Protect^IT

Multifunction Protection and Switchbay Control Unit

REF542*plus*

Industrial^IT enabled

Level 0: Information

ABB

Table of Contents

1 General

The REF542*plus* Multifunction Protection and Switchbay Control Unit is the further development of the former REF542 unit. Like its predecessor, it features the following functions:

Protection

Measurement

Control

Monitoring

All functions mentioned above and power quality functions are integrated in a programmable environment. The exceptional flexibility and scalability of these new generation devices lead to a smart and clean solution where the traditional approach would be ineffective and expensive.

The following figures show examples of the REF542*plus* installation in several switchboards.

Figure 1: REF542*plus* installed in gas insulated switchboards (GIS)

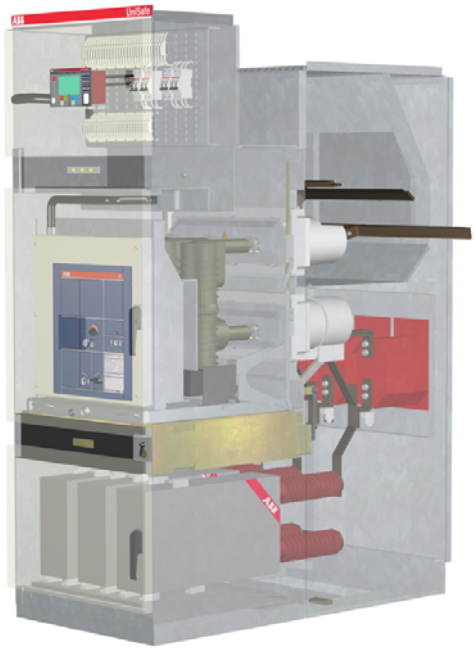


Figure 2: REF542plus installed in an air insulated switchboard (AIS)

The REF542*plus* is based on a real-time microprocessor system. The measurement and protection functions are executed by a **D**igital **S**ignal **P**rocessor (DSP), while a **M**icro **C**ontroller (MC) is executing the control functions. Due to this task separation there is no impact between the start and the trip behavior of the implemented protection scheme, should the control scheme be modified. The **C**ommunication **P**rocessor (CP) is needed for connection to a station automation system. A block diagram of the REF542*plus* is shown in figure 3.

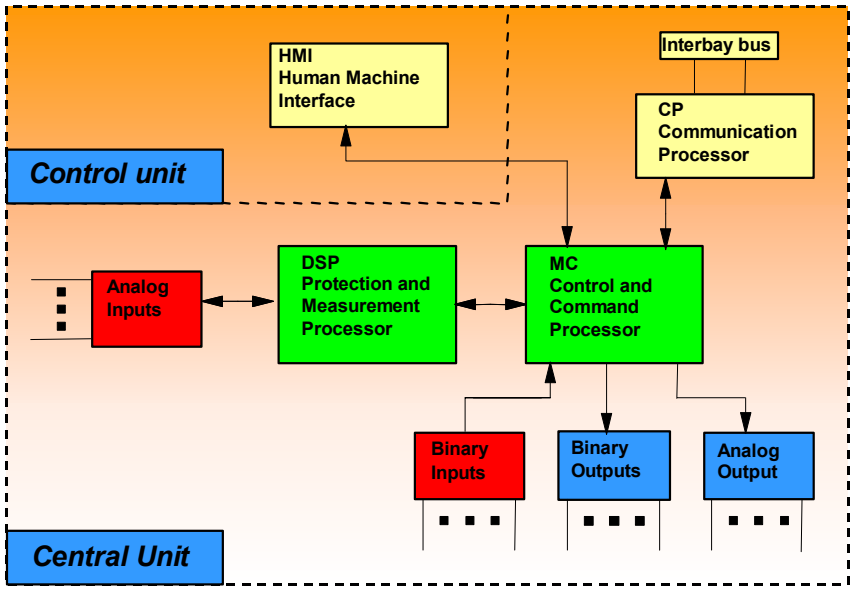


Figure 3: REF542*plus* Block diagram

REF542*plus*, as shown in figure 3, consists of two parts, a Central Unit and a separate **H**uman **M**achine **I**nterface (HMI). The Central Unit contains the power supply, processor and analog and binary **I**nput and **O**utput (I/O) modules, as well as optional modules for supplementary functions.

The HMI Control Unit is a stand-alone unit with its own power supply. It can be installed on the **L**ow **V**oltage (LV) compartment door or in a dedicated compartment close to the Central Unit. The HMI is normally used to set the protection parameters and to locally operate the switching devices in the switchbay. The HMI is connected to the Central Unit by a shielded, isolated twisted pair according to the RS485 interface. Figure 4 shows an installation of the Central Unit and the HMI Control Unit in the LV compartment of a switchboard for the switchbay.

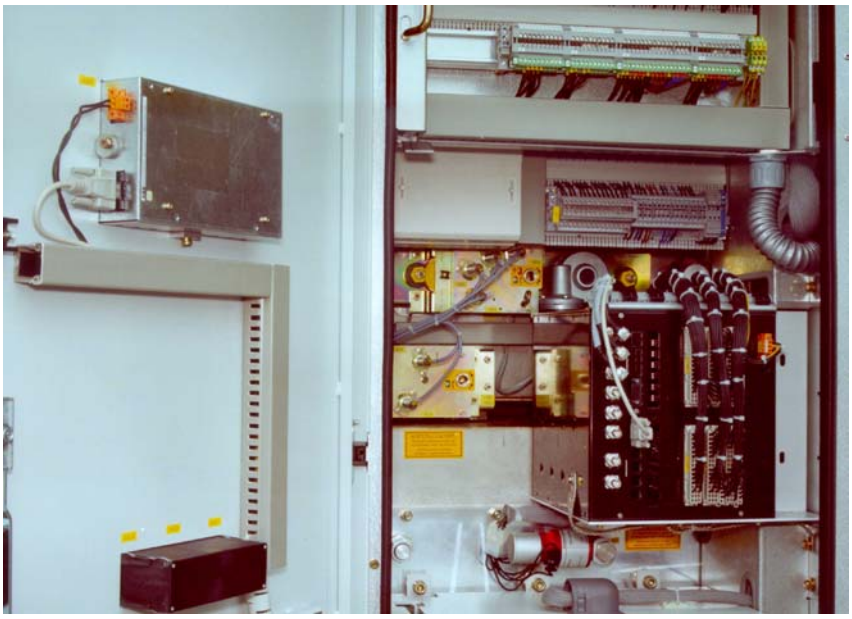


Figure 4: Mounting of the Central Unit in the LV compartment and the HMI on the door

The HMI Control Unit, as shown in figure 5, features a back-illuminated **L**iquid **C**rystal **D**isplay (LCD), eight push buttons, several LEDs and an electronic key interface. The language of the display can be selected via the related configuration software tool, which is also used to define the protection and the control scheme.

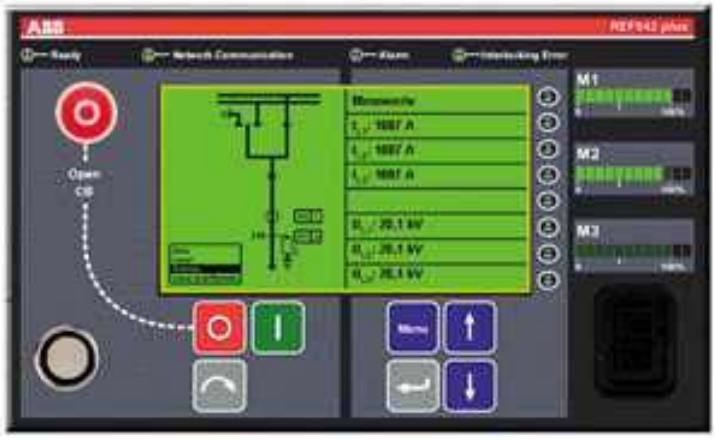


Figure 5: The HMI Control Unit

The left half of the LCD display is reserved for the Single Line diagram. The right half is used to display the appropriate menu or submenu as determined by the user. Two different electronic keys with different access rights are available. Each of the keys are programmed to permit either:

protection functions parameterization of the

mode selection of the control functions

Three freely programmable LED bars have been provided on the front of the HMI Control Unit. Each LED bar consists of ten green and two red LEDs and is user configurable to display any required measurement value. The red LEDs are used to indicate values above the rated value.

The functions of the *REF542plus* can be tailored to the system requirements via a user-specific configuration. The user-specific configuration is loaded during commissioning. For that purpose the configuration computer, normally a personal computer (notebook) running Windows NT, is connected to the optical interface on the front side of the HMI Control Unit.

The interface of the multifunctional unit *REF542plus* to the **M**edium **V**oltage (MV) primary process is as follows:

Analog inputs to measure current and voltage signals from instrument transformers or non conventional sensors

Binary inputs with optical couplers for the galvanic separation of the external signals to be processed;

Binary outputs with conventional mechanical relays or static outputs for the control of switching devices;

Optional four channel analog outputs 0 to 20mA or 4 to 20 mA

Optional connection to ABB or third party station automation system.

REF542plus is a certified product for compliance to the Industrial^{IT} architecture concept of ABB.

Industrial^{IT} products can be effectively combined together into value-added systems and solutions in a “Plug&Produce” manner.

Compliance according to “Level 0: Information” ensures that all relevant product documentation – including the operation manual, instructions for installation and maintenance, electrical and mechanical drawings, test reports and specific order information -is online available, in electronic format, for access via software products and systems based on the ABB Aspect Integrator Platform.

In this way, significant benefits are enabled to the final user for much easier and effective installation, configuration, operation and maintenance of the product in the plant.

Detailed information on Industrial IT is available at http://www.abb.com/industrial it

2 Functions

REF542*plus* Multifunction Protection and Switchbay Control Unit integrates all the secondary functions in a single unit. This multifunctional unit also features a self-monitoring function. All functions are designed as freely configurable software modules. Therefore, a wide range of operation requirements in MV stations can be met without any problems. The versatility of the software makes it possible to use the REF542*plus* on every switchboard independent on the specific application required.

2.1 Configuration

Each application for protection and control can easily be configured by software function modules, which make arbitrary definition of the following features as part of the secondary system possible:

LED's (meaning and colors) for local indication

Single Line diagram to show the status of switching devices

Protection schemes

Control schemes

Interlocking schemes

Automation sequences

All functions in the switchbay can be specified in collaboration with ABB. The result of the configuration is saved and delivered together with the switchboard to the users. By using the "**FU**nctional block" **P**rogramming **LA**nguage (FUPLA) the REF542*plus* Multifunction Protection and Switchbay Control Unit offers engineers, especially those who are not software experts, the opportunity of easily updating the operation and handling of the switchbay.

With REF*542plus* the user has the benefit of a secondary system that is fully integrated in a true programmable controller. This flexibility is very advantageous for defining control functions for automation sequences, which can, for example, include the interlocking of the switching devices, blocking the release of specific protection functions, as well as starting switching sequences.

REF542*plus* multifunctional unit provides a wide range of logical functions so that each required control schemes can be configured. The range of logical functions includes:

AND logic gate

NAND logic gate

OR logic gate

NOR logic gate

XOR logic gate

Bistable and monostable flip flop

Counters

Timers

Pulse generators

Memories

Similar to the free definition of the control scheme, each required protection scheme can be configured by the combination of the available protection function modules. For example, the following protection functions areavailable:

Definite time overcurrent protection

Inverse time overcurrent protection

Directional overcurrent protection

Under- or overvoltage protection

Distance protection

Differential protection for transformer and motor

Thermal protection for cable, transformer and motor

Reverse power protection

Synchronism check

Note The specific software configuration of the required protection scheme can only be carried out in-house at ABB.

The protection scheme parameters can be changed via the HMI Control Unit without using a personal computer. Additional functions can be excuted with a personal computer running the configuration software and connected to the optical interface on the front of the HMI unit.

These additional functions are:

Parameterization of the protection scheme,

Read-out of the current measurement values,

Read-out of the status of the binary inputs and outputs,

Read-out of the fault recorder and

Viewing of the FUPLA logic I/O states

2.2 Operation

A wide range of functions can be controlled and operated using the simple, user-friendly interface on the HMI Control Unit. This user-friendly interface is shown in the following figure.

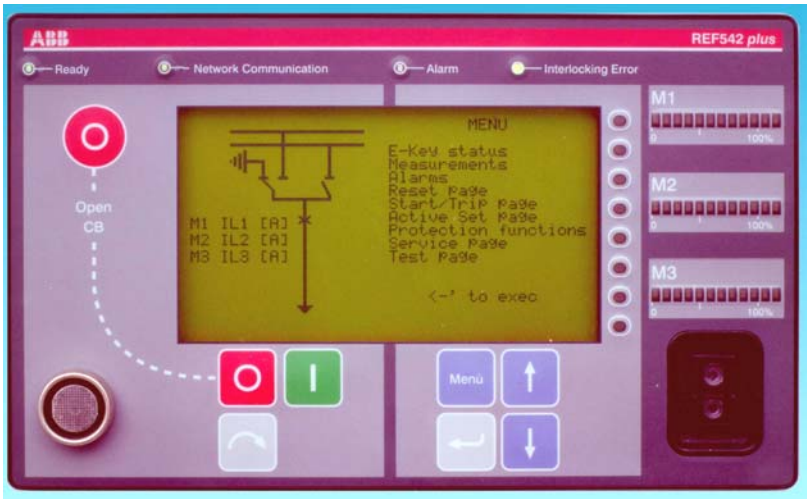


Figure 6: HMI as Control Unit

The HMI consists of the following features:

2.2.1 LCD display

The back-illuminated LCD display of the HMI provides a graphical display of the switching devices in the switchbay controlled by the REF542*plus*. The intensity and the duration of the illumination can be set as required. The Single Line diagram shows the current status of all the switching devices. The right half of the LCD display is for plain text, such as measurement values, main menu and submenus descriptions, protection signals and event recording.

On the LCD display, the following can be shown:

Up to eight switching device icons (when the binary I/O boards with mechanical relays are used, a maximum of seven switching devices can be controlled)

Various icons for motors, transformers, sensors, transducers

A maximum of 40 individual lines.

2.2.2 Status Indication

Four system LEDs, describe in the following chapters, indicate the status of the REF542*plus*.

2.2.2.1 Operational status

On the HMI front panel, the operational status is called 'Ready' and is displayed by a green LED. The unit is not operational when this LED is off, and this occurs for example during the downloading of the configuration for the operation of the switchbay or if a fault condition is detected in the Central Unit.

2.2.2.2 Communication status

On the HMI front panel, this communication status is called 'Network Communication'. If the REF542*plus* is to be connected to a station automation system, the appropriate communications board is required. In this case a green LED is used to indicate the correct operational status of this optional board. The LED color changes to red if a communication failure has occurred.

2.2.2.3 Alarm indication

Several arbitrary alarm conditions can be defined and configured by the user. If one of these conditions is fulfilled, the red LED will be on.

2.2.2.4 Interlocking status

The LED is green if no interlocking conditions have been violated. In case of a switching action, which violates the interlock conditions such as switching a disconnector in the closed condition of the **C**ircuit **B**reaker (CB), the color will change temporarily to red.

2.2.3 LED Indication

Eight freely programmable, three color LED's are provided for local indication. The number of LED display options can be quadrupled through the menu structure. As a result, a total of 32 indication options are available for status indication regarding protection, control, monitoring and supervision functions.

2.2.4 Bar displays

Three freely programmable LED bars are provided for showing the measurement values. The LED bars are used to display arbitrary measurement values as required. Each bar consists of ten green and two red LEDs. The nominal values of each LED bar, which corresponds to the ten green LEDs are defined by the configuration software. If the measurement values are higher than the rated values, the red LEDs will gets illuminated indicating an overload situation.

2.2.5 Control push buttons

The control push buttons are used for operation of the switching devices during local control. A total of eight push buttons are available, four for commanding the primary equipment and four for browsing the display. The emergency push button can be configured in the FUPLA to open the circuit breaker when pressed simultaneously with the normal open push button.

2.2.6 Electronic key

Two different electronic keys are provided. One key can only be used for the protection scheme parametrization. The other one is for control modes selection: local, remote or local/remote. By using these two keys a certain separation between protection and control operation can be achieved. If required a general key that permits access to both modes is provided. The sensor for recognizing which electronic key has been used is located on the front panel of the HMI Control Unit.

2.3 Measurement

REF542*plus* can have a maximum of 8 analogue input channels for measuring current and voltage signals. These channels are organized into three groups.

Group 1 and group 2 have to be homogeneous, that means they can measure 3 currents or 3 voltages. For example, measurement of 1 current and 2 voltages is not allowed. Group 3 can get any type of signals: 2 currents, 2 voltages, 1 current and 1 voltage, etc. Channel 8 in the current REF542*plus* release can be used for measurement purposes only (no protection). REF542*plus* analogue inputs are very flexible, as this flexibility is needed to support all the protection functions of the unit itself.

Group1 and group 2 can be used for homogeneous current or voltage measurements both from instrument transformers and non conventional sensors. Group 3 can be used in a heterogeneous way, as well with instrument transformers as also with sensors. Channel 7 in group3 can be used for earth fault current with current transformer type input; or for the synchronism check function with voltage transformer type input.

The most common configuration uses three current and three voltage inputs and one earth fault current input. All values are shown on the display as primary values. The values registered over an extended time period, for example energy, number of CB operations, maximum and measurement values are permanently saved. Even after power interruptions this data is still available. Using this common configuration, the following measured values are displayed:

2.3.1 Values measured directly

Line currents, three phases

Phase voltages, three phases

Earth current or residual voltage

Frequency

From the above measured quantities the following values can be calculated:

2.3.2 Calculated values

Line voltages, three phases

Earth current or residual voltage

Average value/maximum value current, three-phase (determined over several minutes)

Apparent, active and reactive power

Power factor

Active and reactive energy

Moreover, the following quantities for monitoring purposes can be provided:

2.3.3 Other values

Operating hours

Switching cycles

Total switched currents

Metering pulses from an external metering device (up to 10)

2.4 Protection

The REF542*plus* offers a wide range of functions for protection. As mentioned before, a wide range of protection schemes for the protection of several system components can be configured. The available protection functions can be combined together to form the required protection scheme. Figure 7 shows an example of a configured protection scheme.

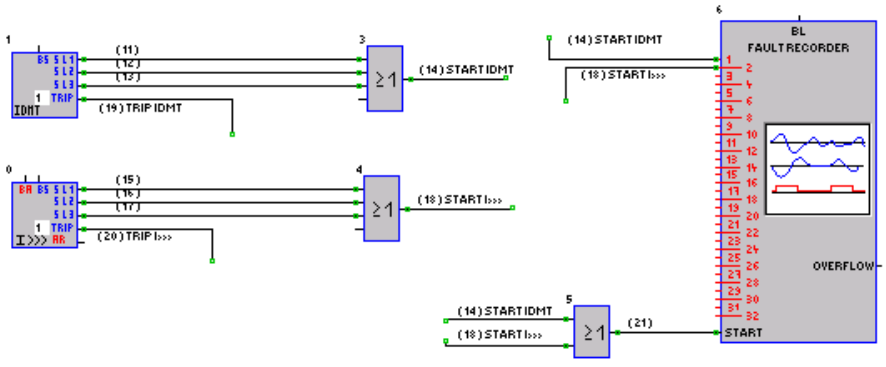


Figure 7: FUPLA protection scheme

2.5 Control

The REF542*plus* permits convenient local operation with full interlocking against switching errors. The switch position of the various switching devices in the switchbay can be shown on the LCD display of the HMI Control Unit. If local control mode is selected, switching actions can be input locally using the control push buttons on the HMI Control Unit. Switching to another control mode can only be achieved by using the correct electronic key.

In remote control mode, only switching actions from a remote control unit like a station automation system are feasible. A special control mode, Local and Remote, is provided for users who want to perform simultaneous Local and Remote switching.

Interlocking between the switchbays connected to the same bus bar system can also be taken into account. This requires the availability of status information of the switching devices to and from other switchbays. The status information must be provided either by a conventional, hard wired ring bus system or by the more sophisticated ABB station automation system. Figure 8 shows an example of a configured control scheme of the CB.

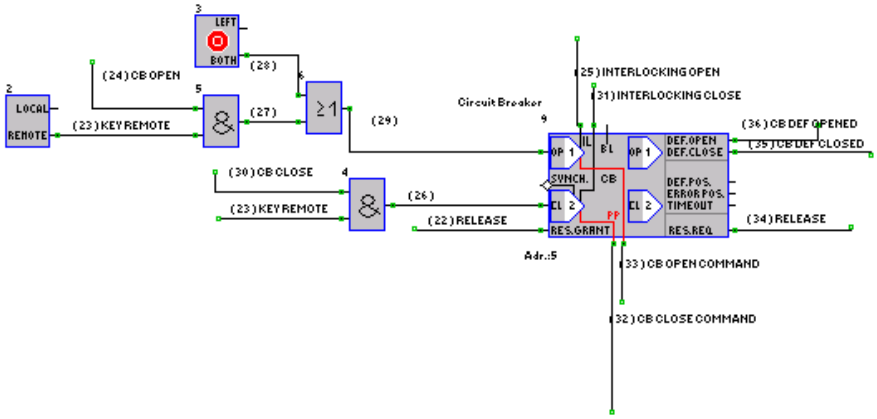


Figure 8: FUPLA control scheme

2.6 Event recording

The last 30 recorded events can be shown locally on the LCD display of the HMI unit. The events are mostly related to protection activities. As well as displaying the event name, additional information about the event, time, date and the RMS value of the short circuit current switched off by the CB are provided. Each event is stamped with the time and date. The time is taken from the internal clock on the REF542*plus*, which can be synchronized by the station automation system. In the next figure, a list of recorded events is shown.

Figure 9: Event list on the LCD of the HMI

2.7 Fault recording

The multifunctional unit REF542*plus* is equipped with a fault recorder module, which record and encode analog and binary data. The number of recorded data channels depends on the initial configuration. Up to seven signals of the analog channels and 32 binary signals can be recorded. The analog input signals are recorded with a sampling rate of 1.2 kHz for a period of at least 1-second and for a maximum of 5 seconds. The recording time is a combination of pre- and post fault time. The records are saved using a typical ring buffer process, i.e. the oldest fault record is always overwritten with a new one. The number of saved fault records depends on the record time. For example, a maximum of 5 fault records can be saved with a recording time of 1s.

Fault records can be exported and converted by the configuration software. The transfer of fault records can be done also via the interbay. Figure 10 shows a record of a cross country fault in an earth fault compensated MV system starting with the earth fault.

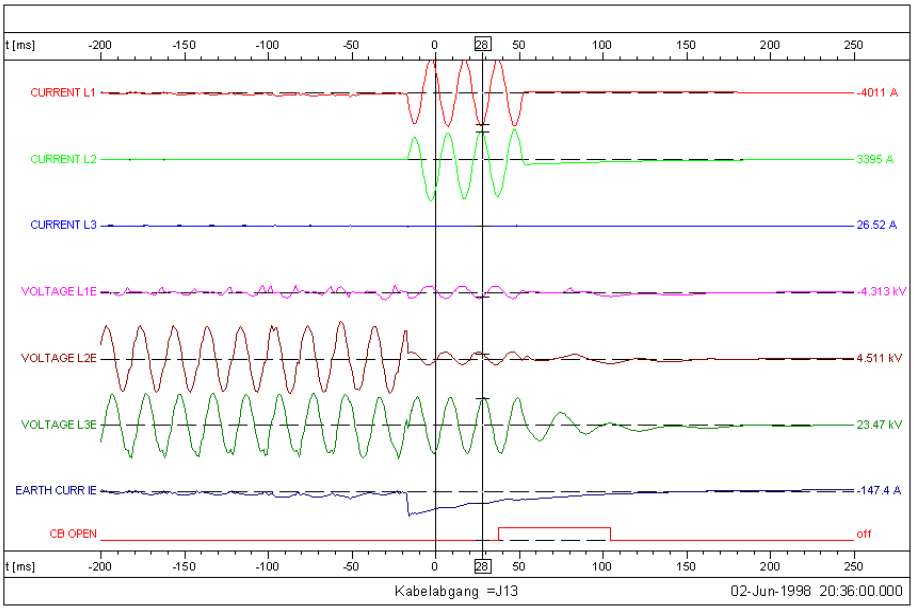


Figure 10: Record of a cross country fault in an MV system

2.8 Real time clock

REF542plus is equipped with an internal real time clock which is used to time stamp events. The internal clock is buffered by a special super capacitor. In case of DC power supply failure, the stored electrical energy in the capacitor ensures continued operation of the internal clock for at least another two hours. The date and time of the clock can be set via the HMI Control Unit.

REF542plus internal clock can be kept synchronized with an external clock in different ways.

When connected to a station automation system, REF542plus is synchronized via interbay bus using the facilities of the used protocol. If better accuracy is required, REF542 plus can be synchronized using the dedicated IRIG-B optical input port and a GPS master clock.

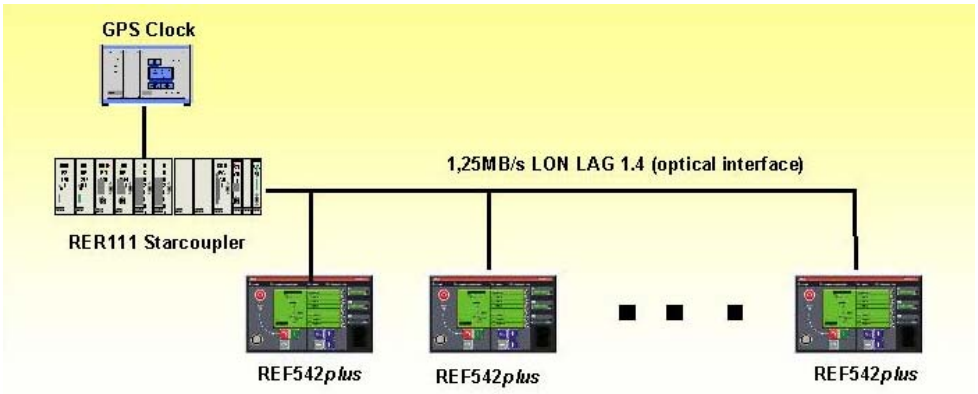


Figure 11: Synchronization of the internal clock by a GPS master clock

2.9 Process interface

An interface to the primary process is needed to carry out the protection, measurement and control schemes. The process interface will be described in the following paragraphs:

2.9.1 Analog inputs

The REF542*plus* Switchbay Protection and Control Unit is designed for connection to non conventional current and voltage sensors as well as to instruments transformers. Thanks to their linear characteristic, modern current and voltage sensors provide greater accuracy and reliability in signal measurement. Compared to instrument transformers, the new sensors have the following advantages:

High accuracy

Compact dimensions

Wide dynamic range

Easy integration in the switchboard

The current sensor is based on the principle of the Rogowski coil and consists of a single air-cored coil. Due to the lack of an iron core, the saturation effects of conventional current transformers do not exist anymore. Current sensors are thus well suited for the deployment of distance protection and differential protection functions.

The current sensor measures the current value using a voltage signal that is proportional to the derivative of the primary current being measured. The numerical integration of the signal is performed using the DSP in the REF542*plus* unit. The current sensors cover a range from 0.5 to 2.0 of the rated current. The 80 A current sensors are for example very suitable for applications between a current range of 40 A to 160 A.

The voltage sensor is based on the principle of the resistive divider from which the signal is obtained and is of a type that cannot be saturated. Therefore, the voltage sensor is linear throughout the measuring range. The output signal is a voltage that is directly proportional to the primary voltage. The next figures shows the combined sensors. The current and voltage sensors are encapsulated into a single resin unit, and that is the reason why they are referred as combined or combi sensors.

Figure 12: Combined sensor

A capacitive divider is incorporated in the combined sensor to provide the power supply for voltage presence indicator lamps.

The output signals of the current and voltage sensors are connected directly to the Central Unit of the REF542*plus*, they do not require adaptation transformers. By using either modern sensors or conventional measurement transformers, the accuracy class 1 can be fulfilled, on condition that the current and voltage measuring values are in the range of the corresponding rated values.

2.9.2 Binary inputs and outputs

The primary switching devices are monitored either through the auxiliary contacts or through the related sensors, which provide the status information of all the switching compartments in the switchbay. Besides that, signals coming from auxiliary components are also monitored. Consequently, at this interface the following actions are achieved:

Control and interlocking of the primary switching device in the switchbay

Control the CBs, disconnectors, earthing switches

Supervision of the spring status, of the continuity of CB open coil, the status of the switching device.

Providing output pulse signals for external energy counting systems .

Control of the disconnectors drive motors

Providing the information regarding internal failure (watchdog).

The inputs of the binary signals are isolated by an opto-coupler. In most applications, binary outputs are implemented with mechanical relays. However, in high level applications, like a switchboard in which motors are directly driven, static power outputs are required. A maximum of 3 binary I/O boards can be installed.

3 Diagnosis and monitoring

The REF542*plus* monitors continuosly the condition of the system, including the switching devices. Maintenance requirements can thus be adapted to the real system condition in order to reduce down times. The following table shows the parameters monitored by the REF542*plus*. All the parameters can also be transmitted to a central control system where they are analyzed and processed, so that the diagnostic systems can be provided with data for reliability calculation to predict the remaining service life and maintenance actions.

Type	Parameters monitored
Software	Diagnostic of REF 542 *plus* unit
Electrical	Auxiliary voltage circuits Power supply to motor operators of the switching device Continuity of windings of the CB opening coil
Mechanical components	State of CB operating mechanism springs Number of mechanical operations Gas pressure respectively density
Time	Count of hours the switching device board in operation. Contact switching time (from closed to open) using events

4 Analog output

An optional analog output module with four configurable outputs can be inserted in the Central Unit. The output signal of this module can be set in the range from 0 to 20 mA or 4 to 20 mA. Each of the four channels can be independently activated and parameterized by the configuration software. The following analog output quantities are selectable:

All voltage quantities directly from the analog inputs

All current quantities directly from the analog inputs

Calculated residual currents

Calculated residual voltages

Calculated apparent, active and reactive power

Calculated power factor

5 Communication

An optional communications board is provided for communication with a station automation system. This can be an ABB station automation system or a third party system. When using the ABB station automation system, all of the information provided by the REF542*plus* can be completely accessed so that the following centralized remote functions can be implemented:

Remote monitoring

Remote control

Remote setting of protection parameters

Remote measurement

Events recording

Monitoring of all switching device

Analyze of fault recorder data

The following protocols for connection to ABB station automation system are available:

SPA-bus

LON-bus according to ABB **L**on **A**pplication **G**uide (LAG) 1.4 definitions

The software library LIB542 is available to interface the REF542*plus* unit in the ABB MicroScada® station automation.

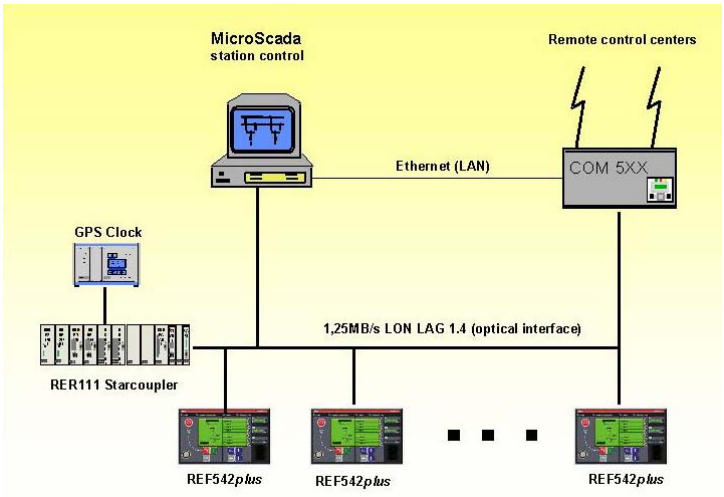


Figure 13: Connection of the RE542*plus* in an ABB station automation system

The following protocols allow REF542 plus to be connected to any third party automation system:

IEC 60870-5-103 standard including the extension for control functions according to VDEW (Vereinigung Deutscher Elektrizitätswerke = association of German utilities)

Dual MODBUS RTU

6 Housing

The REF542*plus* housing for the Central Unit is made from sheet aluminium. Its exterior is chromatized both to protect the housing against corrosion and to gain the shielding against EMC disturbances. The Central Unit allows a safe integration into a switchboard. A standard and a wide case version, as shown in the following figures are available. In the standard case version, two binary I/O boards and an optional communications board can be used. The wide case version contains an additional binary I/O board and the analog output board.

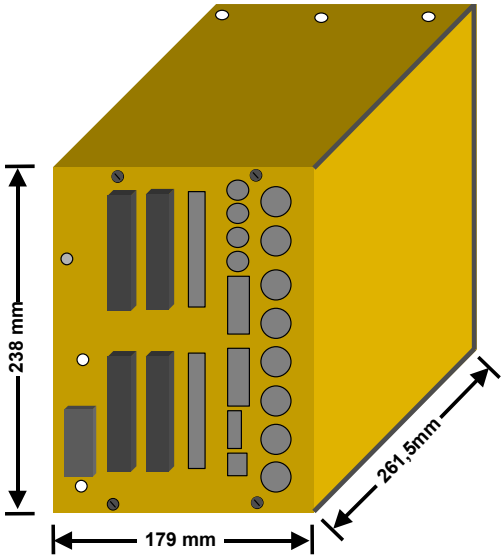


Figure 14: Dimension of the standard case version

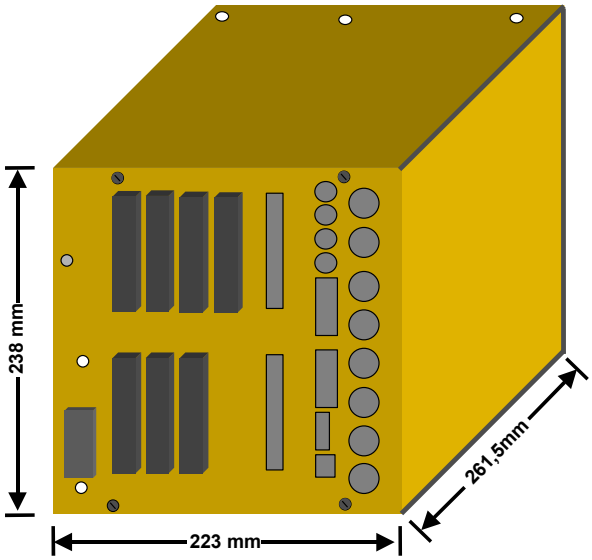


Figure 15: Dimension of the wide case version

The dimension of the HMI Control Unit is shown in the next figure.

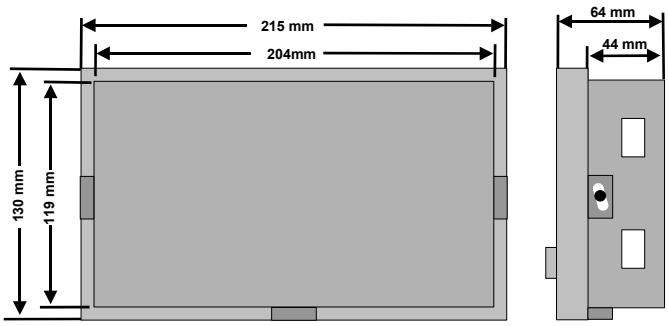


Figure 16: Dimension of the HMI Control Unit

7 Mechanical design

7.1 REF542*plus* standard case version:

2 I/O plug-in boards for control of up to 5 switching devices.

1 optional plug-in communication board

7.2 REF542*plus* wide case version:

3 I/O plug-in boards for control up to 8 switching devices (with static I/O board, only 7 switching devices with mechanical I/O board).

1 optional plug-in board for output of 4 configurable analog signals 0 to 20 mA or 4 to 20 mA.

1 optional communication board.

7.3 Analog inputs

REF542*plus* analog input board is available in different version and can be equipped with the following combination of input current and/or voltage transformer:

3 or 6 current transformers for phase currents

3 or 6 voltage transformers for phase voltages

1 current or voltage transformer for the residual current or voltage

1 current or voltage transformer for measurement purposes

When combined sensors are used the signals are connected byTWINCAM ST plugs.

8 List of the protection functions

The table below illustrates the protection functions in the current REF542plus Release 1.1. Every selected protection function increases the load on the DSP. The configuration software takes care that 100% of DSP processing power is not exceeded.

ANSI Code	Protection Function and the Setting Parameter	DSP Load in %
	Digital Filtering as basic load	16
68	Inrush stabilization (Only in connection with I>> and I>) N = 2.0 … 8.0 M = 3.0 … 4.0 Time = 220 … 100.000 ms	3
67	Overcurrent directional high I>> = 0.05 ... 40.00 In t = 70 ... 300 000 ms	7
67	Overcurrent directional low I > = 0.05 ... 40.00 In t = 220 ... 300 000 ms	7
50	Overcurrent instantaneous I>>> = 0.10 ... 40.00 In t = 20 ... 300 000 ms	3
51	Overcurrent high I>> = 0.05 ... 40.00 In t = 40 ... 300 000 ms	2
51	Overcurrent low I > = 0.05 ... 40.00 In t = 40 ... 300 000 ms	2
51	IDMT Normal-, Very-, Extremely- or Longtime- inverse time characteristic Ie = 0.05 ... 40.00 In K = 0.05 ... 1.5	3
51N	Earth fault high IE>> = 0.05 ... 40.00 In t = 70 ... 100 000 ms	3
51N	Earth fault low IE> = 0.05 ... 40.00 In t = 70 ... 100 000 ms	3
67N	Earth fault directional high IE>> = 0.05 ... 40.00 In t = 40 ... 100 000 ms forward- / backward direction isolated (sin φ) and earthed (cos φ)	3
67N	Earth fault directional low IE> = 0.05 ... 40.00 In t = 40 ... 300 000 ms forward- / backward direction isolated (sin φ) and earthed (cos φ)	3

ANSI Code	Protection Function and the Setting Parameter	DSP Load in %
67N	Earth fault directional sensitive IE> = 0.05 ... 2.00 In t = 120 ... 100.000 ms, for- / backward Angle α = 0 ... 20°, Angle δ = - 180 ... 180° UNE> = 0.05 ...0.70 Un	12
51N	Earth fault IDMT Standard, very, extremely or long time inverse time characteristic, Ie = 0.05 ... 40 In K = 0.05 ... 1,5	3
59	Overvoltage instantaneous U>>> = 0.10 ... 3.00 Un t = 20 ... 300.000 ms	2
59	Overvoltage high U>> = 0,10 ... 3.00 Un t = 70 ... 300 000 ms	2
59	Overvoltage low U> = 0.10 ... 3.00 Un t = 70 ... 300 000 ms	2
27	Undervoltage instantaneous U<<< = 0.10 ... 1.2 Un t = 50 ... 300 000 ms	2
27	Undervoltage high U<< = 0.1 ... 1.2 Un t = 70 ... 300 000 ms	2
27	Undervoltage low U< = 0.1 ... 1.2 Un t = 70 ... 300 000 ms	2
59N	Residual overvoltage high UNE>> = 0.05 ... 3.00 Un t = 40 ... 300 000 ms	2
59N	Residual overvoltage low UNE> = 0.05 ... 3.00 Un t = 40 ... 300 000 ms	2
49	Thermal overload protection (thermal equation 1st order with complete memory function) Tn = 50 ... 400 °C (nominal temperature at In) In (Mot) = 1 ... 10000 A (primary value of the nominal motorcurrent) Tini = 50 ... 120 % Tn (initial temperature at power on) τcool = 10 ... 20.000 s (time constant at I< 0.1 In and n = 0) τwarm = 10 ... 20.000 s (time constant normal) τwarm = 10 ... 20.000 s (time constant at I > 2 In) Tmax = 20 ... 400 °C (maximal temperature) Twarn = 20 ... 400 °C (warn temperature) Tenvi = 50 ... Tnom * Tini (environment temperature) Op. Time = 1.02 … 1000s (additional delay time)	3

ANSI Code	Protection Function and the Setting Parameter	DSP Load in %
51	Motor start protection (adiabatic characteristic) Ie = 0.3 ... 1.2 In (motor current) Is = 1.00 ... 20.00 Ie (start value) t = 70 ... 300 000 ms I> = 0.6 ... 0.8 Is (motor start)	2
51LR	Blocking rotor (definite time characteristic) Ie = 0.3 ... 1.20 In (motor current) Is = 1.00 ... 20.00 Ie (start value) t = 70 ... 300 000 ms	3
66	Number of starts n(warm) = 1 ...10 (number of warm starts) n(cold) = 1 ...10 (number of cold starts) t = 1.02 .. 7200.00 s T (warm) = 20 ... 200 °C (temperature limit warm start)	0
21+79	Distance protection with autoreclosing Net type = high/low ohmic ct – grounding = line side, bus bar side earth start IE> used or unused switching onto faults = normal, overreach zone, trip after start Signal comparison overreach scheme time set = 30 …. 300.000 ms U / I- Start characteristic: I>, IE> and IF> = 0.05 ... 4.00 In UF< = 0.05 ... 0.9 Un Phase selection = cyclic/acyclic Earth factor: k = 0.00 ... 10.00 φ (k) = -60 ... 60° 3 Impedance- and 1 overreachstage: R = 0.05 ... 120 Ω (secondary values) X = 0.05 ... 120 Ω (secondary values) t = 20 ... 10.000 ms 1 directional stage Direction 0 ... 90 bzw.-45 ... 135° t = 25 ... 10 000 ms 1 non directional stage t = 25 ... 10 000 ms 2 shots AR with short/long time reclosing	18
87	Differential protection Transformer group = 0 ... 11 Transformer earthing = primary and or secondary side Nom. current In on the primary/secondary side of the transformer = 0.00 ... 100.000A (prim value) Threshold current = 0.10 ... 0.50 In Unbiased region limit = 0.50 … 5.00 In Slightly biased region threshold = 0.20 ... 2.00 In Slightly biased region limit = 1.00 ... 10.0 In Slope = 0.40 ... 1.00 Trip with Id> = 5.00 ... 40.00 In Blocking by 2^{nd} harmonic = 0.10 … 0.30 In Blocking by 5^{th} harmonic = 0.10 … 0.30 In	22
46	Unbalance load Is = 0.05 ... 0.3 In (start value of the negative phase sequence) K = 2.0 ... 30.0 tReset = 0 ... 200 s Timer decreasing rate = 0 … 100%	9

ANSI Code	Protection Function and the Setting Parameter	DSP Load in %
32	Directional power Nominal real power Pn = 1 ... 1000 000 kW (primary values) Max.reverse load P> = 1 ... 50 % Pn Op. time = 1.02 ... 1000 s forward / backward	2
37	Low load Nominal real power Pn = 50 ... 1000 000 kW (primary values) Minimal load P = 5 ... 100% Pn Minimal current I = 2 ... 20 % In Op. time = 1 ... 1000 s	2
81	Frequency supervision Start value = 0,04 ... 5 Hz time = 1.02 ... 300.00 s	2
25	Synchronism check Start value (Δ U) = 0.02 ... 0.40 Un Time = 0.52 ... 1000.00 s Phasediff (Δ φ) = 5 ... 50°	4
	Fault recorder Recording time = 1000 ... 5000 ms Pre fault time: = 100 ... 2000 ms Post fault setting = 100 ... 4900 ms Max. 5 records	2
55	Power factor controller Power factor = 0,70 ... 1,00 QC0 = 1,000 ... 20000,000 kVAr Series of banks = 1:1:1:1 ... 1:2:4:8 Number of banks : 1 ... 4 Insensitivity = 105 ... 200 % QC0 Threshold = 0 ... 100 % QC0 Switching program = sequential/circuit switching	0

Note

Due to the limitation of the DSP calculation power related to the micro controller not all function blocks can be combined without restrictions. Please refer to the following table for applicable restrictions.

Function block	**Restrictions**
Protection functions	Max. 12 protection functions Max. 120 protection parameters 100% DSP load
Fault recorder	Max. 1 fault recorder and Min. 1 configured protection function
Cycle time of application	Max. 30 ms
Memory object	Max. 1
Power counter	Max. 15
Switching object	Max. 62
Threshold object	Max. 10 per analog input
Direct write-read command	Max. 100
Connections	Max. 700, number of connections 512
Signaling LED's	Max. 32 on 4 sides of 8 LED's each

9 Technical data

9.1 Analog input channels

Accuracy for measurement including the measurement sensors:		Class 1
Accuracy for protection applications:		Class 3
Accuracy of the operation time characteristic	min. ± 20ms or	Class 3

9.1.1 Current and voltage transformer input values

Rated current In	1A or 5A
Rated voltage Un	100V (also suitable for 110V)
Rated frequency fn	50 Hz / 60 Hz

Thermal load capacity

Current path	250 I_n (peak value) dynamic, 100 I_n for 1s, 4 I_n continuous,
Voltage path	2 U_n /√3 continuous.

Consumption

Current path	≤ 0.1 VA with I_n
Voltage path	≤ 0.25 VA with U_n

9.1.2 Current and voltage sensor input values

Voltage at rated current In	150 mV (rms)
Voltage at rated voltage Un	2V (rms)
Rated frequency fn	50 Hz / 60 Hz

9.2 Binary inputs and outputs

Each Binary I/O module has the following number of inputs and outputs:

9.2.1 BIO module with mechanical output relays (version 3)

14 input channels	Possible auxiliary voltage ranges: • 20 to 90 V DC (threshold 14 V DC) • 80 to 250 V DC (threshold 50 V DC) Each input has a minimum fixed filter time of 1 ms. Additional filter time can be configured.	
6 power outputs (channels BO 1 to 6).	Maximum operating voltage Make current Load current Breaking capacity Operating time	250V AC/DC 20 A 12 A 300 W at L/R <15 ms 6 ms
2 signal outputs (BO7 and 8) and 1 Watchdog output (WD)	Maximum operating voltage Make current Load current Breaking capacity Operating time	250 V AC/DC 8 2 A 90W at L/R <10ms 5 ms
Optional: 1 Static signal output on BO7	Maximum operating voltage Make current Load current Breaking capacity Operating time	250 VDC 1.5 A peak 0.7 A continuous 62W at L/R <3 ms 1 ms
1 coil supervision circuit for channel BO2		

9.2.2 BIO module with static outputs

14 inputs (BI 1-14)	Auxiliary voltage range • 48 to 265 VDC (Threshold 35 VDC) Each input has a minimum fixed filter time of 5 ms. Additional filter time can be configured.	
3 power outputs (BO1,2 and 7)	Operating voltage	48 to 265 VDC
	Make current	70 A for t ≤ 10 ms
	Load current	12 A for t ≤ 30 s
	Operating time	1 ms
4 power outputs (BO3 to 6)	Operating voltage	48 to 265 V DC
	Make current	16 A for t ≤ 10 ms
	Load current	10 A for t ≤ 30 s
	Operating time	1 ms
2 Signal outputs and 1 Watchdog output	Operating voltage	48 to 265 V DC
	Make current	0.3 A
	Operating time	1 ms
2 coil supervision circuits for channel BO1 and 2 Power Transistor feedback on 8 Transistor		

9.3 Interfaces

9.3.1 HMI Control Unit:

Optical/electrical standard interface RS 232 to the Notebook PC (at the front)

Electrical isolated standard interface RS 485 to the Central Unit (at the rear)

9.3.2 Central Unit:

Electrical isolated standard interface RS 485 to the HMI

Electrical standard service interface RS 232 for updating the firmware

9.4 Analog output board (optional)

Four channel 0 to 20 mA or 4 to 20 mA

9.5 Communication (optional)

SPABUS, optical interface with snap-in type connector for plastic fiber or standard F-SMA connector for glass fiber (multi mode)

LON (according to ABB LAG1.4), optical interface with ST connector for glass fiber (multi mode)

IEC 60870-5-103 with extension according to VDEW guidelines for controlling, optical interface with ST connector for glass fiber (multi mode)

Dual MODBUS RTU, electrical interface with two RS485 ports or optical interface with two standard ST connector for glass fiber (multi mode)

9.6 Power supply

9.6.1 Central Unit

Rated voltage	110 VDC (-15%, +10%), 220 VDC (-15%, +10%) or 48 to 220 VDC (-15%, +10%)
Power consumption	≤ 18 W (base version with 1 BIO)
Inrush current	≤ 10 A peak value

9.6.2 HMI Control Unit

Rated voltage:	For auxiliary voltage in the range of: • 48 … 110 VDC (-15%, +10%) • 110 … 220 VDC (-15%, +10%)
Power consumption	≤ 6 W

9.7 Environmental conditions

Ambient operation temperature	-5 ..+ 55°C
Ambient transport and storage temperature	-20..+70°C
Ambient humidity	Up to 95% without condensation

9.8 Degree of protection by enclosure

9.8.1 Central Unit

Housing	IP20

9.8.2 RHMI Control Unit

Front	IP 54
Rear	IP 22

10 Type test

10.1 Protection function

All relevant tests are performed according to IEC 60255 standard series.

ANSI Code	Protection Function and the Setting Parameters	Test Procedure
68	Inrush stabilization	IEC 60255-3
67	Overcurrent directional high	IEC 60255-12
67	Overcurrent directional low	IEC 60255-12
50	Overcurrent instantaneous	IEC 60255-3
51	Overcurrent high	IEC 60255-3
51	Overcurrent low	IEC 60255-3
51	IDMT, Normal-, Very-, Extremely- or Longtime-inverse time characteristic	IEC 60255-3
51N	Earth fault high	IEC 60255-3
51N	Earth fault low	IEC 60255-3
67N	Earth fault directional high	IEC 60255-12
67N	Earth fault directional low	IEC 60255-12
67N	Earth fault directional sensitive	IEC 60255-12
51N	Earth fault IDMT, Normal, very, extremely or long time inverse time characteristic,	IEC 60255-3
59	Overvoltage instantaneous	IEC 60255-3
59	Overvoltage high	IEC 60255-3
59	Overvoltage low	IEC 60255-3
27	Undervoltage instantaneous	IEC 60255-3
27	Undervoltage high	IEC 60255-3
27	Undervoltage low	IEC 60255-3
59N	Residual overvoltage high	IEC 60255-3
59N	Residual overvoltage low	IEC 60255-3
49	Thermal overload protection (thermal equation 1st order with complete memory function)	IEC 60255-8
51	Motor start protection (adiabatic characteristic)	IEC 60255-3
51LR	Blocking rotor (definite time characteristic)	IEC 60255-3
66	Number of starts	
21+79	Distance protection with autoreclosing	IEC 60255-16
87	Differential protection	IEC 60255-13
46	Unbalance load	IEC 60255-3
32	Directional power	IEC 60255-12
37	Low load	IEC 60255-12

ANSI Code	Protection Function and the Setting Parameters	Test Procedure
81	Frequency monitoring	IEC 60255-3
25	Synchronism check	IEC 60255-12
	Fault recorder	IEC 60255-24
55	Power factor controller	IEC 60255-12

10.2 Electro magnetic compatibility

All relevant tests are according to the following standard series:

- IEC 60255 for electromagnetic compatibility and product standard
- EN 610000 for electromagnetic compatibility.
- EN 50263 for measuring relays and protection equipment
- EN 60694 + IEC 60694 Amd.1:2000 for common specifications for high-voltage switchgear and control gear standards.

10.2.1 Emission test

These tests are valid for both, the Central Unit and the HMI Control Unit.

Port	Frequency range	Limits	Basic standard	Test procedure	Class/ level
Enclosure	30 - 230 MHz	50 dB(µV/m) quasi peak, measured at 3 m distance	EN 55022	EN 55022	Group 1 Class A
	230 - 1000 MHz	57 dB(µV/m) quasi peak, measured at 3m distance			
Power Supply	0.15 - 0,50 MHz	79 dB(µV) quasi peak, 66 dB(µV) average	EN 55022	EN 55022	Group 1 Class A
	0.5 - 5 MHz	73 dB(µV) quasi peak, 60 dB(µV) average			
	5 MHz - 30 MHz	73 dB(µV) quasi peak, 60 dB(µV) average			

10.2.2 Immunity tests - enclosure port

These test are valid for both, the Central Unit and the HMI Control Unit.

Environmental phenomena	Test specification	Units	Basic standard	Test procedure	Class/ level
Radiated radio frequency electromagnetic field, Amplitude modulated	80 – 1000 10 80	MHz V/m (unmod, rms) % AM (1 kHz)	EN 61000-4-3	IEC 61000-22-3	3
Radiated electromagnetic field from digital radio telephones, Pulse modulated	900 ± 5, 10 50 200	MHz V/m (unmod., rms) Duty cycle % Rep. Frequency Hz	EN 61000-4-3	IEC 61000-22-3	3
Electrostatic discharge	6 (Contact discharge) 8 (Air discharge)	KV (charge voltage) KV (charge voltage)	EN 61000-4-2	EN 60255-22-2	3
Power frequency magnetic field	50 30 300	Hz A(rms)/m (continuous) A(rms)/m (3 sec)	EN 61000-4-8	EN 61000-4-8	4

10.2.3 Immunity tests - power supply port

These test are valid for both, the Central Unit and the HMI Control Unit.

Environmental phenomena	Test specification	Units	Basic standard	Test procedure	Class/ Level
Conducted disturbance induced by radio-frequency fields, amplitude modulated	0,15 – 80 10 80 150	MHz V (unmod., rms) % AM (1 kHz) ohms Source impedance	EN 61000-4-6	IEC 60255-22-6 and IEC 60694	3
Fast transients	5/50 4 4	Tr/Th ns kHz repetition frequency kV (peak)	EN 61000-4-4	IEC 60255-22-4 and IEC 60694	4
1 MHz burst Differential mode Common mode	1 75 400 200 1 2,5	MHz frequency Tr ns Hz repetition frequency ohms Source impedance kV (peak) kV (peak)	EN 61000-4-12	IEC 60255-22-1 and IEC 60694	3
Surge Differential mode Common mode source	1,2/50 (8/20) 1 2 12	Tr/Th us kV charge voltage kV charge voltage ohms Source impedance	EN 61000-4-5	EN 61000-4-5	3
Voltage Interruption	100 50	% reduction ms interruption time	EN 61000-4-29	IEC 60255-11	3
Voltage Ripple	10	% of d.c. component	EN 61000-4-17	IEC 60694	2
Insulation Central unit	2 or 3 5	kV/AC 1 Minute kV/DC 1 Minute kV impulse 1,2/50us; 0.5J	IEC60255-5	IEC60255-5	
Insulation HMI control unit	2 or 3 4	kV/AC 1 Minute kV/DC 1 Minute kV impulse 1,2/50us;0.5J	IEC60255-5	IEC60255-5	

10.2.4 Immunity tests - communication ports

These test are valid for both, the Central Unit and the HMI Control Unit.

Environmental phenomena	Test specification	Units	Basic standard	Test procedure	Class/ level
Conducted disturbance induced by radio-frequency fields, amplitude modulated	0,15 – 80 10 80 150	MHz V (unmod., rms) % AM (1 kHz) ohms Source impedance	EN 61000-4-6	IEC 60255-22-6	3
Fast transients	5/50 5 2	Tr/Th ns kHz repetition frequency kV (peak)	EN 61000-4-4	IEC 60694 and IEC 60255-22-4	4
1 MHz burst Differential mode Common mode	1 75 400 200 1 2.5	MHz frequency Tr ns Hz repetition frequency ohms Source impedance kV (peak) kV (peak)	EN 61000-4-12	IEC 60694 and IEC 60255-22-1	3
Insulation	2	kV/AC 1 Minute	IEC60255-5	IEC60255-5	

10.2.5 Immunity tests – binary input and output ports

These test are valid for Binary IO version 3

Environmental phenomena	Test specification	Units	Basic standard	Test procedure	Class/ level
Conducted disturbance induced by radio-frequency fields Amplitude modulated	0.15 – 80 10 80 50	MHz V (unmod, rms) % AM (1 kHz) ohms Source impedance	EN 61000-4-6	EN 61000-4-6	3
Fast transients	5/50 4 4	Tr/Th ns kV (peak) kHz repetition frequency	EN 61000-4-4	IEC 60694 and IEC 60255-22-4	4
1 MHz burst	1 75 400 200 1 2,5	MHz frequency Tr ns Hz repetition frequency ohms Source impedance kV (peak) kV (peak)	EN 61000-4-12	IEC 60694 and IEC 60255-22-1	3
Surge Differential mode Common mode	1,2/50 (8/20) 1 2 42	Tr/Th µs kV charge voltage kV charge voltage ohms Source impedance	EN 61000-4-5	EN 61000-4-5	3
Insulation	2 5	kV/DC 1 Minute kV impulse 1,2/50 µs; 0.5J	IEC60255 -5	IEC60255-5	N.A.

10.3 Insulation resistance

Greater than >100MOhm 500V DC

10.4 Mechanical robustness

According to IEC 60255-21-1

10.5 Climatic conditions

Cold test according to IEC 60068-2-1

Dry heat test according to IEC 60068-2-2

11 Connection Diagram

11.1 Connector Plate

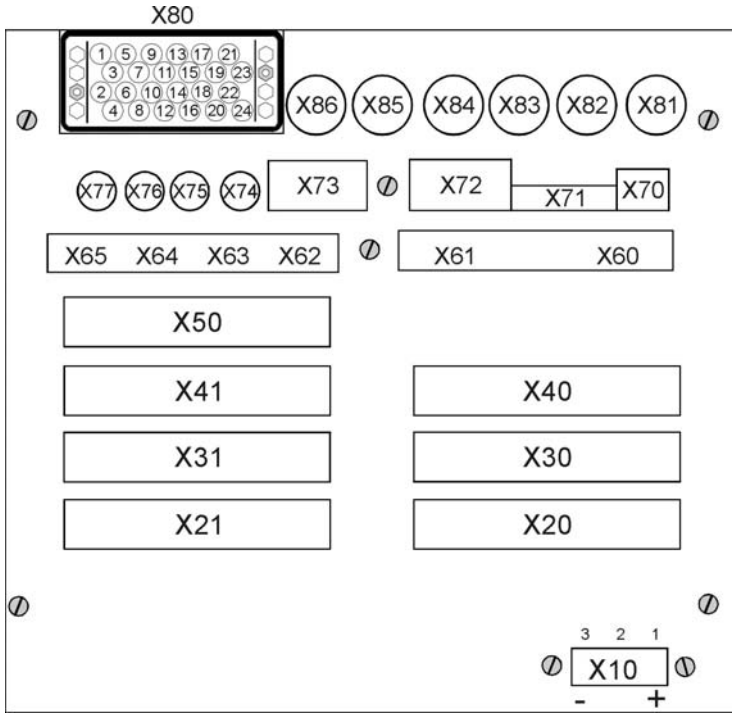


Figure 17: REF542*plus* connector plate for the wide case mixed analog input version

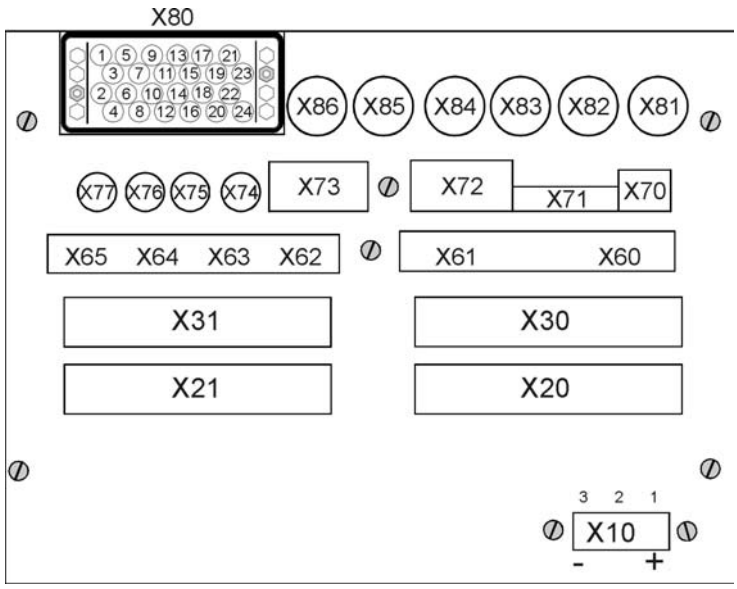


Figure 18: REF542*plus* connector plate for the short case mixed analog input version

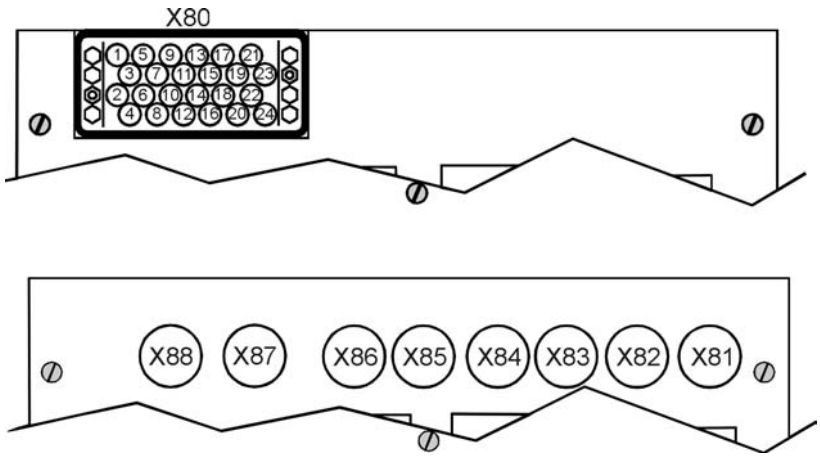


Figure 19: REF542*plus* connector plate for analog input with transformers or with sensors

11.2 HMI Control Unit

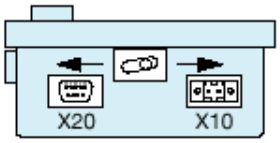


Figure 20: Power Supply and communication connection for HMI Control Unit

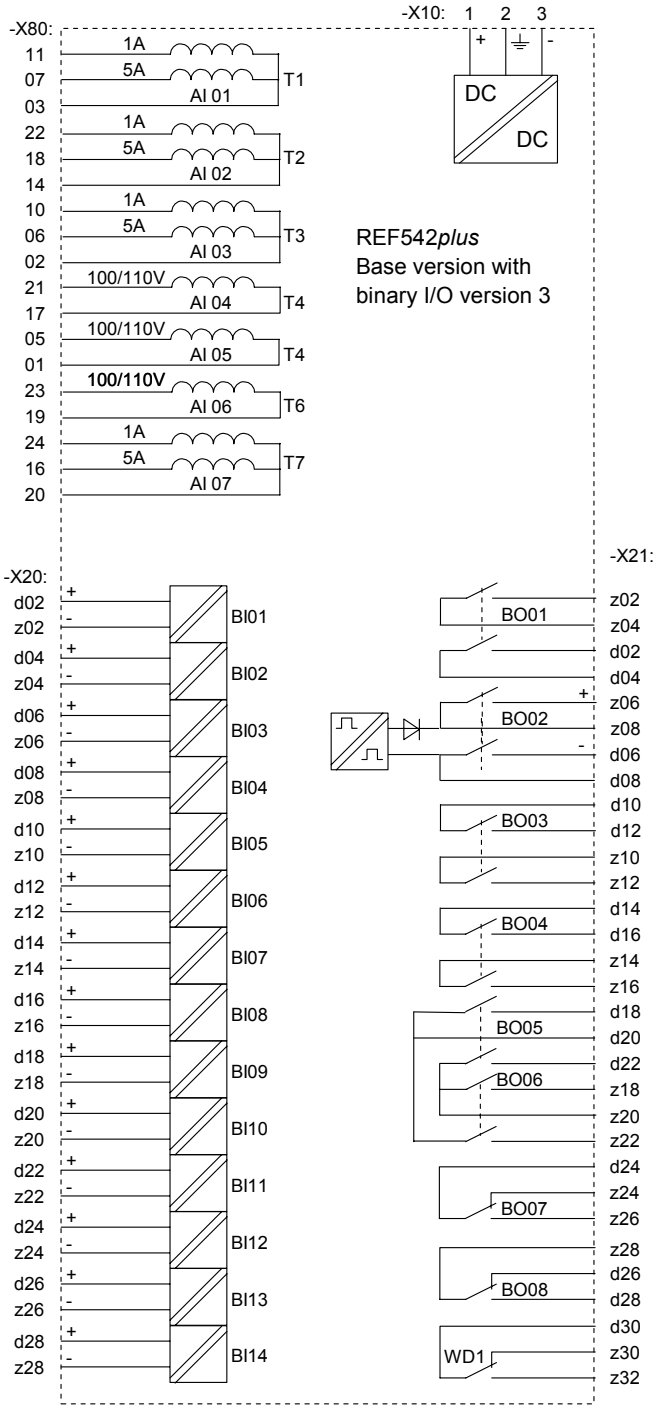
- X10: Power Supply
  - 1: L+
  - 2: L-

- X20: RS 485 to Central Unit

11.3 REF542*plus* with mechanical binary I/O

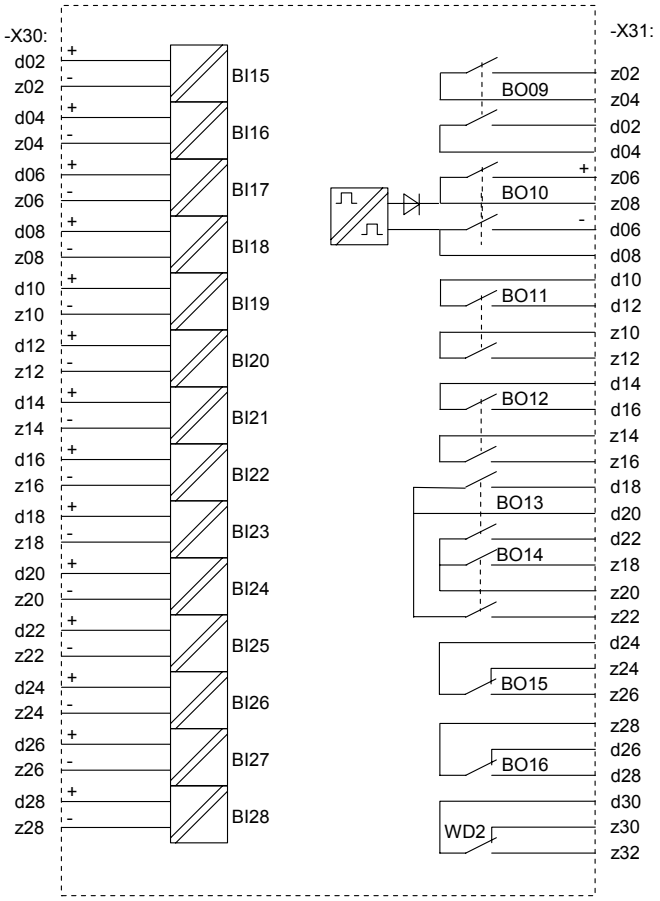
Example of REF542*plus* base version with one mechanical binary I/O version 3 (BIO3). Extension up to two additional mechanical binary I/O version 3 (BIO3) possible. Other configurations of the analog input board available, e.g. mixed configuration for input transformers and sensors connection.

Note: Please connect the right polarity on binary output BO02.



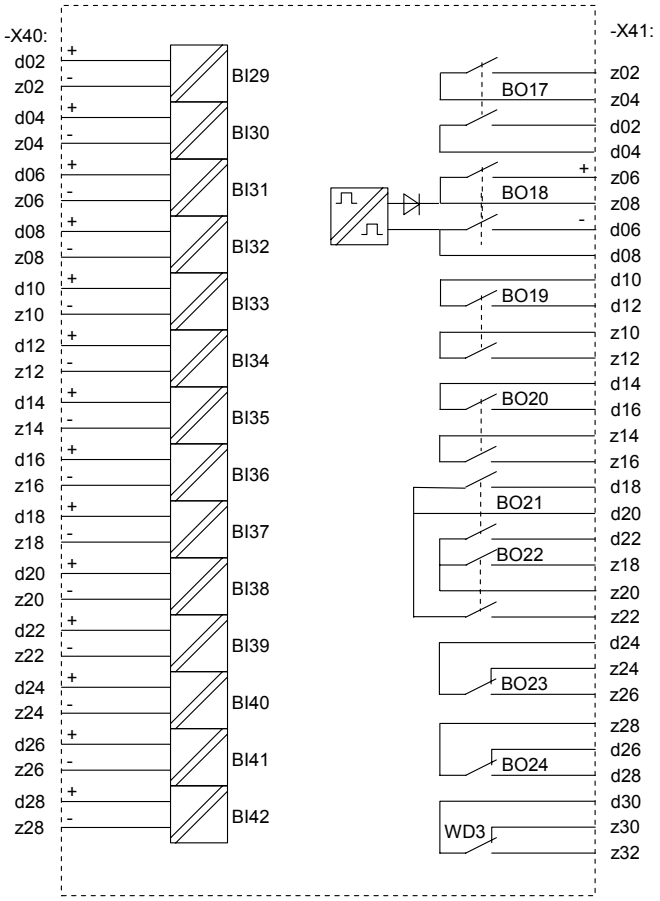
Extension with second additional mechanical binary I/O version 3 (BIO3)

Note: Please connect the right polarity on BO 10



Extension with third additional mechanical binary I/O version 3 (BIO3)

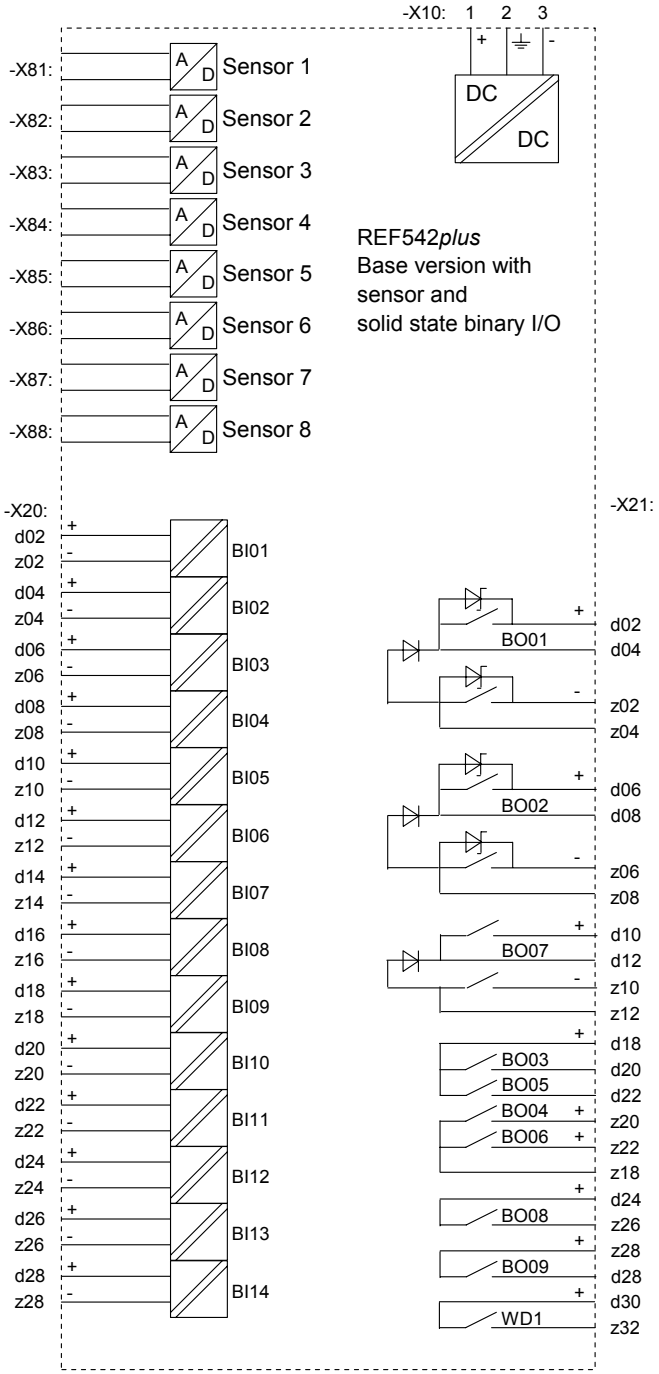
Note: Please connect the right polarity on BO 18



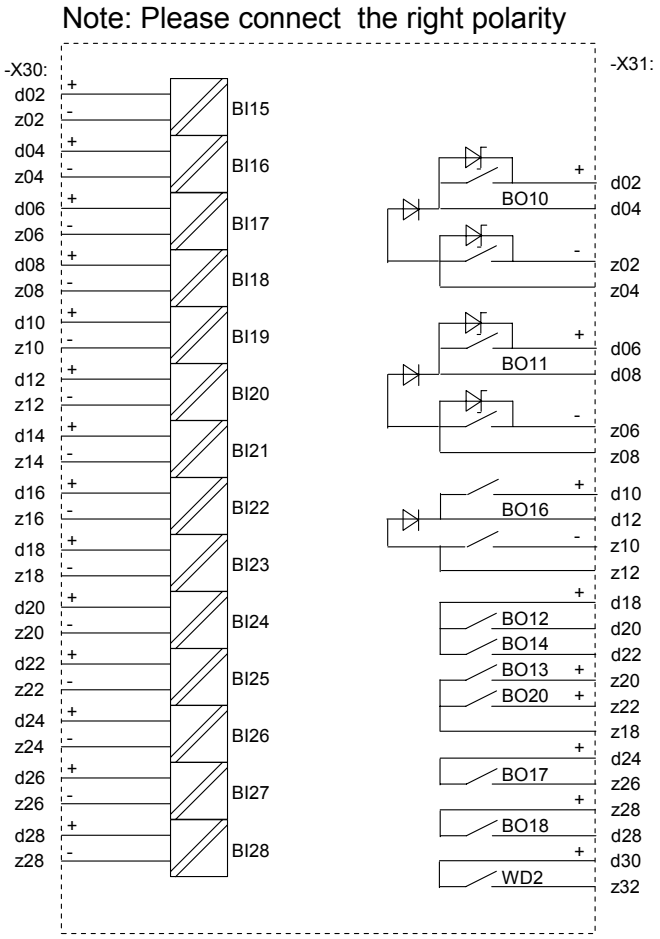
11.4 REF542*plus* with solid state binary I/O

Example of REF542*plus* base version for sensor connection with one solid state binary I/O. Extension up to two additional solid state binary I/O possible. Other configurations of the analog input board available, e.g. mixed configuration for input transformers and sensors connection.

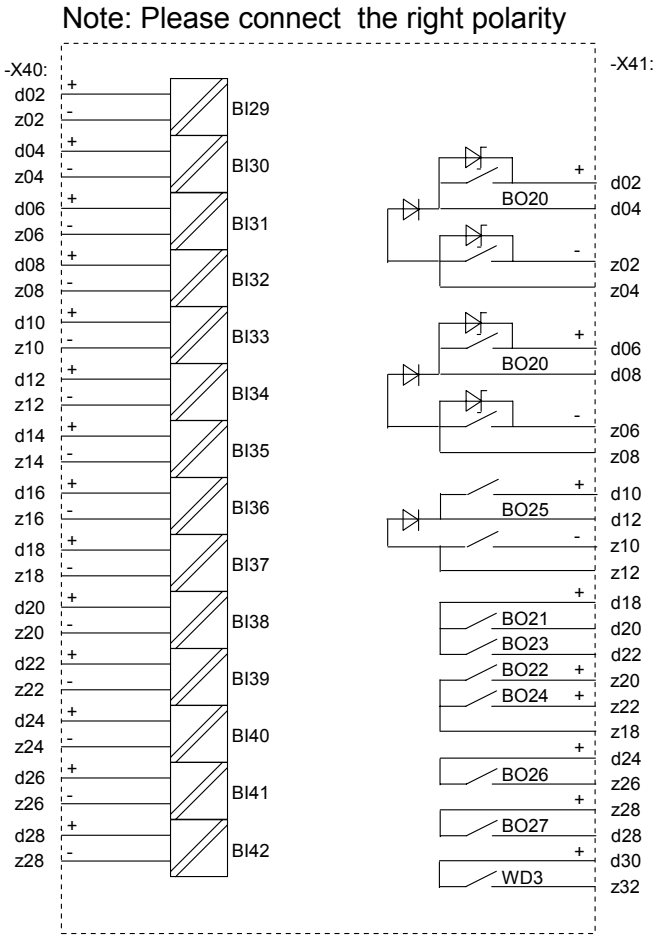
Note: Please connect the right polarity



Extension with second solid state binary I/O.



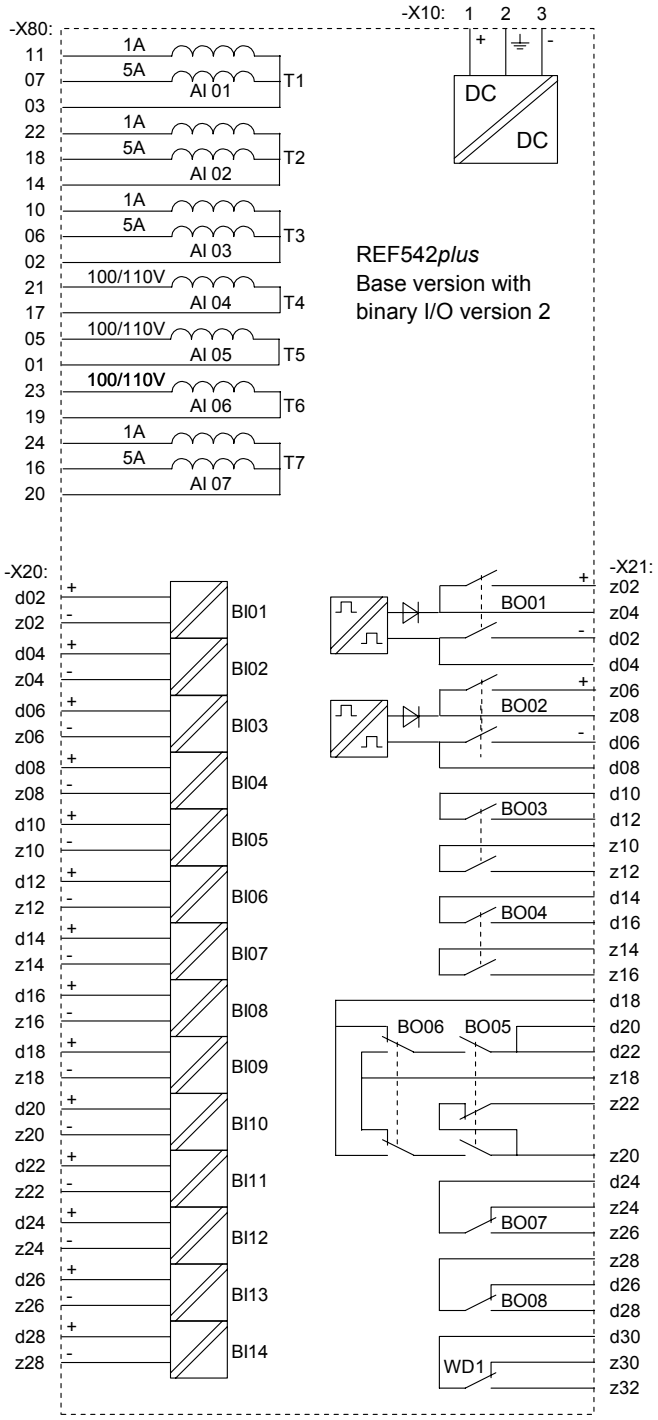
Extension with third additional solid state binary I/O



11.5 REF542*plus* with mechanical binary I/O (version 2)

For the time being the REF542*plus* can only be delivered with binary I/O version 2. Extension up to two additional mechanical binary I/O version 2 (BIO2) possible. Other configurations of the analog input board available, e.g. mixed configuration for input transformers and sensors connection.

Note: Please connect the right polarity on binary output BO01 and BO2.



11.6 Analog input board versions

REF542plus can have at most 8 analog input channels. They can be from instrument transformers of from non-conventional sensors. Also mixed combinations are possible, with some inputs from instrument transformers and others from sensors. The table below lists all the supported combinations.

Table 1: List of the variation of the analog input board

AI 1	AI 2	AI 3	AI 4	AI 5	AI 6	AI 7	AI 8
Sensor	Sensor	Sensor	Sensor	Sensor	Sensor	Sensor	Sensor
Sensor	Sensor	Sensor	Sensor	Sensor	Sensor	CT 1/5A	
Sensor	Sensor	Sensor	Sensor	Sensor	Sensor		CT 1/5A
Sensor	Sensor	Sensor	Sensor	Sensor	Sensor	CT (EF)	CT 1/5A
Sensor	Sensor	Sensor	Sensor	Sensor	Sensor	CT (EF)	VT 100V
Sensor	Sensor	Sensor	VT 100V	VT 100V	VT 100V		
Sensor	Sensor	Sensor	VT 100V	VT 100V	VT 100V	CT 1/5A	
Sensor	Sensor	Sensor	VT 100V	VT 100V	VT 100V	CT (EF)	VT 100V
Sensor	Sensor	Sensor	CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	
Sensor	Sensor	Sensor	VT 100V	VT 100V	VT 100V	VT 100V	
						VT 100V	CT 1/5A
			VT 100V	VT 100V	VT 100V		
			VT 100V	VT 100V	VT 100V	VT 100V	CT 1/5A
			VT 100V	VT 100V	VT 100V	VT 100V	
CT 1/5A	CT 1/5A	CT 1/5A					
CT 1/5A	CT 1/5A	CT 1/5A				CT 1/5A	
CT 1/5A	CT 1/5A	CT 1/5A				CT (EF)	
CT 1/5A	CT 1/5A	CT 1/5A	VT 100V	VT 100V	VT 100V		
CT 1/5A	CT 1/5A	CT 1/5A	VT 100V	VT 100V	VT 100V		CT 1/5A
CT 1/5A	CT 1/5A	CT 1/5A	VT 100V	VT 100V	VT 100V	CT (EF)	CT 1/5A
CT 1/5A	CT 1/5A	CT 1/5A	VT 100V	VT 100V	VT 100V	CT (EF)	VT 100V
CT 1/5A	CT 1/5A	CT 1/5A	VT 100V	VT 100V	VT 100V	VT 100V	
CT 1/5A	CT 1/5A	CT 1/5A	VT 100V	VT 100V	VT 100V	VT 100V	CT 1/5A
CT 1/5A	CT 1/5A	CT 1/5A	VT 100V	VT 100V	VT 100V	CT 1/5A	
CT 1/5A	CT 1/5A	CT 1/5A	VT 100V	VT 100V	VT 100V	CT (EF)	
CT 1/5A	CT 1/5A	CT 1/5A	VT 100V	VT 100V	VT 100V	CT 1/5A	1VT 100V
CT 1/5A	CT 1/5A	CT 1/5A	VT 100V	VT 100V	VT 100V	CT 1/5A	CT 1/5A
CT 1/5A	CT 1/5A	CT 1/5A	VT 100V	VT 100V	VT 100V	CT (EF)	CT (EF)
CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A		
CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	CT (EF)	
CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	CT (EF)	VT 100V
CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	CT 1/5A	

AI 1	AI 2	AI 3	AI 4	AI 5	AI 6	AI 7	AI 8
VT 100V	VT 100V	VT 100V	VT 100V	VT 100V	VT 100V		
VT 100V	VT 100V	VT 100V	VT 100V	VT 100V	VT 100V	CT (EF)	CT (EF)
VT 100V	VT 100V	VT 100V	VT 100V	VT 100V	VT 100V	VT 100V	

CT (EF) is a special input transformer to measure the earth fault current in isolated or with Petersen coil compensated system by means of cable current transformer. For the setting of the related analog input the primary nominal current of the cable current transformer must be divided by 5.

The connections to the Compel connectors for the analog input board are shown in the next following figures. The connection of AI07 and AI08 can principally be derived, depending on the input transformer used.

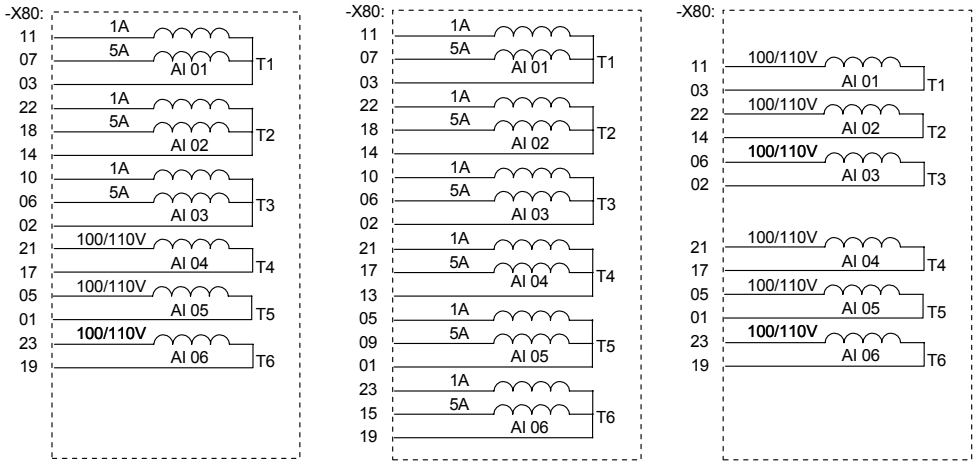


Figure 21: Connections of the analog input with transformer for AI01 to AI06

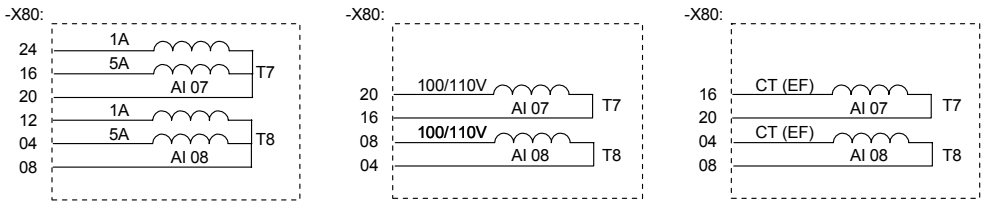


Figure 22: Connections of the analog input with transformer for AI07 to AI08

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