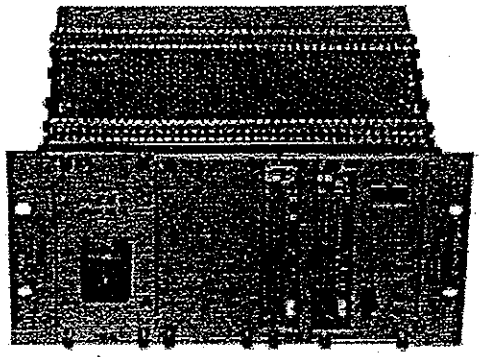
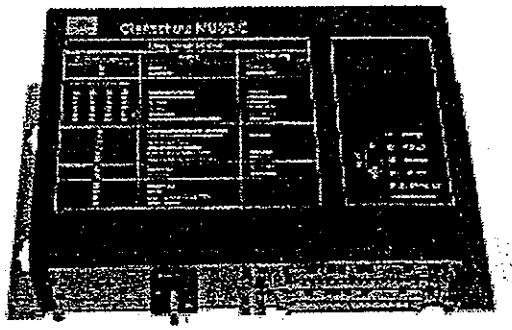
System Description

S-IE21.21-en

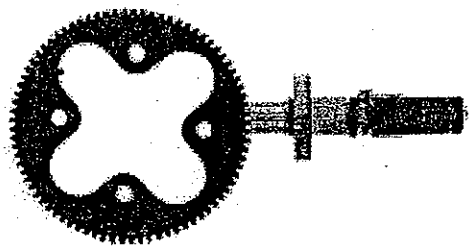
02/2001 Rev.02

Wheel Slide Control Systems Series MGS2

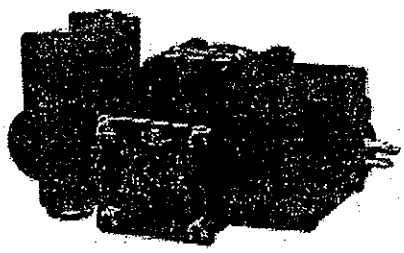




Control units based on the ESRA electronic system



Rotating gear / Speed sensor



Anti-skid valve

KNORR-BREMSE
Systems for Rail Vehicles

Contents

1 Introduction

The MGS2 and MGS2-C systems have grown from KNORR-BREMSE's proven experience in the field of "microprocessor-based wheel slide control". The control units are based on ESRA, the KNORR-BREMSE Electronic System for Railway Applications. This technology makes the MGS2 series suitable for a wide variety of applications.
This Description applies basically to both systems (MGS2 and MGS2-C), but refers separately to differences.

1.1 Technological development

Since its UIC approval in 1981, the KNORR-BREMSE MGS1 microprocessor-based wheel slide control system has performed consistently well for many railway administrations.

All parts of the system – speed sensors/rotating gears, control units, control logic and anti-skid valves – have been developed and improved continuously over the years.

In 1991, on presenting its AGeS wheel slide control system for freight cars, KNORR-BREMSE introduced a control unit featuring new hardware technology and faster logic timing.

The modular ESRA system engineered by KNORR-BREMSE from the microprocessor technology of the AGeS is capable of performing all kinds of control functions in rail vehicles.

The MGS2 series is "applied ESRA technology".

Unlike its predecessor, the model MGS2 has:

- large-scale integration,
- state-of-the-art SMD technology,
- compact size,
- improved control precision,
- far-reaching diagnostic capabilities, and
- a service terminal having a graphical user interface.

1.2 Salient features of the MGS2 series

MGS2 meets the requirements of UIC Code 541-05 for the construction of wheel slide control systems. It already includes provisions for the use of enhanced functionality, i.e. "wheel roll monitoring", in new vehicles running at top speeds above 200km/h.

MGS2 control units conforming to the ESRA standard can be combined with, or integrated in, other KNORR applications, such as brake controllers and electronic driver's brake valves.

19" electromechanical technology makes many different shapes and designs possible. It yields full-width and half-width racks (i.e. 84 TE and 42 TE), and highly compact housings for special applications and mounting scenarios.

MGS2-C is a compact design which can be used equally well outside a cabinet. It is therefore most suitable for vehicles in which analog wheel slide control systems are going to be replaced by microprocessor-based arrangements.

Although MGS2 is suited to a very wide variety of vehicles and applications, its boards are all nevertheless standard.
The customer benefits twofold: the number of components is minimized and costs are reduced.

MGS2 units adapt optimally to different vehicles, yet all comply with the same technical standards and operate on the same control principle.

The control logic of the MGS2 system

- reliably prevents the wheelsets from locking in all kinds of weather, even in the face of extremely low adhesion due to wet leaves on the rails,
- regulates the brake force at low adhesion values, greatly improving the mean coefficient of adhesion and minimizing the stopping distance,
- consumes little compressed air, even when braking is prolonged and adhesion is low, and avoids depleting the brake system.

Further performance features of MGS2:

- Non-wearing speed sensors/rotating gears
- Quick-reaction anti-skid valves with a pressure holding phase
- Speed sensors and anti-skid valves powered by the MGS2 control unit
- Monitoring of speed sensors and anti-skid valves
- Floating relay contacts, switched according to speed for door and electromagnetic track brake control
- Speed signal output (frequency)
- Optional extras include automatic sanding, odometer function, wheel flange lubrication, brake signal processing, bogie diagnostics, special brake release and wheel spin control.
- Provision for interfacing with vehicle bus systems
- Power-saving "standby" mode at standstill
- Non-volatile fault memory
- 4-character alphanumeric display

- Serial RS232 interface to connect the service terminal
- Low-cost maintenance thanks to self-testing, fault display and high-grade reliability
- Suitability for use in all rail vehicles (passenger cars, metros, mass transit systems and locomotives).

This description discusses the standard version of the MGS2 wheel slide control system for vehicles with up to four individually controlled, pneumatically braked wheels or wheelsets.

2 Working principle of MGS2

2.1 Control loop

The MGS2 wheel slide control system forms a control loop through the brakes and wheelsets.

The speed sensor detects the speed of the wheel without physical contact and sends a proportional frequency signal to the control unit.

The control unit evaluates the frequencies from all of the vehicle's speed sensors and generates signals enabling the anti-skid valve to control the brake cylinder pressure. The gradient for increasing or decreasing the brake cylinder pressure can be lowered by "pulsing".

The control loop adjusts the brake cylinder pressure to the instantaneous wheel-to-rail adhesion, keeping the wheels within their optimum range of slip and ensuring maximum possible brake force transmission.

2.2 Control logic

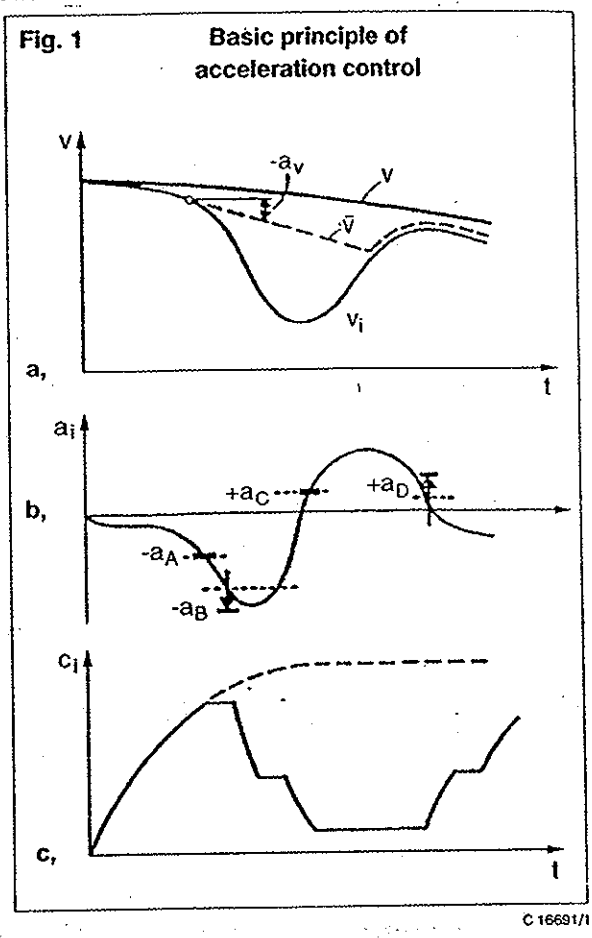
2.2.1 Acceleration control

The principle of brake pressure control at one of the wheels is plotted against acceleration in Fig. 1. Acceleration control accounts for both the rate of acceleration and the variation per unit time.

When a wheel starts to lock, its circumferential speed (v_i) falls and the wheel deceleration (a_i) exceeds the first threshold a_A. As a result, the controller maintains constant pressure C_i in the brake cylinder.

Increasing wheel deceleration causes the pressure C_i to decrease step by step once the threshold a_B has been crossed.

Fig. 1 Basic principle of acceleration control



Falling pressure allows the wheel to accelerate again. When the small positive acceleration value a_C is reached, the brake pressure stops falling and assumes a constant level.

Optimum wheel-to-rail adhesion is reached when wheel acceleration exceeds its maximum value. Wheel slip is now within its stable range. The brake cylinder pressure C_i is therefore raised step by step once the wheel acceleration falls below the threshold value a_D.

2.2.2 Wheel slip control

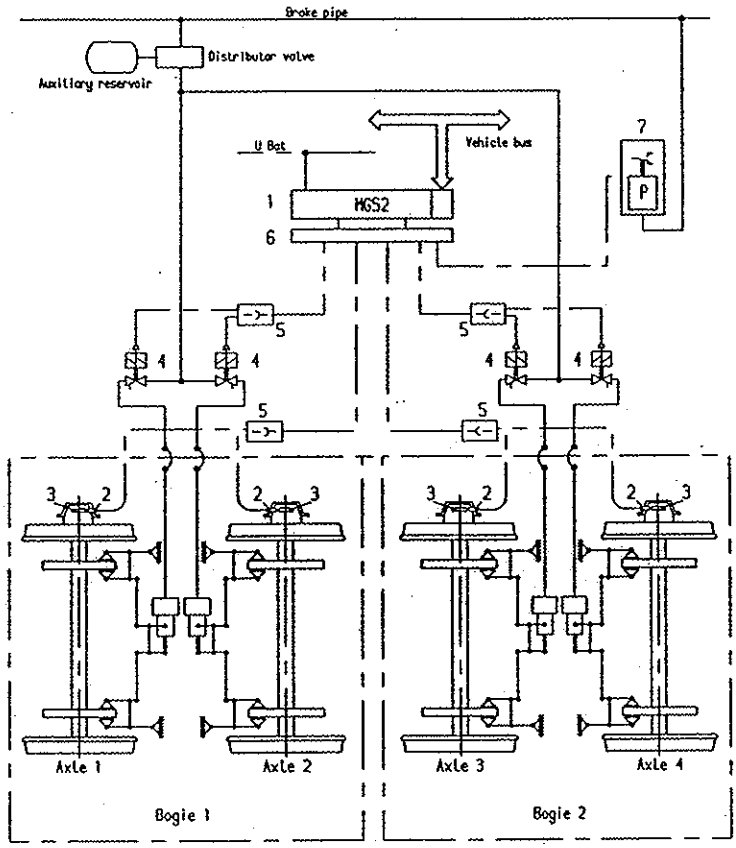
The MGS2 control unit does not measure the actual vehicle speed. Instead, it calculates a fictitious one for reference from all the individual wheel speeds.

MGS2 selects the highest wheel speed present at any one moment, and bridges sharp drops by substituting an equivalent straight line (cf. Fig. 1a) for the real speed when wheel deceleration exceeds the limit a_V.

Optimum slip is ascertained on the basis of the fictitious vehicle speed. The control unit adjusts the wheel speed to this slip by evaluating the wheel acceleration.

Extremely poor adhesion may cause all the wheel speeds to fall simultaneously by a considerable amount. In this case, the control unit allows the wheelsets to dwell in the slip for only a limited time. For this purpose, it raises the fictitious vehicle speed accordingly, making the brake cylinders vent in return.

Fig. 2 Layout of a wheel slide control system on board a vehicle



1	MGS2 control unit (connection to vehicle optional)	4	Anti-skid valve
2	Speed sensor	5	Terminal box
3	Rotating gear	6	Terminal block
		7	Pressure switch

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3 Engineering concept of the wheel slide control system

Fig. 2 is a schematic presenting the components of the MGS2 wheel slide control system. It also shows how these parts are integrated in the mechanical brake system of a four-axle passenger car.

3.1 MGS2 control units

Demands for maximum flexibility have led to the development of MGS2 control units in a modular 19" system. All the boards in the control unit conform to Eurocard format.

The half-19" rack (see Fig. 3) for the standard version of the control unit contains the ESRA boards MB04, EB01 and a power board PB.

Version MGS2-C is designed for wall mounting. It contains the same ESRA boards, but its man-machine interface (MMI) is fitted in the housing cover.

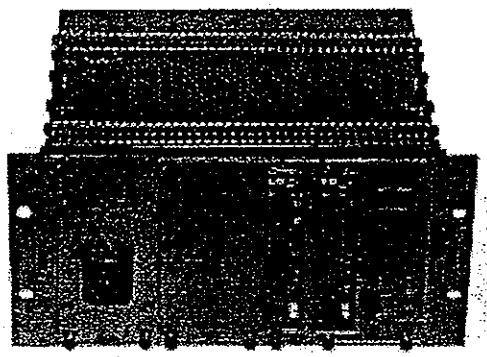
Peripheral input and output signals are delivered to the boards through front-panel connectors. Connection is by 3-row, 48-pin female connectors to DIN 41612, Type F.

The power board is fed through a DIN 43650 connector on the front.

MGS2 control units can be rated for battery voltages of between 24V±30% and 110V±30%. Changing the power board is all that has to be done to adapt the power board to a certain battery voltage.

The ambient temperatures cover the range from −40°C to +70°C as standard.

Fig. 3 **MGS2 series control units**



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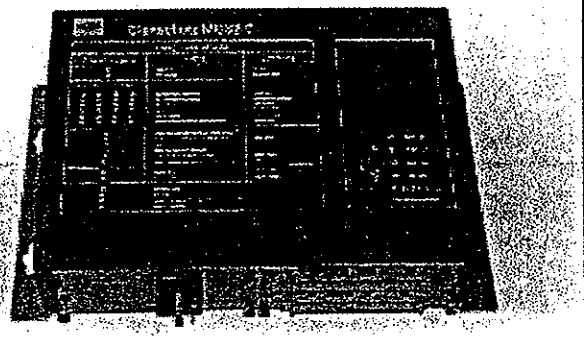
MGS2 in a half-19" rack



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MGS2-C with the MMI in the cover

3.1.1 Power board

The power board is housed in a closed box. Its front panel has two yellow LEDs indicating the operating state. The battery voltage is delivered through a front-panel connector.

The power board supplies all the voltages for powering the boards, actuators and sensors. A 24V source is used to power the anti-skid valves from the MGS2 control unit; this means that all valves are of the 24V type, regardless of the battery voltage.

If the vehicle is left to stand idle for any length of time, the MGS2 control unit can be switched over to a "standby" mode of low primary current consumption (standstill sleeper mode). The unit is reactivated by a pressure switch (cf. No. 7 in Fig. 1) at a preselected level in the brake pipe.

3.1.2 Boards MB04 / MB03

Wheel slide control – i.e. acceleration and slip control – is implemented entirely on board MB03 or MB04.

MB03 contains all the electronic peripherals for individual wheel slide control at up to four wheels or wheelsets. The anti-skid valves are powered by 24V from board MB03.

The only difference between boards MB03 and MB04 is that MB04 has a man-machine interface (MMI) integrated in its front panel.

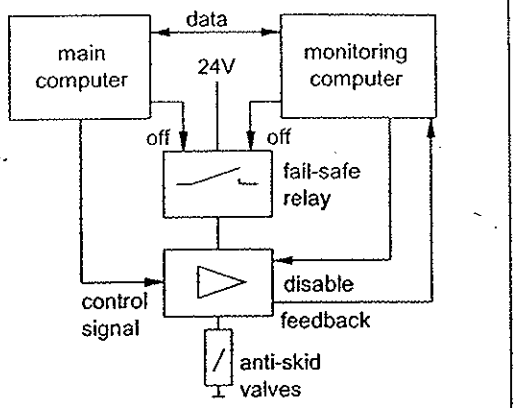
Features of boards MB04 / MB03:

- Microcontroller for the main computer
- Second microcontroller for monitoring and fail-safe tasks
- Four configurable input circuits for the speed sensors
- Short-circuit-proof feeders to power the speed sensors
- Four input circuits for analog frequency sensors (voltage or current input)
- Eight semiconductor output stages for four anti-skid valves with two magnets each
- Two mechanical relays to cut off the magnet valves for safety in response to a malfunction

Fail-safe functions (see Fig. 4):

- The monitoring computer supervises the activation times of the power output stages.
- Both computers are monitored reciprocally for hardware failures.
- Both computers cut off the output stages in two groups of four outputs each in response to malfunctioning.

Fig. 4 Monitoring by a second processor



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Diagnostic functions:

- The main computer monitors the switch outputs for short-circuits and open circuits.
- The speed sensors are monitored for short-circuits and open circuits. Sensor power is cut off automatically in response to short-circuiting.

Man-machine interface

MGS2 has a man-machine interface (MMI) integrated in its front panel, whereas MGS2-C has one fitted in the housing cover.

The MMI peripherals comprise

- a 9-pin Sub-D female connector for the RS232 interface (to connect a terminal),
- a 4-character alphanumeric display, and
- four control keys

3.1.3 Board EB01

EB01 is an extension board in the MGS2 control unit. It provides digital inputs and outputs which are utilized for supplementary functions such as door control. EB01 may be omitted if no supplementary functions are required.

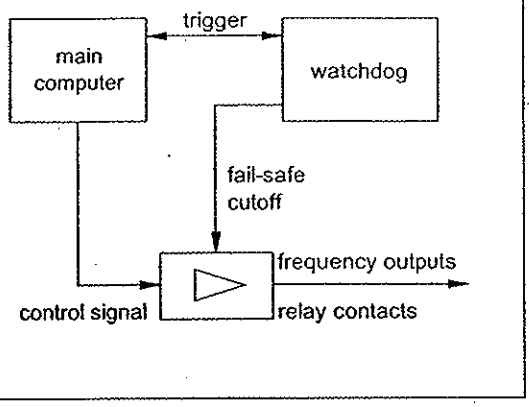
Features of the extension board:

- Microcontroller serving for the main computer
- Watchdog
- Eight digital inputs, galvanically isolated from MGS2 potential, the outputs and one another. Two of the inputs can be configured as frequency inputs via the software.
- A signal can be generated from up to four binary inputs to switch over the power board from "standby" mode to "normal operation".
- Eight relay outputs, galvanically isolated from MGS2 potential, the inputs and one another. Four of the relays can be used as both make and break switches. The other four have just a make contact function.
- Two galvanically isolated frequency outputs

Fail-safe functions (see Fig. 5):

- The watchdog monitors the main computer for hardware failures.
- The outputs are switched off in response to a fault or failure.

Fig. 5 Monitoring by the watchdog



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Diagnostic function:

- The states of the relays are monitored by the microcontroller through feedback contacts.

3.1.4 Specifications (MGS2 standard control unit)

Speed sensor inputs	Number	4 (configurable for voltage or current sensors)
	Input frequency	1 Hz – 10 kHz
	Max. speed	450 km/h
Analog sensor inputs	Number	4 (configurable as voltage or current inputs)
	Input voltage	0 V – 12 V
	Input current	0 mA – 25 mA
Binary inputs	Number	8 (2 being configurable as frequency inputs)
	Input voltage	0 V – 143 V
	Input frequency	1 Hz – 500 Hz
Anti-skid valve outputs	Number	8 output stages for 4 valves
Relay outputs	Number	8
	Max. switching current	1 A
	Max. switching voltage	143 V
	Max. switching power	20 W
Frequency outputs	Number	2
	Voltage range	0 V – 143 V
	Output frequency	10 Hz – 1 kHz
Serial interface	RS232	
Possible power supply voltages	24 V±30%, 36 V±30%, 48 V±30%, 72 V±30%, 110 V±30% DC	
Maximum power consumption	about 80 W (for driving four KNORR anti-skid valves)	
No-load power consusmption	about 14.4 W	
Power consumsption on standby	about 1.2 W	
Safe ambient temperature	$-40°C \leq T \leq +70°C$ (static air, free convection)	
Rack	19", 3 HE high, 42 TE wide	
Weight	about 3.2 kg	

The number of inputs and outputs can be extended beyond standard by the addition of boards from the ESRA system.

Standard functions

- Pneumatic wheel slide control for up to four individual wheels/wheelsets
- Door control signals
- "Cumulative error" message
- Speed contact for the electtromagnetic track brake

Supplementary functions (others on request)

- Wheel roll monitoring
- Bogie diagnostics
- Special brake release
- Speedometer output (frequency signal)
- Automatic sanding
- Odometer pulse
- Distance marking pulse for wheel flange lubrication
- "Wheel slide" signal
- Wheel slide control for regenerative brake
- Wheel spin control

3.2 Speed sensors

The MGS2 control unit can be operated with a variety of speed sensors. The best technical solution for new applications is KNORR's GI6 speed sensor with a current output. The GI5 version with a voltage output is equally suitable for this task. The speed sensors come as "single" or "double" types depending on the application for which they are intended.

The speed sensor scans a ferromagnetic rotating gear (tooth module 2) that is centered over the axle. It works without physical contact and does not wear.
The air gap between the rotating gear and sensor is 0.4 to 1.4mm.

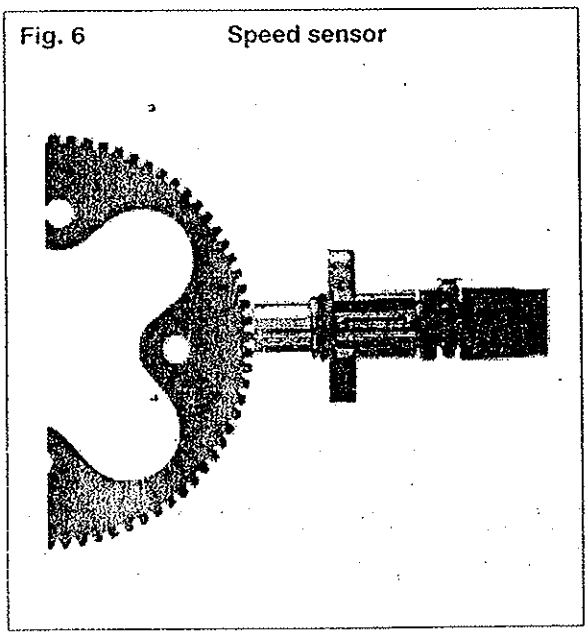
The magnetoresistive speed sensor GI6 operates in the range between 0 Hz and 4 kHz. Its output current is I_1 for LOW and I_2 for HIGH. The frequency of the digital current signal is directly proportional to the circumferential speed of the rotating gear. The output current of the sensor assumes the value I_1 or I_2 when the vehicle is parked.

The MGS2 control unit monitors the speed sensors for correct operation at both standstill and on the move. Open circuits and faults to ground are identified.

The electronic part of the speed sensors withstands short-circuiting, prevents reversal of its polarity and resists EMC interference.

The design of the rotating gears depends on the type of wheelset used. Rotating gears with 80 teeth are used as standard.

Fig. 6 Speed sensor



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3.3 Anti-skid valves

The anti-skid valve works as an actuator in the wheel slide control loop, and is operated by the MGS2 control unit.

It serves to reduce the brake cylinder pressure C step by step, or increase it similarly again to the value set by the distributor valve.

MGS2 wheel slide control systems are all fitted with anti-skid valves having low-power valve magnets (≤7.5W).

KNORR anti-skid valves GV12-ESRA and GV21-ESRA incorporate two control diaphragms which are pre-controlled by valve magnets.

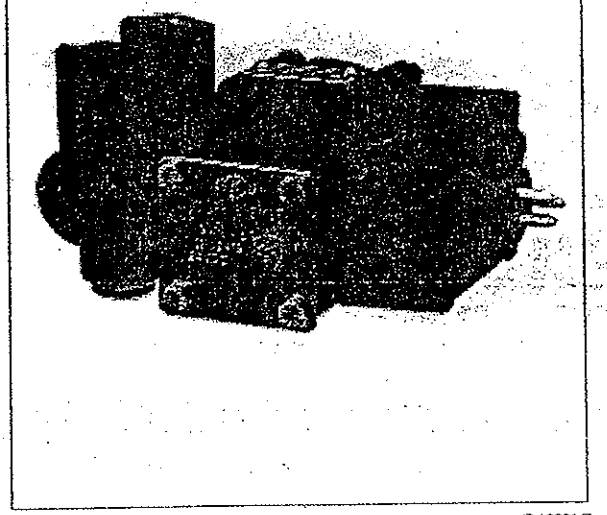
KNORR anti-skid valve GV19-ESRA has control pistons in place of diaphragms, and is used for spring-actuated brakes.

The valves have a very fast response.

GV12-ESRA	Used mainly for passenger cars and multiple units
GV21-ESRA	Used wherever substantial brake cylinder volumes need to be controlled (e.g. in locomotives).

The working principle of the anti-skid valves is discussed fully in the "Descriptions" written for each of them.

Fig. 7 Anti-skid valve



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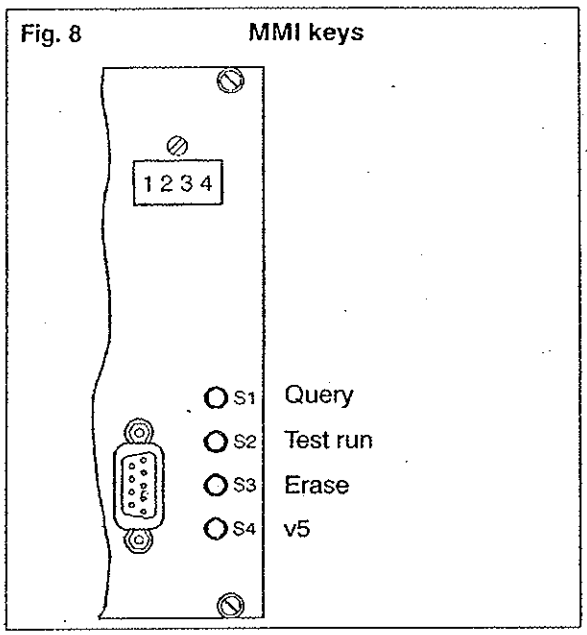
4 Diagnostic functions

Test runs can be started, and the fault memory read or erased through the man-machine interface (MMI) on the MGS2 control unit.

Inputs can be read, outputs written to, and system data retrieved via RS232 using a PC with the accompanying MGS2 service terminal software.

If the control unit is in its power-saving "standby" mode, it can be reactivated by the press of a key on the MMI.

Fig. 8 MMI keys



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4.1 Test runs

Three different test runs can be started at the press of a key in the standard version of MGS2.

Test runs are terminated automatically when a speed signal higher than 3 km/h is identified.

4.1.1 "Valve control" test run

The "fail-safe" circuit is normally passive and only comes into action when a fault occurs.

The "valve control" test run verifies the operation of the "fail-safe" circuit. It simulates unacceptably long activation times at the anti-skid valves, and initiates supervision of valve cutoff by the monitoring computer.

The operator can start the test run at standstill by pressing key "S2" on the MMI for about one second.

The display shows "8888" for the first three seconds of the test run, and then switches to "89". Faults found by the test are displayed at the end of the run. Volatile faults that have occurred at some time on the move and disappeared again in the meantime (e.g. loose contacts), are displayed after the number "95". The display switches to "99" if the fault memory is still empty at the end of the test run.

The electromagnetic track brakes of systems designed to DB Specification are lowered into position during the "valve control" test run.

WARNING — Risk of injury
(see also Section 4.1.3)

4.1.2 "Door control" test run

Pressing key "S4" on the MMI for about one second starts the test run for door control signals.

The display reads "8888" for three seconds once the "door control" test run is activated. The door control relays are then activated for one minute, and the code number "89" is displayed simultaneously.

4.1.3 "Electromagnetic track brake" test run

If the vehicles are equipped with electromagnetic track brakes, the operator can activate the relay for the "electromagnetic track brake contact" by pressing the associated button (if any). This step verifies the lowering of the electromagnetic track brakes. The display first reads "8888" and then switches to "89" after three seconds.

WARNING — Risk of injury

Injury is imminent during the test run on the electromagnetic track brakes. This is because the brakes have to be lowered into position for this purpose.

4.2 Displaying the software version

Pressing the "S1" and "S2" keys simultaneously for about one second shows the software version on the display.

4.3 Fault memory

4.3.1 Retrieving faults from memory

The display reads "99" if the fault memory is empty and no keys are pressed. It shows code number "95" if only volatile faults are in memory. The code identifying the first fault will appear if current faults are found.

Fault retrieval is in accordance with UIC Code 557 "Diagnostics in passenger cars".

The display reads "8888" to begin with, when the key "S1" is pressed to start a query.

All current faults are displayed for three seconds each if the query key is held down for more than one second, yet for less than three seconds. The display subsequently reads "95" and then shows the volatile faults.

If the query key is held down for more than three seconds, the above display sequence will not be returned automatically. The query key must be pressed again (>1 sec.) to step the display in this case. Retrieval is terminated if no key is pressed for at least 10 minutes.

Activating a test run will similarly terminate fault retrieval.

4.3.2 Erasing faults from memory

The fault memory is erased when the erase key "S3" is pressed for about one second.

However, persistent faults will be entered instantly again in the fault memory.

4.4 Service terminal

A PC can be connected as a service terminal to the MMI's RS232 interface.

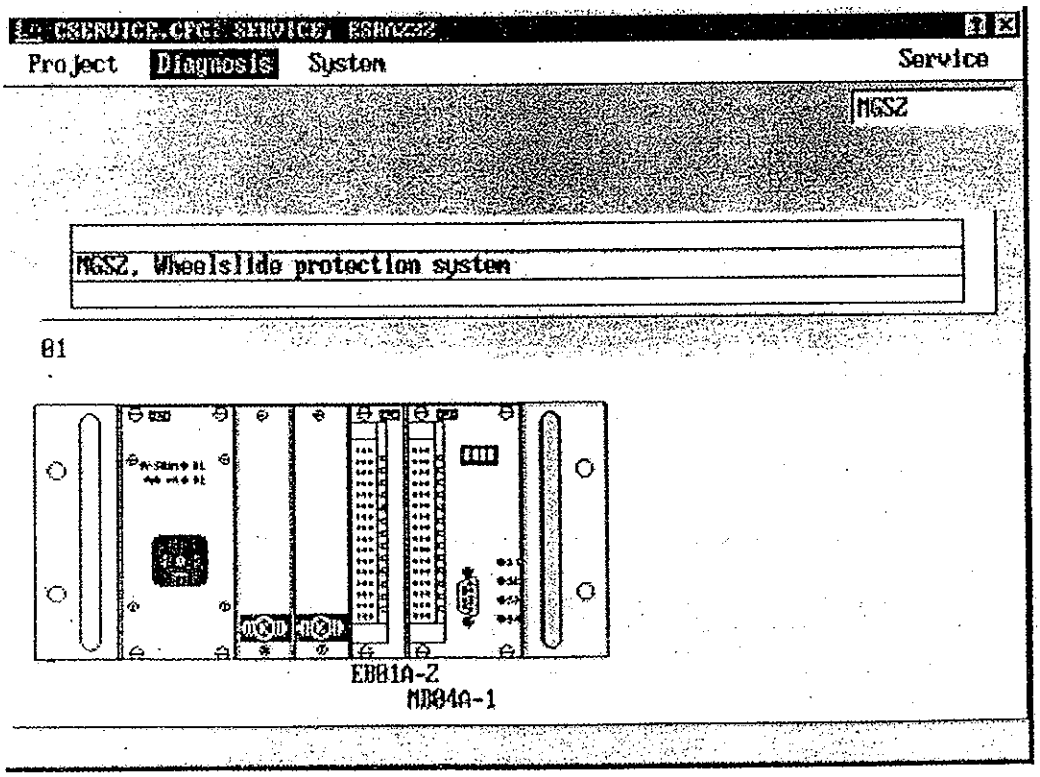
The MGS2 service terminal software has a user-friendly, graphical interface offering a wide range of diagnostic capabilities and testing functions (see Fig. 9).

For instance, all of the control unit's input quantities can be presented on screen, or outputs can be activated when the vehicle is standing idle.

The service terminal verifies the configuration of the unit and the software version. Vehicle-specific software modifications can be set from the service terminal without changes to the hardware.

A software package for data entry and acquisition can be had as an extension to the service terminal.

Fig. 9 **User interface of the service terminal**



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4.5 Diagnostic table (standard version[1])

Display	Fault	Source	Connected with:
02	Digital I/Os	Board EB01A	
03	Central processing unit	Board MB04A	
10	Time-out	Board MB04A	Wheelset 1
11	Short-circuit/open circuit	Speed sensor 1/feeder	
12	Signal error	Speed sensor 1	
13	Short-circuit	Valve 1/feeder	
14	Open circuit	Valve 1/feeder	
15	Safety monitor defective (test run)	Board MB04A	
20	Time-out	Board MB04A	Wheelset 2
21	Short-circuit/open circuit	Speed sensor 2/feeder	
22	Signal error	Speed sensor 2	
23	Short-circuit	Valve 2/feeder	
24	Open circuit	Valve 2/feeder	
25	Safety monitor defective (test run)	Board MB04A	
30	Time-out	Board MB04A	Wheelset 3
31	Short-circuit/open circuit	Speed sensor 3/feeder	
32	Signal error	Speed sensor 3	
33	Short-circuit	Valve 3/feeder	
34	Open circuit	Valve 3/feeder	
35	Safety monitor defective (test run)	Board MB04A	
40	Time-out	Board MB04A	Wheelset 4
41	Short-circuit/open circuit	Speed sensor 4/feeder	
42	Signal error	Speed sensor 4	
43	Short-circuit	Valve 4/feeder	
44	Open circuit	Valve 4/feeder	
45	Safety monitor defective (test run)	Board MB04A	
70	Speed signal fault, door control		
71	Speed signal fault, electromag. track brake	Board EB01A	
72	Fault at one wheelset		
73	Fault at several wheelsets		
74	Safety monitor fault	Board MB04A	
c8	Activation fault, cumulative fault signalling	Board EB01A	
S2	Connector defect, board EB01A	Board EB01A	
S3	Connector defect, board MB04A	Board MB04A	
8888	Display test		
89	Test running		
95	Volatile faults		
99	System good		

1) The diagnostic table can be extended suitably for a given vehicle application.