Software Requirement Specification For Metro Amsterdam HVAC System

Release History

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Revision Table

Revision	Date	Revised Sections, Description, Reason for changes
01	2010-9-21	Create the first issue
02	2011-6-17	Modify slumber mode and emergency mode description. Modify set point temperature calculation
03	2012-2-6	

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Content

1 ABBREVIATIONS AND DEFINITIONS

AC	Alternate current
AI…	Analogue input with number
APSE	Auxiliary Power Supply Equipment
AQ...	Analog output with number
CDR	Condenser
CDF	Condenser Fan
CPR	Compressor
DQ...	Digital output with number
DI...	Digital input with number
DF…	Internal variable to indicate fault information
ESF	Supply Air Fan emergency ventilation
F	Fault signal
FAS	Fresh air temperature sensor
FPC	FAIVELEY controller
HVAC	Heating Ventilation and Air Conditioning
INV	(emergency) Inverter
INVOK	(emergency) Inverter OK signal
KM	General contactor name
MLOK	Main line power supply OK feedback
MONA	FAIVELEY Service Software
MVB	Multi-function vehicle bus
PID	proportional–integral–derivative
RAS	Return air temperature sensor
SAS	Supply air temperature sensor
TBD	To Be Decided
t°	temperature
T_e	Ambient air temperature
T_d	Duct (supply) air temperature
Tic	Set point value
TCMS	Train control and monitor system

I / O	Input / Output
0L	Signal logically 0
1L	Signal logically 1
SAF	Supply Air Fan
SFRT	SHANGHAI FAIVELEY Railway Technology Co., Ltd
LP	Compressor Low Pressure switch
HP	Compressor High Pressure switch
UH	Unit heater
Ti	Average of Compartment air T° & Return air T°
TCN	Train Communication Network
VCU	Vehicle Controller Unit
Z_TMT_...	Internal variable to start test mode by MONA user

2 Introduction

2.1 Objective

The objective of this software requirement specification is to specify the function of the Saloon air conditioning system required for Amsterdam metro HVAC system.

2.2 HVAC unit components

Cab unit:

The main components of the Saloon unit are:

- One compressor with low and high pressure switch
- One condenser fan
- One supply air fan with low and high speed respectively in HAVC
- One electrical heater in HVAC, with safety elements
- Two temperature sensors: One fresh air dampers and one return air damper
- One liquid line solenoid and one hot gas bypass solenoids
- One supply air fan with low and high speed respectively in aerotherm
- One electrical heater in aerotherm, with safety elements

2.3 Control system

An FPC08 digital controller is used for temperature regulation. All functions of the air-conditioning system are regulated automatically and the air-conditioning system is also monitored automatically.

Supply air, recirculation air and external temperature sensors and pressostats and thermostats transfer the information to the controller which generates control commands for the switching elements.

If the temperature of the recirculation air deviates from that setting at the controller, with the system switched on by the mode switch or signal via train bus, the air-conditioning system is switched automatically in cooling or heating mode. The supply air ventilator is ON, thus it is ensured that the air is filtered and enriched with fresh air in any case.

The control of the HVAC unit is linked to the TCMS via CAN interface for the purpose of diagnosis and status information.

3 General control

3.1 Reference documents

Software must follow the requirements of the following documents:

- Za537189 Operation Manual Service Program Mona
- TI_KS97_Ver 4 Technical information for Air Conditioning System
- KS97_SQAP_01 Software Quality Assurance Plan
- KS97C000.000A.S4 Electric diagram for HVAC System

3.2 Network topology of HVAC controllers

The network topology of the HVAC controllers is as following:

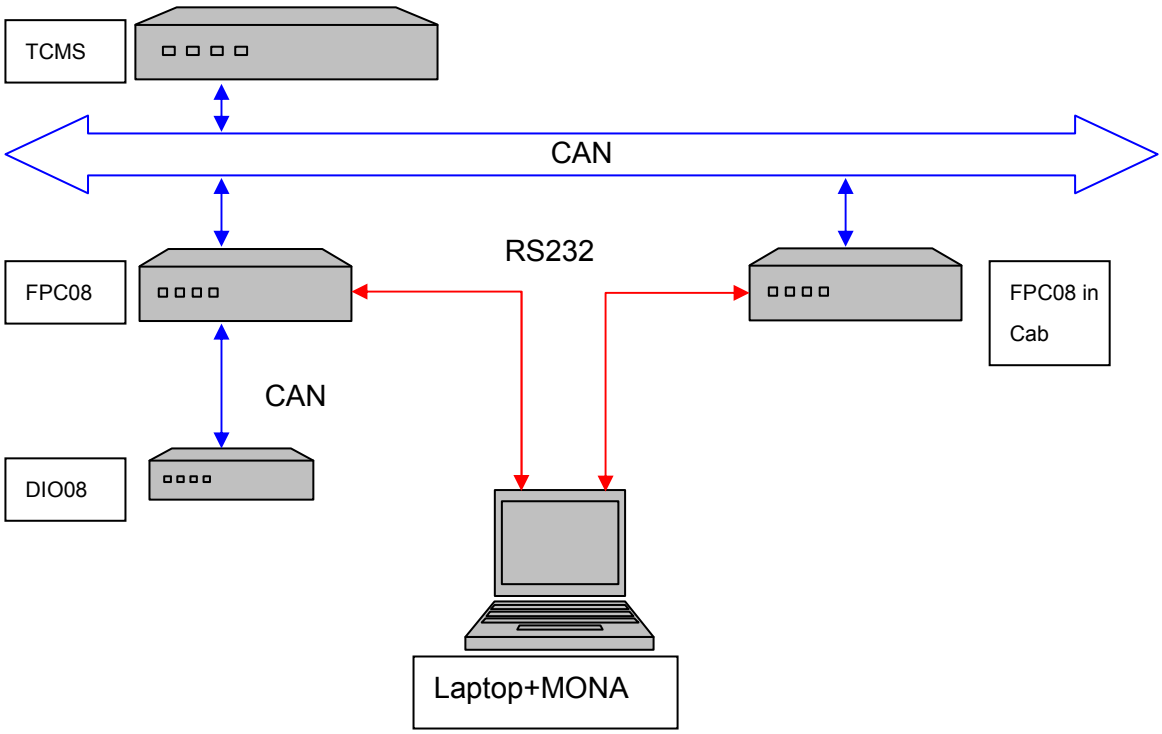


Figure 3-1: Network topology

3.3 General operation

3.3.1 General functions

Main function of the control system is ensuring adequate comfort regarding room temperature, supply air temperature and air volumes in accordance with the requirements. Changing conditions such as different outside temperature, solar radiation, humidity, and changes of supply voltage are to be compensated.

Furthermore the control system has to monitor the proper function of all components and has to transfer detailed diagnosis information to the central diagnosis system in cases of faults. Dangerous conditions are to be prevented.

HVAC controller FPC and TCMS will communicate via CAN network. FPC shall send the status of the HVAC unit as well as the outside temperature and the interior temp to TCMS.

Service functions such as software-download, the start of test-modes or signal recording are to be feasible via the RS232-interface. For maintenance purpose FAIVELEY offers the special developed Maintenance software Mona.

3.3.2 HVAC start up self-test mode

A self-test is performed when the controller is powered on for the first time and test mode is not activated by MONA. Self test sequence will be activated once each time after the controller is powered ON for the 1st time.

In this process, the controller tests all temperature sensors, tests the train bus system initialization and etc. Then the controller records the result of self-test. After self test process, the controller switches to the mode selected by the mode switch.

DQ_XX and DI_XX please refer to chapter 5 “Software interfaces”.

3.3.3 Test mode realized by MONA

Each component can be tested with FAIVELEY maintenance software called MONA. The detail method of test mode realized by MONA is described in the control function description of each component in the next chapters such as supply fan, condenser fan, compressor, and so on.

During test mode, the system fault information light shall flash ON.

3.3.4 Operation modes

This section gives an overview of how to define operation mode and status signal, and also internal status. Three kinds of signals can affect the operation mode of HVAC unit. They are:

- Signals from TCMS via CAN
- Signals from hardwired inputs
- Signals from maintenance software MONA

Although the signals from TCMS can affect the operation mode more frequently, the signals from maintenance software and from hardwired inputs have higher priority. See below:

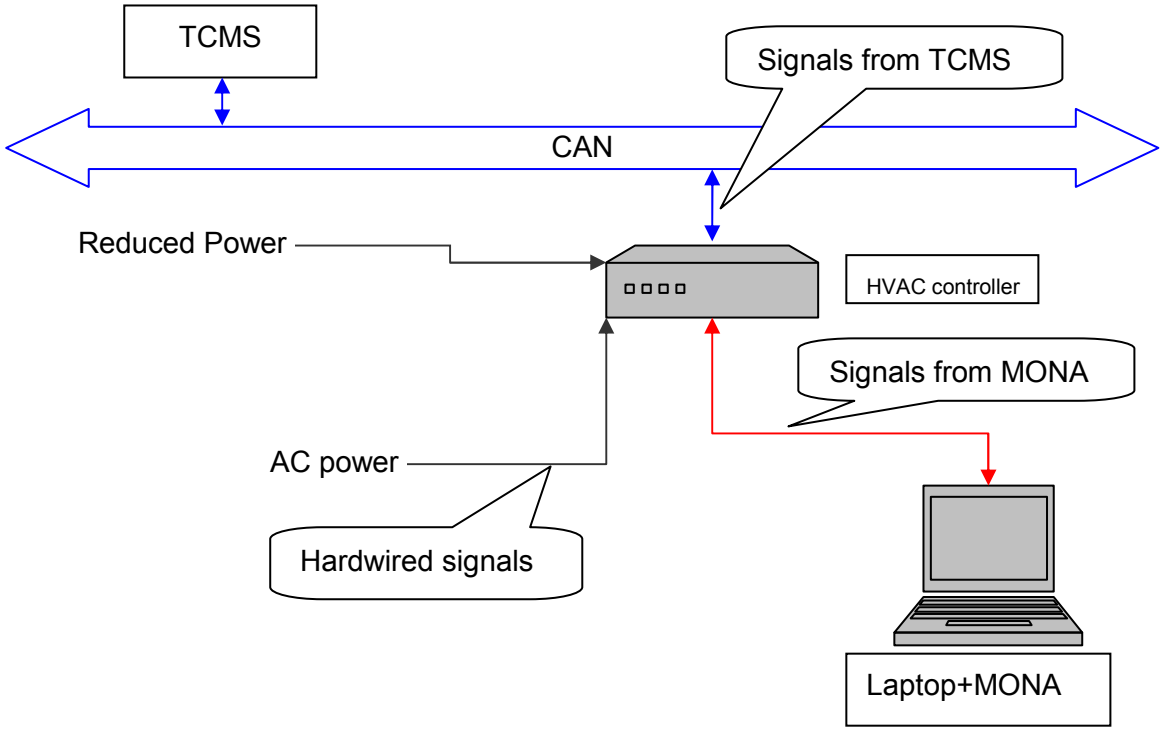


Figure 3-2: Signals affecting the operation modes

In case of testing, commissioning and maintaining, FPC communicates with a laptop running maintenance software MONA. Compared with signals from hardwired inputs, signals from MONA have the highest priority. FPC can detect the link with MONA automatically and set ‘Z_MONA_CONNECTED’=1L, send signal ‘ACTIVE_MONA’=1L to TCMS.

An internal variable ‘Z_SMLEVEL’ can be set from MONA directly. IF ‘Z_SMLEVEL’=9 (default), MONA just supervise the situation of FPC, can’t affect FPC to change operation mode. But if ‘Z_SMLEVEL’ is set to 0, FPC will be controlled by MONA only and will set the internal status ‘M_MTN’ =1L, sends signal ‘ACTIVE _MTN’ =1L to TCMS.

For the detailed description of maintenance software MONA, refer to chapter 7.

The control of the HVAC unit is separated into following modes:

- Self test procedures during startup
- Test mode via Mona
- OFF mode (Hardwired AC power Not OK signal or signal from TCMS)
- Emergency mode (from power detector)
- Emergency heating mode (Aerotherm system, hard wire)
- Slumber mode
- Automatic (normal) mode, both for HVAC and Aerotherm

Control switches:

There are 2 separate switches to manage the speed of ventilation for the HVAC unit and the aerotherm unit, in addition, there is 1 temperature setting switch to adjust the setting temperature. All these 3 switches are located on cab's desk.

- Switch for the HVAC unit: OFF / Low Ventilation / High Ventilation. (SA2)
- Switch for the aerotherm unit: OFF / Low Ventilation / High Ventilation / Emergency heating (SA3).
- When the unit switch is in position "Low Ventilation" the system regulates the heating or the cooling system (depends of the need of the cab) with the fan in low speed.
- When the unit switch is in position "High Ventilation" the system regulates the heating or the cooling system (depends of the need of the cab) with the fan in high speed.
- The values for the temperature adjustment are -2 / -1 / 0 / 1 / 2 / 3 / 4 K.(SA1)

In "Automatic mode" of HVAC, control of ventilation or cooling or heating is dependent on the temperature set point and temperatures of return air, supply air and fresh air from TCMS.
Starting sequence of HVAC module cooling is:

- Supply air fans
- Compressors\Condenser fans

The controller starts relevant modes depending on train bus information, temperature (inside and outside), Furthermore the controller receives feedback from the components and derives the current operation condition. The controller classifies failures and errors are stored in event memory. Operating conditions and error messages will be sent from the digital controller to the train system via train bus.

OFF mode

If the AC power supply for unit is not OK or the switch on driver desk “SA2” and “SA3” send the “OFF” signal to the HVAC controller, the HVAC will run in Off mode. Only the controller is powered. Ventilation and air conditioning are forbidden. If the OFF mode is active, the TCMS system receives all available signals, such as temperatures.

Automatic mode

In automatic mode, the HVAC unit will be controlled by the controller. Cooling, heating and ventilation are allowed. HVAC unit performs according to the defined temperature regulation. The set point of the passenger compartment temperature can be adjusted to the value with SA1 offset switch from -2 / -1 / 0 / 1 / 2 / 3 / 4 K. .

Emergency mode

The emergency mode will be activated automatically in case of missing 400V auxiliary power and the voltage and frequency of power supply from train is 250Vac 35Hz. (AI_04_PWR = 10±2°C). The mode information will display on the service Mona. However, the function is achieved through hard wire.

Slumber mode

The objective of this Slumber mode is to maintain a predefined temperature inside the vehicle.

The temperature set point in this mode is 5°C. SFRT will determine the appropriate T° value to insure an internal temperature greater than 5°C. The parameters will be defined during the climatic tests.

The TCMS authorises heating in slumber mode thanks to CAN signal “authorization of both HVAC cabs. The parameters of slumber mode are as same as that of normal mode except that:

- The setting temperature is 5°C (will be checked during the climatic tests on the car)
- Cooling is not allowed

3.3.5 Priority of operation modes

Here is the flow chart of the operation mode, it is defined the priority of the modes like this.

From highest to lowest priority: SELFTEST>TEST>OFF>Emergency> Slumber> Automatic.

3.3.6 HVAC Sub modes under auto mode

In automatic mode, the HVAC unit will be completely controlled by the controller. Cooling, heating and ventilation are allowed. Temperature regulation is calculated according to what is described in chapter 4.1 “internal set point creation”.

According to the calculation of return air and fresh air, there are cooling modes can be set by controller.

- Cooling mode: when the calculated value is more than 5% of cooling needing and cooling needing is more than heating needing, the HVAC unit will run with compressor;
- Heating mode: when the calculated value is more than 5% of heating needing and heating needing is more than cooling needing, the HVAC unit will run with heaters;
- When there isn’t cooling and heating needing, the HVAC will turn to “Ventilation” mode, the HVAC system will stop the compressor, heater, condenser fan, only the supply air fan is running which used to provide fresh air.

The refrigerant circuit is equipped with a hot gas bypass regulator. As soon as the requiring the compressor start, then the solenoid valve is opened. When the cooling demand is under a level (less than 40% capacity) causing the evaporation pressure and temperature to be under a certain unwanted value, the bypass regulator opens allowing hot gas to flow directly into the evaporator and raises evaporation pressure to an acceptable level. The suction (evaporation) pressure is the control-parameter for the bypass regulator.

3.3.7 HVAC mode related internal variables

Variable name	Description	Function
M_TEST	read	Internal variable test mode for saloon (by MONA)
M_OFF	read	Internal variable off mode
M_AUTO	read	Internal variable auto mode (normal mode)
M_Slumber	read	internal variable slumber mode
M_EMC	read	internal variable emergency mode
M_EMH	read	internal variable emergency heating mode

Variable name	Description	Function
A_Y_COOL	set	Internal variable cooling needing
A_Y_HEAT	set	Internal variable unit heater heating needing
A_Te	Read, from CAN	Internal variable average outside air temperature from CAN signal
A_Ti	Read, from AI	Internal variable average inside air temperature
A_Tic	set	Internal variable set-point temperature calculated according to UIC553
A_Tic_Offset	set	Internal variable set-point temperature after offset has been added

3.3.8 Summary Components' Actions in Related Modes

Component / Mode	OFF	Emergency	Emergency Heating	Normal-Cooling	Normal-Heating	Normal-Vent	Slumber
SA2 (HVAC Switch)	OFF			High/Low speed			
Supply air fan1	OFF	ON	OFF	ON	ON	ON	ON
Compressor/Condenser fan	OFF	OFF	OFF	ON	OFF	OFF	OFF
Unit Heater	OFF	OFF	OFF	OFF	ON	OFF	ON
SA3 (Aerotherm Switch)	OFF		EMH	High/Low speed			
Supply air fan2	OFF	OFF	ON	ON	ON	ON	ON
Heater2	OFF	OFF	ON	OFF	ON	OFF	ON

Note:

- There are 2 switches on cab desk for control the HAVC mode and aerotherm mode.
- SA2 provides HVAC with OFF, Low speed of SAF1, high speed of SAF1;
- SA3 provides aerotherm with OFF, low speed of SAF2, high speed of SAF2 and emergency heating mode;

3.4 Refrigerant Circuit of the HVAC Unit

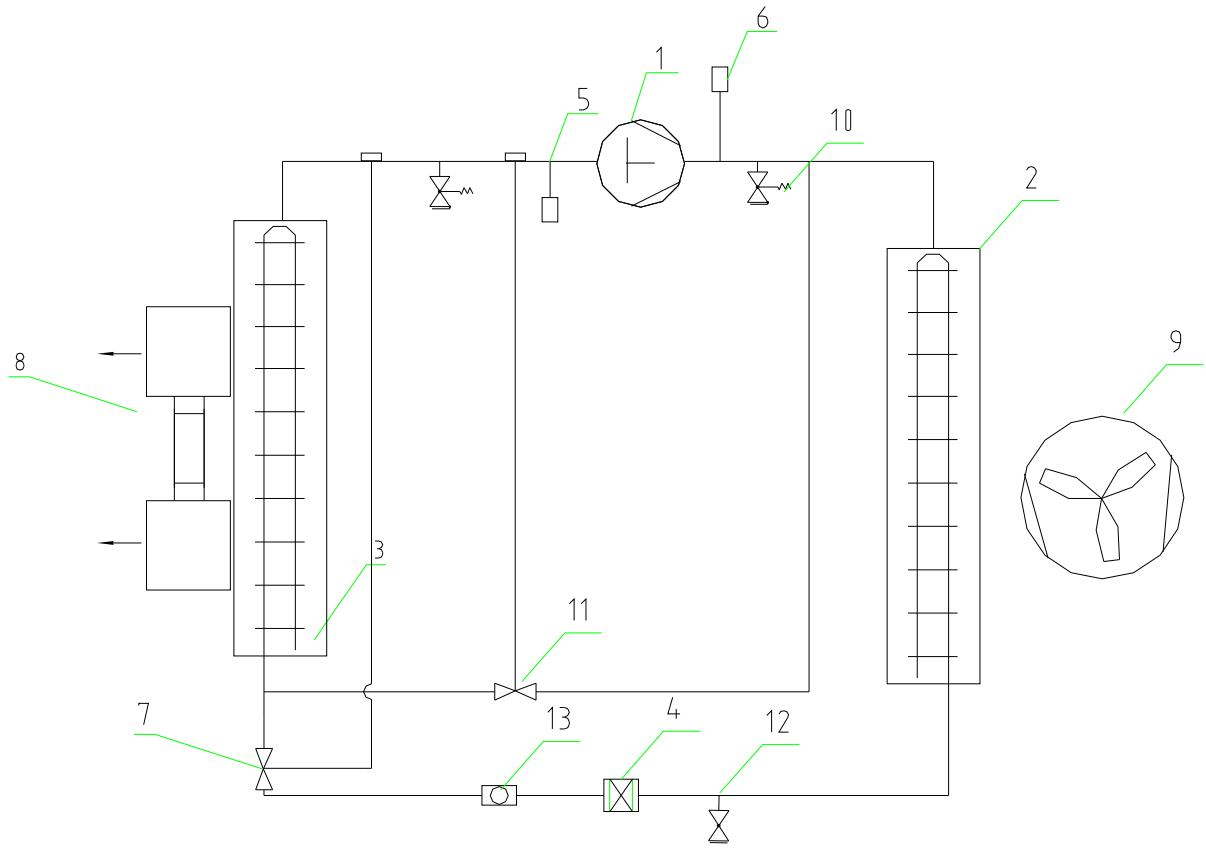


Figure 3-3: refrigerant circuit of saloon unit

No.	Components	Qty	No.	Components	Qty
1	Compressor	1	7	Expansion valve	1
2	Condenser	1	8	Supply air fan	1
3	Evaporator	1	9	Condenser fan	1
4	Filter dryer	3	10	Schrader valve	2
5	Low pressure switch	1	11	Hot-gas bypass	1
6	High pressure switch	1	12	Charging valve	1
13	Sight-glass/moisture indicator	1			

4 Auto Mode Control Functions

4.1 Internal set point temperature creation

4.1.1 HVAC set point temperature creation

If the HVAC runs at automatic mode, the internal set point (goal temperature) is calculated as following:

If Te >=20°C, then Tic = 20+ 0.4(Te -20)+T_offset)*

If Te < 20°C, then Tic = 20+T_offset

Notes:

Te is ambient air temperature from train side via CAN bus. *Tic* is the set point temperature calculated according to EN 14750-1 cat B.

The set point temperature can be adjusted to the value within -2K to +4K which is defined by switch SA1

The result is memorized (M_Tic=calculated set point of saloon unit).

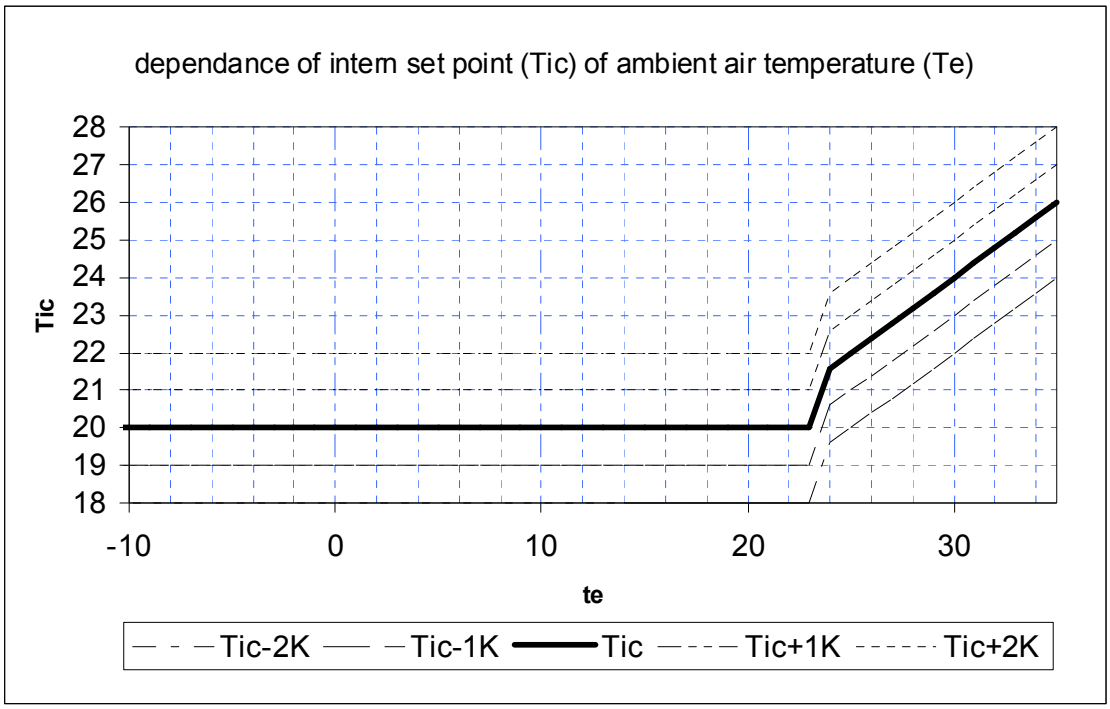
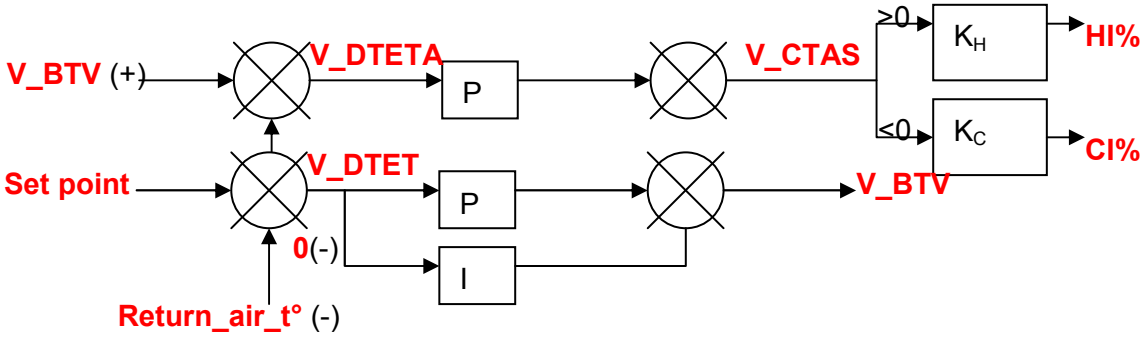


Figure 4-1: Dependance of intern setpoint of ambient air temperature

4.2 Calculation of Cooling / Heating Needing

First, the controller calculates Tic (set point temperature), Ti (inside temperature). Tic is calculated as described above:

The cooling capacity shall be controlled in dependence of the return and ambient (fresh air) air temperature. The calculation is designed as a PID regulator. The main value for calculation is depended on the return air temperature sensor, corrected by ambient temperature (fresh air sensor).



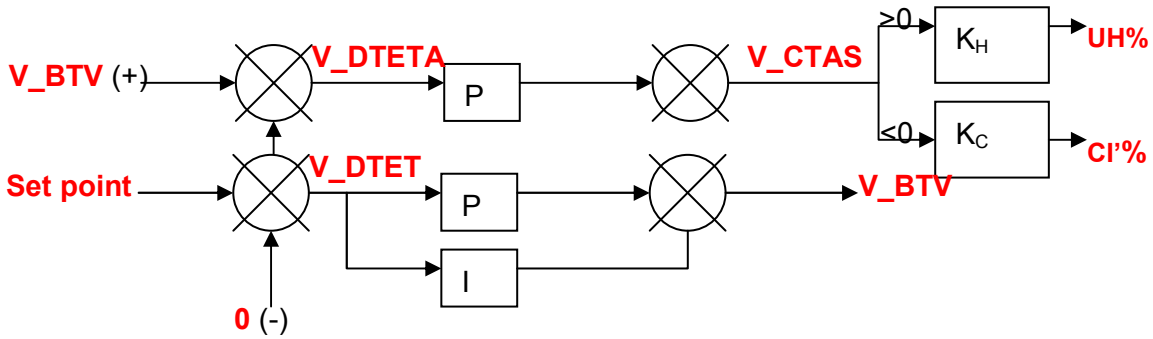
The object is to determine, according to the temperatures of air and the set point, the necessities in warmth or in cold for the air conditioning of the vehicle.

Two functions condition the realization of the heating or the refrigerating: the need, and the tendency.
The object of the needing is to determine ON/OFF for cooling and heating devices.
The object of the tendency is to avoid fast change of mode vent – cool – vent –heat.

Calculated result:

Cooling need: A_Y_COOL

Heating need: A_Y_HEAT



The calculation and the temperature recalculation will be adjusted during the tests.

4.3 Cooling / Heating and Ventilation Mode

4.3.1 Cooling / Half Cooling

In auto mode the controller will decide the HVAC system should be in what sub mode according to all the digital inputs and analog inputs information. The HVAC system is completely controlled by FPC. First, the controller calculates Tic (set point temperature), Ti (inside air temperature). Tic is calculated as described in 4.1.1 “HVAC set point temperature creation”,

By calculating Ti, Tic, cooling needing, and heating needing, HVAC can work in cooling, heating, or ventilation mode. The purpose is to regulate Ti in range of Tic±1.5°C.

1. If cooling need A_Y_COOL <= 5%, compressor shuts down
2. If A_Y_COOL > 5%, and A_Y_Cool > A_Y_heat, compressor starts.

4.3.2 Heating mode

There is a unit heater equipped for each HVAC unit. Heating needing A_Y_HEAT is calculated for unit heater.

If A_Y_HEAT > 5%, and the compressor has stopped for more than 4min, unit heater switches on, heating mode starts.

There are 2 heaters in cab, one is roof heater (DQ_02_UH1) and the other is the aerotherm heater (DQ_05_UH2). The priority for the heating inside the cab: the aerotherm has the higher priority and start 1st before to use the roof heater.

4.3.3 Ventilation mode

If there is no cooling need, no heating need for the unit heater in auto mode, then the HVAC is in auto ventilation mode and the compressor and heater stop.

4.4 Fault diagnosing

The controller shall diagnose the temperature sensors and the compressor, condenser fan, supply air fan and the unit heater.

Temperature sensor:
Return air temperature sensor, If AI_01_RAS >80 or <-20, RAS fault DF_RAS shall be activated and be recorded.
It is similar to the supply air temperature sensor.

Components' fault diagnosing is described in chapter 6 Main components control

5 Software interfaces

5.1 Digital outputs

Digital Outputs		
N°	*Pin*	Function
DQ_01_SAF2	*P3: 5*	Aerotherm unit supply fan contactor KM6 (relay KA2) control
DQ_02_UH1	*P3: 4*	HVAC unit heater contactor KM4 control
DQ_03_SAF1	*P3: 3*	HVAC unit supply fan contactor KM3 control
DQ_04_CPR	*P3: 2*	Compressor contactor KM1 and condenser fan contactor KM2 control
DQ_05_UH2	*P3: 7*	Aerotherm unit heater contactor KM5 control
DQ_06_Y1	*P3: 8*	Liquid line solenoid valve Y1 control
DQ_07_Y2	*P3: 9*	Bypass solenoid valve Y2 control
DQ_08_FPCOK	*P3: 10*	Controller FPC08 is OK

5.2 Digital inputs

Digital Inputs		
N°	*Pin*	Function
DI_01_CPR	*P3: 12*	Compressor contactor KM1 and condenser fan contactor KM2 feedback
DI_02_UH1	*P3: 13*	HVAC unit heater contactor KM4 feedback
DI_03_SAF1	*P3: 14*	HVAC unit supply fan contactor KM3 feedback
DI_04_UH2	*P3: 15*	Aerotherm unit heater contactor KM5 feedback
DI_05_SAF2	*P3: 16*	Aerotherm unit supply fan contactor KM6 (relay KA2) feedback
DI_06_LP	*P3: 17*	Compressor low pressure LP feedback
DI_07_ESAF	*P3: 18*	Emergency ventilation contactor KM9 feedback
DI_08_EMH	*P3: 19*	Emergency heating is ON

5.3 NTC inputs

NTC Inputs		
N°	Pin	*Function*
AI_01_SAS	P2: 6, 13	*Supply air temperature sensor input*
AI_02_RAS	P2: 8, 7	*Return air temperature sensor input*
AI_03_PWR	P2: 10, 11	*Power status detection*
AI_04_SA1TSS	P2: 12, 5	*Temperature selection switch SA1 input*
AI_05_SA2MFS	P2: 14, 9	*Mode and fan speed switch SA2 input*
AI_06_SA3MFS	P2: 16, 4	*Mode and fan speed switch SA3 input*

6 Main components control

6.1 Supply air fan control

6.1.1 Description of SAF1 function

Supply air fan 1 is the main component of the HVAC system. HVAC system can't work without supply air fan 1 which is checked through the circuit breaker. SAF can work at all modes except off mode.

6.1.2 Internal variables related to SAF1

Variable name	Description	Function
DI_03_SAF1	ON=1L, DI	HVAC unit supply fan contactor KM3 feedback
DQ_03_SAF1	ON=1L, DO	HVAC unit supply fan contactor KM3 control
AI_05_SA2MFS	OFF 180C, High speed 66C, Low speed 47C	*Mode and fan speed switch SA2 input*
M_TEST	read	HVAC unit test mode
M_OFF	read	HVAC unit off mode
M_AUTO	read	HVAC unit auto mode
M_EMC	read	HVAC unit emergency mode
M_Slumber	read	HVAC unit slumber mode

6.1.3 SAF1 operating condition

When HVAC system starts and there isn't "HVAC OFF" command, supply air fan will start. The reason is that air volume is very important for HVAC system.
Without the SAF, there's no compressor or heater running.

When the power 400V is missing and 250V is detected, the supply air fan will run under emergency mode with KM9 control which is provided by the hard wire.

6.1.4 SAF1 fault diagnosing

The running of SAF will be checked during all the running time of SAF. Detail fault diagnosing is as following:

Code or name	Description	Reason of failure	Gravity(*)
DF_SAF1H	High speed supply air fan fault	- Thermal overload protection QF3 triggers - Temperature protector FR01 triggers - Or feedback of contactor KM03 is missing - When SA2 is high speed position	1
DF_SAF1L	Low speed supply air fan fault	- Thermal overload protection QF3 triggers - Temperature protector FR01 triggers - Or feedback of contactor KM03 is missing - When SA2 is low speed position	1
DF_ESAF	Emergency supply air fan fault	- Thermal overload protection QF3 triggers - Or feedback of contactor KM9 is missing	1

Note: for the information of gravity, please refer to the chapter 6.3.2.

6.2 Compressor and Condenser fan control

6.2.1 Description of compressor and condenser fan function

Each cooling circuit consists of one compressor and one condenser fan; additionally there is high pressure switch (hard wire connected), low pressure switch and some specific mechanical cooling parts (dryer, capillary, sight class).

The HP switch protects the circuit against over heating and destroys.
The controller FPC supervises LP switch.
Thermo protection of compressor is integrated in the feeding of CPR contactor.
Thermo protection can also cause a failure of compressor contactor.
That's the reason for restart of compressor 1minute after having taken a break.

Each compressor is allowed to start 6 times per hour.
For symmetrical operation, it is defined a restart release only after 6 minutes.
The minimum of delay after switching off is set to 3 minutes.
Purpose is to forbid frequent starting of the compressor.

The running of the compressor is depended on the cooling capacity calculated by the controller. (Internal calculation) The solution regarding a unit is:
0-5%: compressors stop
5-100%: compressor/condenser fan is allowed (This value can be regulated)

6.2.2 Internal variables related to CPR/CDF

Variable name	Description	Function
DI_01_CPR	ON=1L, DI	Compressor contactor KM1 and condenser fan contactor KM2 feedback
DI_06_LP	ON=1L, DI	Compressor high pressure HP feedback
DQ_04_CPR	ON=1L, DO	Compressor contactor/Condenser fan KM1 and condenser fan contactor KM2 control
DQ_06_Y1	ON=1L, DO	Liquid line solenoid valve Y1 control
DQ_07_Y2	ON=1L, DO	Bypass solenoid valve Y2 control
M_TEST	read	HVAC unit test mode
M_OFF	read	HVAC unit off mode
M_AUTO	read	HVAC unit auto mode
M_EMC	read	HVAC unit emergency mode

6.2.3 Start and regulation of the compressor

The HVAC unit will require compressor starting if following conditions meet:

- The HVAC is running in “Cooling” mode
- SAF1 is running properly
- 6mins has elapsed after last start
- 3min has elapsed after switching off of the corresponding CPR
- There isn’t any fault for CPR

6.2.4 Switching off condition of CPR

Compressor would be shut down under the following conditions:

- The HVAC isn’t running in “Cooling” mode
- The supply air fan 1 is stopped
- Any fault of the compressor
- In case the outside temperature is below 10°C
- In case the duct temperature is below 5°C
- There is high or low pressure fault detected
- 400V power is missed

Notes:

1. LP switch event is neglected for 120s during start-up of the compressor.
2. Error message due to high pressure, if there is more than 3 times, the compressor stops until the service restart (“OFF” mode)
3. Error message due to low pressure, if it keeps active 120s after the compressor starts up, and if there triggers more than 6 times per hour, the compressor stops until the service restart (“OFF” mode)

6.2.5 CPR Fault Diagnosing

The running of CPR will be checked during all the running time of CPR. Detail fault diagnosing is as following.

Diagnosis Code	Description	Reason of failure	What’s happen?
6	CPR/CDF thermo/contactor	- Thermal overload protection triggers	CPR/CDF stops running temporarily for 1min.

Diagnosis Code	Description	Reason of failure	What's happen?
	fault SW address: DF_CTHHP	- Or feedback of contactor KM1&2 is missing	CPR/CDF is forbidden when the fault is active. The fault can only reset by SA2 switch to "OFF" if the event happens 3 times. Information is sent to TCMS.
7	CPR low pressure switch fault SW address: DF_CLP	- The refrigerant pressure inside CPR1 cooling circuit is too low - The fault is ignored 120s during start-up of CPR1	CPR stops running temporarily for 1min. CPR is forbidden when the fault is active. The fault can only reset by power off the FPC08 if the event happens 6 times. Permanent fault is sent to TCMS.
8	CPR1 fault	- One of fault 6, 7 is active	----

6.3 Unit heater control

6.3.1 Description of unit heater function

Every unit is equipped with one unit heater.
Unit heater is applied to supply warm air into the cab in heating mode.

Overload protection input can also cause a failure of unit heater and cause a restart of unit heater some times after having taken a break.

6.3.2 Internal variables related to unit heater

Variable name	Description	Function
DI_02_UH1	ON=1L, DI	HVAC unit heater contactor KM4 feedback with heater overload
DQ_02_UH1	ON=1L, DO	HVAC unit heater contactor KM4 control
M_TEST	read	HVAC unit test mode
M_OFF	read	HVAC unit off mode
M_AUTO	read	HVAC unit auto mode
M_SLUMBER	read	HVAC unit slumber mode
M_EMC	read	HVAC unit emergency mode

6.3.3 Start condition of unit heater

To start the heater in auto mode, following conditions must be available:

- The HVAC is running in “Heating” mode;
- 4 min has elapsed since the compressors stopped;
- SAF is running properly;
- There isn’t any fault for heater.

6.3.4 Unit heater operating conditions

Function of the unit heater is to prevent cold outside air blowing directly into the carriage.

- If A_Y_HEAT <= 5%, unit heater shuts down
- If 5% < A_Y_HEAT <= 100%, unit heater runs as following

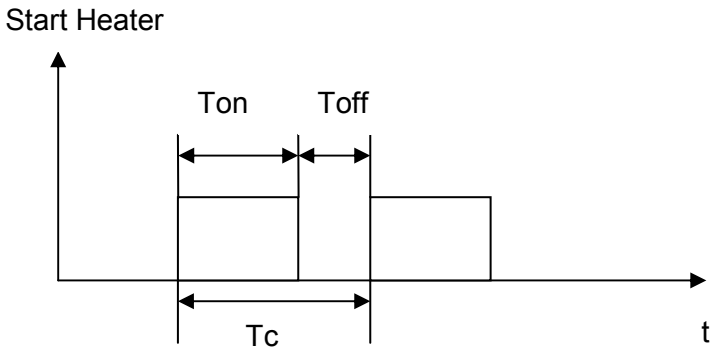


Figure 6-1: running time of the heater

Ton and Tc are internal timers. Tc is valued by the programmer.
The ON time ratio of heater **Ton / Tc = A_Y_HEAT%** is to be tested.

6.3.5 Switching off condition of unit heater

Unit heater must be shut down under the following conditions:

- The HVAC isn't running in "Heating" mode;
- Any fault of SAF;
- Any fault of unit heater.
- 400V is missing or M_EMC

Notes:

1. Over t° / over load protection event is neglected for 5s during start-up of the unit heater;
2. Error message due to over load (over t°) protection, if there is more than 3 times, unit heater stops until the service restart.

6.3.6 Unit heater fault diagnosing

The running of unit heater will be checked during all the running time of unit heater.
Detail fault diagnosing is as following:

Code or name	Description	Reason of failure	Gravity
DF_UH1	Unit heater	- QF4 triggers	2

	1fault	- Unit heater 1 contactor KM4 is missing when DQ_02 is on - Unit heater overload	

6.4 Supply air fan 2 of Aerotherm

In addition, each cab will be equipped with one compact aerotherm unit, which is located under the driver's desk. The aerotherm unit consists of supply air fan and one electrical heater with safety elements.

6.4.1 Description of SAF2 Functions

When switch SA3 is put on the position low speed or high speed, the supply air fan2 will run which is controlled by DQ_01 except EMC mode.

6.4.2 Internal Variables Related to SAF2 Functions

Variable name	Description	Function
DI_05_SAF2	ON=1L, DI	Aerotherm unit supply fan contactor KM6 (relay KA2) feedback
DQ_01_SAF2	ON=1L, DO	Aerotherm unit supply fan contactor KM6 (relay KA2) control
M_TEST	read	HVAC unit test mode
M_OFF	read	HVAC unit off mode
M_AUTO	read	HVAC unit auto mode
M_EMH	read	HVAC unit emergency heat mode
M_EMC	read	HVAC unit emergency mode

6.4.3 Start condition of supply air fan 2

To start the supply air fan of aerotherm, following conditions must be available:

- The SA3 is put in "high speed" or "low speed" or "emergency heat" mode;
- 400V is OK;
- No any fault of heater;

6.4.4 Stop condition of supply air fan 2

Take in account the different positions for different modes.

- The SA is put in "off" mode;
- 400V is missing;

- Any fault of heater;

6.4.5 SAF2 fault diagnosing

The running of SAF will be checked during all the running time of SAF. Detail fault diagnosing is as following:

Code or name	Description	Reason of failure	Gravity(*)
DF_SAF2H	High speed supply air fan fault	- Thermal overload protection QF6 triggers - Temperature protector FR02 triggers - Or feedback of contactor KM6 is missing - When SA3 is high speed position	2
DF_SAF2L	Low speed supply air fan fault	- Thermal overload protection QF6 triggers - Temperature protector FR02 triggers - Or feedback of contactor KM6 is missing - When SA3 is low speed position	2

6.5 Heater2 of Aerotherm

6.5.1 Description of heater2 of aerotherm

One heater is installed under the cab desk. The heater is applied to supply warm air into the cab in heating mode with HVAC unit heater together.

Overload protection input can also cause a failure of unit heater and cause a restart of unit heater some times after having taken a break.

The driver can put the aerotherm switch in position "Emergency heating". Heater of the aerotherm is switch on but the temperature is not regulated. The safety of the heater is assure by the thermostat.

6.5.2 Internal variables related to heater2 of aerotherm

Variable name	Description	Function
DI_04_UH2	ON=1L, DI	Aerotherm unit heater contactor KM5 feedback

Variable name	Description	Function
DQ_05_UH2	ON=1L, DO	Aerotherm unit heater contactor KM5 control
M_TEST	read	HVAC unit test mode
M_OFF	read	HVAC unit off mode
M_AUTO	read	HVAC unit auto mode
M_EMH	read	HVAC unit emergency heat mode
M_EMC	read	HVAC unit emergency mode

6.5.3 Operation condition of heater2 of aerotherm

To start the heater in auto mode, following conditions must be available:

- The HVAC is running in “Heating” or “emergency heat” mode;
- 4 min has elapsed since the compressors stopped;
- SAF2 is running properly;
- There isn’t any fault for heater of aerotherm.
- Control logic is combined with unit heater;
-

6.5.4 Switching off condition of heater2 of aerotherm

Heater2 must be shut down under the following conditions:

- The HVAC isn’t running in “Heating” or “emergency heat” mode;
- Any fault of SAF2;
- Any fault of heater2.
- 400V is missing or M_EMC

Notes:

3. Over t° / over load protection event is neglected for 5s during start-up of the heater2;
4. Error message due to over load (over t°) protection, if there is more than 3 times, heater2 stops until the service restart.

6.5.5 Heater2 of aerotherm fault diagnosing

The running of heater2 will be checked during all the running time of heater2. Detail fault diagnosing is as following:

Code or name	Description	Reason of failure	Gravity
DF_UH2	heater 2 fault	- QF5 triggers - Heater 2 contactor KM5 is missing when DQ_05 is on - Heater overload	2
DF_EMH	heater 2 fault in emergency heating mode	- QF5 triggers - Heater 2 contactor KM5 is missing when DQ_05 is on - Heater overload	2

Notes:

5. Over t° / over load protection event is neglected for 5s during start-up of the heater;
6. Error message due to over load (over t°) protection, if there is more than 3 times, heater stops until the service restart.

6.6 Main components' supervision

There are listed the table of running time and numbers of start regard the follow devices:

Slot (MONA)	Slot (Internal)	Function	Remarks	
1	0	Supply fan 1 high speed	SAF1H	
2	1	Supply fan 1 low speed	SAF1L	
3	2	Supply fan 2 high speed	SAF2H	
4	3	Supply fan 2 low speed	SAF2L	
5	4	Emergency ventilation	ESAF	
6	5	Compressor /Condenser fan	CPR/CDF	
7	6	Solenoid valve	Y1	
8	7	Hot gas bypass valve	Y2	
9	8	Unit heater	UH1	
10	9	Aerotherm heater	UH2	
11	10	Reserved	Reserved	
12	11	Reserved	Reserved	

Slot (MONA)	Slot (Internal)	Function	Remarks	
13	12	Reserved	Reserved	
14	13	Reserved	Reserved	
15	14	Reserved	Reserved	
16	15	Reserved	Reserved	

6.7 Diagnosis code

6.7.1 Diagnosis code (YANGYAN modified on Apr.25)

The diagnosis code is listed below; any others would be added or modified during commissioning if needed.

Code number	Function (event)	Remark Intern	gravity	Name
1	Supply fan1 control contactor KM3 fault or high speed contactor KM7 fault or thermo protector FR1 fault when SA2 speed request is high vent	1	1	DF_SAF1H
2	Supply fan1 control contactor KM3 low speed contactor KM8 fault or thermo protector FR1 fault when SA2 speed request is low vent	2	1	DF_SAF1L
3	Supply fan 2 control contactor KM6 or high speed contactor KM10 fault or thermo protector FR2 fault when SA3 speed request is high vent	3	1	DF_SAF2H
4	Supply fan 2 control contactor KM6 or low speed contactor KM11 fault or thermo protector FR2 fault when SA3 speed request is low vent	4	1	DF_SAF2L
5	Supply fan emergency ventilation contactor KM9 fault or thermo protector FR1 fault when power is in emergency mode	5	1	DF_ESAF
6	CPR contactor KM1 or thermo protector QF01 fault or CDF contactor KM2 or thermo protector QF02 fault	6	2	DF_CTHHP

Code number	Function (event)	Remark Intern	gravity	Name
	or HP fault			
7	Compressor low pressure LP fault	7	2	DF_CLP
8	One or more of DF_CTHHP, DF_CLP are active	8	2	DF_FAIL_CPR
9	Unit heater 1 KM4 or heater1 overload fault	9	2	DF_UH1
10	Unit heater 2 KM5 or heater2 overload fault	10	2	DF_UH2
11	Emergency heater KA5 fault	11	2	DF_EMH
12	400V AC power line fault	12	2	DF_MLF
13	250V Dectected	13	2	DF_AC250
14	Supply air temperature sensor fault	14	3	DF_SEN_SAS
15	Return air temperature sensor fault	15	3	DF_SEN_RAS
16	The serial number of FPC08	23	15	FPC_SN

6.7.2 Description

Classification of Gravity is valid for the device which is described. The gravity of the error description in the following section is same.
If more faults come together, please check the chapter of function
Description of Gravity:

[1]…Serious fault (Subsystem fault), maintenance after current turn required
[2]…Medium fault (Subsystem reduced load), maintenance after service required,
[3]…Slight fault (Component fail, unit OK), maintenance required,
[15]…Event supervision, no fault

Procedure for fault gravity generation (take in account special position of ventilation):

- If a component fail, a slight fault is generated (failure of sensor, fan, flap, detector, heater)
- If a subsystem works with reduced load, a medium fault is generated (failure of cooling, one supply fan, one emergency fan)
- If a subsystem fault a serious fault is generated (failure of ventilation, emergency ventilation, emergency inverter)

7 Maintenance Software- MONA

7.1 What's MONA?

MONA is maintenance software, dedicated for the supervision of the HVAC systems. It connects on any FPC controller and provides powerful maintenance & diagnosis functions to our customers, such as:

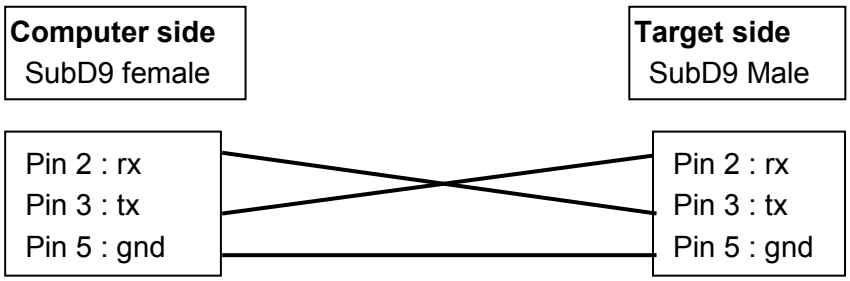
- Displaying a concrete real-time overview of the system, including working modes, temperature survey, and quick fault sum-up.
- Recording interesting signals during an unlimited time, with off-line "replay" functions
- Exhaustive event memory management including event contexts
- Supervision of HVAC component (running time, number of starts) during the complete life of the device.
- Test mode control
- Parameter changing
- I/O visualization
- Output forcing
- <F> Can bus control
- Download of application software

7.2 Communication principles

7.2.1 Physical Layer

MonA uses the RS232 maintenance link of the FPC controller. On the other side, it should be connected to any serial port (COM) of a PC computer. It requires a standard crossed RS232 cable, with mounted respectively male and female SubD9 connectors.

One unique FPC may be connected on this link.



Via USB interface it is possible to download the user software into FPC24/2 and to start the service program MonA.

7.2.2 Data link layer

The exchange mechanism is based upon Master/Slave communication. The master is the PC computer, and the slave the FPC target controller.

Request / Response: [slv][fc][id][pn][No.][info(?)][crc(2)].

[slv] : FPC number (always 1).

[fc] : Function code, refers to the requested function.

[id] : identifier of the frame (always 0).

[pn] : packet numbering. (always 0).

[No.] : size of the [info(?)] data in bytes.

[info] : information data, size according to the requested function.

[crc] : CRC16 of the frame, performed on the complete frame.

7.2.3 Application layer

Three communication access points are available in Mona.

1) Direct access

Some functions (checksum control, application version) are realized by direct function call.

2) Reserved variables

All generic functions such as Event Memory management, can bus control, component supervision… requires reserved variables. These may be forced and read. This is intended to avoid re-configuration for each new project.

3) Application variables

For project specific functions (overview, recording, test-modes), all variables can be read without any constraints by direct call in the symbol file (appli.tst) of the project.

Remark: For test modes, rules should be respected while naming the variables, see below.

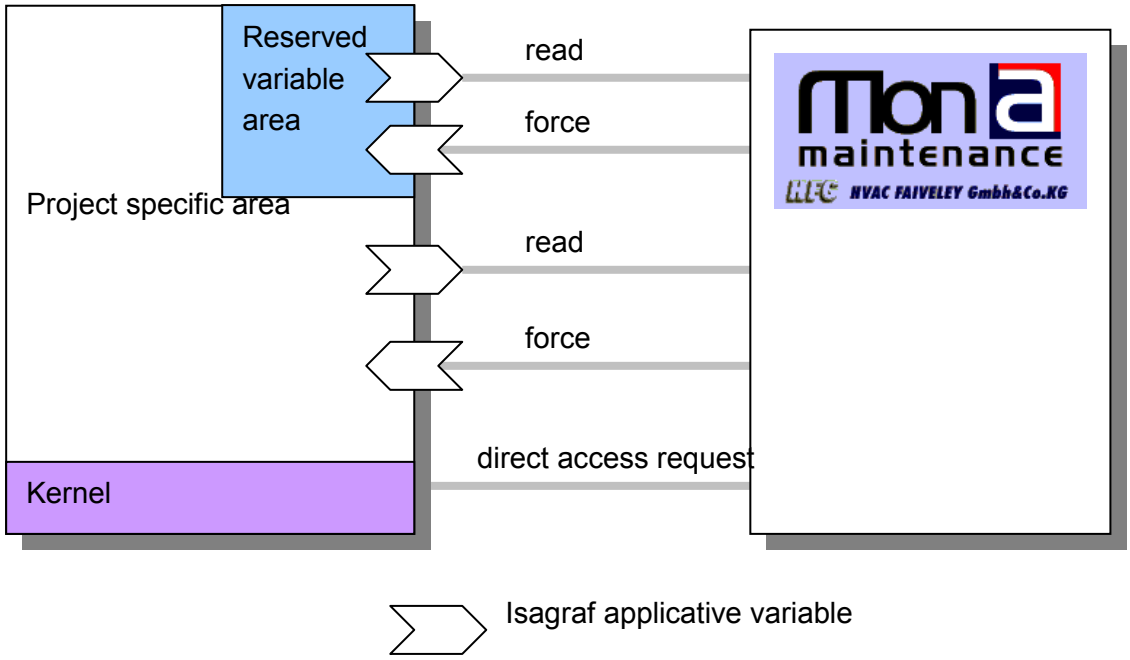


Figure 7-1: communication access points of Mona

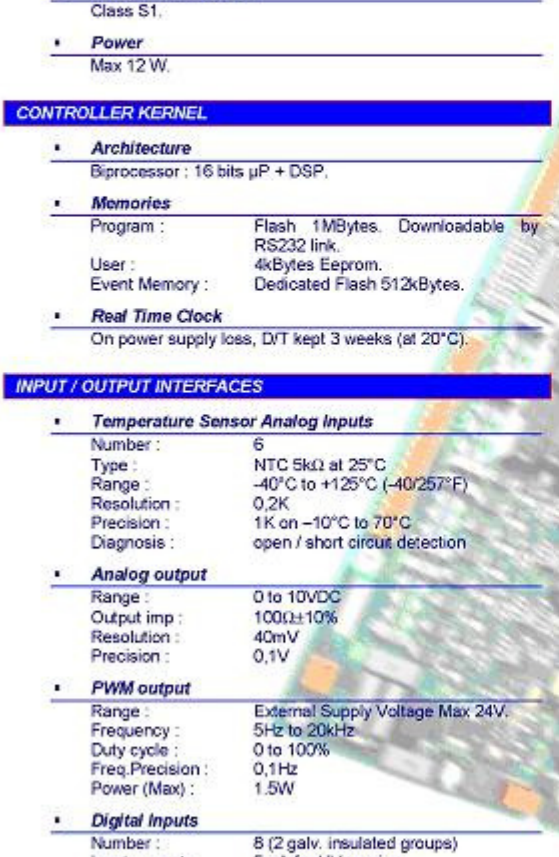
The application software is compatible with current operating platforms, for example, Windows 98, NT, ME, 2000 & XP. The exact functionality shall be coordinated with the customer. Diagnostic group signals, which are defined later, can be transmitted from the HVAC via MVB-Interface to the leading VCU.

8 CONTROLLER FPC08 & DIO8 – TECHNICAL DATA

8.1 Technical data of controller FPC08

FAIVELEY TRANSPORT

HVAC Controller FPC08
Technical Data



POWER SUPPLY

- **Operating Nominal Voltage**

24V DC	(LV version)
36 to 48V DC	(MV version)
72 to 110V DC	(HV version)

- **Range**

Acc. to EN50155 : 0,7Un to 1,25Un.

- **Voltage Interruption**

Class S1.

- **Power**

Max 12 W.

CONTROLLER KERNEL

- **Architecture**

Biprocessor : 16 bits µP + DSP.

- **Memories**

Program :	Flash 1MBytes. Downloadable by RS232 link.
User :	4kBytes Eeprom.
Event Memory :	Dedicated Flash 512kBytes.

- **Real Time Clock**

On power supply loss, D/T kept 3 weeks (at 20°C).

INPUT / OUTPUT INTERFACES

- **Temperature Sensor Analog Inputs**

Number :	6
Type :	NTC 5kΩ at 25°C
Range :	-40°C to +125°C (-40/257°F)
Resolution :	0,2K
Precision :	1K on –10°C to 70°C
Diagnosis :	open / short circuit detection

- **Analog output**

Range :	0 to 10VDC
Output imp :	100Ω±10%
Resolution :	40mV
Precision :	0,1V

- **PWM output**

Range :	External Supply Voltage Max 24V.
Frequency :	5Hz to 20kHz
Duty cycle :	0 to 100%
Freq.Precision :	0,1Hz
Power (Max) :	1.5W

- **Digital Inputs**

Number :	8 (2 galv. insulated groups)
Input current :	5mA for HV version 10mA for LV & MV version

- **Digital Outputs**

Number :	8 (2 galv. insulated groups)
Type :	Relay (Normally Open)
Switching voltage :	Max 150VDC / 250VAC
Switching capacity :	Max 50W per output
Switching current :	Max 2A on resistive load

MAINTENANCE & DIAGNOSIS CAPABILITIES

- **Service Interface**

Type :	RS232 (Sub-D-9 poles)
Data rate :	4,8k to 115,2 kBit/s

- **Event Recording**

Memory type :	Non volatile (dedicated Flash 512kB)
Data saved :	Complete snapshot of the system + user configurable data.

- **HVAC Component Supervision**

Permanent supervision of main HVAC actuators (working hours and start count).

- **Maintenance & Diagnosis tool**

Through Faiveley's mon-e PC software :
- Graphic and realistic overview of the HVAC system
- Direct to Disk recording of all signals
- Test mode control

COMMUNICATION, NETWORK, TRAIN BUS INTERFACES

- **CAN bus interface**

Design compliant with Bosch® specifications.	
Data format :	2.0A - 2.0B (optional).
Data rate :	Max 1MBits/s
Medium type :	Twisted pair acc to ISO11898
Connections :	2xSub-D-9 poles Male & Female
Termination resistor :	Included. Active by bridge connector.

- **RS485 bus interface**

Design compliant with EIA485 standard.	
Type :	2 wire model.
Termination resistor :	Included. Active by bridge connector.
Bias resistors :	Pull up&down resistor included. Active by bridge connector.

- **Optional network interface (optional)**

- LON® 78,8k FTT-X1 PC104 with Lonmark® capabilities.
- MVB Siemens PC104. Class 1.3.
- MVB Duagon D114 PC104. Class 1.x.

ENVIRONMENTAL CONDITIONS

Temp° Range :	-25°C to 70°C (-13/158°F) Class T3
Relative humidity :	Max. 95%. 75% average.
Shock & vibration :	Acc to EN61373. Cat 1 - Class B. 7,9 / 3,5 / 5,5 m/s² between 5 & 150 Hz / 5h. Shocks : 30 m/s² during 30 ms

CE - ELECTROMAGNETIC COMPATIBILITY

All conducted / radiated emission and susceptibility compliant with EN50155 & EN50121-3-2.

MECHANICAL DATA

Housing :	Stainless steel
Dimensions :	370 x 135 x 45 mm
Weight :	1.7kg (all options mounted)
Connectors :	Wago 734 Serie.
Protection class :	IP20.
Fire & smoke class :	NFF-16-101, UL94 / CEI 60695-1.

9 Resistance value of the NTC temperature sensor

°C	0	1	2	3	4	5	6	7	8	9	10
-30	88 500	43 200	99 300	105 200	113 400	120 300	128 000	136 400	146 400	156 800	167 000
-20	48 535	51 450	54 550	57 850	61 400	65 200	69 520	73 600	78 200	83 150	88 500
-10	27 665	29 215	30 865	32 620	34 490	36 475	38 590	40 845	43 245	45 805	48 535
- 0	16 325	17 185	18 095	19 055	20 080	21 165	22 310	23 530	24 825	26 200	27 665
0	16 325	15 515	14 750	14 025	13 345	12 695	12 085	11 505	10 960	10 440	9 950
10	9 950	9 485	9 045	8 625	8 230	7 855	7 500	7 160	6 840	6 535	6 245
20	6 245	5 970	5 710	5 460	5 225	**5 000**	4 786,5	4 583,5	4 388,5	4 203,5	4 028,5
30	4 028,5	3 861,5	3 701,5	3 548,5	3 403,5	3 265,0	3 133,5	3 008,5	2 888,5	2 773,5	2 663,3
40	2 663,3	2 558,5	2 458,5	2 363,5	2 271,5	2 185,0	2 100,5	2 020,0	1 945,0	1 871,5	1 801,5
50	1 801,5	1 733,5	1 670,0	1 608,0	1 549,5	1 493,0	1 439,0	1 387,0	1 337,5	1 289,5	1 244,0
60	1 244,0	1 200,0	1 158,0	1 117,5	1 078,5	1 041,5	1 005,5	971,0	938,0	906,5	876,0
70	876,0	846,5	818,0	791,0	765,0	739,5	715,5	692,0	670,0	648,5	627,5
80	627,50	607,50	588,50	570,00	552,00	535,00	518,00	502,00	486,85	472,00	457,65
90	457,65	443,85	430,50	417,65	405,15	393,35	381,65	370,50	359,65	349,35	339,15
100	339,15	329,50	320,15	311,00	302,15	293,65	285,50	277,50	269,85	262,50	255,15
110	255,15	248,35	241,50	235,00	228,65	222,50	216,65	210,85	205,35	200,00	194,65
120	194,65	189,65	184,85	180,00	175,30	170,85	166,55	162,35	158,25	154,30	150,47

Between 0 and 70 °C, the accurate is less than 0,2°K