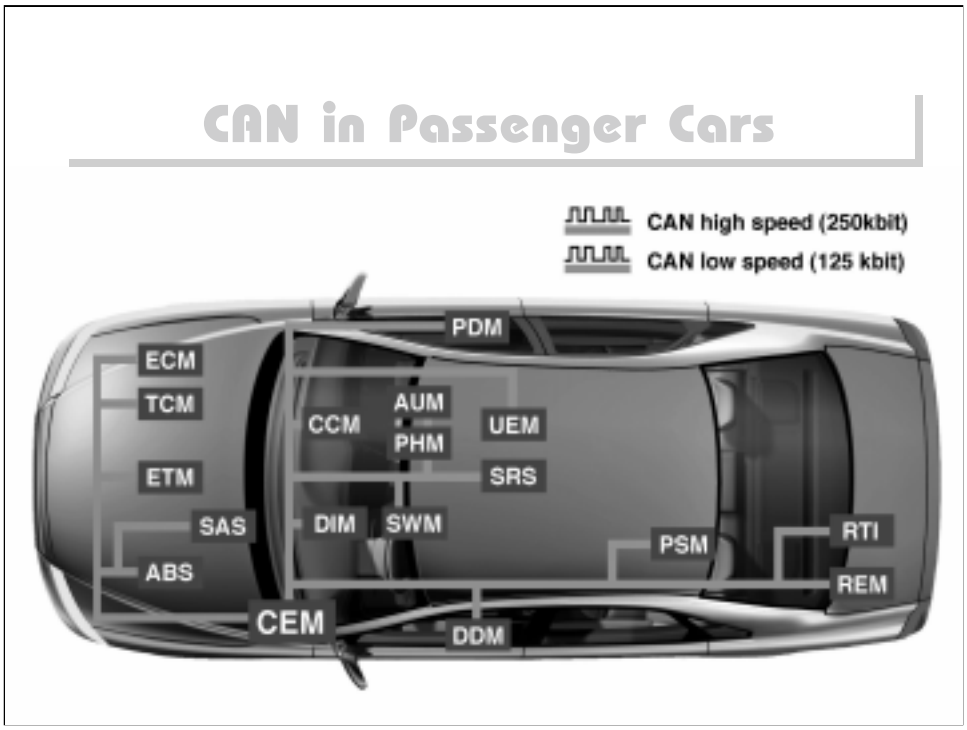
CAN networks are used in powerengine applications connecting several ECUs (electronic control units). Daimler-Benz was the first manufacturer, which implemented CAN in the engine management. Today most of the Daimler-Benz's passenger cars and trucks are using CAN-based engine management systems running 500 kbit/s. Most of the other European automobile manufacturers also have implemented CAN (e.g. Audi, BMW, Renault, Saab, Volkswagen, Volvo).

In addition, some passenger cars are equipped with CAN-based multiplex systems connecting body electronic ECUs. These networks have lower baudrates, e.g. 125 kbit/s. Most of same are using not the high-speed transceivers compliant with ISO 11898, but proprietary fault-tolerant transceivers.

A third class of CAN-based networks in passenger cars is connecting entertainment devices.

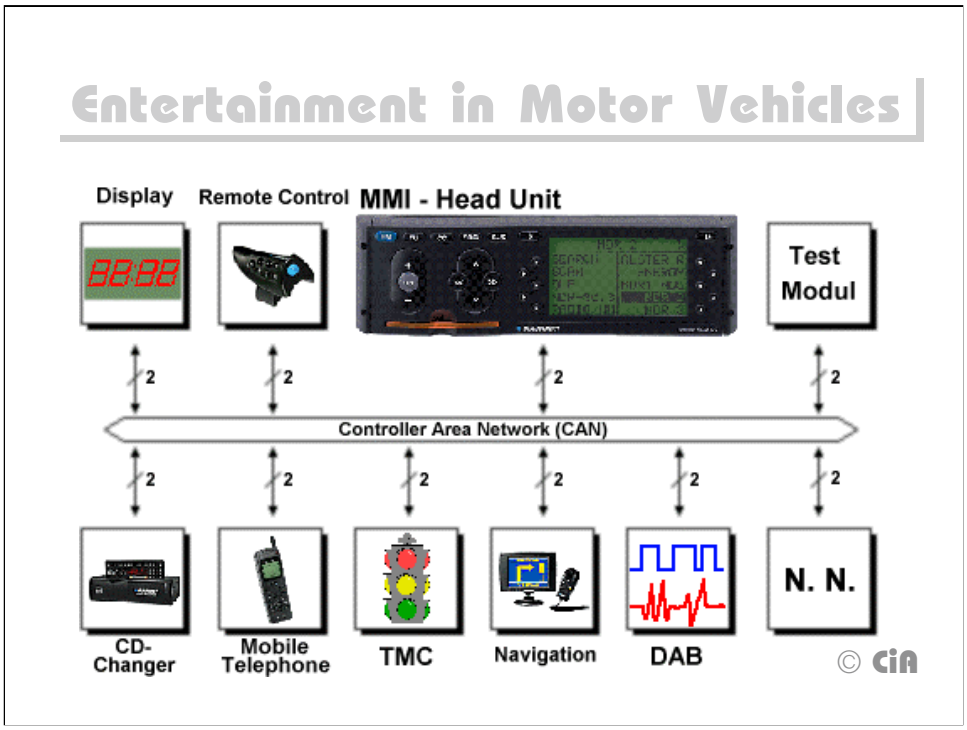
In Europe, all passenger cars will have to provide a standardized diagnostic interface. Within international standardization bodies a CAN-based solution is under development, so in the near future every passenger car must have one CAN node in minimum.

Volkswagen is developing an automatic car test pilot system based on multiple CANopen networks.

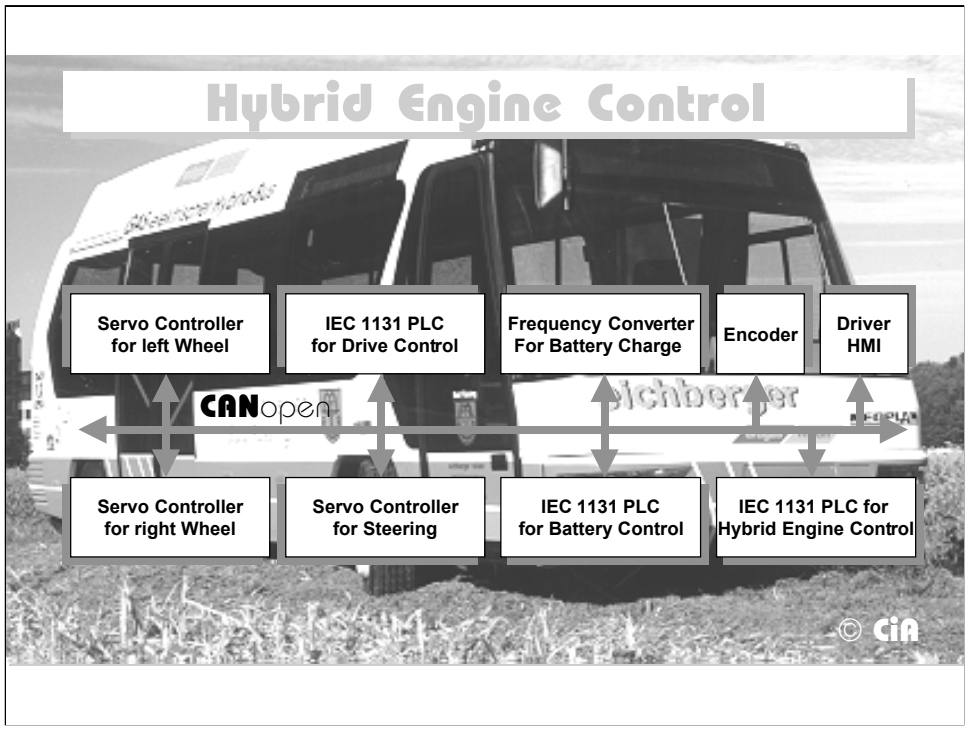


Not only DaimlerChrysler is using CAN networks. The shown car from Volvo uses a CAN high-speed network for engine management and a CAN low-speed network for body electronics. Volkswagen has implemented a low-speed CAN network for the door control units. Other European carmakers will also implement CAN networks.

The just released ISO 15765 standard (Diagnostics on CAN) is a standardized CAN interface for diagnostic purposes and will be mandatory in Europe. It describes physical layer, data link layer, application layer, and how to use the Keyword 2000 services.



The CAN-based MCNet transmission protocol developed by Bosch supports connection-oriented communication. The first MCNet-compatible devices from Blaupunkt (automotive radio variants and a CD changer) have been commercially available since the middle of 1996. MCNet will also be used in OEM projects.



Neoplan has developed a hybrid bus. The engine developed by BMW can use Diesel or natural gas. The engine generates AC voltage, which is converted in DC voltage by a frequency converter to load the on-board battery. The battery powers the two servomotors, which drive directly and separately the rear wheels. There is no more an axis. The frequency converter and the servos produced are controlled by standard PLCs. The programming environment used is IEC 1131 compatible, and the communication is done via CANopen.

The CANopen network also connects the servo controller for steering and the human machine interface for the driver. Not yet linked to CANopen are the encoders, but these will be integrated in the next version. Neoplan's development engineers were surprised because of the short time they needed to integrate all the devices to the CANopen network. One of the reason was that there were already available IEC 1131 function blocks for CANopen services as well as for the motion controllers.

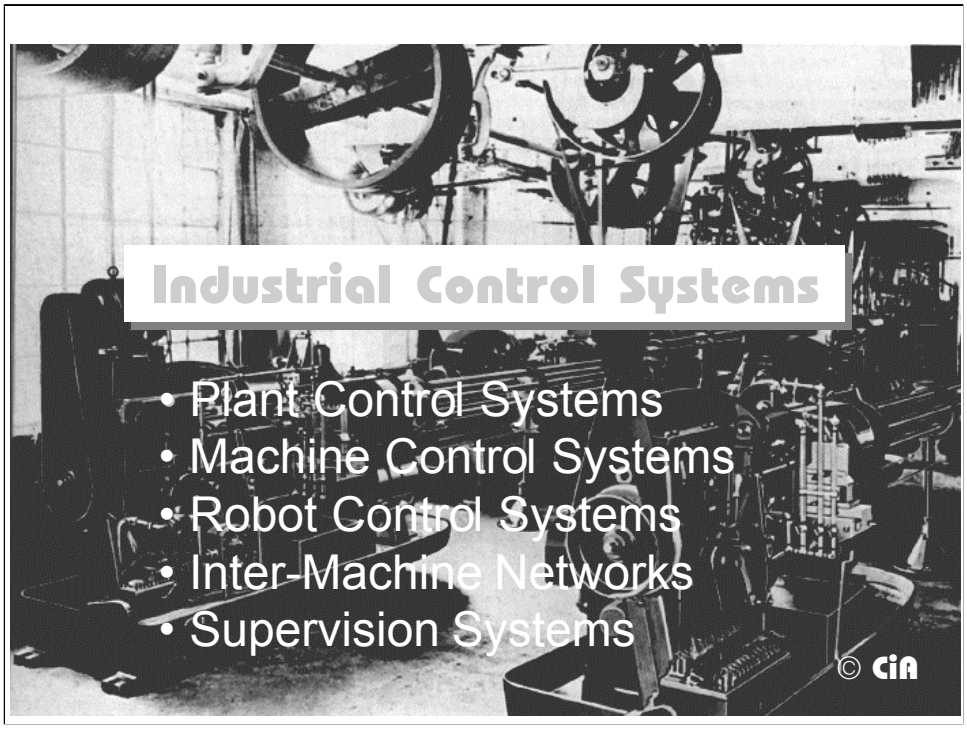
Several trains and coaches are using CAN networks to connect the brake control units. Others communicate via CAN to sub-systems (e.g. from Adtranz, Schaltbau). The Cargo Sprinter of the Deutsche Bahnen uses the CAN-based <EBAS> system for automatic brake control, freight car monitoring and diagnostics. CiA has established the CANopen SIG Railways specifying several railway-specific device profiles such as for door control, brake control, and gateways to train bus systems. In these activities the major suppliers of devices and system integrators are invloved.

CiA (CAN in Automation) and VDV (Verband Deutscher Verkehrsbetriebe) members are developing jointly a CANopen-based passenger information system. The CANopen network will substitute the IBIS network. It connects for example ticket canceling machines, displays, passenger counter, etc. The standardized CANopen Application Profile (CiA DSP-407) for Public Transportation will be published in Spring 1999. The first installation is used in buses and trams of the BVG (Berliner Verkehrsbetriebe).

Multanova is using CAN networks in measuring equipment for traffic safety and law enforcement. The CAN-based MultaStar system for red light surveillance and speed detection realizes the several functions in intelligent nodes separately.

In several mobile machines CAN networks link ECUs as well as sensors and actuators. In many agriculture and forestry machines (e.g. from Fendt, Claas, John Deere) CAN is used since many years. Other off-road application examples are wheelchairs from Permobil (Sweden) and Zaugg (Switzerland), forklifts from Jungheinrich/Steinbock and Linde/Wagner, backhoe loaders from Fermec, and excavators from Orenstein & Koppel. CiA and VDMA are specifying CANopen device profiles for ECUs used in off-road vehicles. First truck-based cranes using CANopen were introduced (e.g. from Faun) in 1997.

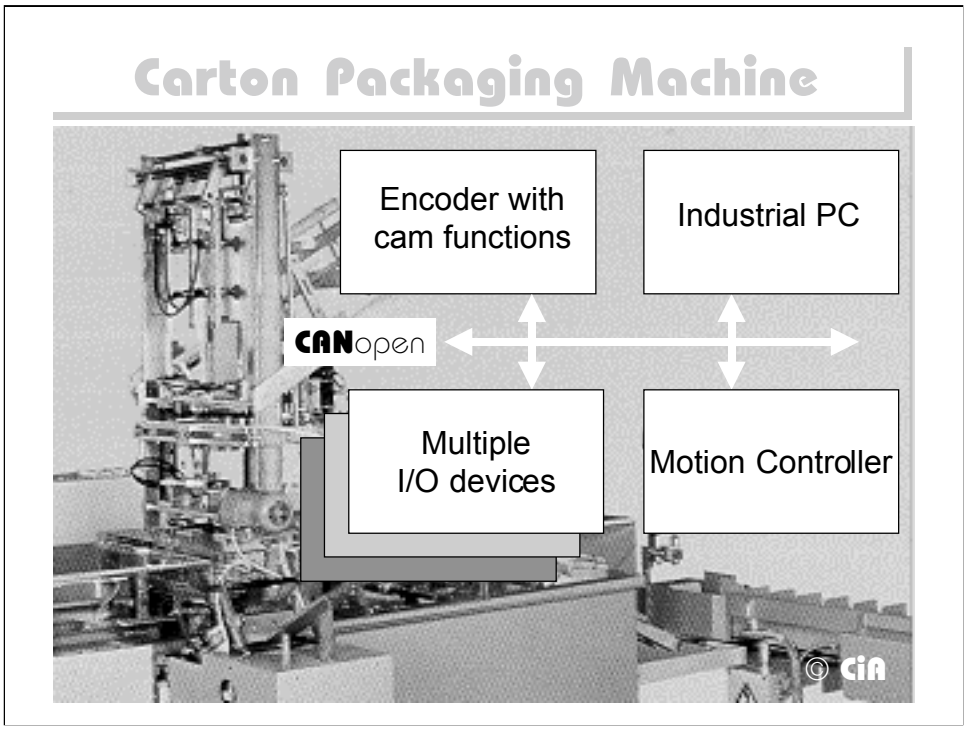
But CAN networks are also used in maritime electronics. MTU has developed a monitoring and control system. First introduced in 1994, this system has been installed in more than 150 ships. Kongsberg Norcontrol is developing a similar system based on CANopen protocols. The CANopen SIG Maritime Electronics is going to specify a framework for integration networks based on CANopen. Major issues will be the network redundancy and the flying NMT master.



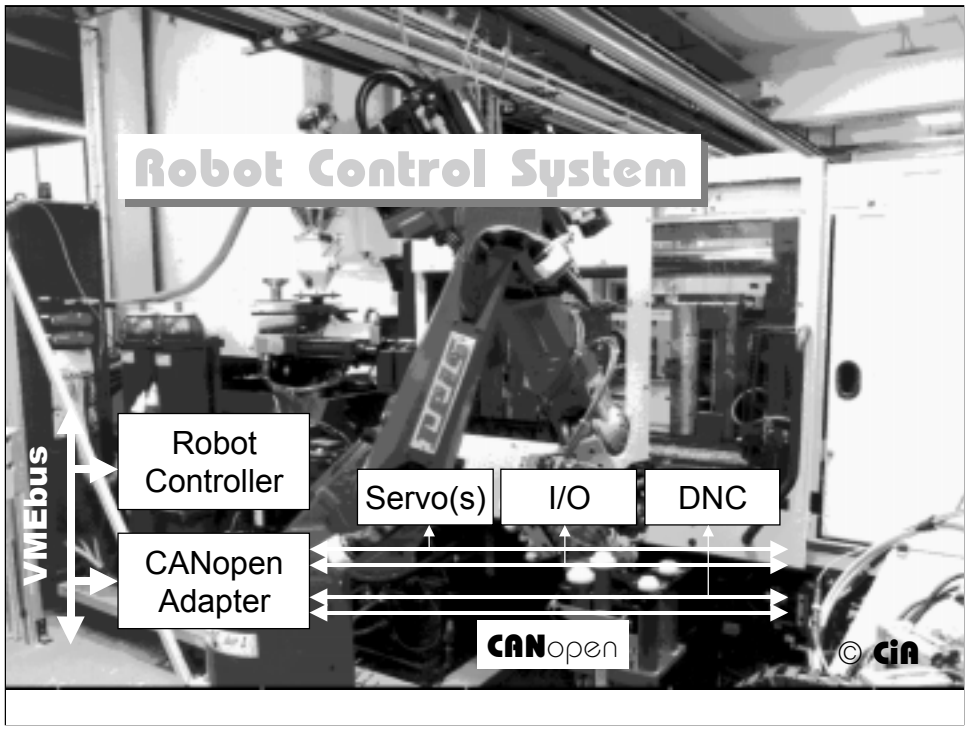
CAN-based networks are heavily used in any kind of industrial networks. In the beginning, the manufacturers specified their proprietary higher-layer protocols. Nowadays, most of the new designs are based on one of the standardized higher-layer protocols, such as CANopen, DeviceNet, or Smart Distributed Systems.

Typical examples are control systems for textile machines (e.g. from Cezoma, Lindauer Dornier, Rieter, Schlafhorst, Sulzer), printing and post-printing machines (e.g. from Heidelberger, Ferag) as well as packaging machines (e.g. from EDF, Island Beverages, Northrup King, Soudronic, TetraPak, Wepamat). Other examples are bending machines (e.g. from EHT), wood processing machines (e.g. from Homag), production cells (e.g. from Bosch, Gebr. Heller), semiconductor manufacturing equipment (e.g. from Applied Materials), quality test center (e.g. Miele).

One other important application filed in industrial automation is robot control. ABB, Bosch, Engel, Kuka, and others have already implemented embedded CAN networks as well as open network interfaces. But CAN is also used in logistics center (e.g. Edeka) to control 650-meter long rail-mounted pallet line. Hartmann & Braun uses CAN in its supervision systems since several years.



The VM969 carton packaging machine produced by Wepamat (Germany) was introduced at the FachPack trade fair in 1997. The CANopen network connects a PC-based control, multiple I/O devices and several motion controllers as well as encoders with cam functionality. The absence of a separate cam switching device is evidently an advantage. In addition, the CANopen network allows direct communication between the absolute rotary encoder and the other devices.

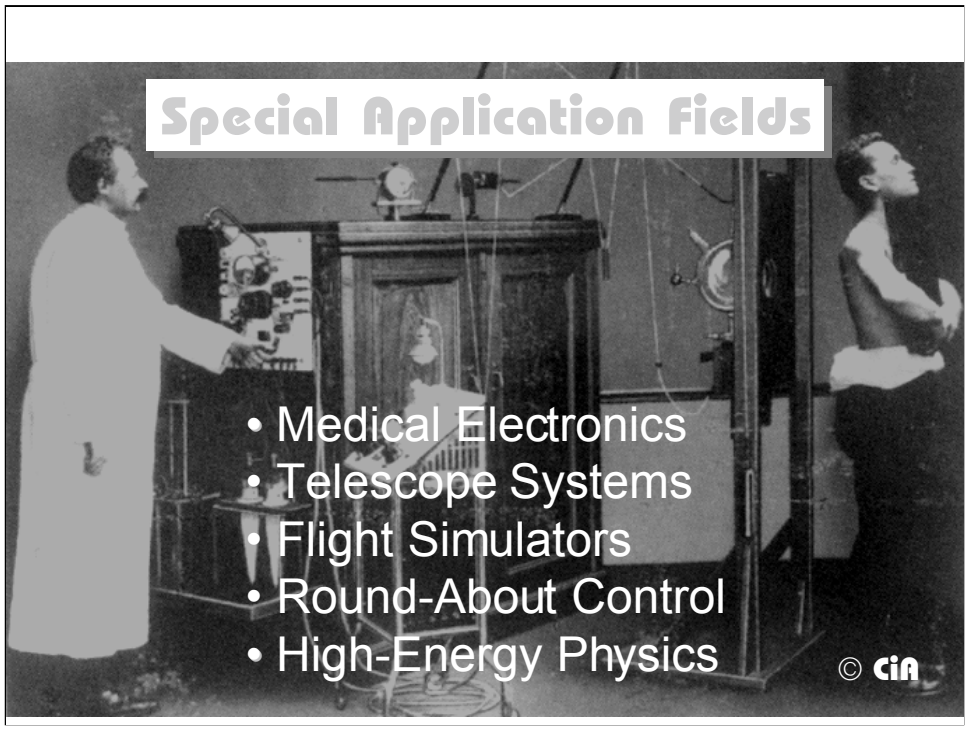


Reis Robotics has designed a CANopen-based distributed control system. The VMEbus-based robot controller is equipped with M-Module carrier boards containing two mezzanine cards providing two CANopen interfaces each. The 68332 microcontroller on the M-Modules run the CANopen master software. The CANopen networks connect several servo controllers, I/O devices, and numerical control units. In addition, the CANopen networks can be used to communicate to other robot controllers.

In two-line operation with 5 servo drives each per network (3 R_PDOs and 2 T_PDOs) and synchronization cycle of 10 ms, a baud-rate of 500 kbit/s will result in a bus-load of about 60% per line.

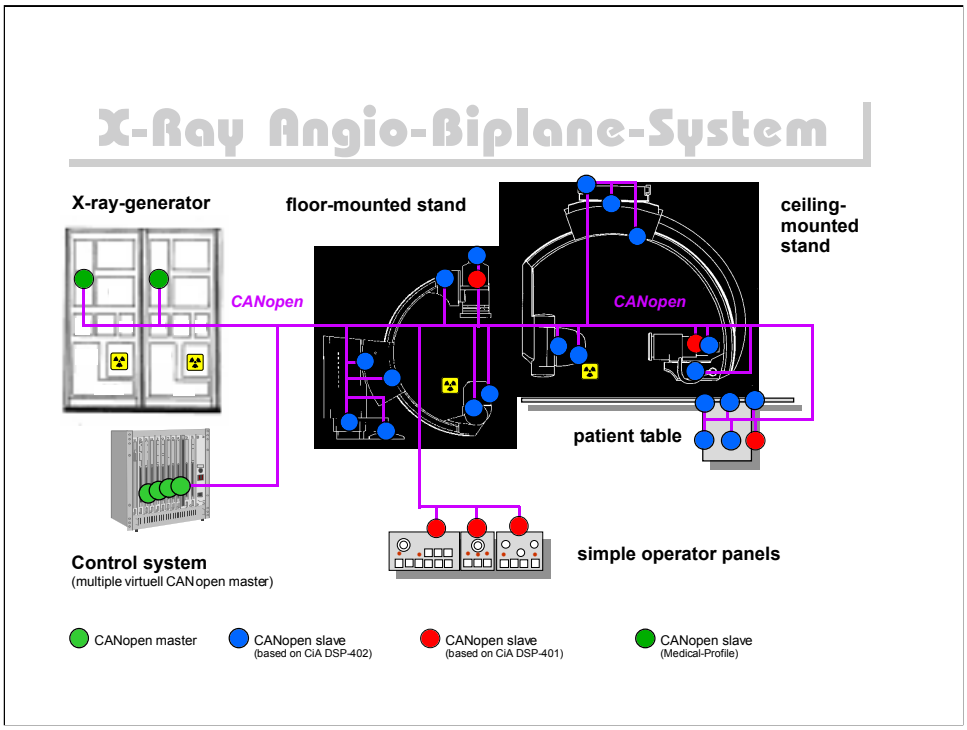
In building automation, CAN networks are mainly used for sub-networks, but not as a backbone network. Typical applications are air-condition systems (e.g. from Colt International), heating and cooling systems (e.g. Buderus), integrated room control (e.g. several office buildings in Switzerland), lighting control systems (e.g. Bank of Lisboa, University of Lausanne).

CAN Networks are often chosen for safety-critical systems, such as stage and backstage control systems (e.g. Saarland Hall in Saarbruecken, Suedwestfunk in Baden-Baden) as well as lift and elevator control systems (e.g. from Kone, Orenstein & Koppel, Otis, Telelift). In other applications CAN networks monitors the fire department in Bochum (Germany), the window-shade control system of the Schweizerische Bankverein.

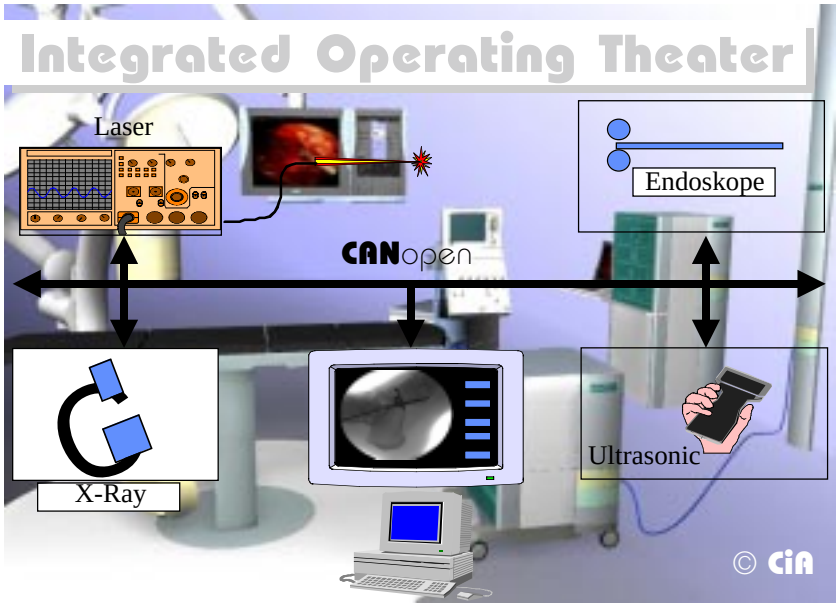


There are many application fields, in which CAN networks are at home. Since several years some major manufacturers of medical equipment are using CAN (e.g. Combat Diagnostics, Dräger, Fresenius, GE Medical Systems, Philips Medical Systems, Siemens, Storz Endoskope). Siemens has decided to use CANopen as higher-layer protocol.

Other special applications are telescope systems (e.g. Observatory in Hawaii and Greenwhich, Zeiss), round-about controllers (e.g. Paramount), flight simulators (e.g. Eurocopter), high-energy physical experiments (e.g. at Bessy, Desy, CERN, NIKHEF), and cow-shed monitoring systems (e.g. from Impulsa).



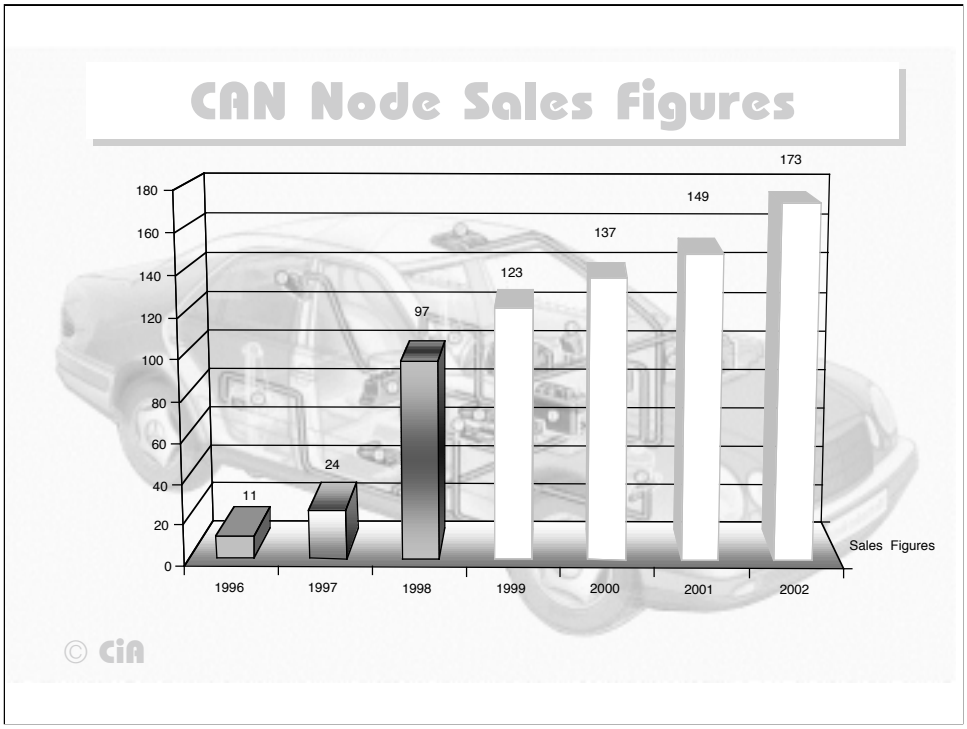
The X-ray angio-biplane-system from Siemens is using for internal communication CANopen-based networks. Similar system manufactured by General Electric Medical Systems, Philips Medical Systems, and Toshiba also implements CAN-based embedded networks.



CANopen networks will not only be used for equipment internal communication but also for inter-device networking. In operating theaters all necessary medical equipment will be linked to CANopen. For this application the CANopen SIG Medical is developing a framework and application profile featuring hot swapping capability without any configuration.

Embedded networks are an important domain of CAN. Besides automotive applications, embedded CAN networks are used in some professional washing machines, vending machines (e.g. petrol pump controller from Scheidt & Bachmann), copy machines (e.g. from Océ).

Some companies uses embedded CAN networks as device backplane (e.g. Hartmann & Braun in PLCs, Murrlektronik in I/O modules) or as device systems bus (e.g. Lenze in motion controllers).

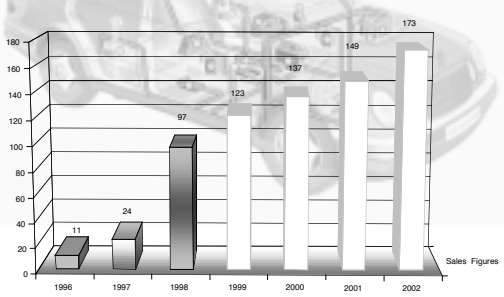


CiA publishes annually the CAN node sales figures. Therefore CiA accumulates all the sales figures of the CAN controller manufacturers and verifies these with the sales figures of the CAN transceiver chips. In 1998, there were sold about 97 millions of CAN nodes; 80% were installed in Europe, and 80% of these in Germany. About 80% of the nodes are used in automotive applications, the others are installed in other application fields mainly in embedded networks and industrial control systems.

The published forecast figures represent design-ins, that means they are conservative. That is also the reason that there are no figures for the year of 2003. In the next decade, the big three US car manufacturers also will use CAN in minimum in powerengine applications. In addition, CiA has some indications that the Far East car manufacturers are investigating heavily in CAN technologies. That is why CiA expects on ongoing increase of the sales figures for the next ten years.

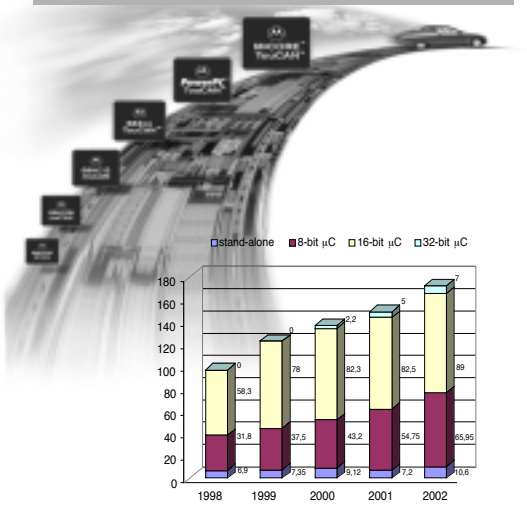
The still falling prices for CAN controller and transceiver chips will open new markets for Controller Area Network, even in very price-critical applications.

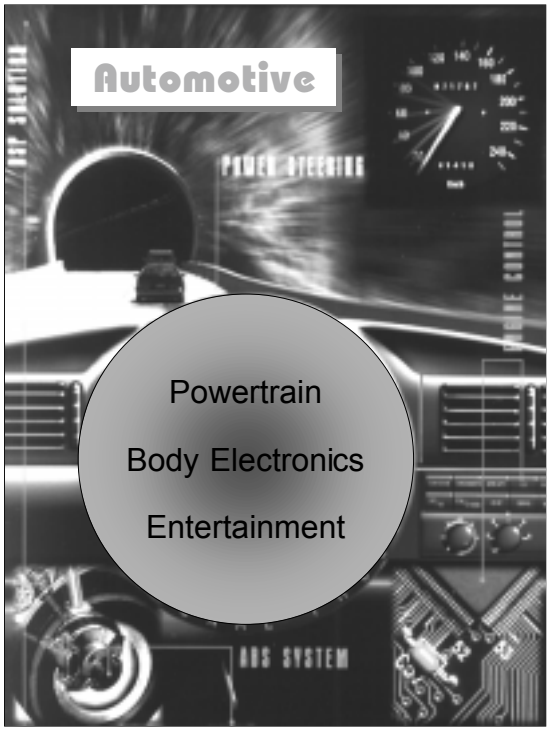
CAN Node Sales Figures



CiA has accumulated the entire CAN protocol controller manufacturers sales figures for 1998 and their estimations for the next years. Compared with the last years survey you can see that the result for 1998 is higher than expected, 97 millions instead of 59.8 millions. These figures are very conservative, because CiA did not consider sales figures from CAN chip manufacturers, which did not respond to the questionnaire. Sales figures for 2000 and the following years do not include all expected CAN nodes in cars produced in USA and Far East. Also not included are new application fields such as domestic appliances and other high-volume embedded systems. By beginning of this year, there were installed more than 140 millions of CAN controllers.

CAN Node Sales Figures

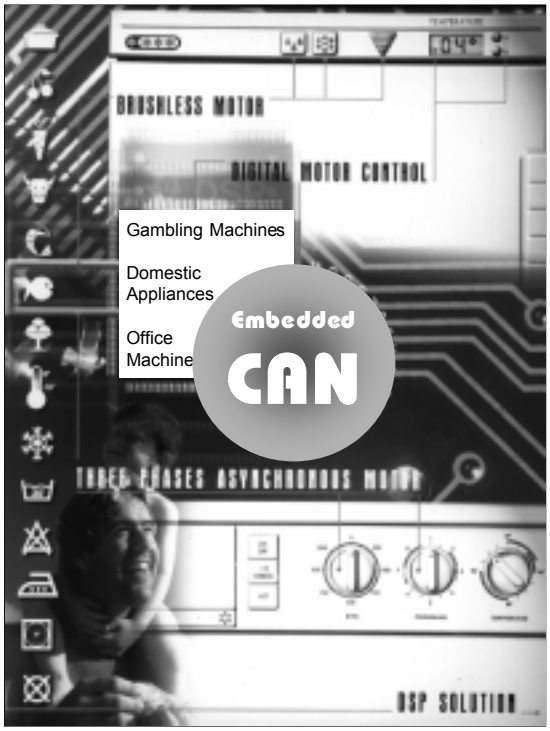




CAN was originally developed for automotive applications. Since 1992, high-end cars are equipped with CAN networks in powerengine and body electronics. The first CAN connected entertainment equipment arrived 1996. Most of the European car manufacturers have decided to use CAN networks in minimum in powertrain applications. American car manufacturers will start volume production of CAN-based ECU networks in the beginning of the next decade as well as vehicle producers in Far East.

Automotive applications are the highest volume CAN application. About 80 percent of the installed CAN controller chips will be used in vehicles. All the CAN implementations made by more than 15 semiconductor manufacturers are designed accordingly to the requirements of the automotive industry.

Within national and international standardization bodies several CAN-based solutions are under development such as higher-layer protocols (J1939, OSEK/VDX) and additional physical layer specifications (J2284).



CAN is well suited for embedded network applications. This includes internally networked devices, modules, and even machines. Typical applications are domestic appliances, gambling machines, round-abouts, office machines, serial backplanes, and vending machines. Often these embedded networks use simple layer-2 protocols that are not ‘open’.

Embedded CAN networks are also implemented in military target systems. To design embedded networks it is comfortable to use environments like CAN Kingdom, which is not a higher-layer protocol but allow to design well optimized CAN-based real-time systems.

CAN networks are used in a broad range of industrial and general purpose control applications. In particular, CAN -based solutions are well suited when motion control or other intelligent function is required. Most of the robots and handling systems are using CAN networks.

In industrial and general purpose applications ‘open’ communication is highly required. There are different standardized higher-layer protocols available, such as CANopen and DeviceNet.