The Adtranz Communications and Control System - the future on board

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**Abstract**

New technologies like the Train Communication Network and the 32-bit technology have led to significant improvements in the traction control systems already existing within ABB Daimler-Benz Transportation. The new Adtranz Communication & Control (C&C) system consists of the so-called vehicle control units and powerful distributed I/O modules connected to the multifunction vehicle bus (MVB). The interface between the wire train bus (WTB) and the MVB is provided by the Adtranz TCN Gateway. Subsystems, like door control or brakes, are connected through MVB medium interface boards in an open manner in conformance with the TCN specifications.

The new Adtranz C&C system will be introduced in a migrational way, based on the MICAS and TRACS system from the former ABB Transportation (ABB Henschel in Germany) and the GEATRAC system from the AEG Transportation (AEG Schienenfahrzeuge in Germany). This evolutionary approach allows a step-by-step migration process which combines well-proven technology with the most advanced technology currently available on the market.

**1 Introduction**

The challenge of an ever-rising demand for the transfer of both people and goods can be met most efficiently by rail transportation systems, which at same time provide the highest level of environmental compatibility. To keep up with present and future requirements, however, the rail vehicles used have to be equipped with high-performance control systems.
The Adtranz communication and control (C&C) system has been designed to meet all the requirements imposed today on state-of-the-art automation systems for rail-borne vehicles.

It combines the most advanced features:
- Conformance with open-system standards
- Interoperability ensured by the Train Communication Network (TCN)
- Direct self-control (DSC) for fast-response drive systems
- Flexibility thanks to modular design of both hardware and software
- Up-to-the-future technology, e.g. SMD and 32-bit technology
- Compact design and robust mechanical construction
- Reusable solutions for applications, created with the aid of powerful tools
- Optimal performance even in harsh environments in conformance with the requirements of EN 50155 for electronic equipment used in rail vehicles

The Adtranz C&C system supports all functions of
- the train control level
- the vehicle control level
- the subsystem and drive control level.

Figure 1: Pyramid of functional levels for traction control systems

Its main applications include high-speed trains, metros, electric and diesel-electric locomotives for main-line, regional and local trains, passenger coaches and high-performance light rail rapid transit trains. The HK underground in Berlin and the German Railways' class BR 145 locomotives are among the more recent examples (see application examples).
2 Architecture

2.1 Functional levels of the traction control system

The operation of rail vehicles involves a large number of typical tasks which have to be supported by the control system. These include, for example:

- Train control
- Control of the drive converters
- Motoring/braking
- Diagnostics
- Voice communication
- Air conditioning
- Door control
- Lighting
- Seat reservation
- Passenger information, e.g.
  announcements, displays, audio (ELA), video, telephones

The overall control system can be divided into three functional levels to which the various tasks are assigned:

- Train control level
  for tasks concerning the train as a whole,
  e.g. vehicle identification, train control

- Vehicle control level
  for functions within individual vehicles,
  e.g. door control, passenger information

- Subsystem and drive control level
  e.g. drives, brakes, converters for auxiliaries

2.2 TCN – Train Communication Network

The ever-increasing amount of information generated and exchanged in today's rail vehicles requires extremely powerful communication links on all three levels of a train control system (i.e. train, vehicle, and subsystems/drive control). In addition to the data related to normal operation of the drive system, detailed diagnostic data as well as messages intended for the passengers, for example, also have to be transferred. Standardized open communication systems provide an economical and reliable means to handle data volumes on this scale.

Data exchange in Adtranz C&C systems takes place over a Train Communication Network (TCN) based on the international IEC 332 (CD) standard proposal, which has already proven its worth in practical use. Since 1991, more than 500 locomotives have been equipped with TCNs by Adtranz. Moreover, since 1994, TCNs have been ordered for about 500 vehicles intended for use in local and regional service, some of which have already been delivered.
The TCN to IEC 332 (CD) consists of a train bus (Wire Train Bus, WTB) and a vehicle bus (Multifunction Vehicle Bus, MVB). The network structure corresponds to the seven-layer ISO/OSI model. The layers 3 to 7 (Real-Time Protocols, RTP) are identical in all bus types. However, different Link Layers (LL) and Physical Layers (PHY) are used in the train bus and the vehicle bus, since these layers are optimized with regard to the requirements of the control level concerned. The TCN also includes a Management Layer which performs the functions of supervising and controlling the entire network.

<table>
<thead>
<tr>
<th>Layer</th>
<th>TCN (WTB/MVB)</th>
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<tbody>
<tr>
<td>7</td>
<td>Application</td>
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<td>6</td>
<td>Presentation</td>
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<td>MVB-PHY</td>
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### Figure 2: Structure of the TCN based on the seven-layer ISO/OSI model.

Both the WTB and the MVB distinguish between process and message data. Process data are time-critical source-addressed data broadcast in a deterministic manner in the form of small data packets containing general process variables. Message data, on the other hand, are destination-addressed data providing, for example, status or diagnostic information. They are transmitted in the form of data sets of larger size or even downloaded as complete programs in the commissioning phase.

**WTB – Wire Train Bus**

The use of a standardized WTB provides what is generally referred to as "interoperability" between vehicles. This means that, provided that they support this standard, vehicles from different manufacturers can be coupled together and exchange data without any problems. During the train inauguration performed over the WTB, the individual vehicles in a train are automatically configured as bus nodes within a very short time.

**MVB – Multifunction Vehicle Bus**

The vehicle bus is used to transfer data within individual vehicles. Since the structure of the MVB layers 1 and 2 is relatively simple, the functions of these two layers can be implemented by means of hardware (for process data). The MVB can thus be used as a sensor/actuator bus for simple I/O units which do not have to be programmed.
2.3 Fit for the future with 32-bit technology

The 32-bit technology and the standardization of the Train Communication Network (TCN) are two important factors which have greatly contributed to the ongoing evolution of the tried-and-tested Adtranz communication & control system. The multifunction vehicle bus (MVB), in particular, represents a significant improvement in the implementation of distributed control systems. Special input/output modules designed to take full advantage of the MVB’s capabilities can now be installed locally in a highly decentralized manner. The most important I/O units connected to the MVB can be duplicated for redundancy, and the vehicle bus can be segmented. This allows the implementation of a consistently redundant dual-channel configuration where needed. Furthermore, cycle time restrictions for the I/O functions are a thing of the past, since even with the maximum number of units connected, the MVB’s baud rate of 1.5 Mbits/s ensures that these functions can be performed with the required bus cycle time. The I/O modules are supplied from the vehicle battery, typically via the equipment served by the modules.

The following input/output modules are available:
- DX: 10 digital inputs, 6 digital outputs
- DI: 16 digital inputs
- AX: 4 analog inputs, 2 analog outputs
- AIN: 15 analog inputs for NTC temperature sensors

Figure 3: The distributed I/O modules of the Adtranz C&C System

A powerful 32-bit CPU has been developed. It is available in two different versions: the plug-in PCB, and the stand-alone unit (vehicle control unit, or VCU) with built-in power supply. The stand-alone version is provided with an enclosure similar to that of the I/O modules and can be installed at any location. This option combines the advantages afforded by the modular design of the processing station with the benefits of a decentralized system.
Technical data:
Central processing units (VCU/PCB):
- Motorola MC68360 32-bit microprocessor
- Serial EEPROM (1 Kbit/4 Kbits)
- Flash EPROM (8 MB/8 MB)
- Dynamic RAM (4 MB/ - )
- Static RAM (2 MB/2 MB), partly battery-backed
- Direct connection to MVB
- C96 expansion socket for piggyback interface (PBI)

Figure 4: Vehicle Control Unit of the Adtranz C&C system in plug-in PCB
(as part of the Gateway) and stand-alone versions

The link between the MVB and other bus systems, such as the wire train bus
(WTB), for example, is established by a gateway, which is also available with 32-
bit technology since it contains the CPU mentioned above. Units of this type will
be used in the Gardermoen vehicles in Norway, the DOSTO 2000 double-deck
coaches of the Swiss Federal Railways, the IC 2 DMU rapid transit vehicles in
Denmark, the C20 metro in Stockholm, Sweden, and the German Railways' BR
145 locomotives.
As already mentioned above, the gateway can also be used for connecting the MVB or WTB to other busses. This can be of tremendous importance especially in cases where standard devices, e.g., from the automotive field, with different busses (e.g., CAN) are used.

IFZ Sensor/Aktor Bus = IFZ Vehicle I/O Bus
WTB Zugbus = WTB Wire Train Bus
MVB Fahrzeugbus = MVB Multifunction Vehicle Bus
andere = Other
Bussysteme = bus systems

Fig. 6 Possible extensions of the TCN through the use of the Adtranz gateway

Other components of the Adtranz C&C systems include:
- COMC: Communication controller for routing functions and additional serial interfaces
- BC: Bus coupler for bus segmentation
- SC: Star coupler

2.4 Communication with subsystems

Subsystems, like door control, brakes, etc., are connected to the Adtranz C&C system through the MVB. For this purpose, Adtranz offers an MVB Medium Interface Board (MIB) that can be easily integrated into the subsystems concerned. This MVB MIB is available for the three different physical layers of the MVB and with different mechanical features, i.e., for direct rack mounting or piggyback mounting.
For the MVB software, Adtranz offers a software package called PD-Light which uses the MVB class 2 mode, but with process data only. This mode is sufficient for most subsuppliers and has been used successfully in various applications (see application examples).

The easy connection of the subsystems testifies to the openness of the Adtranz C&C system achieved mainly through strict implementation of the MVB standard.

2.5 Drive control system

Adtranz offers a lean range of products for controlling the PWM (pulse-width-modulated) inverters in vehicles of all power ratings, from tramcars to high-power locomotives. This standardized traction control platform is the result of the extensive field experience gained with traction control processes, combined with the use of components based on state-of-the-art technology which provide a high degree of flexibility in programming and customization. This allows the products to be manufactured on a large scale, which affords significant advantages in all product stages, both for the manufacturer - in development and production - and, even more importantly, for the customer - through reduced expenditure on procurement, servicing and spare parts inventories.

The traction motor controller is a typical processor unit with application-independent interfaces. Since signal processing is the main function of this unit, the signal processor is supplemented by a fast A/D converter and a time-controlled I/O unit. All functions involved in the acquisition of measured values (amplifiers with input-side shunts, opto-electric conversion, speed measurement) are combined in a single peripheral unit for GTO or IGBT applications. The hardware protection mechanisms, which are different for GTO and IGBT inverters, are also implemented in these units. As the last stage before outputting of the switching commands, these mechanisms protect the system against interferences from outside, including short circuits, as well as against the effects of faults in the control process which may result, for example, from a failure of the power supply to the electronic equipment. All interventions by the protection system are logged for diagnostic purposes.

Technical data:

Traction motor controller
80C196 controller, 16 MHz
- 8 analog 10-bit inputs for measured-value acquisition
- 4/2 timer-supervised inputs for frequency/speed acquisition
- 4/6 timer-controlled outputs for pulse control, e.g. for braking chopper
- Operation of the peripheral unit
  - Binary inputs
- Binary outputs
- Dual-port RAM interface to station bus and signal processor
- 128 Kbits x 16 bits flash ROM
- 16 Kbits x 16 bits RAM
- TMS 320 signal processor, 40 MHz
- 7 analog 12-bit inputs for fast measured-value acquisition (10 μs)
- Binary inputs
- Binary outputs
- Timer/PWM unit
  - Inverter pulse control
  - Acquisition of checkback signals
- 16 Kbits x 16 bits RAM

GTO peripheral unit 12 VW 05 and IGBT peripheral unit 12 VW 04
- Load resistors/difference amplifiers for all required measuring signals
- Rotary-transducer evaluation
- Temperature-measuring channels for Pt 100
- Timer ensuring strict compliance with timing requirements
- Optical/electrical and electrical/optical conversion for gate-unit control via fiber-optic cables
- Programmable current/voltage comparators for all protection functions
- Diagnostic register for fault tracking in case of protective interventions

Figure 7: Drive Control

2.6 Diagnostics

For operators of rail transportation systems, the life-cycle costs of the vehicles, as well as their availability and reliability, are becoming more and more important. The cost of maintenance and repair represents a significant portion of a vehicle's
operating cost. It is therefore essential that repair and maintenance downtimes be reduced to a minimum. This is achieved with the aid of MAINTELLIGENCE®, the intelligent maintenance system.

MAINTELLIGENCE® comprises two subsystems:

- MICWDIAG
- KEVIN

2.6.1 MICWDIAG
The workshop diagnostics system known as MICWDIAG is a PC-based program which helps the vehicle specialists to determine the causes of a defect and to identify the smallest replaceable parts. It supports users by providing fault-specific repair information based on the expert knowledge stored in the system. A fault-oriented scratchpad also allows information to flow into the system to further expand the knowledge base which will be available for subsequent evaluations of diagnostic data in the workshop.

2.6.2 KEVIN
KEVIN (knowledge-based evaluation of vehicle information) is an expert system designed to identify the causes of faults in vehicles. KEVIN enables the maintenance crew to determine the causes of defects without having to call in a vehicle specialist. Its capability to provide this support is based on its knowledge about the structure and the functions of the vehicle concerned. The required information is stored in the system's knowledge base. KEVIN runs on Macintosh computers and will in the future also be available for PC-compatible operating systems.

The data evaluated by KEVIN and MICWDIAG are held in a battery-backed memory in the central processing unit. They are stored in the form of a fault-pattern diagnosis for each fault occurring in the system.

2.7 CAPE/C - user access to the Adtranz C&C system
User access is a central aspect in a traction control system, since it is the single most important factor in determining its user-friendliness and, consequently, the speed and efficiency which can be achieved when working on a particular project. For this reason, CAPE/C (Computer-Aided Project Engineering for Control Systems) user access to Adtranz communication and control systems is currently being planned and in part already being introduced. The tools offered cover the following activities:
Bidding phase
- Project management
- Functional design
- Configuration
- Hardware design

- Software design
- Installation, commissioning
- Online test and debugging
- Documentation, updating

All data generated in the course of a project are stored in a object-oriented database. This database is directly accessed by all tools, which eliminates any need for data to be transferred back and forth in the form of files and thus helps to ensure data consistency.

The hardware configuration of an Adtranz system is determined in the hardware design phase. In this process, the equipment needed, its interconnections (e.g. MVB) and the types of data to be exchanged are defined. Programming of the various C&C units, using function blocks (IEC 1131, in preparation) or high-level languages, for example, is carried out in the CAPE/C software design process. Once a particular application has been completed, it can be stored in a library of standard solutions and is available for reuse at a later time, making project work more efficient and economical. CAPE/C also includes powerful tools for commissioning and testing which are fully integrated with all the other tools.

CAPE/C runs under WINDOWS NT on desktop computers and portable PCs provided with an interface card for connection to the Train Communication Network. To program the hardware units, the units concerned are connected to CAPE/C either directly, i.e. via their RS 232 interface, or, for centralized programming (in preparation) over the bus system. CAPE/C provides the complete documentation in an electronic form (multimedia).

Antrieb = drive
Bremse = brake
Bremssteuerung = brake control
Führerpult = driver's desk
Drehgestell = bogie 1

Figure 8: Computer Aided Project Engineerig for Control System CAPE/C
330 Computers in Railways

3 Migration Strategy

The merger of the rail operations of ABB and Daimler-Benz into ABB Daimler-Benz Transportation (Adtranz) lead to a situation where several control systems existed within the new company. However, the new Adtranz C&C system has been designed to ensure a smooth transition from the existing control systems to the new one.

The Berlin HK underground project and the BR 145 locomotive of German Railways are excellent examples of the successful migration to the new C&C system.

3.1 Application Example - HK Underground Trains

The Berlin HK underground project is an excellent example of the GEATRAC control system of the former AEG Schienenfahrzeuge GmbH being used in combination with the new Adtranz C&C system. The interface between these two systems is the MVB. While the GEATRAC system is used for train control, the new parts of the Adtranz C&C system are used for handling the I/O part as well as the train communication level, i.e., communication over the WTB via the gateway. Most of the subsystems are connected to the MVB using the MVB Medium Interface Boards and the corresponding PD-Light software described in chapter 2.4.

This evolutionary approach allows a step-by-step migration which is achieved by using well-proven technology together with the most advanced technology currently available on the market.

3.2 Application Example - Class BR 145 locomotive

The BR 145 locomotive is another outstanding example of a perfect migration strategy from the MICAS control system of the former ABB Henschel AG to the new Adtranz C&C system from ABB Daimler-Benz Transportation.

In this locomotive, the performance of the MICAS-S system has been improved by adding several new Vehicle Control Units of the plug-in PCB type to the rack. These new CPU boards have replaced the former MICAS-S CPU boards and are used together with the drive control boards described in chapter 2.5 to handle the vehicle/train control tasks as well as the drive control functions. These tasks are combined in the so-called integrated control device (ISG, Integriertes Steuergerät).

The Adtranz I/O modules connected to the MVB are used for the I/O signals. The subsystems, such as the MFA (Modulare Führerstandsanzeige), for example, are also connected to the MVB, in most cases using the MVB-MIBs and the PD-Light software (see chapter 2.4).
The BR 145 locomotive is another example of the benefits of the migration strategy pursued by ABB Daimler-Benz Transportation. Well-proven technology, like the MICAS control system, is combined with the modern, advanced technology of the new Adtranz C&C modules. With this approach, the experience gained in previous projects can be used, existing solutions can be reused, and the benefits of the most advanced technology can be fully integrated.

**Abbreviations**

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<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>BC</td>
<td>Bus Coupler</td>
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<td>CAPE/C</td>
<td>Computer Aided Project Engineering for Control Systems</td>
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<td>COMC</td>
<td>Communication Controller</td>
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<td>C&amp;C</td>
<td>Communication and Control</td>
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<td>KEVIN</td>
<td>Knowledge-based Evaluation of Vehicle Information</td>
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<td>MICWDIAG</td>
<td>MICAS Workshop Diagnostics System</td>
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<td>MFA</td>
<td>Modulare Führerstandsanzeige</td>
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<td>MVB</td>
<td>Multifunction Vehicle Bus</td>
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<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
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<td>PD</td>
<td>Process Data</td>
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<td>SC</td>
<td>Star Coupler</td>
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<td>TCN</td>
<td>Train Communication System</td>
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<tr>
<td>VCU</td>
<td>Vehicle Control Unit</td>
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<td>WTB</td>
<td>Wire Train Bus</td>
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