MONOBLOC UNIT - AEROTHERM V17

Service Manual

Thank you very much for purchasing our product.
Before using your unit, please read this manual carefully and keep it for future reference.

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2nd Version

SO30173 to SO30181

English

CONTENTS

Part 1

General Information

1 Unit Capacities and External Appearance

1.1 Unit Capacities

Table 1-1.1: Capacity range

Capacity	5kW	7kW	10kW	12kW	14kW	16kW
MONOBLOC V17 (1Ph)	SO30173	SO30174	SO30175	SO30176	SO30177	SO30178

Capacity	12kW	14kW	16kW			
MONOBLOC V17 (3Ph)	SO30179	SO30180	SO30181			

1.2 External Appearance

Table 1-1.2: Unit appearance

5/7kW   10-16kW

Part 2

Component Layout and Refrigerant Circuits

1 Layout of Functional Components

Models 5 and 7kW

Figure 2-1.1: top view

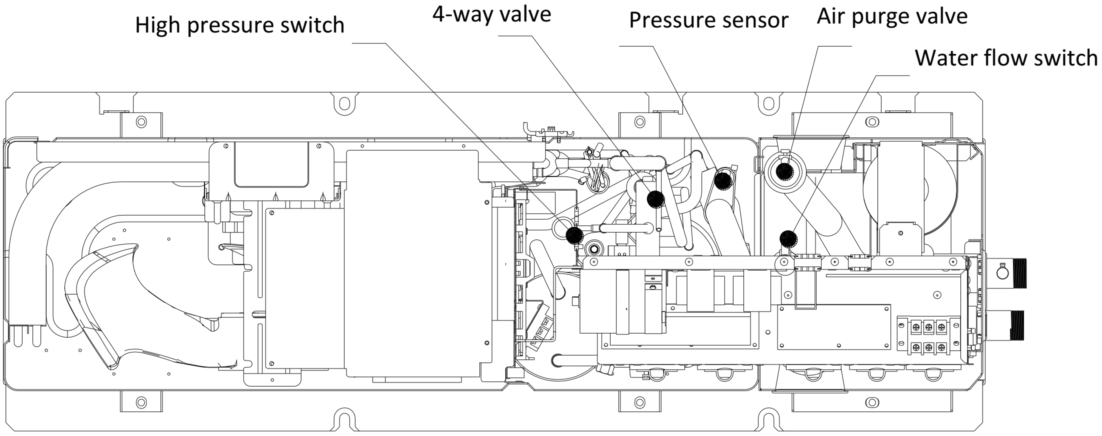


Figure 2-1.2: front view

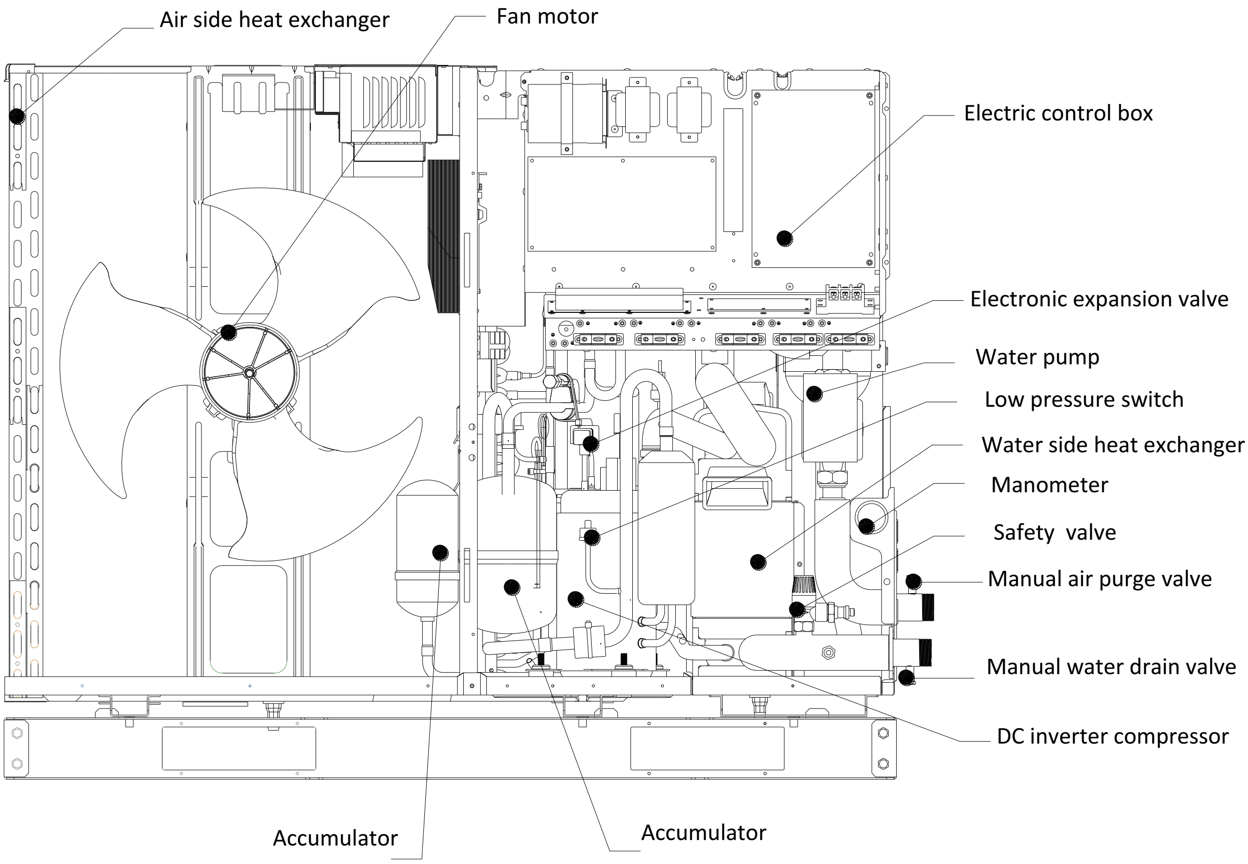
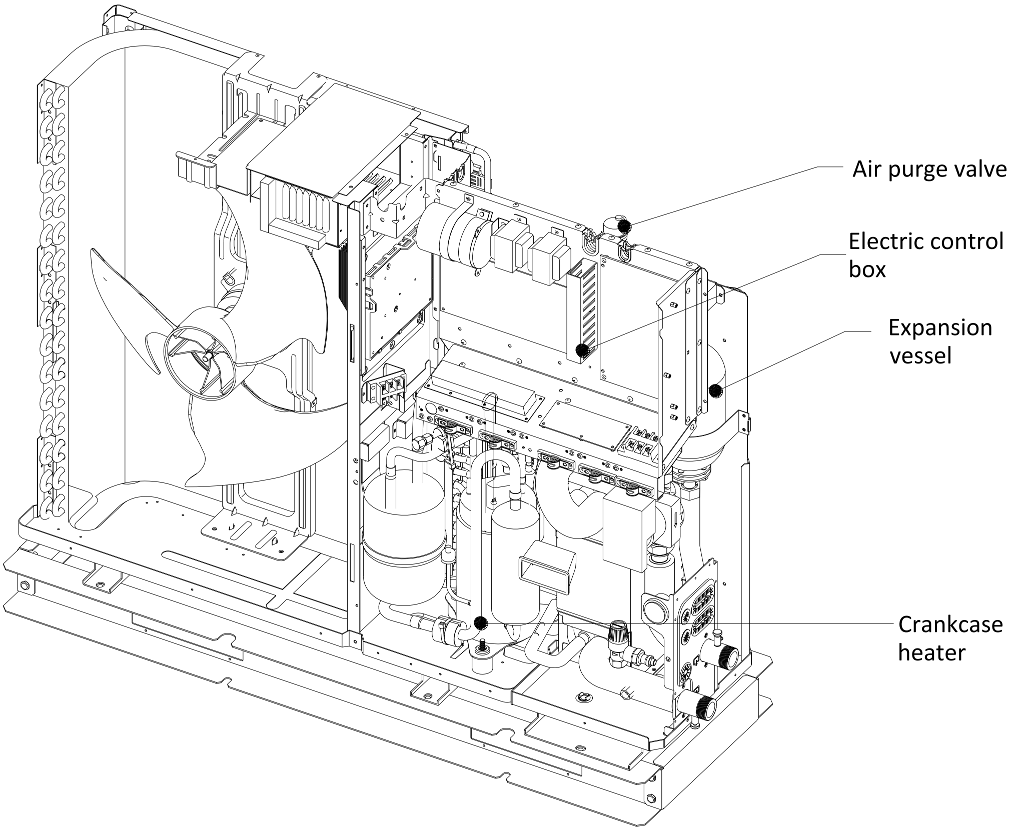


Figure 2-1.3: oblique view



Models 10 to 16kW

Figure 2-1.4: top view

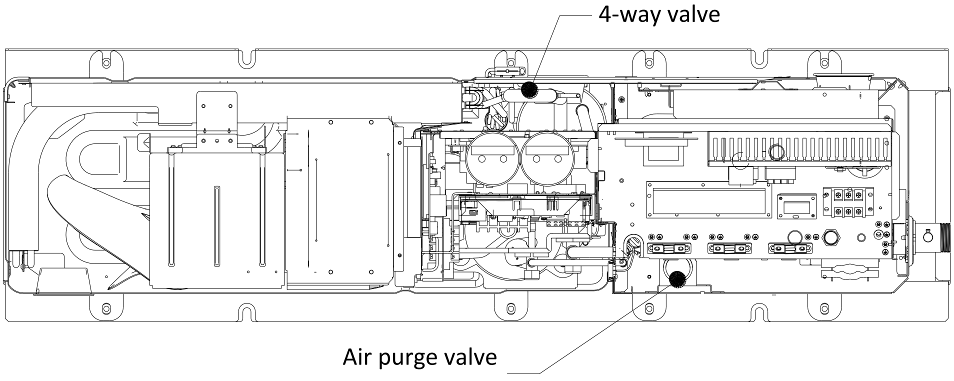


Figure 2-1.5: front view

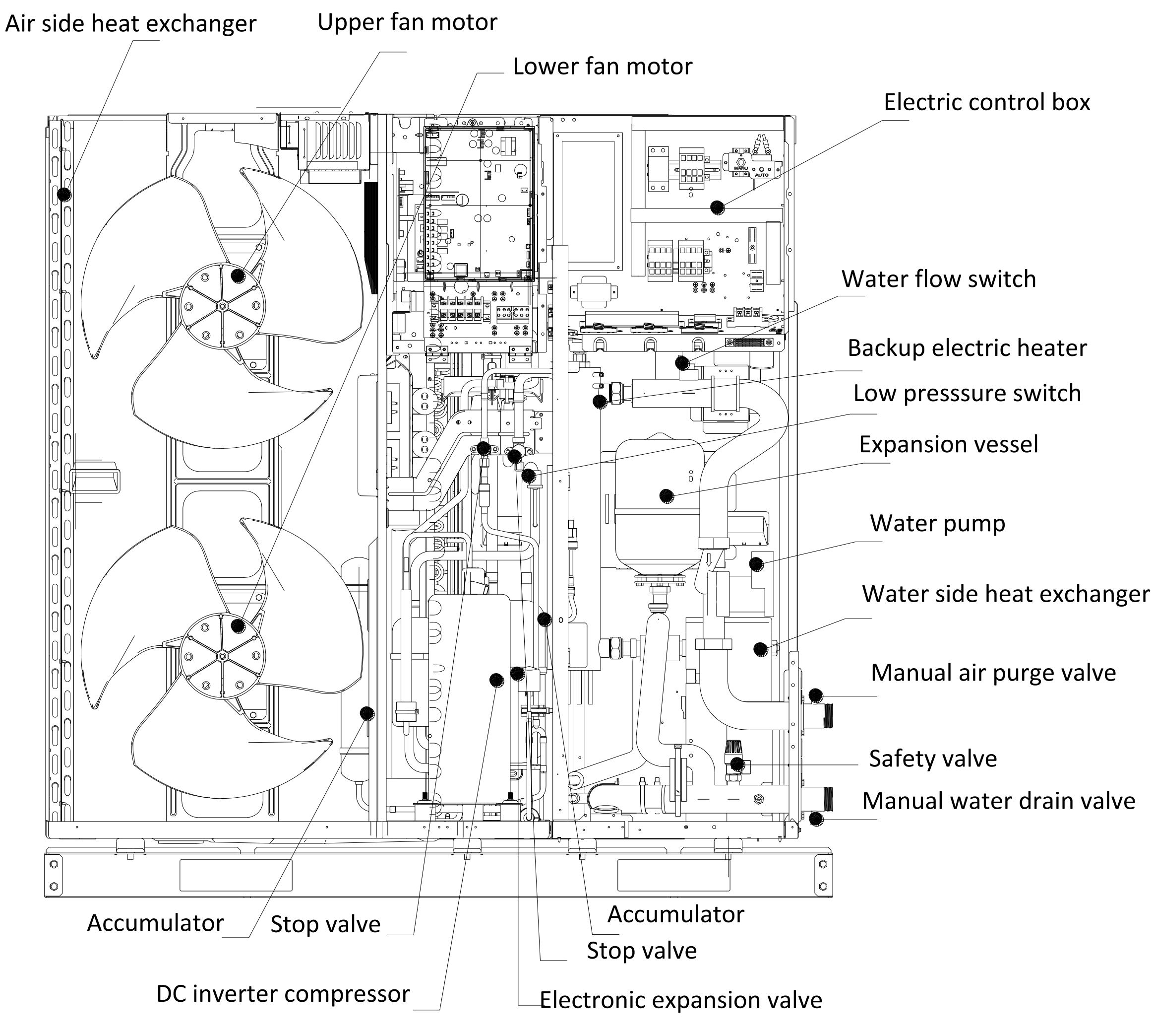
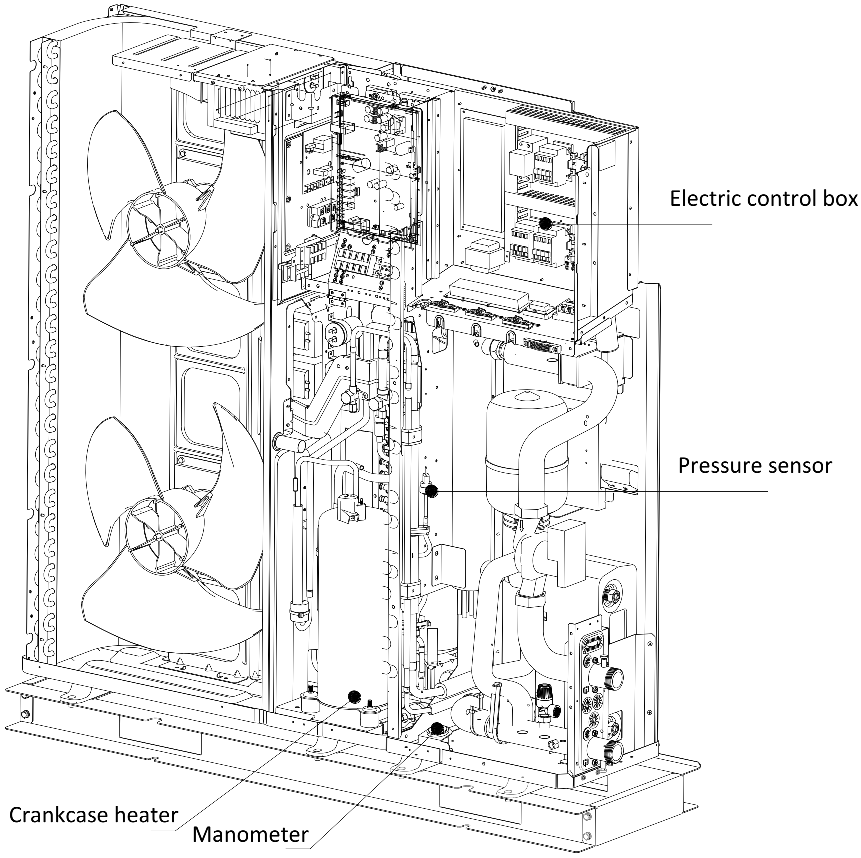


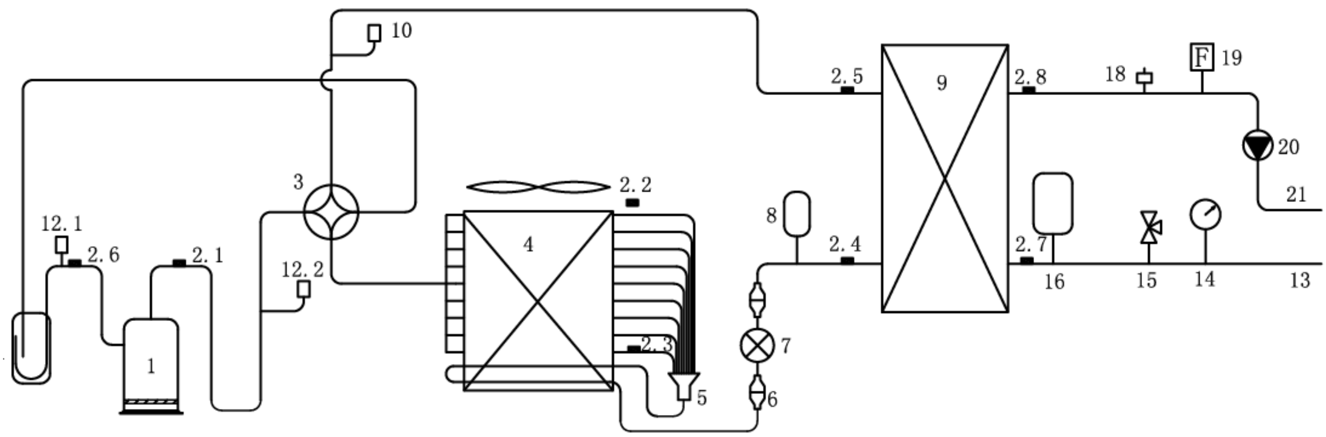
Figure 2-1.6: oblique view



2 Piping Diagrams

Models 5 and 7kW

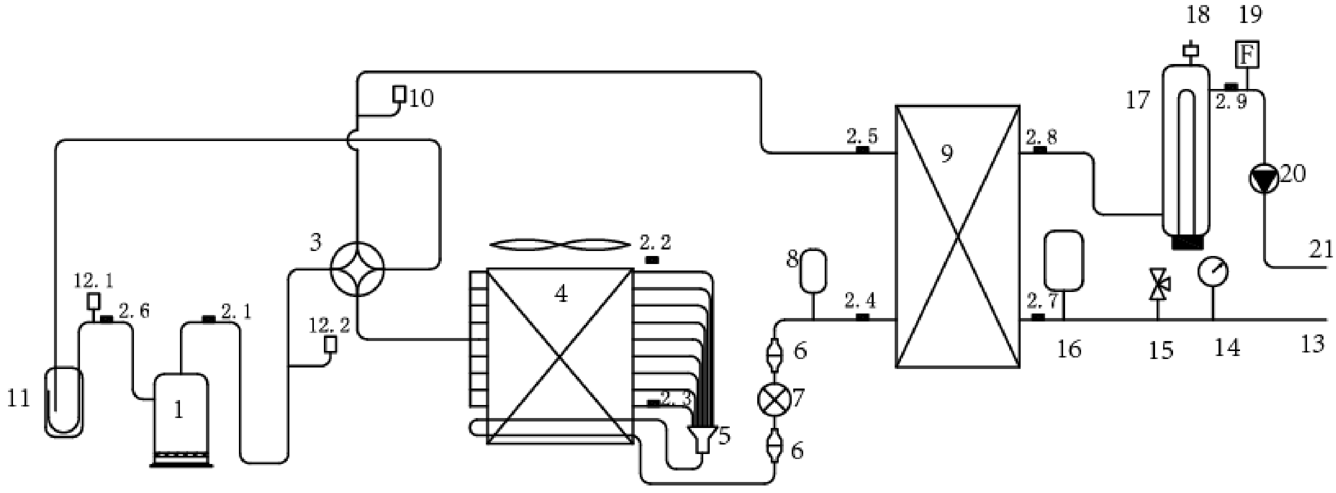
Figure 2-2.1: piping diagram



Legend			
1	Compressor	8	Accumulator
2.1	Discharge pipe temperature sensor	9	Water side heat exchanger
2.2	Outdoor ambient temperature sensor	10	Pressure sensor
2.3	Air side heat exchanger refrigerant outlet temperature sensor	11	Accumulator
2.4	Water side heat exchanger refrigerant inlet (liquid pipe) temperature sensor	12.1	Low pressure switch
2.5	Water side heat exchanger refrigerant outlet (gas pipe) temperature sensor	12.2	High pressure switch
2.6	Suction pipe temperature sensor	13	Water inlet
2.7	Water side heat exchanger water inlet temperature sensor	14	Manometer
2.8	Water side heat exchanger water outlet temperature sensor	15	Safety valve
3	4-way valve	16	Expansion vessel
4	Air side heat exchanger	18	Air purge valve
5	Distributor	19	Water flow switch
6	Filter	20	Water pump
7	Electronic expansion valve	21	Water outlet

Models 10 to 16kW

Figure 2-2.2: piping diagram



Legend			
1	Compressor	8	Accumulator
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2.2	Outdoor ambient temperature sensor	10	Pressure sensor
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2.5	Water side heat exchanger refrigerant outlet (gas pipe) temperature sensor	12.2	High pressure switch
2.6	Suction pipe temperature sensor	13	Water inlet
2.7	Water side heat exchanger water inlet temperature sensor	14	Manometer
2.8	Water side heat exchanger water outlet temperature sensor	15	Safety valve
2.9	Backup electric heater water outlet temperature sensor	16	Expansion vessel
3	4-way valve	17	Backup electric heater
4	Air side heat exchanger	18	Air purge valve
5	Distributor	19	Water flow switch
6	Filter	20	Water pump
7	Electronic expansion valve	21	Water outlet

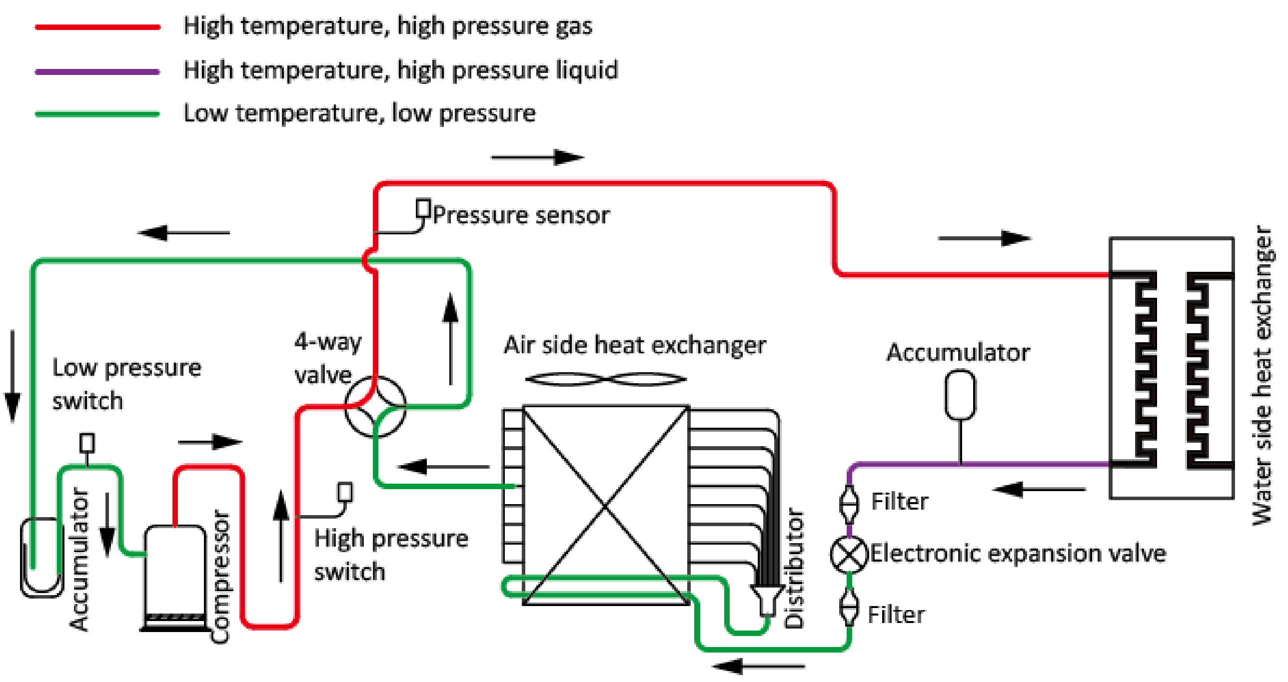
Key components:

1. **Accumulator:**
   Stores liquid refrigerant and oil to protect compressor from liquid hammering.
2. **Electronic expansion valve (EXV):**
   Controls refrigerant flow and reduces refrigerant pressure.
3. **Four-way valve:**
   Controls refrigerant flow direction. Closed in cooling mode and open in heating mode. When closed, the air side heat exchanger functions as a condenser and water side heat exchanger functions as an evaporator; when open, the air side heat exchanger functions as an evaporator and water side heat exchanger function as a condenser.
4. **High and low pressure switches:**
   Regulate refrigerant system pressure. When refrigerant system pressure rises above the upper limit or falls below the lower limit, the high or low pressure switches turn off, stopping the compressor.
5. **Air purge valve:**
   Automatically removes air from the water circuit.
6. **Safety valve:**
   Prevents excessive water pressure by opening at 43.5 psi (3 bar) and discharging water from the water circuit.
7. **Expansion vessel:**
   Balances water system pressure. (Expansion vessel volume: 2L in 5/7kW units and 5L in 10-16kW units.)
8. **Water flow switch:**
   Detects water flow rate to protect compressor and water pump in the event of insufficient water flow.
9. **Backup electric heater:**
   Provides additional heating capacity when the heating capacity of the heat pump is insufficient due to very low outdoor temperature. Also protects the external water piping from freezing.
10. **Manometer:**
    Provides water circuit pressure readout.
11. **Water pump:**
    Circulates water in the water circuit.

3 Refrigerant Flow Diagrams

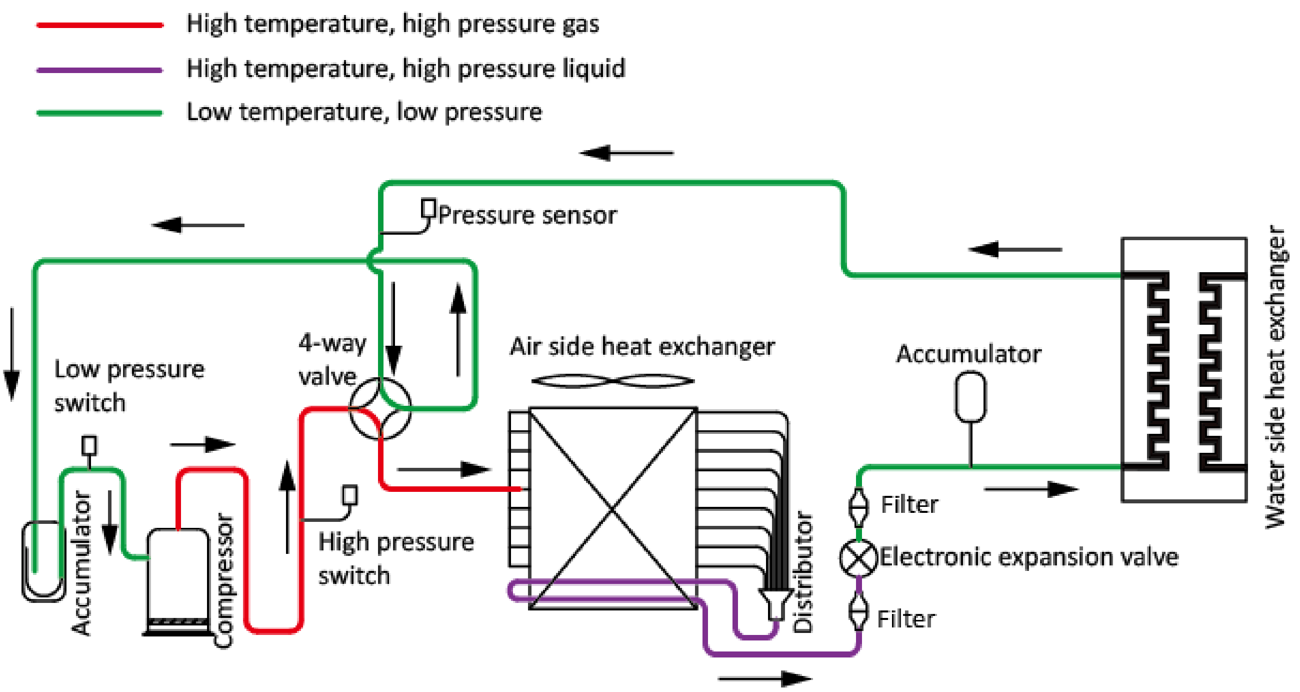
Heating and domestic hot water operation

Figure 2-3.1: Refrigerant flow during heating or domestic hot water operation



Cooling and defrosting operation

Figure 2-3.2: Refrigerant flow during cooling and defrosting operations



Part 3

Control

1 Stop Operation

The stop operation occurs for one of the following reasons:

1. Abnormal shutdown: in order to protect the compressors, if an abnormal state occurs the system makes a 'stop with thermo off' operation and an error code is displayed on the outdoor unit PCB digital displays and on the user interface.
2. The system stops when the set temperature has been reached.

2 Standby Control

2.1 Crankcase Heater Control

The crankcase heater is used to prevent refrigerant from mixing with compressor oil when the compressors are stopped. The crankcase heater is controlled according to outdoor ambient temperature and the compressor on/off state. When the outdoor ambient temperature is above 8°C or the compressor is running, the crankcase heater is off; when the outdoor ambient temperature is at or below 8°C and either the compressor has been stopped for more than 3 hours or the unit has just been powered-on (either manually or when the power has returned following a power outage), the crankcase heater turns on.

2.2 Water Pump Control

When the outdoor unit is in standby, the internal and external circulator pumps run continuously.

3 Startup Control

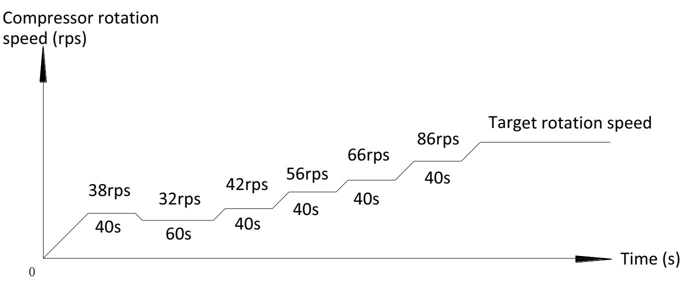
3.1 Compressor Startup Delay Control

In initial startup control and in restart control (except in oil return operation and defrosting operation), compressor startup is delayed such that a minimum of the set re-start delay time has elapsed since the compressor stopped, in order to prevent frequent compressor on/off and to equalize the pressure within the refrigerant system. The compressor re-start delays for cooling and heating modes are set on the user interface. Refer to the M-Thermal Mono Engineering Data Book Part 3, 7.5 “COOL MODE SETTING Menu” and Part 3, 7.6 “HEAT MODE SETTING Menu”.

3.2 Compressor Startup Program

In initial startup control and in re-start control, compressor startup is controlled according to outdoor ambient temperature. Compressor startup follows one of two startup programs until the target rotation speed is reached. Refer to Figures 3-4.1, 3-4.2 and 3-4.3.

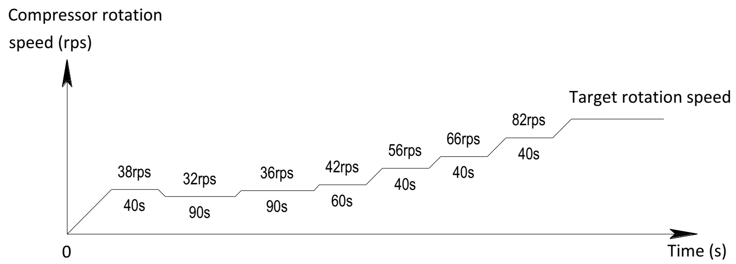
Figure 3-4.1: Compressor startup program[1,2] *when ambient temperature is above 4°C*



Notes:

1. Once the first, 40-second stage of the program is complete, the program proceeds to the subsequent stages in a step-by-step fashion and exits when the target rotation speed has been reached.
2. This program is used on all M-Thermal Mono models: 5kW to 16kW, single phase and three phase.

Figure 3-4.2: **Models 5 and 7kW** *compressor startup program*[1] *when ambient temperature is at or below 4°C*

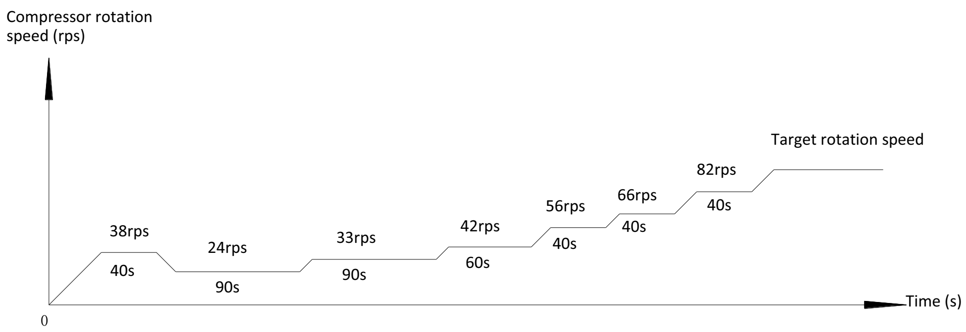


Notes:

1. Once the first, 40-second stage of the program is complete, the program proceeds to the subsequent stages in a step-by-step fashion and exits when the target rotation speed has been reached.

Part 3 - Control

Figure 3-4.3: **Models 10 to 16kW** *compressor startup program[1] when ambient temperature is at or below 4°C*



Notes:

1. Once the first, 40-second stage of the program is complete, the program proceeds to the subsequent stages in a step-by-step fashion and exits when the target rotation speed has been reached.

3.3 Startup Control for Heating and Domestic Hot Water Operation

Table 3-4.1: Component control during startup in heating and domestic hot water modes

Component	Wiring diagram label	5/7kW	10-16kW	Control functions and states
Inverter compressor	COMP	●	●	Compressor startup program selected according to ambient temperature[1]
DC fan motor / Upper DC fan motor	FAN1 / FAN_UP	●	●	Fan run at maximum speed[2]
Lower DC fan motor	FAN_DOWN		●	
Electronic expansion valve	EXV	●	●	Position (steps) from 0 (fully closed) to 480 (fully open), controlled according to outdoor ambient temperature, discharge temperature and suction superheat
Four-way valve	ST	●	●	On

Notes:

1. Refer to Figure 3-4.1, Figure 3-4.2 and Figure 3-4.3 in Part 3, 4.2 “Compressor Startup Program”.
2. Refer to Table 3-5.3 in Part 3, 5.6 “Outdoor Fan Control”.

3.4 Startup Control for Cooling Operation

Table 3-4.2: Component control during startup in cooling mode

Component	Wiring diagram label	5/7kW	10-16kW	Control functions and states
Inverter compressor	COMP	●	●	Compressor startup program selected according to ambient temperature[1]
DC fan motor / Upper DC fan motor	FAN1 / FAN_UP	●	●	Fan run at maximum speed[2]
Lower DC fan motor	FAN_DOWN		●	
Electronic expansion valve	EXV	●	●	Position (steps) from 0 (fully closed) to 480 (fully open), controlled according to outdoor ambient temperature, discharge temperature and suction superheat
Four-way valve	ST	●	●	Off

Notes:

1. Refer to Figure 3-4.1, Figure 3-4.2 and Figure 3-4.3 in Part 3, 4.2 “Compressor Startup Program”.
2. Refer to Table 3-5.3 in Part 3, 5.6 “Outdoor Fan Control”.

4 Normal Operation Control

4.1 Component Control during Normal Operation

Table 3-5.1: Component control during heating and domestic hot water operations

Component	Wiring diagram label	5/7kW	10-16kW	Control functions and states
Inverter compressor	COMP	●	●	Controlled according to load requirement from hydronic system
DC fan motor / Upper DC fan motor	FAN1 / FAN_UP	●	●	Controlled according to outdoor heat exchanger pipe temperature
Lower DC fan motor	FAN_DOWN		●	
Electronic expansion valve	EXV	●	●	Position (steps) from 0 (fully closed) to 480 (fully open), controlled according to discharge temperature, suction superheat and compressor speed
Four-way valve	ST	●	●	On

Table 3-5.2: Component control during cooling operation

Component	Wiring diagram label	5/7kW	10-16kW	Control functions and states
Inverter compressor	COMP	●	●	Controlled according to load requirement from hydronic system
DC fan motor / Upper DC fan motor	FAN1 / FAN_UP	●	●	Controlled according to outdoor heat exchanger pipe temperature
Lower DC fan motor	FAN_DOWN		●	
Electronic expansion valve	EXV	●	●	Position (steps) from 0 (fully closed) to 480 (fully open), controlled according to discharge temperature, suction superheat and compressor speed
Four-way valve	ST	●	●	Off

4.2 Compressor Output Control

The compressor rotation speed is controlled according to the load requirement. Before compressor startup, the M-Thermal Mono outdoor unit determines the compressor target speed according to outdoor ambient temperature, leaving water set temperature and actual leaving water temperature and then runs the appropriate compressor startup program. Refer to Part 3, 4.2 “Compressor Startup Program”. Once the startup program is complete, the compressor runs at the target rotation speed.

During operation the compressor speed is controlled according to the rate of change in water temperature, the refrigerant system pressure and the refrigerant temperature.

4.3 Compressor Step Control

The running speed of four-pole compressors (used on 5-7kW models) in rotations per second (rps) is half the frequency (in Hz) of the electrical input to the compressor motor. The running speed of six-pole compressors (used on all other models) in rotations per second (rps) is one third of the frequency (in Hz) of the electrical input to the compressor motor. The frequency of the electrical input to the compressor motors can be altered at a rate of 1Hz per second.

4.4 Four-way Valve Control

The four-way valve is used to change the direction of refrigerant flow through the water side heat exchanger in order to switch between cooling and heating/DHW operations. Refer to Figures 2-3.1 and 2-3.2 in Part 2, 3 “Refrigerant Flow Diagrams”.

During heating and DHW operations, the four-way valve is on; during cooling and defrosting operations, the four-way valve is off.

4.5 Electronic Expansion Valve Control

The position of the electronic expansion valve (EXV) is controlled in steps from 0 (fully closed) to 480 (fully open).

- At power-on:
  - The EXV first closes fully, then moves to the standby position (304 (steps)). After 30 seconds the EXV moves to an initial running position, which is determined according to operating mode and outdoor ambient temperature. After a further 150 seconds, the EXV is controlled according to suction superheat and discharge temperature. Once a further 6 minutes have elapsed, the EXV is then controlled according to suction superheat, discharge temperature and compressor speed.
- When the outdoor unit is in standby:
  - The EXV is at position 304 (steps).
- When the outdoor unit stops:
  - The EXV first closes fully, then moves to the standby position (304 (steps)).

4.6 Outdoor Fan Control

The speed of the outdoor unit fan(s) is adjusted in steps, as shown in Table 3-5.3.

Table 3-5.3: Outdoor fan speed steps

Fan speed index	Fan speed (rpm)					
	5kW	7kW	10-16kW (1Ph)		12-16kW (3Ph)	
			Upper fan[1]	Lower fan[2]	Upper fan[1]	Lower fan[2]
0	0	0	0	0	0	0
1	300	300	300	-	300	-
2	340	340	330	300	330	300
3	400	400	400	380	400	380
4	450	450	460	440	460	440
5	520	520	520	500	520	500
6	600	600	630	610	630	610
7	680	680	780	760	780	760
8	730	730	-	-	-	-
9	800	800	-	-	-	-

Notes:

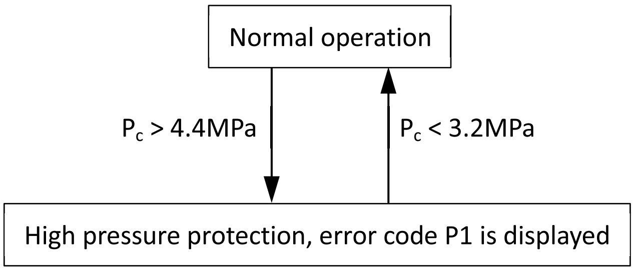
1. The upper fan is labelled FAN_UP in the wiring diagram. Refer to the M-Thermal Mono Engineering Data Book Part 2, 4 “Wiring diagram”.
2. The lower fan is labelled FAN_DOWN in the wiring diagram. Refer to the M-Thermal Mono Engineering Data Book Part 2, 4 “Wiring diagram”.

5 Protection Control

5.1 High Pressure Protection Control

This control protects the refrigerant system from abnormally high pressure and protects the compressor from transient spikes in pressure.

Figure 3-6.1: High pressure protection control



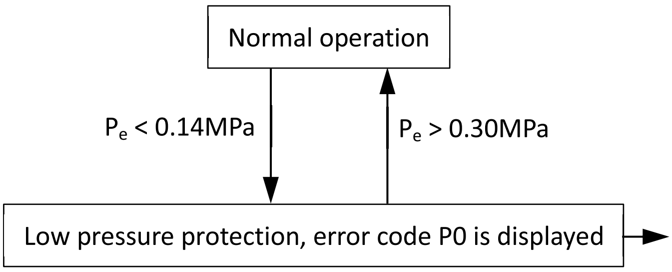
Notes:
1. P_c: Discharge pressure

When the discharge pressure rises above 4.4MPa the system displays P1 protection and the unit stops running. When the discharge pressure drops below 3.2MPa, the compressor enters re-start control.

5.2 Low Pressure Protection Control

This control protects the refrigerant system from abnormally low pressure and protects the compressor from transient drops in pressure.

Figure 3-6.2: Low pressure protection control



When P0 protection occurs 3 times in 60 minutes, the HP error is displayed. When an HP error occurs, a manual system restart is required before the system can resume operation.

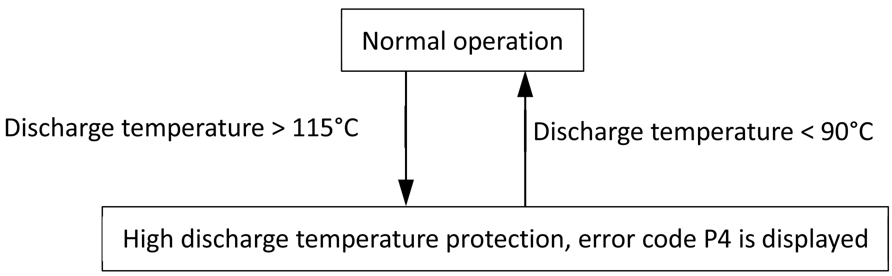
Notes:
1. P_e: Suction pressure

When the suction pressure drops below 0.14MPa the system displays P0 protection and the unit stops running. When the suction pressure rises above 0.3MPa, the compressor enters re-start control.

5.3 Discharge Temperature Protection Control

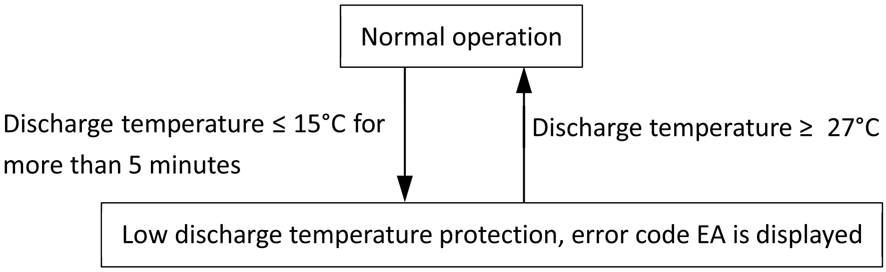
This control protects the compressor from abnormally high temperatures and transient spikes in temperature.

Figure 3-6.3: High discharge temperature protection control



When the discharge temperature rises above 115°C the system displays P4 protection and the unit stops running. When the discharge temperature drops below 90°C, the compressor enters re-start control.

Figure 3-6.4:Low discharge temperature protection control



When the discharge temperature is at or below 15°C for more than 5 minutes, the system displays EA protection and the unit stops running. When the discharge temperature rises to 27°C or higher, the compressor enters re-start control.

5.4 Compressor Current Protection Control

This control protects the compressor from abnormally high currents.

Figure 3-6.5: Compressor current protection control

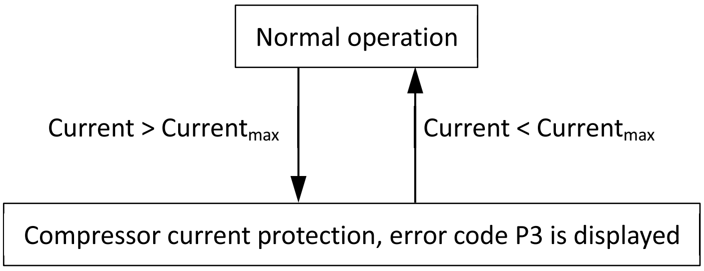


Table 3-6.1: Current limitation for compressors

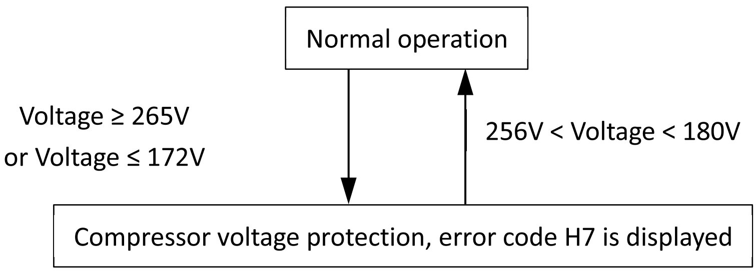
Model name	Models 5 and 7kW	Models 10 to 16kW (1Ph)	Models 10 to 16kW (3Ph)
Compressor model	TNB220FFEMC	ATQ420D1UMU	ATQ420D2UMU
Current$_{max}$	20A	31A	15A

When the compressor current rises above Current$_{max}$ the system displays P3 protection and the unit stops running. When the compressor current drops below Current$_{max}$, the compressor enters re-start control.

5.5 Voltage Protection Control

This control protects the M-Thermal Mono from abnormally high or abnormally low voltages.

Figure 3-6.4: Compressor voltage protection control



When the phase voltage of AC power supply is at or above 265V for more than 30 seconds, the system displays H7 protection and the unit stops running. When the phase voltage drops below 265V for more than 30 seconds, the refrigerant system restarts once the compressor re-start delay has elapsed. When the phase voltage is below 172V, the system displays H7 protection and the unit stops running. When the AC voltage rises to more than 180V, the refrigerant system restarts once the compressor re-start delay has elapsed.

5.6 DC Fan Motor Protection Control

This control protects the DC fan motors from strong winds and abnormal power supply. DC fan motor protection occurs when any one of the following the following three sets of conditions are met:

- Outdoor ambient temperature is at or above 4°C and actual fan speed differs from target fan speed by 200rpm or more for more than 3 minutes.
- Outdoor ambient temperature is below 4°C and actual fan speed differs from target fan speed by 300rpm or more for more than 3 minutes.
- Actual fan speed is less than 240rpm for more than 20 seconds.

When DC fan motor protection control occurs the system displays the H6 error code and the unit stops running. After 3 minutes, the unit restarts automatically. When H6 protection occurs 10 times in 120 minutes, the HH error is displayed. When an HH error occurs, a manual system restart is required before the system can resume operation.

5.7 Water Side Heat Exchanger Anti-freeze Protection Control

This control protects the water side heat exchanger from ice formation. The water side heat exchanger electric heater is controlled according to outdoor ambient temperature, water side heat exchanger water inlet temperature and water side heat exchanger water outlet temperature.

In heating mode, if the outdoor temperature falls below 3°C and either the water side heat exchanger water inlet temperature or water side heat exchanger water outlet temperature are below 25°C, the water side heat exchanger electric heater turns on. When the outdoor ambient temperature rises above 5°C and either the water side heat exchanger water inlet temperature or water side heat exchanger water outlet temperature are above 30°C, the water side heat exchanger turns off.

When water side heat exchanger anti-freeze protection occurs the system displays error code Pb and the unit stops running.

6 Special Control

6.1 Oil Return Operation

In order to prevent the compressor from running out of oil, the oil return operation is conducted to recover oil that has flowed out of the compressor and into the refrigerant piping. When the oil return operation is being conducted, the outdoor unit refrigerant system main PCB displays code d0.

Timing of oil return operation:

- When the compressor cumulative operating time with running rotation speed less than 42rps reaches 6 hours.

The oil return operation ceases when any one of the following three conditions occurs:

- Oil return operation duration reaches 5 minutes.
- Compressor stops.
- Mode change command is received.

Tables 3-7.1 show component control during oil return operation in cooling mode.

Table 3-7.1: Outdoor unit component control during oil return operation in cooling mode

Component	Wiring diagram label	5/7kW	10-16kW	Control functions and states
Inverter compressor	COMP	●	●	Runs at oil return operation rotation speed
DC fan motor / Upper DC fan motor	FAN1 / FAN_UP	●	●	Controlled according to outdoor heat exchanger pipe temperature
Lower DC fan motor	FAN_DOWN		●	
Electronic expansion valve	EXV	●	●	304 (steps)
Four-way valve	ST	●	●	Off

Tables 3-7.2 show component control during oil return operation in heating and DHW modes.

Table 3-7.2: Outdoor unit component control during oil return operation in heating and DHW modes

Component	Wiring diagram label	5/7kW	10-16kW	Control functions and states
Inverter compressor	COMP	●	●	Runs at oil return operation rotation speed
DC fan motor / Upper DC fan motor	FAN1 / FAN_UP	●	●	Controlled according to outdoor heat exchanger pipe temperature
Lower DC fan motor	FAN_DOWN		●	
Electronic expansion valve	EXV	●	●	304 (steps)
Four-way valve	ST	●	●	On

6.2 Defrosting Operation

In order to recover heating capacity, the defrosting operation is conducted when the outdoor unit air side heat exchanger is performing as a condenser. The defrosting operation is controlled according to outdoor ambient temperature, air side heat exchanger refrigerant outlet temperature and the compressor running time.

The defrosting operation ceases when any one of the following three conditions occurs:

- Defrosting operation duration reaches 10 minutes.
- The air side heat exchanger refrigerant outlet temperature is above 8°C for more than 10 seconds.
- The air side heat exchanger refrigerant outlet temperature is above 10°C.

Table 3-7.3: Component control during defrosting operation

Component	Wiring diagram label	5/7kW	10-16kW	Control functions and states
Inverter compressor	COMP	●	●	Runs at defrosting operation rotation speed
DC fan motor / Upper DC fan motor	FAN1 / FAN_UP	●	●	Off
Lower DC fan motor	FAN_DOWN		●	
Electronic expansion valve	EXV	●	●	Fully open
Four-way valve	ST	●	●	Off

6.3 Force Cooling Operation

The force cooling operation helps the refrigerant recovering before removal the water side heat exchanger.

The force cool mode can be ended by pushing the button on the outdoor refrigerant system main PCB named “force-cool” for 5s or this mode will be ended automatic if the system has operated force cool mode for more than 30 minutes.

Table 3-7.4: Component control during force cool operation

Component	Wiring diagram label	5/7kW	10-16kW	Control functions and states
Inverter compressor	COMP	●	●	Runs at force cooling operation rotation speed
DC fan motor / Upper DC fan motor	FAN1 / FAN_UP	●	●	Runs at force cooling operation speed
Lower DC fan motor	FAN_DOWN		●	
Electronic expansion valve	EXV	●	●	304 (steps)
Four-way valve	ST	●	●	Off

6.4 Fast DHW Operation

Fast DHW operation is used to quickly meet a requirement for domestic hot water when DHW priority has been set on the user interface. Refer to the M-Thermal Mono Engineering Data Book Part 3, 7.4 “DHW MODE SETTING Menu”.

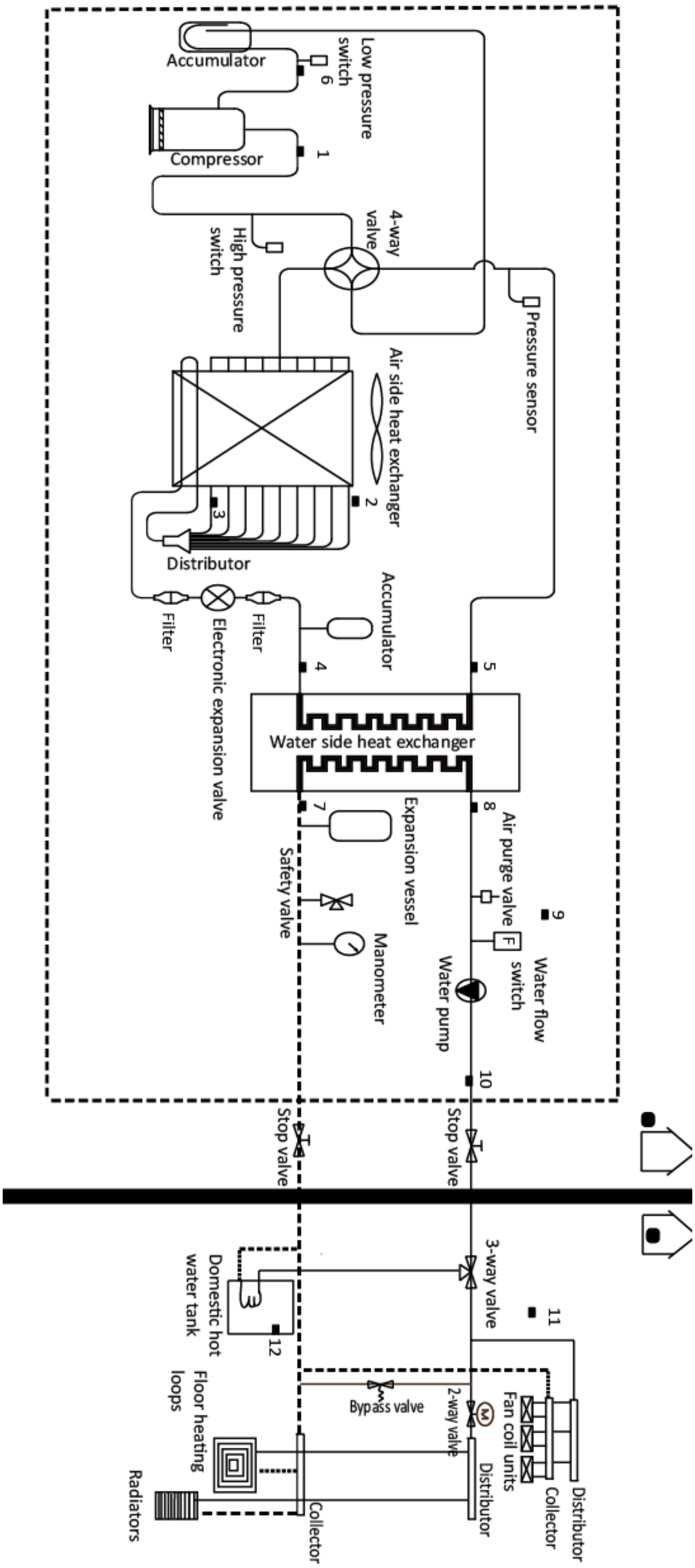
Domestic hot water demand priority can be ended by changing the switch on controller from "on" to "off".

Table 3-7.5: Component control during fast DHW operation

Component	Wiring diagram label	5/7kW	10-16kW	Control functions and states
Inverter compressor	COMP	●	●	Controlled according to load requirement
DC fan motor / Upper DC fan motor	FAN1 / FAN_UP	●	●	Controlled according to outdoor heat exchanger pipe temperature
Lower DC fan motor	FAN_DOWN		●	
Electronic expansion valve	EXV	●	●	Position (steps) from 0 (fully closed) to 480 (fully open), controlled according to discharge superheat
Four-way valve	ST	●	●	On
Tank electric heater	TBH	●	●	On

7 Role of Temperature Sensors in Control Functions

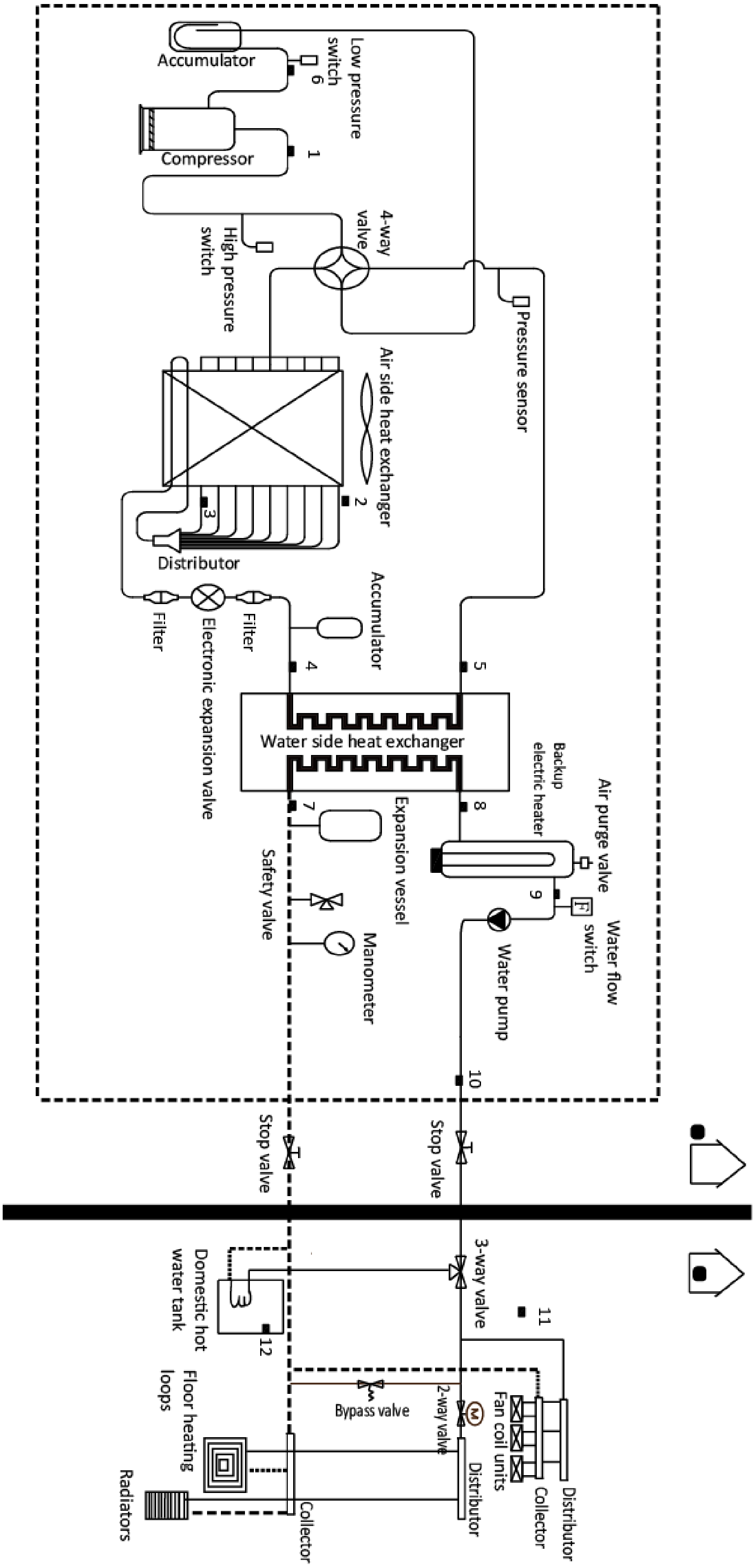
Figure 3-7.1: Location of the temperature sensors on 5/7KW unit systems



Notes:

1. The names and functions of the temperature sensors labelled 1 to 12 in this figure are detailed in Table 3-7.1.

Figure 3-7.2: Location of the temperature sensors on 10-16KW unit systems[1]



Notes:

1. The names and functions of the temperature sensors labelled 1 to 12 in this figure are detailed in Table 3-7.1.

Table 3-7.1: Names and functions of the temperature sensors

Number	Sensor name[1]	Sensor code	Mode	Control functions
1	Discharge pipe temperature sensor	Tp	Heating	▪ Electronic expansion valve control[2] ▪ Discharge superheat control
			Cooling	▪ Electronic expansion valve control[2] ▪ Outdoor fan control[3] ▪ Discharge superheat control
2	Outdoor ambient temperature sensor	T4	Heating	▪ Compressor startup control[4] ▪ Compressor output control[5] ▪ Electronic expansion valve control[2] ▪ Defrosting operation control[7] ▪ Low pressure protection control[7] ▪ Crankcase heater control[9]
			Cooling	▪ Compressor startup control[4] ▪ Compressor output control[5] ▪ Electronic expansion valve control[2] ▪ Outdoor fan control[3] ▪ Crankcase heater control[9]
3	Air side heat exchanger refrigerant outlet temperature sensor	T3	Heating	▪ Electronic expansion valve control[2] ▪ Defrosting operation control[7] ▪ Outdoor fan control[3]
			Cooling	▪ Compressor output control[5] ▪ Outdoor fan control[3]
4	Water side heat exchanger refrigerant inlet (liquid pipe) temperature sensor	T2B	Heating DHW	▪ Compressor output control[5]
5	Water side heat exchanger refrigerant outlet (gas pipe) temperature sensor	T2	Heating	▪ Freeze prevention control[10]
6	Suction pipe temperature sensor	Th	Heating Cooling	▪ Electronic expansion valve control[2]
7	Water side heat exchanger water inlet temperature sensor	Tw_in	Heating Cooling	▪ Freeze prevention control[10]
8	Water side heat exchanger water outlet temperature sensor	Tw_out	Heating Cooling DHW	▪ Compressor output[5] and on/off control[6] ▪ Freeze prevention control[10]
9	Backup electric heater water outlet temperature sensor	T1	Heating	▪ Compressor output control[5] ▪ Backup electric heater control ▪ DHW priority control[11] ▪ Auto mode control
			Cooling	▪ Compressor output[5] and on/off control[6] ▪ Auto mode control
			DHW	▪ Compressor output control[5] ▪ Backup electric heater control ▪ DHW priority control[11]
10	Auxiliary heat source water outlet temperature sensor	T1B	Heating	▪ Auxiliary heat source control ▪ Compressor output control[5]
11	Room temperature sensor	Ta	Heating Cooling	▪ Auto mode control ▪ Climate related curve ▪ Compressor output control[5]
12	Domestic hot water tank temperature sensor	T5	DHW	▪ Disinfection operation control ▪ DHW tank immersion heater control ▪ Backup electric heater control ▪ Auxiliary heat source control ▪ Solar energy kit control ▪ Compressor output control[5] ▪ DHW priority control[11]

Notes:
1. Sensor names in this service manual referring to refrigerant flow is named according refrigerant flow during cooling operation refer to Part 2, 3 “Refrigerant Flow Diagrams”.
2. Refer to Part 3, 4.5 “Electronic Expansion Valve Control”.
3. Refer to Part 3, 4.6 “Outdoor Fan Control”.
4. Refer to Part 3, 3 “Startup Control”.
5. Refer to Part 3, 4.2 “Compressor Output Control”.
6. Refer to Part 3, 1 “Stop Operation”.
7. Refer to Part 3, 6.2 “Defrosting Operation”.
8. Refer to Part 3, 5.2 “Low Pressure Protection Control”.
9. Refer to Part 3, 2.1 “Crankcase Heater Control”.
10. Refer to Part 3, 2.2 “Freeze Prevention Control”.
11. Refer to Part 3, 6.4 “Fast DHW Operation”.

Part 4

Diagnosis and Troubleshooting

1 Outdoor Unit Electric Control Box Layout

Models 5 and 7kW

Figure 4-1.1: Electric control box front view

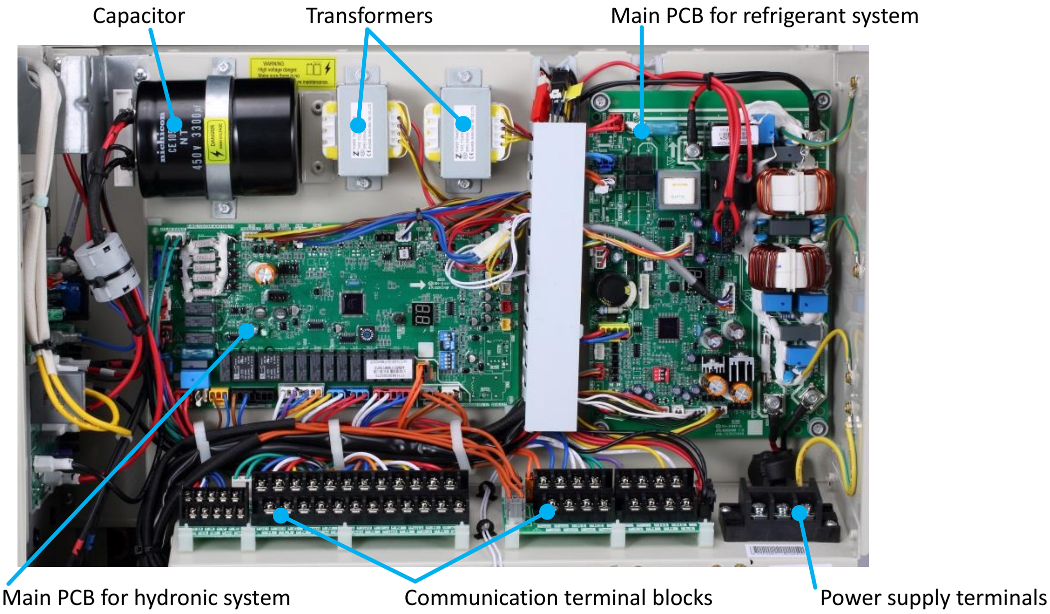
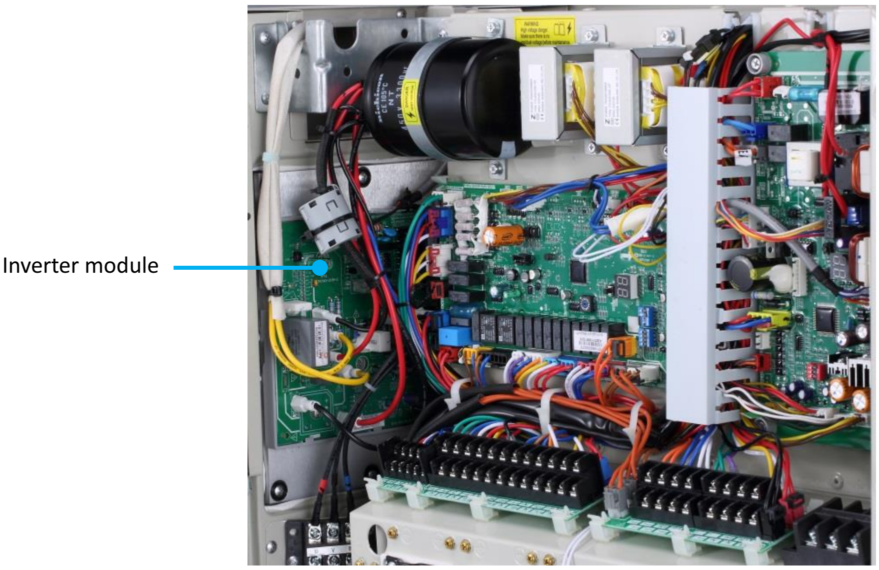


Figure 4-1.2: Electric control box side view



Models 10 to 16kW (1Ph)

Figure 4-1.3: Electric control box front view

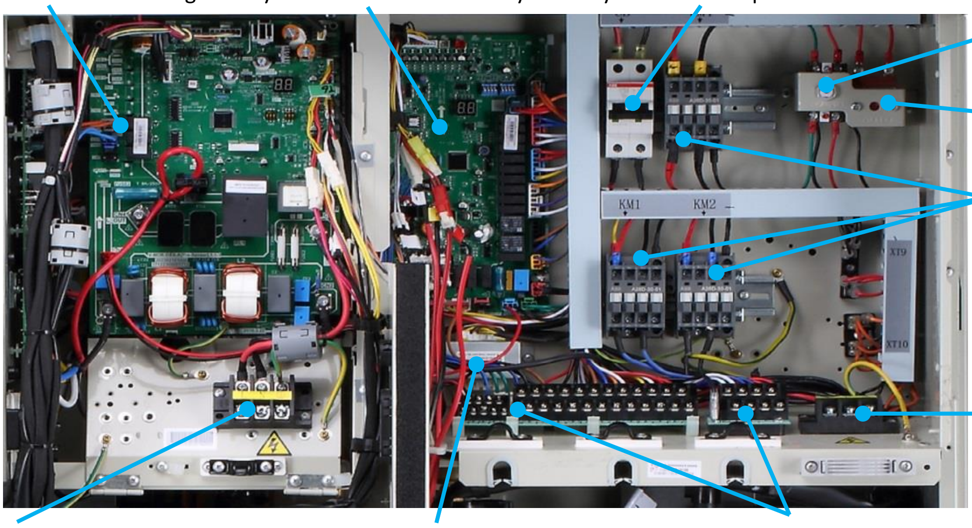
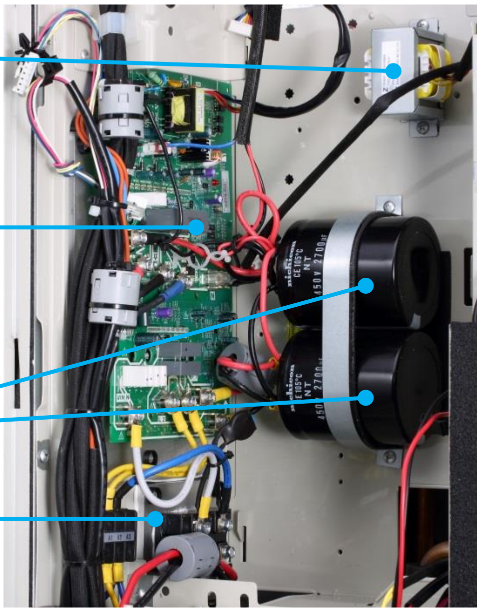


Figure 4-1.4: Electric control box side view



Models 10 to 16kW (3Ph)

Figure 4-1.5: Electric control box front view – top layer

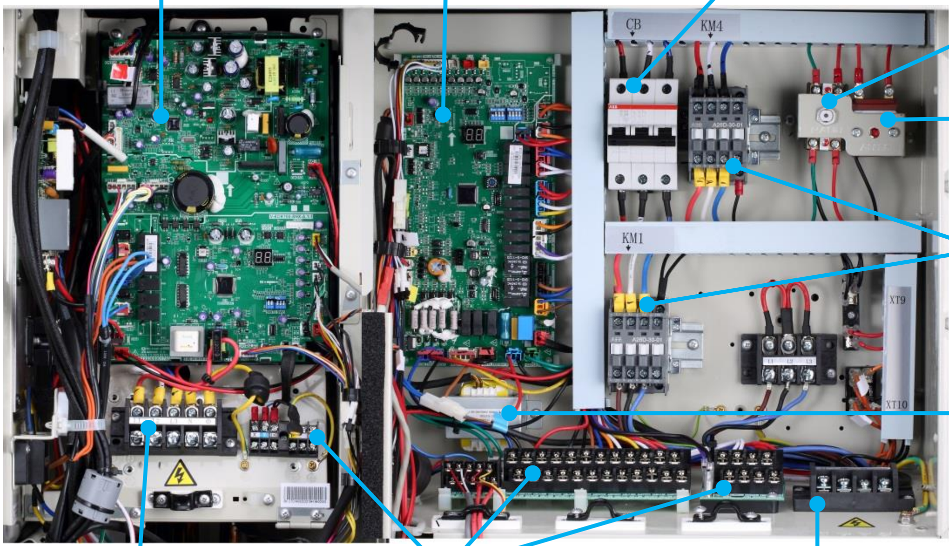
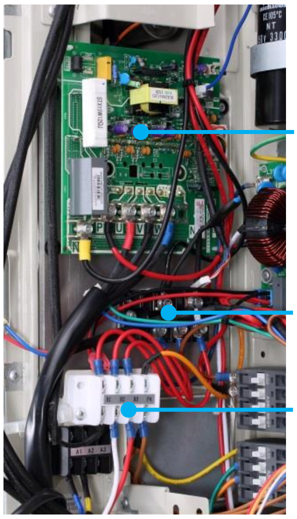


Figure 4-1.6: Electric control box front view – bottom layer

Figure 4-1.7: Electric control box side view



2 Outdoor Unit PCBs

2.1 Types

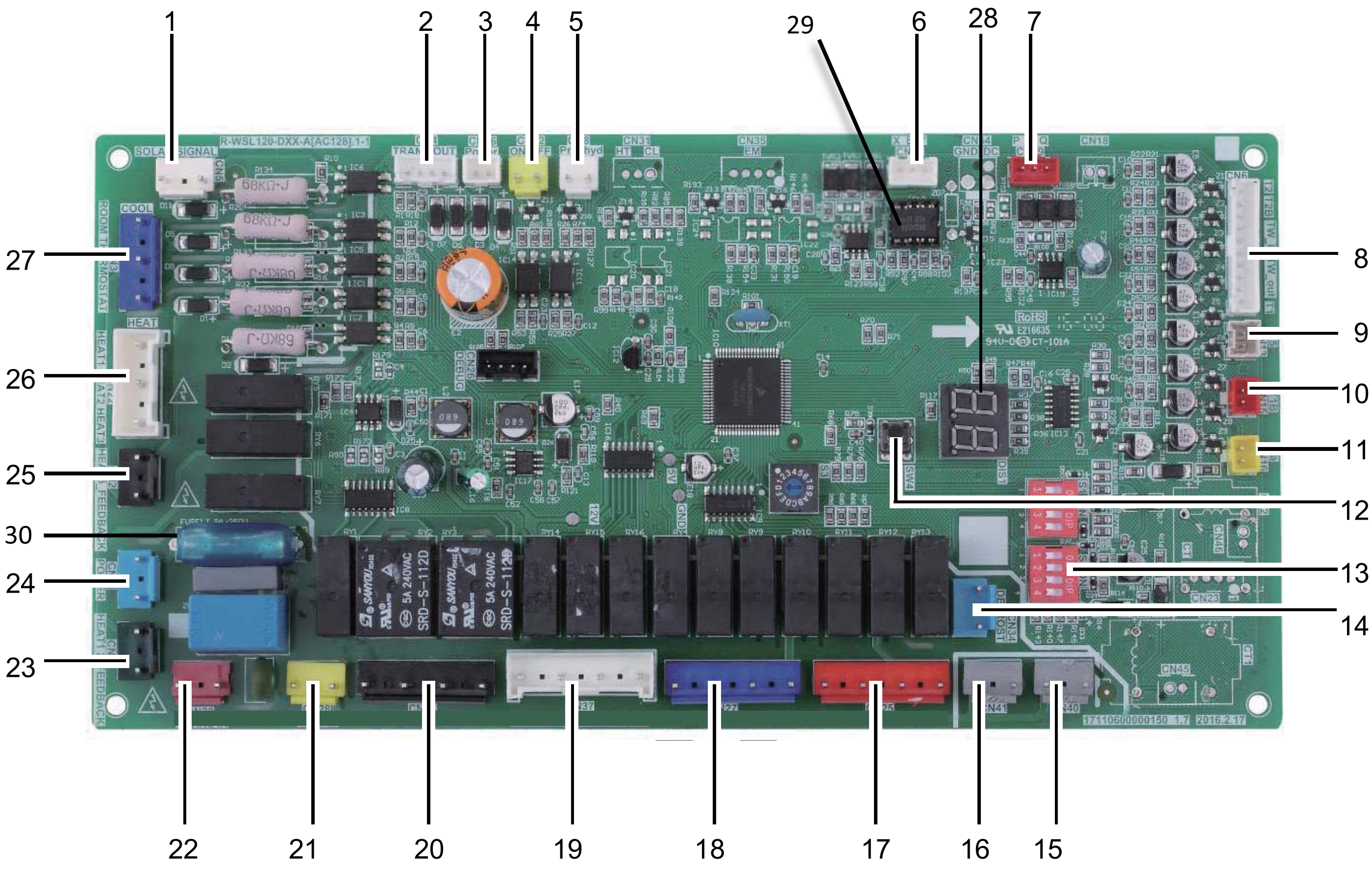
M-Thermal Mono outdoor units have two main PCBs – one for the hydronic system and one for the refrigerant system. The hydronic system main PCB is the same on all M-Thermal Mono models. There are three types of refrigerant system main PCB: one for the 5/7kW single phase models, one for the 10kW to 16kW single phase models and one for the 12kW to 16kW three phase models.

In addition to the two main PCBs, all models also have an inverter module and the three phase models also have a filter board.

The locations of each PCB in the outdoor unit electric control boxes are shown in Figures 4-1.1 to 4-1.7 in Part 4, 1 "Outdoor Unit Electric Control Box Layout".

2.2 Main PCB for Hydronic System

Figure 4-2.1: Outdoor unit main PCB for hydronic system[1, 2]



Notes:

1. This PCB is used on all M-Thermal Mono models: 5kW to 16kW, single phase and three phase.
2. Label descriptions are given in Table 4-2.1.

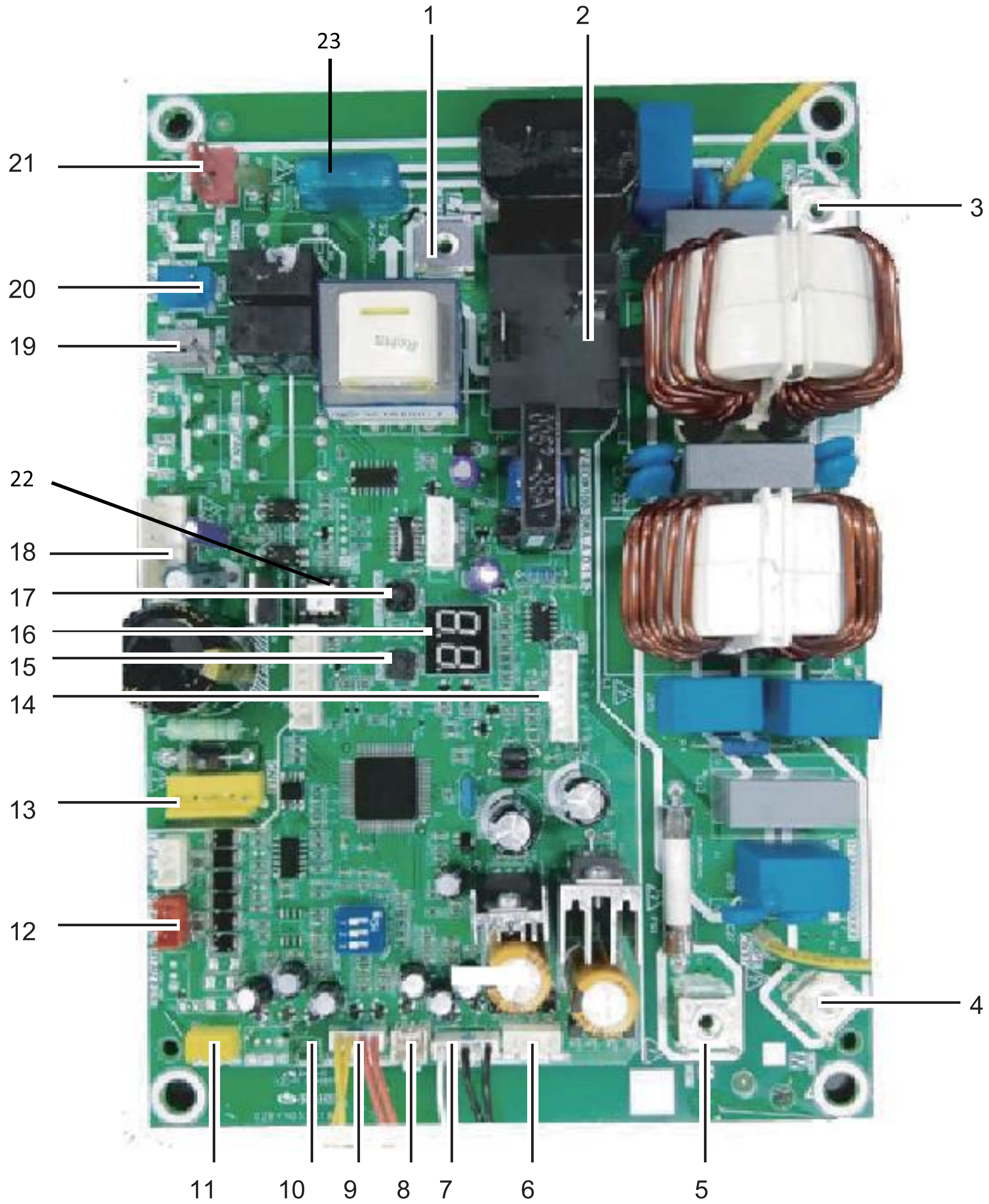
Table 4-2.1: Main PCB for hydronic system

Label in Figure 4-2.1	Code	Content
1	CN5	Solar energy signal input connection
2	CN4	Transformer power output
3	CN36	Power supply to user interface
4	CN12	Remote switch connection
5	CN8	Water flow switch connection
6	CN14	Refrigerant system main PCB connection
7	CN19	User interface connection
8	CN6	▪ Water side heat exchanger water outlet temperature sensor (Sensor TW_out) connection ▪ Water side heat exchanger water inlet temperature sensor (TW_in) connection ▪ Backup electric heater water outlet temperature sensor (T1) connection ▪ Water side heat exchanger refrigerant outlet (gas pipe) temperature sensor (T2) connection ▪ Water side heat exchanger refrigerant inlet (liquid pipe) temperature sensor (T2B) connection
9	CN13	Domestic hot water tank temperature sensor (T5) connection
10	CN15	Auxiliary heat source water outlet temperature sensor (T1B) connection
11	CN16	Room temperature sensor (Ta) connection
12	SW4	Check button
13	S1, S2	DIP switches
14	CN34	Defrost connection
15	CN40	Anti-freeze electric heater connection (internal)
16	CN41	Anti-freeze electric heater connection (internal)
17	CN25	▪ External heating source connection ▪ Operation output connection
18	CN27	▪ External anti-freeze electric heat tape connection ▪ Solar energy signal output connection ▪ Remote alarm connection
19	CN37	▪ External circulator pump connection ▪ Pipe pump connection ▪ Mixing station pump connection ▪ 2-way valve (SV2) connection
20	CN24	▪ 3-way valve (SV1) connection ▪ Reserved (SV3)
21	CN28	Internal circulator pump connection
22	CN20	Transformer power input
23	CN1	Manual reset thermal cutout connection
24	CN21	Power input
25	CN2	Reserved (Feedback port for external temperature switch)
26	CN22	Backup electric heater connection
27	CN3	Room thermostat connection
28	DIS1	Digital display
29	IC18	EEPROM
30	FUSE1	Fuse

2.3 Main PCBs for Refrigerant System, Inverter Modules and Filter Boards

Models 5 and 7kW

Figure 4-2.2: outdoor unit main PCB for refrigerant system[1]



Notes:

1. Label descriptions are given in Table 4-2.2.

Table 4-2.2: outdoor unit main PCB for refrigerant system

Label in Figure 4-2.2	Code	Content
1	CN28	Bridge rectifier input connection L to inverter module
2	CN4	Refrigerant system main PCB connection
3	CN27	Bridge rectifier input connection N to inverter module
4	CN10	AC power input N
5	CN11	AC power input L
6	CN24	Transformer power output
7	CN9	White: Outdoor ambient temperature sensor (T4) connection Black: Air side heat exchanger refrigerant outlet temperature sensor (T3) connection
8	CN8	Discharge pipe temperature sensor (Tp) connection
9	CN13	Yellow: High pressure switch connection Red: Low pressure switch connection
10	CN11	Suction pipe temperature sensor (Th) connection
11	CN14	Pressure sensor connection
12	CN29	Communication port for connection to hydronic system main PCB
13	CN18	P/N/+18V power input
14	CN17	Communication port for connection to inverter module
15	SW2	Check button
16	DIS1	Digital display
17	SW1	Force cool button
18	CN34	Fan connection (fan control and power supply to fan motor)
19	CN7	Power supply to crankcase heater
20	CN6	4-way valve drive port
21	CN19	Transformer power input
22	IC23	EEPROM
23	FUSE3	Fuse

Figure 4-2.3: outdoor unit inverter module

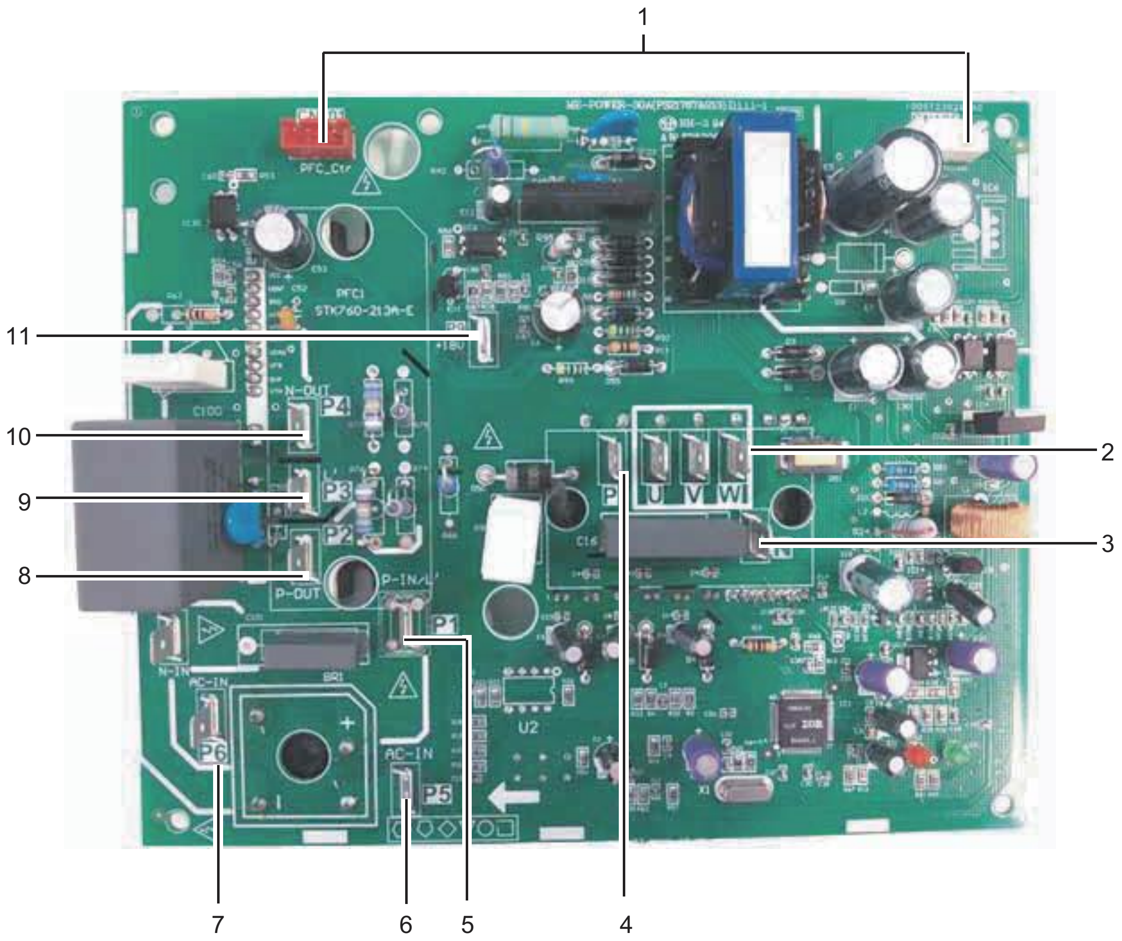
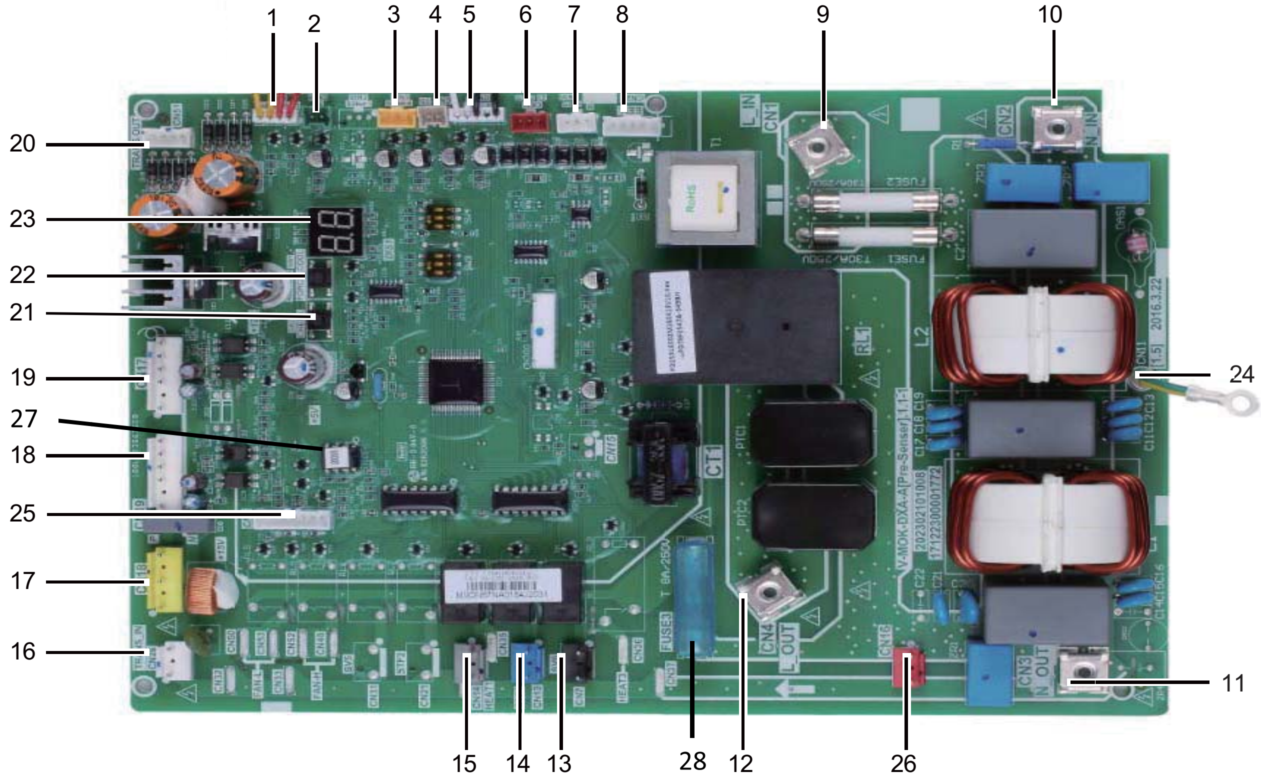


Table 4-2.3: outdoor unit inverter module

Label in Figure 4-2.3	Code	Content
1	CN101, CN105	Connections to main PCB for refrigerant system
2	U V W	Compressor connections
3	N	IPM module input port N
4	P	IPM module input port P
5	P1	Inductor power input
6	P5	Bridge rectifier input
7	P6	Bridge Rectifier input
8	P2	PFC module output port P
9	P3	Inductor input output
10	P4	PFC module output port N
11	P9	+18V power output

Models 10 to 16kW (1Ph)

Figure 4-2.4: outdoor unit main PCB for refrigerant system[1]



Notes:

1. Label descriptions are given in Table 4-2.4.

Table 4-2.4: outdoor unit main PCB for refrigerant system

Label in Figure 4-2.4	Code	Content
1	CN12	Yellow: High pressure switch connection Red: Low pressure switch connection
2	CN24	Suction pipe temperature sensor (Th) connection
3	CN28	Pressure sensor connection
4	CN8	Discharge pipe temperature sensor (Tp) connection
5	CN9	White: Outdoor ambient temperature sensor (T4) connection Black: Air side heat exchanger refrigerant outlet temperature sensor (T3) connection
6	CN10	Communication port for connection to hydronic system main PCB
7	CN30	Reserved
8	CN22	Electronic expansion valve drive port
9	CN1	Power input L
10	CN2	Power input N
11	CN3	Power output port to bridge rectifier live wire
12	CN4	Power output port for bridge rectifier neutral wire
13	CN7	Reserved
14	CN13	4-way valve drive port
15	CN14	Power supply to crankcase heater
16	CN26	Transformer power input
17	CN18	P/N/+18V power input
18	CN19	Lower fan control port
19	CN17	Upper fan control port
20	CN15	Transformer power output
21	SW2	Check button
22	SW1	Force cool button
23	DIS1	Digital display
24	CN11	Ground wire
25	CN6	Communication port for inverter module
26	CN16	Power supply to hydronic system main PCB
27	IC23	EEPROM
28	FS2	Fuse

Figure 4-2.5: outdoor unit inverter module

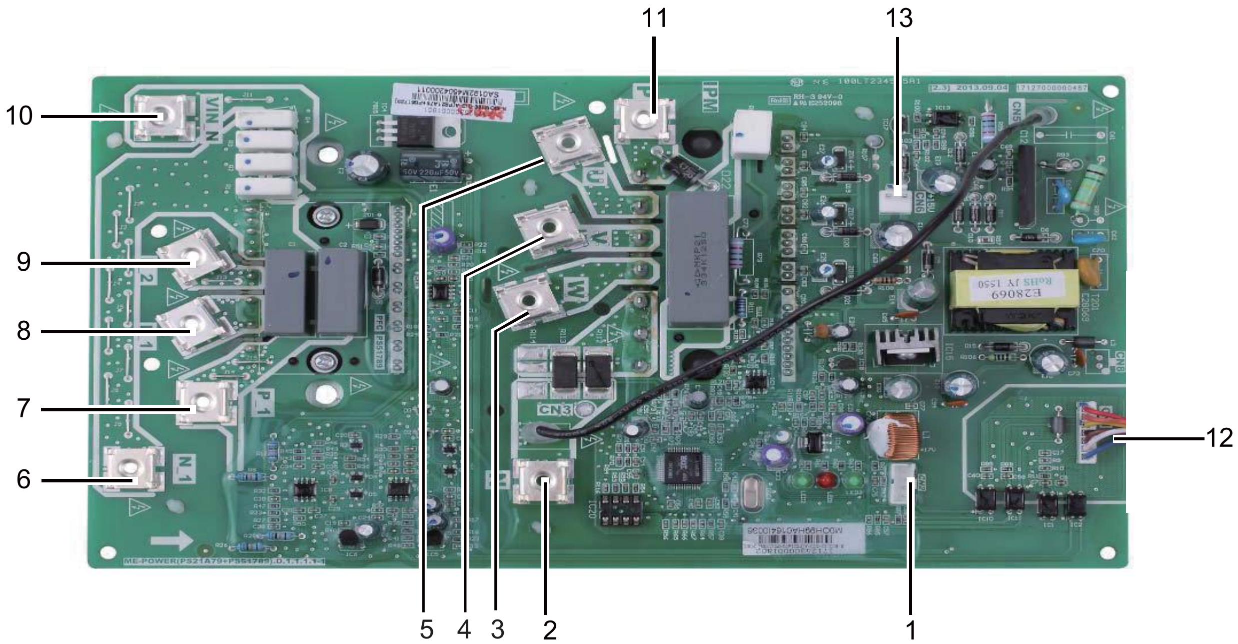
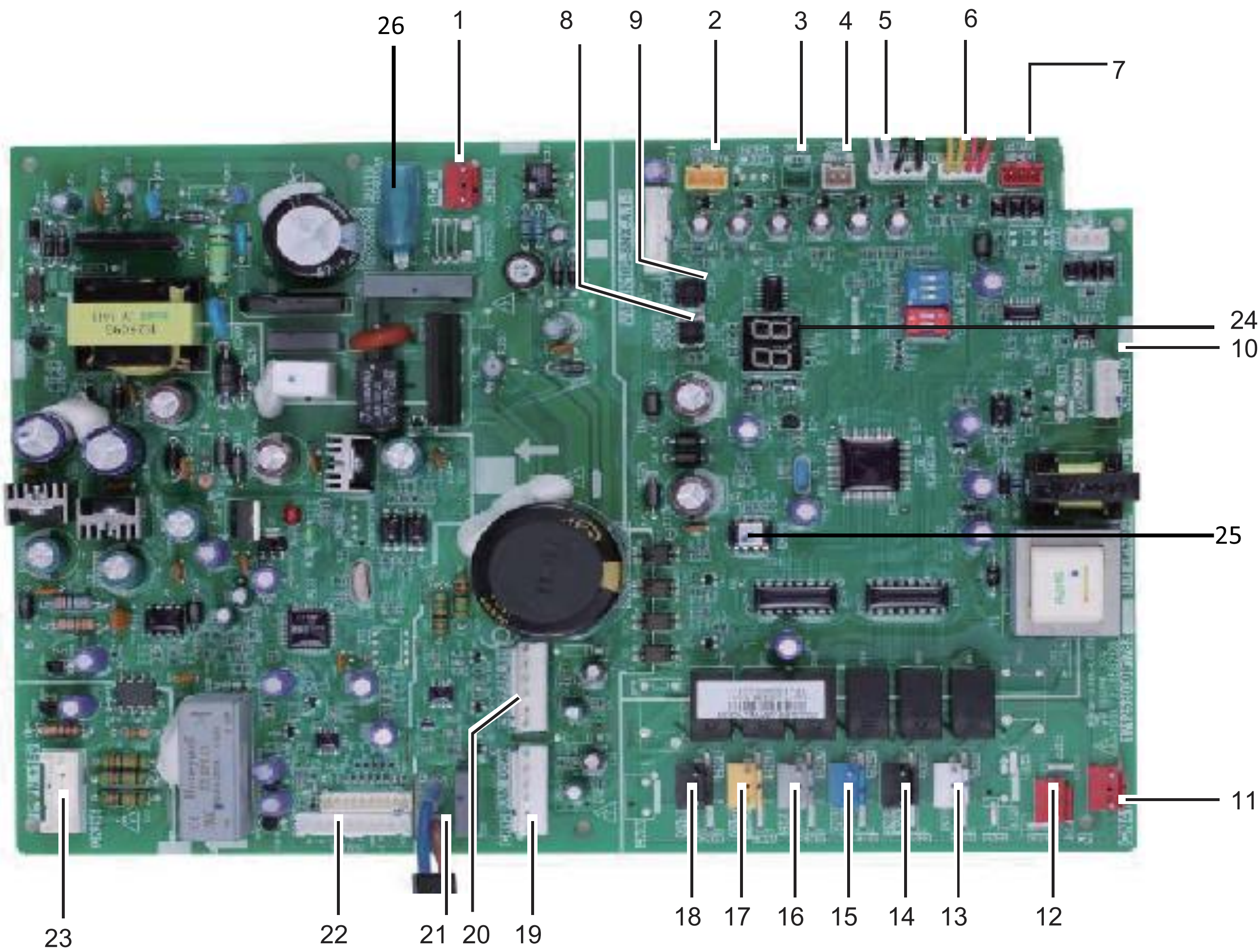


Table 4-2.5: outdoor unit inverter module

Label in Figure 4-2.5	Code	Content
1	CN2	Reserved
2	N	IPM module input port N
3	W	Compressor connections
4	V	
5	U	
6	N_1	PFC module output port N
7	P_1	PFC module output port P
8	L_1	Power input port for PFC inductor
9	L_2	Power input port for PFC inductor
10	VIN-N	Input port N for PFC module
11	P	IPM module input port P
12	CN1	Connections to main PCB for refrigerant system
13	CN6	+15V

Models 10 to 16kW (3Ph)

Figure 4-2.6: outdoor unit main PCB for refrigerant system [1]

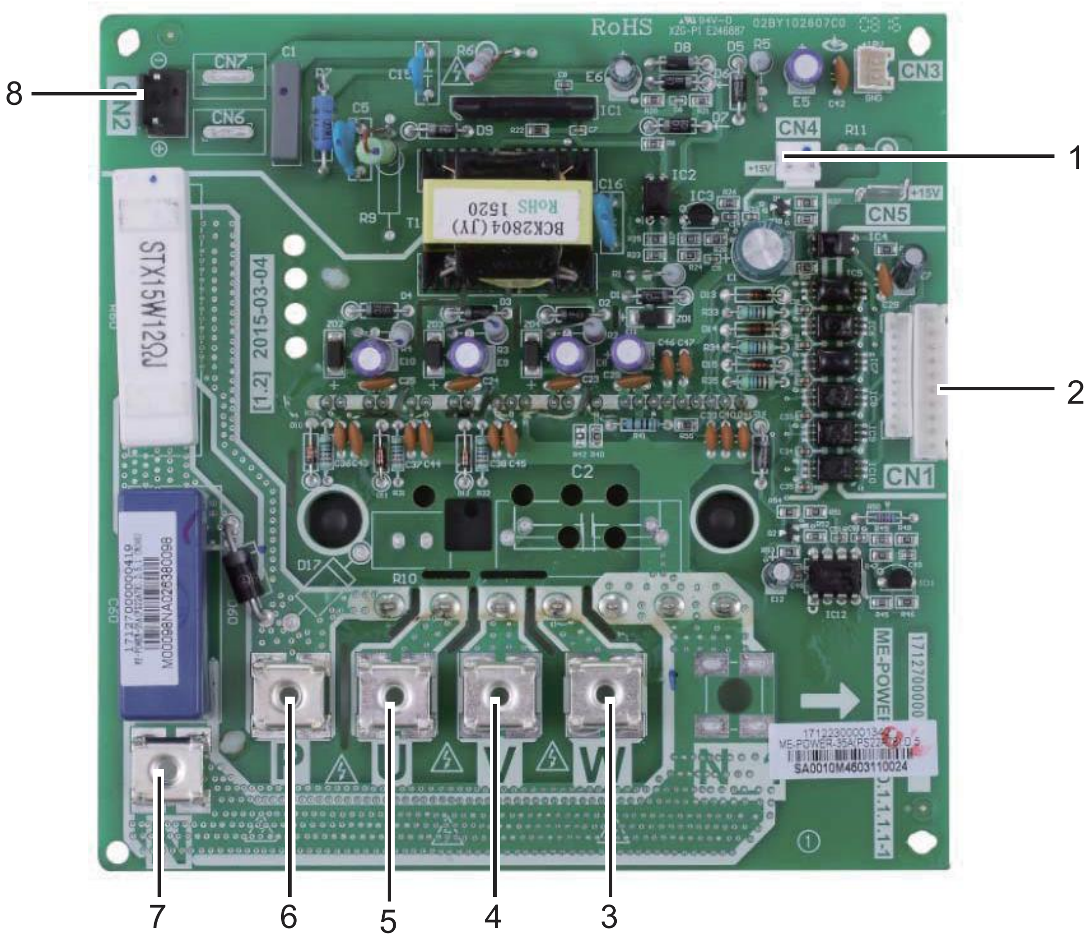


Notes:

1. Label descriptions are given in Table 4-2.6.

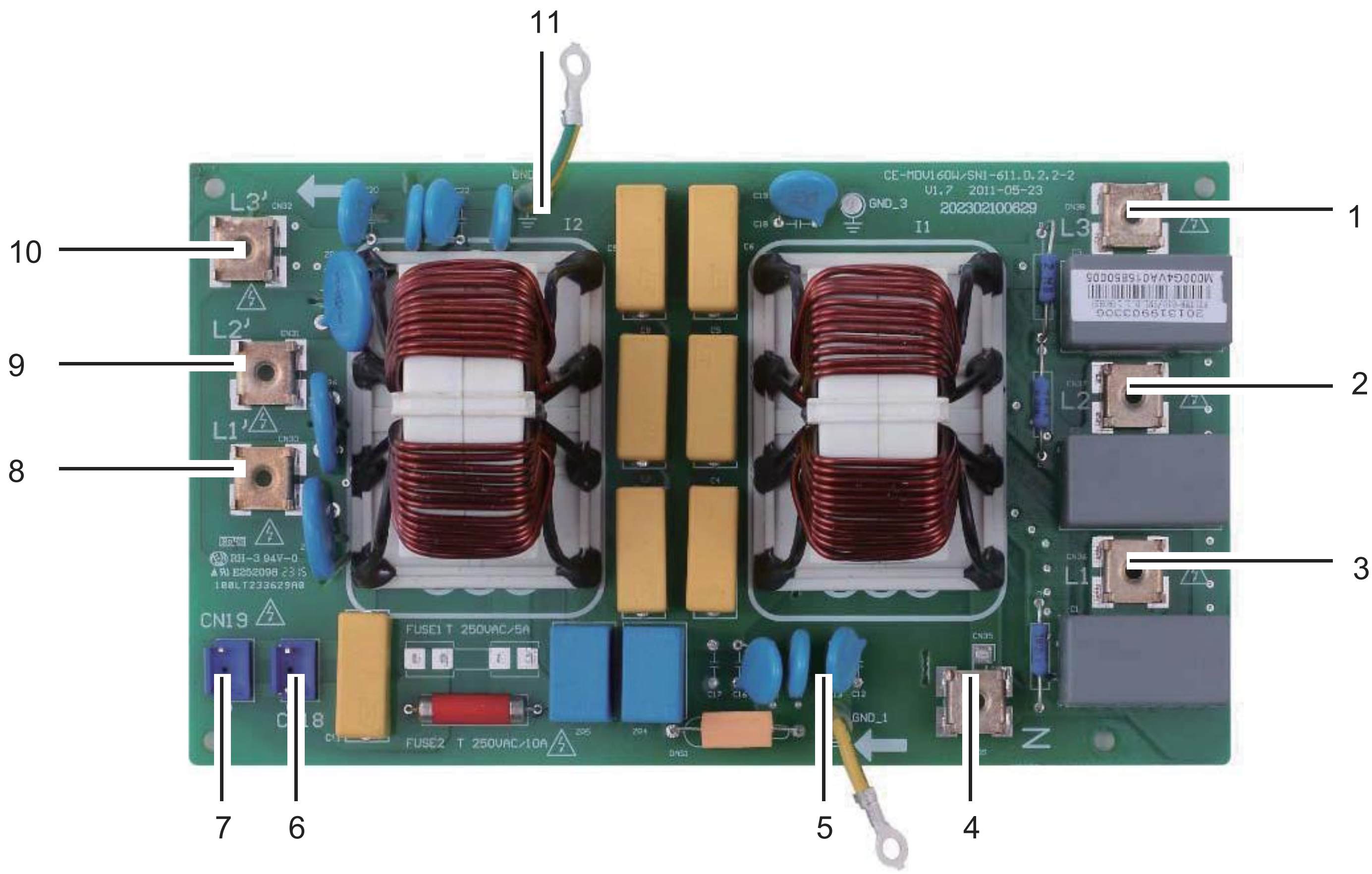
Label in Figure 4-2.6	Code	Content
1	CN250	Power supply for the main PCB
2	CN36	Port for pressure sensor
3	CN4	Port for suction temperature sensor
4	CN8	Port for discharge temperature
5	CN9	White: Outdoor ambient temperature sensor (T4) connection Black: Air side heat exchanger refrigerant outlet temperature sensor (T3) connection
6	CN6	Yellow: High pressure switch Red: Low pressure switch
7	CN10	Communicate port between hydronic system PCB and main PCB of refrigerant system
8	SW1	Force cool button
9	SW2	Check button
10	CN22	Port for electrical expansion value
11	CN41	Port for power supply
12	CN4	Power supply for hydronic system
13	CN63	PFC control port
14	CN64	Reserved
15	CN65	Port for 4-way valve
16	CN66	Port for electric heating tape
17	CN67	PTC control
18	CN68	Reserved
19	CN19	Port for down fan
20	CN17	Port for up fan
21	CN70, CN71	Power supply port for module
22	CN201	Communication port for IPDU
23	CN205	F Port for voltage check
24	DIS1	Digital Displays
25	IC23	EEPROM
26	FUSE51	Fuse

Figure 4-2.7: outdoor unit inverter module



Label in Figure 4-2.7	Code	Content
1	CN4	+15V port
2	CN1	MCU connection
3	W	Compressor connections
4	V	
5	U	
6	P	IPM module input port P
7	N	IPM module input port N
8	CN2	Refrigerant system main PCB connection

Figure 4-2.8: outdoor unit filter board



Label in Figure 4-2.8	Code	Content
1	L3	Power supply L3
2	L2	Power supply L2
3	L1	Power supply L1
4	N	Power supply N
5	GND_1	Ground wire
6	CN18	Power supply for load such as 4-way valve and crank heater of compressor
7	CN19	Power supply for refrigerant system main control board
8	L1’	Power filtering output L1
9	L2’	Power filtering output L2
10	L3’	Power filtering output L3
11	GND_1	Ground wire

2.4 Check Buttons

2.4.1 Main PCB for hydronic system SW4 system check button

Button SW4 is used to check the parameters of the hydronic system. Refer to Table 4-2.1 First, press Button SW4 for 3 seconds and the first parameter (operating mode) will be displayed. Then, on each subsequent press, the next parameter is displayed.

Table 4-2.9: SW4 system check

Number	Parameters displayed on digital display	Remarks
1	Operating mode	0: off; 2: cooling; 3: heating; 5: DHW.
2	Output requirement before correction (kW)	Actual value = value displayed
3	Corrected output requirement (kW)	Actual value = value displayed
4	M-Thermal Mono leaving water temperature (°C)	Actual value = value displayed
5	Auxiliary heating source leaving water temperature (°C)	Actual value = value displayed
6	Target leaving water temperature calculated from climate-related curves (°C)	Actual value = value displayed
7	Room temperature (°C)	Actual value = value displayed
8	DHW tank temperature (°C)	Actual value = value displayed
9	Heating mode: Water side heat exchanger refrigerant inlet temperature (°C) Cooling mode: Water side heat exchanger refrigerant outlet temperature (°C)	Actual value = value displayed
10	Heating mode: Water side heat exchanger refrigerant outlet temperature (°C) Cooling mode: Water side heat exchanger refrigerant inlet temperature (°C)	Actual value = value displayed
11	Water side heat exchanger water outlet temperature (°C)	Actual value = value displayed
12	Water side heat exchanger water inlet temperature (°C)	Actual value = value displayed
13	Outdoor ambient temperature (°C)	▪ When no decimal point is displayed: • Temperature is ≥ -9°C • Actual value = value displayed ▪ When decimal point is displayed between the two digits: • Temperature is ≤ -10°C • Actual value = value displayed x -10 • Example: “1.2” indicates -12°C
14	Backup electric heater first element current (A)	Actual value = value displayed
15	Backup electric heater second element current (A)	Actual value = value displayed
16	Most recent code	“--” is displayed if no error or protection events have occurred since start-up
17	Error or protection code previous to most recent code	“--” is displayed if no error or protection events have occurred since start-up
18	Error or protection code previous to 17	“--” is displayed if no error or protection events have occurred since start-up
19	Hydronic system main PCB software version	
20	----	

2.4.2 Main PCB for refrigerant system SW2 system check button

Button SW2 is used to check the parameters of the refrigerant system. Refer to Table 4-2.2 First, press Button SW2 for 3 seconds and the first parameter (operating mode) will be displayed. Then, on each subsequent press, the next parameter is displayed.

Table 4-2.10: SW2 system check

Number	Parameters displayed on digital display	Remarks
1	Operating mode	0: standby; 2: cooling; 3: heating; 4 forced cooling.
2	Fan speed index	Refer to Note 1
3	Compressor target speed command from hydronic system (rps)	Actual value = value displayed
4	Compressor target speed after restriction by the compressor output control (rps)	Actual value = value displayed
5	Heating mode: Air side heat exchanger refrigerant inlet temperature (°C) Cooling mode: Air side heat exchanger refrigerant outlet temperature (°C)	Actual value = value displayed
6	Outdoor ambient temperature (°C)	▪ When no decimal point is displayed: • Temperature is ≥ -9°C • Actual value = value displayed ▪ When decimal point is displayed between the two digits: • Temperature is ≤ -10°C • Actual value = value displayed x -10 • Example: “1.2” indicates -12°C
7	Discharge temperature (°C)	When the temperature < 100 °C, actual value = value displayed. When the temperature ⩾ 100 °C, actual value = value displayed × 10
8	Suction temperature (°C)	Actual value = value displayed
9	EXV position	Steps = value displayed × 8
10	Compressor current (A)	Actual value = value displayed
11	DC voltage	Actual value = value displayed × 10
12	Air side heat exchanger refrigerant pressure (MPa)	Actual value = value displayed
13	Refrigerant system main PCB software version	
14	Most recent error or protection code	“nn” is displayed if no error or protection events have occurred since start-up
15	--	

Notes:

1. The fan speed index is related to the fan speed in rpm as described in Table 3-5.3 in Part 3, 5.6 “Outdoor Fan Control”.

2.4.3 Digital Display Output

Table 4-2.11: Digital display output in different operating states

Outdoor unit state	Parameters displayed on hydronic system DSP1	Parameters displayed on refrigerant system DSP1	
On standby	0	0	
Normal operation	Leaving water temperature (°C)	Running speed of the compressor in rotations per second	
Error or protection	Error or protection code	Error or protection code	
System check	Refer to Table 4-2.9	Refer to Table 4-2.10	

3 Error Code Table

Table 4-3.1: Error code table

Error code	Content[1]	Displayed on	Remarks
E0, E8	Water flow failure	User interface and hydronic system main PCB	
E1	Phase sequence error	User interface and refrigerant system main PCB	Only applies to 3-phase models
E2	Communication error between outdoor unit and user interface	User interface and hydronic system main PCB	
E3	Backup electric heater exchanger water outlet temperature sensor error	User interface and hydronic system main PCB	Sensor T1
E4	Domestic hot water tank temperature sensor error	User interface and hydronic system main PCB	Sensor T5
E5	Air side heat exchanger refrigerant outlet temperature sensor error	User interface and refrigerant system main PCB	Sensor T3
E6	Outdoor ambient temperature sensor error	User interface and refrigerant system main PCB	Sensor T4
E9	Suction pipe temperature sensor error	User interface and refrigerant system main PCB	Sensor Th
EA	Discharge pipe temperature sensor error	User interface and refrigerant system main PCB	Sensor Tp
Ed	Water side heat exchanger water inlet temperature sensor error	User interface and hydronic system main PCB	Sensor Tw_in
EE	Hydronic system EEPROM error	User interface and hydronic system main PCB	
H0	Communication error between refrigerant system main control chip and hydronic system main control chip	User interface, refrigerant system main PCB and hydronic system main PCB	
H1	Communication error between refrigerant system main control chip and inverter driver chip	User interface and refrigerant system main PCB	
H2	Water side heat exchanger refrigerant outlet (gas pipe) temperature sensor error	User interface and hydronic system main PCB	Sensor T2B
H3	Water side heat exchanger refrigerant inlet (liquid pipe) temperature sensor error	User interface and hydronic system main PCB	Sensor T2
H5	Room temperature sensor error	User interface and hydronic system main PCB	Sensor Ta
H6, HH	DC fan error	User interface and refrigerant system main PCB	
H7	Abnormal main circuit voltage	User interface and refrigerant system main PCB	
H8	Pressure sensor error	User interface and refrigerant system main PCB	

Notes:

1. Sensor names in this service manual referring to refrigerant flow is named according refrigerant flow during cooling operation refer to Part 2, 3 “Refrigerant Flow Diagrams”.

Table continued on next page …

Table 4-3.1: Error code table *(continued)*

H9	Auxiliary heat source water outlet temperature sensor error	User interface and hydronic system main PCB	Sensor T1B
HA	Water side heat exchanger water outlet temperature sensor error	User interface and hydronic system main PCB	Sensor Tw_out
HF	Refrigerant system EEPROM error	User interface and refrigerant system main PCB	
P0, HP	Low pressure protection	User interface and refrigerant system main PCB	
P1	High pressure protection	User interface and refrigerant system main PCB	
P3	Compressor current protection	User interface and refrigerant system main PCB	
P4	Discharge temperature protection	User interface and refrigerant system main PCB	
P5	High temperature difference between water side heat exchanger water inlet and water outlet temperatures protection	User interface and hydronic system main PCB	
P6	Inverter module protection	User interface	Displayed on user interface when any of L0, L1, L2, L4, L5, L7, L8 or L9 occur
L0	Inverter module protection	Refrigerant system main PCB	
L1	DC bus low voltage protection	Refrigerant system main PCB	
L2	DC bus high voltage protection	Refrigerant system main PCB	
L4	MCE error	Refrigerant system main PCB	
L5	Zero speed protection	Refrigerant system main PCB	
L7	Phase sequence error	Refrigerant system main PCB	
L8	Compressor frequency variation greater than 15Hz within one second protection	Refrigerant system main PCB	
L9	Actual compressor frequency differs from target frequency by more than 15Hz protection	Refrigerant system main PCB	
Pb	Water side heat exchanger anti-freeze protection	User interface and hydronic system main PCB	
Pd	High temperature protection of refrigerant outlet temperature of condenser in cooling mode	User interface and refrigerant system main PCB	
PP	Water side heat exchanger inlet temperature is higher than outlet temperature in heating mode	user interface and hydronic system main PCB	

4 Troubleshooting

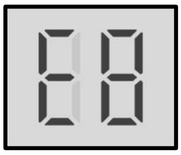
4.1 Warning

Warning ⚠

- All electrical work must be carried out by competent and suitably qualified, certified and accredited professionals and in accordance with all applicable legislation (all national, local and other laws, standards, codes, rules, regulations and other legislation that apply in a given situation).
- Power-off the outdoor units before connecting or disconnecting any connections or wiring, otherwise electric shock (which can cause physical injury or death) may occur or damage to components may occur.

4.2 E0, E8 Troubleshooting

4.2.1 Digital display output



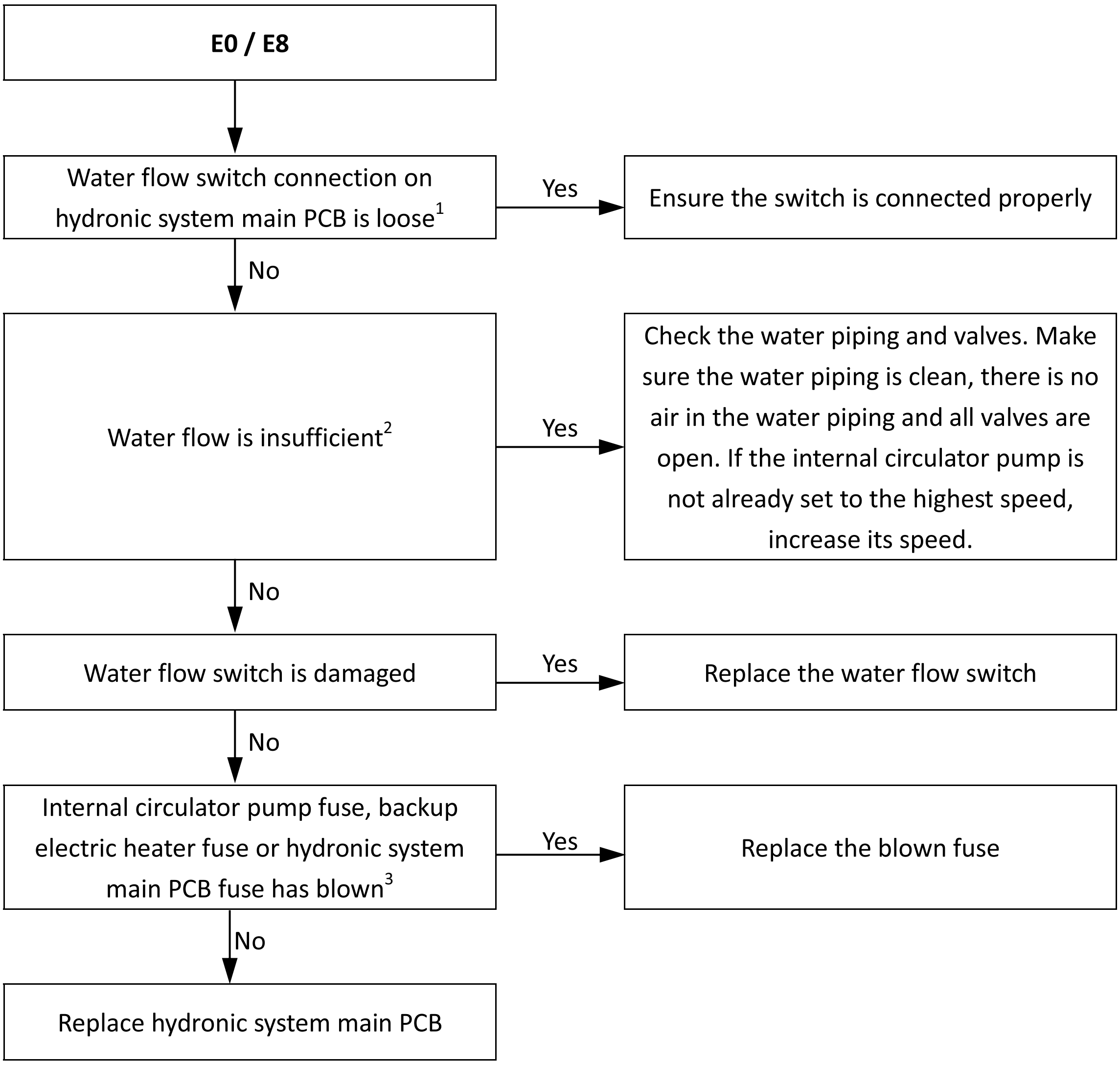
4.2.2 Description

- Water flow failure.
- E0 indicates E8 has displayed 3 times. When an E0 error occurs, a manual system restart is required before the system can resume operation.
- M-Thermal Mono stops running.
- Error code is displayed on hydronic system main PCB and user interface.

4.2.3 Possible causes

- The wire circuit is short connected or open.
- Water flow rate is too low.
- Water flow switch damaged.

4.2.4 Procedure



Notes:
1. Water flow switch connection is port CN8 on the main PCB for hydronic system (labeled 5 in Figure 4-2.1 in Part 4, 2.2 “Main PCB for Hydronic System”).
2. Check water pressure on the manometer. If the water pressure is not > 1 bar, water flow is insufficient. Refer to Figure 2-1.2 and 2-1.6 in Part 2, 1 “Layout of Functional Components”.
3. The fuse is labeled 30 in Figure 4-2.1 in Part 4, 2.2 “Main PCB for Hydronic System”.

4.3 E1 Troubleshooting

4.3.1 Digital display output

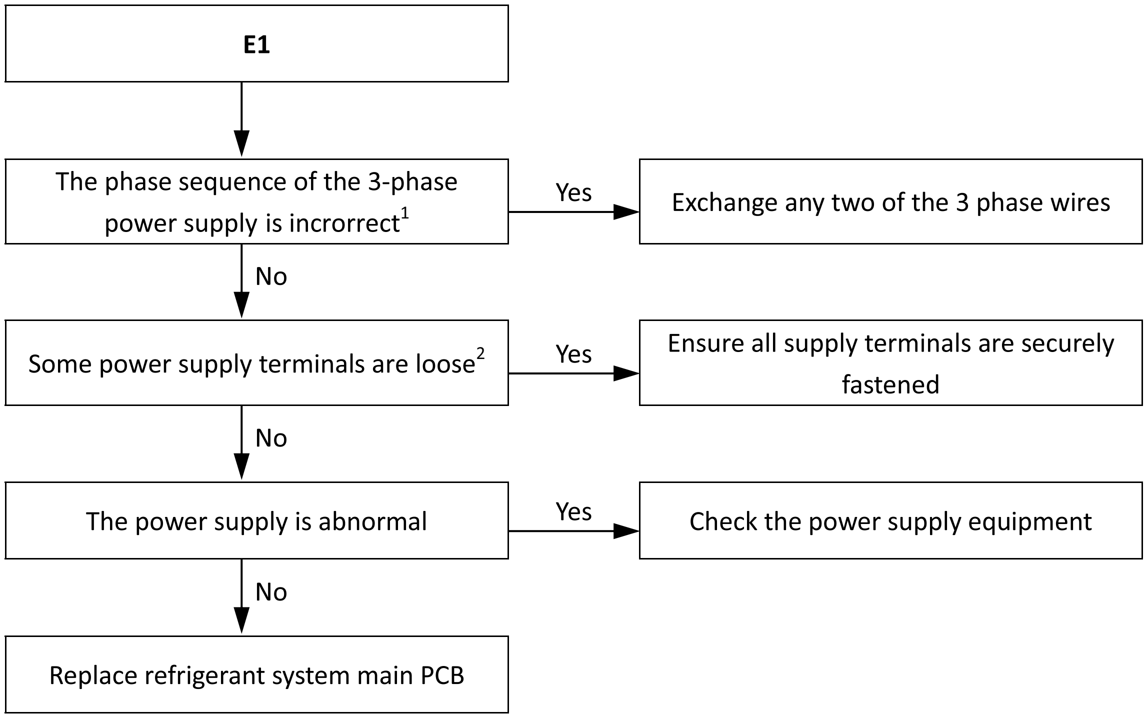
4.3.2 Description

- Phase sequence error.
- Only applies to 3-phase models.
- M-Thermal Mono stops running.
- Error code is displayed on refrigerant system main PCB and user interface.

4.3.3 Possible causes

- Power supply phases not connected in correct sequence.
- Power supply terminals loose.
- Power supply abnormal.
- Main PCB damaged.

4.3.4 Procedure



Notes:

1. The A, B, C terminals of 3-phase power supply should match compressor phase sequence requirements. If the phase sequence is inverted, the compressor will operate inversely. If the wiring connection of each outdoor unit is in A, B, C phase sequence, and multiple units are connected, the current difference between C phase and A, B phases will be very large as the power supply load of each outdoor unit will be on C phase. This can easily lead to tripped circuits and terminal wiring burnout. Therefore if multiple units are to be used, the phase sequence should be staggered, so that the current is distributed among the three phases equally.
2. Loose power supply terminals can cause the compressors to operate abnormally and compressor current to be very large.

4.4 E2 Troubleshooting

4.4.1 Digital display output

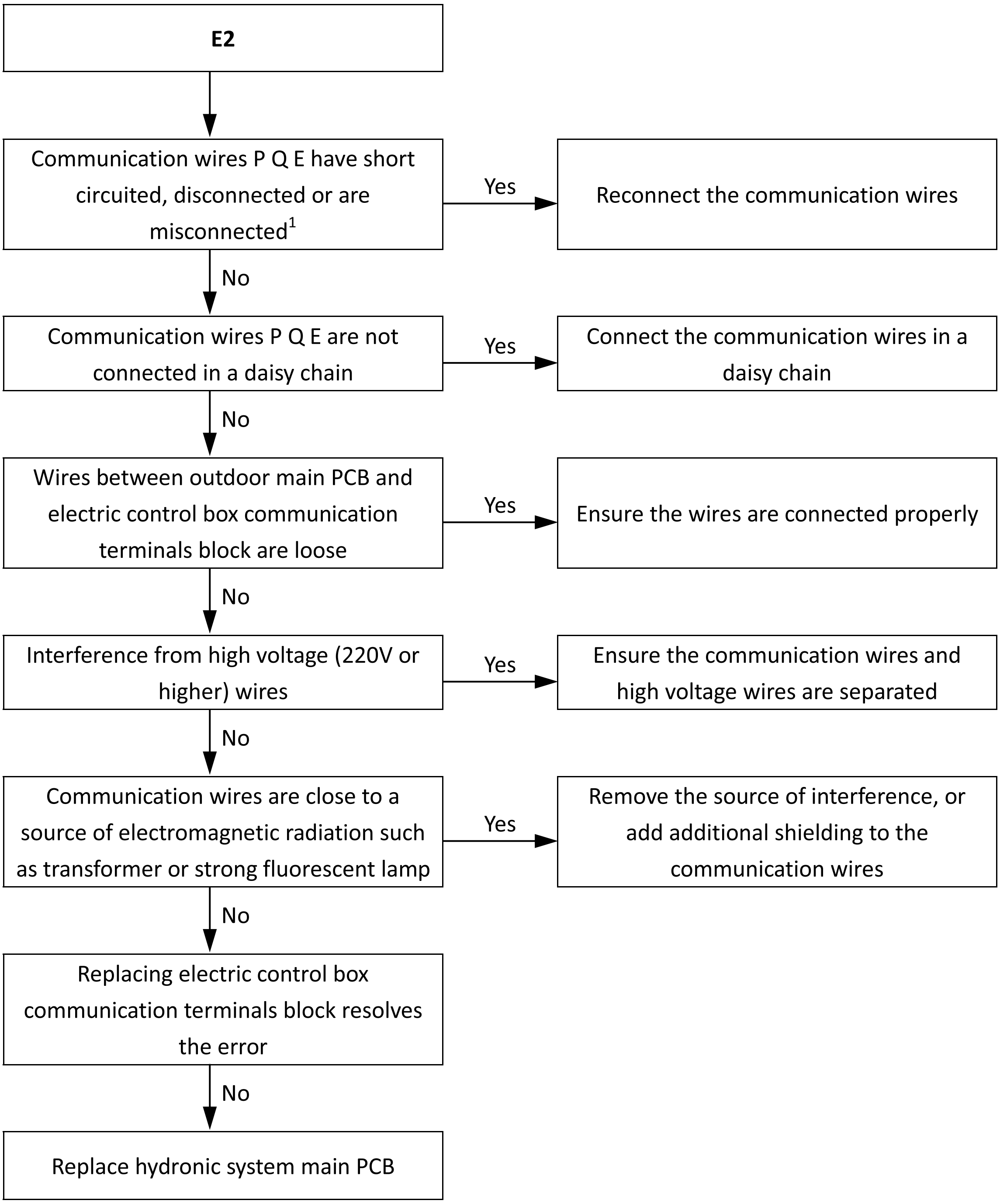
4.4.2 Description

- Communication error between outdoor unit and user interface.
- M-Thermal Mono stops running.
- Error code is displayed on hydronic system main PCB and user interface.

4.4.3 Possible causes

- Communication wires between outdoor unit and user interface not connected properly.
- Communication wiring P Q E terminals misconnected.
- Loosened wiring within electric control box.
- Interference from high voltage wires or other sources of electromagnetic radiation.
- Damaged main PCB or electric control box communication terminals block.

4.4.4 Procedure

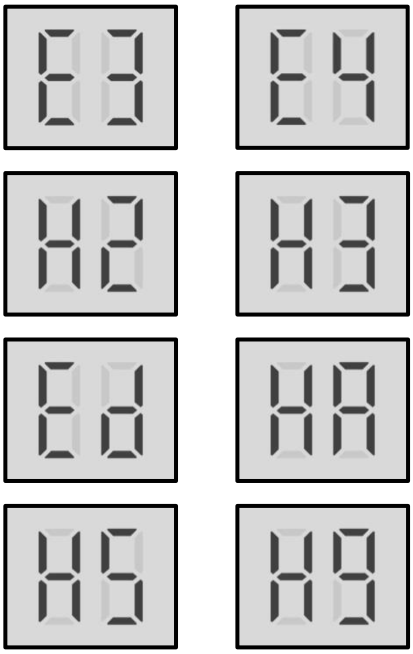


Notes:

1. Measure the resistance among P, Q and E. The normal resistance between P and Q is 120Ω, between P and E is infinite, between Q and E is infinite. Communication wiring has polarity. Ensure that the P wire is connected to P terminals and the Q wire is connected to Q terminals.

4.5 E3, E4, H2, H3, Ed, HA, H5, H9 Troubleshooting

4.5.1 Digital display output



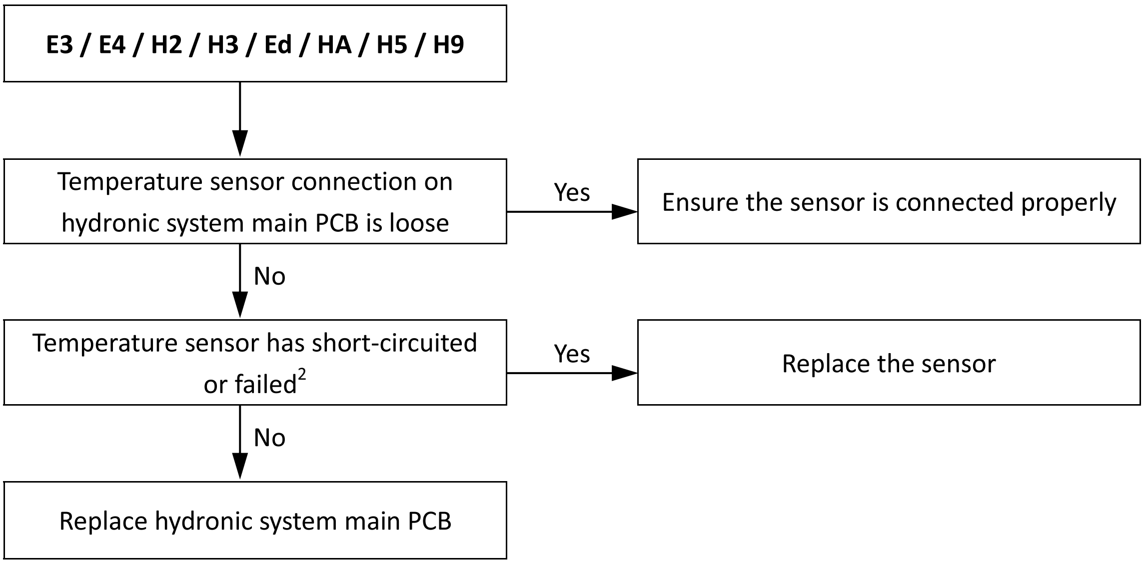
4.5.2 Description

- E3 indicates a backup electric heater water outlet temperature sensor error.
- E4 indicates a domestic hot water tank temperature sensor error.
- H2 indicates a water side heat exchanger refrigerant outlet (gas pipe) temperature sensor error.
- H3 indicates a water side heat exchanger refrigerant inlet (liquid pipe) temperature sensor error.
- Ed indicates a water side heat exchanger water inlet temperature sensor error.
- HA indicates a water side heat exchanger water outlet temperature sensor error.
- H5 indicates a room temperature sensor error.
- H9 indicates an auxiliary heat source water outlet temperature sensor error.
- M-Thermal Mono stops running.
- Error code is displayed on hydronic system main PCB and user interface.

4.5.3 Possible causes

- Temperature sensor not connected properly or has malfunctioned.
- Damaged hydronic system main PCB.

4.5.4 Procedure

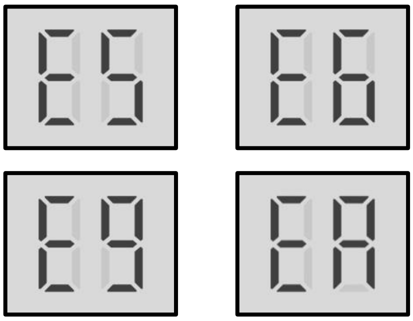


Notes:

1. Backup electric heater water outlet temperature sensor, water side heat exchanger refrigerant inlet (liquid pipe) temperature sensor, water side heat exchanger refrigerant outlet (gas pipe) temperature sensor, water side heat exchanger water inlet temperature sensor and water side heat exchanger water outlet temperature sensor connections are port CN6 on the hydronic system main PCB (labeled 8 in Figure 4-2.1 in Part 4, 2.2 "Main PCB for Hydronic System"). Domestic hot water tank temperature sensor connection is port CN13 on the hydronic system main PCB (labeled 9 in Figure 4-2.1 in Part 4, 2.2 "Main PCB for Hydronic System"). Auxiliary heat source water outlet temperature sensor connection is port CN15 on the hydronic system main PCB (labeled 10 in Figure 4-2.1 in Part 4, 2.2 "Main PCB for Hydronic System"). Room temperature sensor connection is port CN16 on the hydronic system main PCB (labeled 11 in Figure 4-2.1 in Part 54, 2.2 "Main PCB for Hydronic System").
2. Measure sensor resistance. If the resistance is too low, the sensor has short-circuited. If the resistance is not consistent with the sensor's resistance characteristics table, the sensor has failed. Refer to Table 4-5.1 or 4-5.3 in Part 4, 5.1 "Temperature Sensor Resistance Characteristics".

4.6 E5, E6, E9, EA Troubleshooting

4.6.1 Digital display output



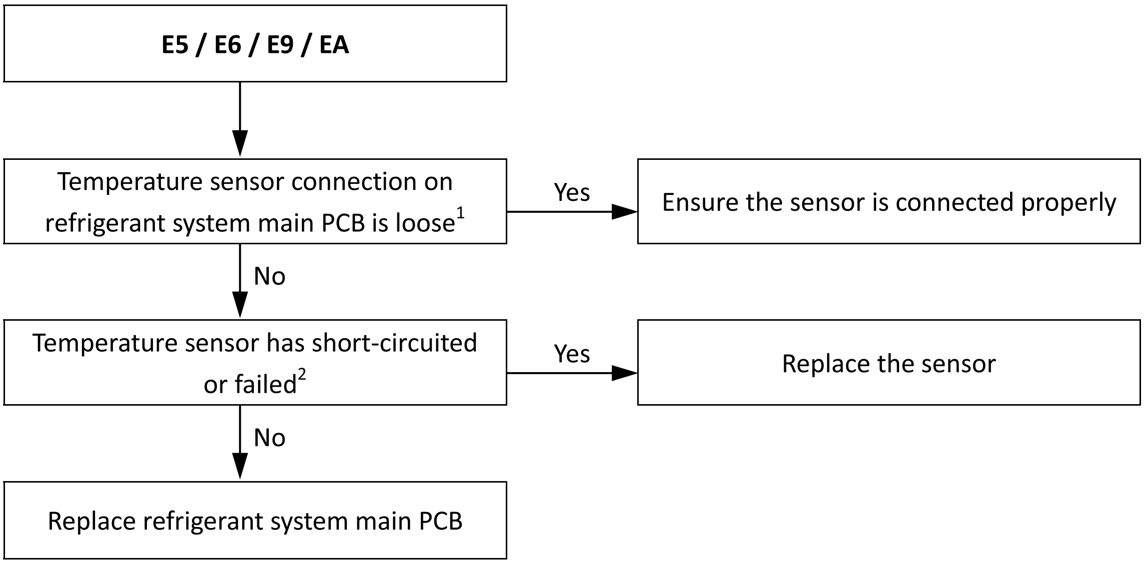
4.6.2 Description

- E5 indicates an air side heat exchanger refrigerant outlet temperature sensor error.
- E6 indicates an outdoor ambient temperature sensor error.
- E9 indicates a suction pipe temperature sensor error.
- EA indicates a discharge temperature sensor error.
- M-Thermal Mono stops running.
- Error code is displayed on refrigerant system main PCB and user interface.

4.6.3 Possible causes

- Temperature sensor not connected properly or has malfunctioned.
- Damaged refrigerant system main PCB.

4.6.4 Procedure

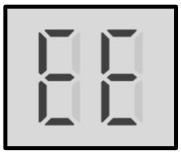


Notes:

1. Air side heat exchanger refrigerant outlet temperature sensor and outdoor ambient temperature sensor connections are port CN9 on the refrigerant system main PCB (labeled 7 in Figure 4-2.2 in Part 4, 2.3 "Main PCBs for Refrigerant System, Inverter Modules and Filter Boards", (labeled 5 in Figure 4-2.4 and Figure 4-2.6 in Part 4, 2.3 "Main PCBs for Refrigerant System, Inverter Modules and Filter Boards"). Discharge pipe temperature sensor connection is port CN8 on the refrigerant system main PCBs (labeled 8 in Figure 4-2.2 and labelled 4 in Figures 4-2.4 and 4-2.6 in Part 4, 2.3 "Main PCBs for Refrigerant System, Inverter Modules and Filter Boards"). Suction pipe temperature sensor connection is port CN11 on the models 5 and 7kW outdoor unit refrigerant system main PCB (labeled 8 in Figure 4-2.2 in Part 4, 2.3 "Main PCBs for Refrigerant System, Inverter Modules and Filter Boards"), port CN24 on the models 10 to 16kW (1Ph) outdoor unit refrigerant system main PCB (labeled 2 in Figure 4-2.4 in Part 4, 2.3 "Main PCBs for Refrigerant System, Inverter Modules and Filter Boards") and port CN4 on the models 10 to 16kW (3Ph) outdoor unit refrigerant system main PCB (labeled 3 in Figure 4-2.6 in Part 4, 2.3 "Main PCBs for Refrigerant System, Inverter Modules and Filter Boards").
2. Measure sensor resistance. If the resistance is too low, the sensor has short-circuited. If the resistance is not consistent with the sensor's resistance characteristics table, the sensor has failed. Refer to Table 4-5.1, and Table 4-5.2 in Part 4, 5.1 "Temperature Sensor Resistance Characteristics".

4.7 EE Troubleshooting

4.7.1 Digital display output



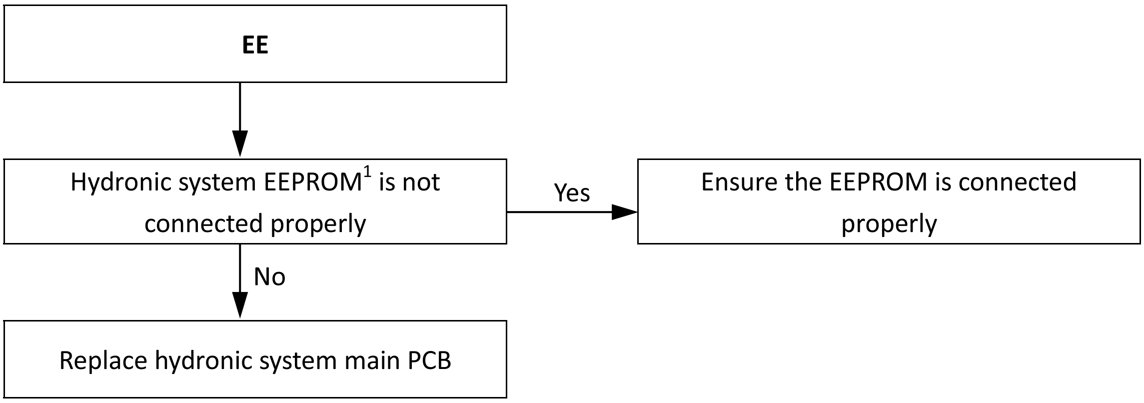
4.7.2 Description

- Hydronic system EEPROM error.
- M-Thermal Mono stops running.
- Error code is displayed on hydronic system main PCB and user interface.

4.7.3 Possible causes

- Hydronic system main PCB EEPROM is not connected properly.
- Hydronic system main PCB damaged.

4.7.4 Procedure



Notes:

1. Hydronic system main PCB EEPROM is designated IC18 on the hydronic system main PCB (labeled 29 in Figure 4-2.1 in Part 4, 2.2 "Main PCB for Hydronic System").

4.8 HF Troubleshooting

4.8.1 Digital display output

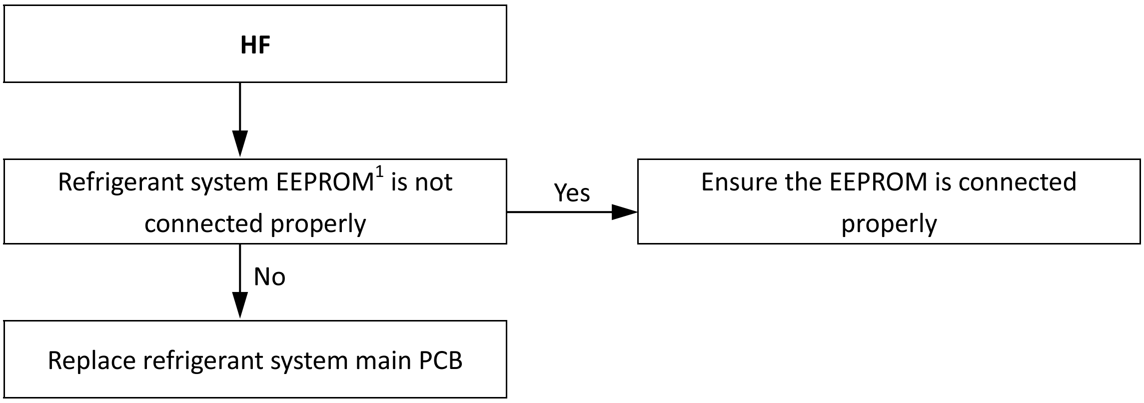
4.8.2 Description

- Refrigerant system EEPROM error.
- M-Thermal Mono stops running.
- Error code is displayed on refrigerant system main PCB and user interface.

4.8.3 Possible causes

- Refrigerant system main PCB EEPROM is not connected properly.
- Refrigerant system main PCB damaged.

4.8.4 Procedure



Notes:

1. Refrigerant system main PCB EEPROM is designated IC23 on the refrigerant system main PCBs (labeled 22 in Figure 4-2.2 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”, labeled 27 in Figure 4-2.4 in Part 4, 2.2 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”, labeled 25 in Figure 4-2.6 in Part 4, 2.2 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”).

4.9 H0 Troubleshooting

4.9.1 Digital display output

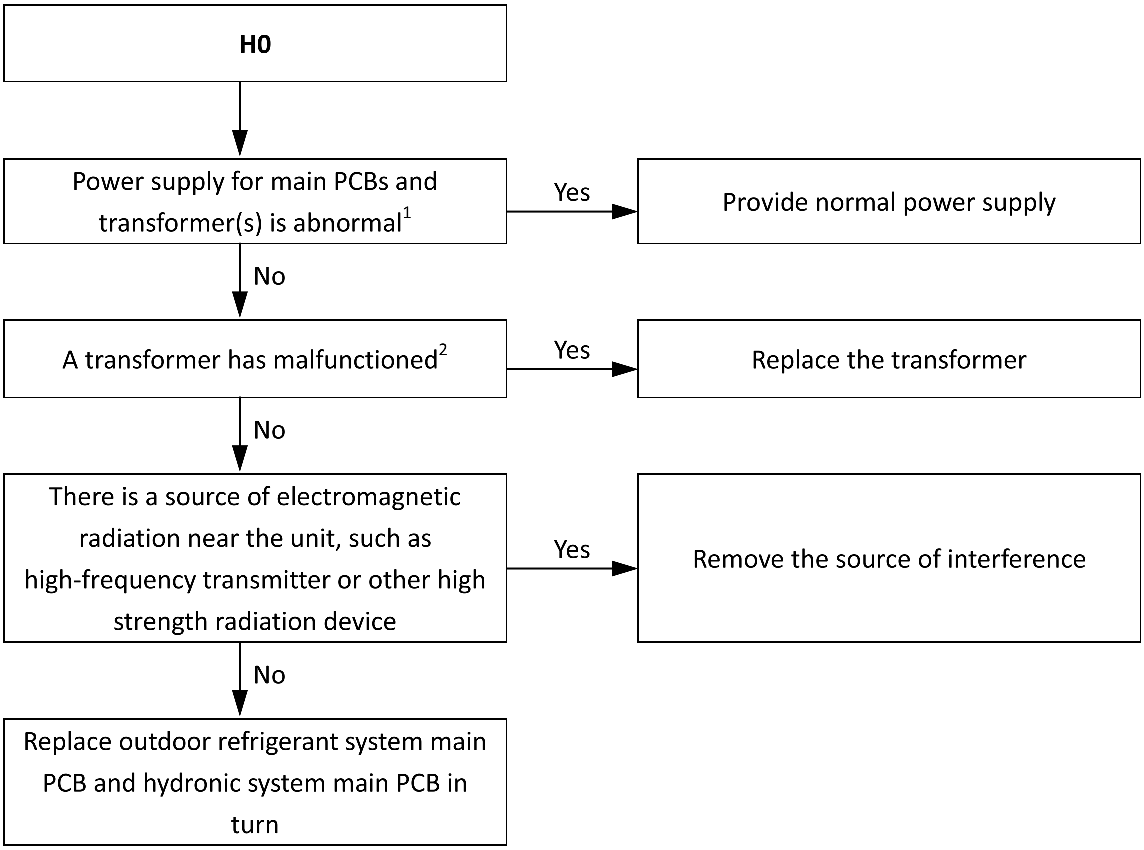
4.9.2 Description

- Communication error between refrigerant system main control chip and hydronic system main control chip.
- M-Thermal Mono stops running.
- Error code is displayed on hydronic system main PCB, refrigerant system main PCB and user interface.

4.9.3 Possible causes

- Power supply abnormal.
- Transformer malfunction.
- Interference from a source of electromagnetic radiation.
- Refrigerant system main PCB or hydronic system main PCB damaged.

4.9.4 Procedure



Notes:

1. Measure the voltages of transformer(s) input port and on the main PCB. The normal voltage between transformer input port terminals is 220V, between GND and 18V is 18V. If one or more of the voltages are not normal, the power supply for main PCB and transformer is abnormal.
2. Measure the voltages of transformer(s) output port ports. If the voltages are not normal, the transformer has malfunctioned.

4.10 H1 Troubleshooting

4.10.1 Digital display output

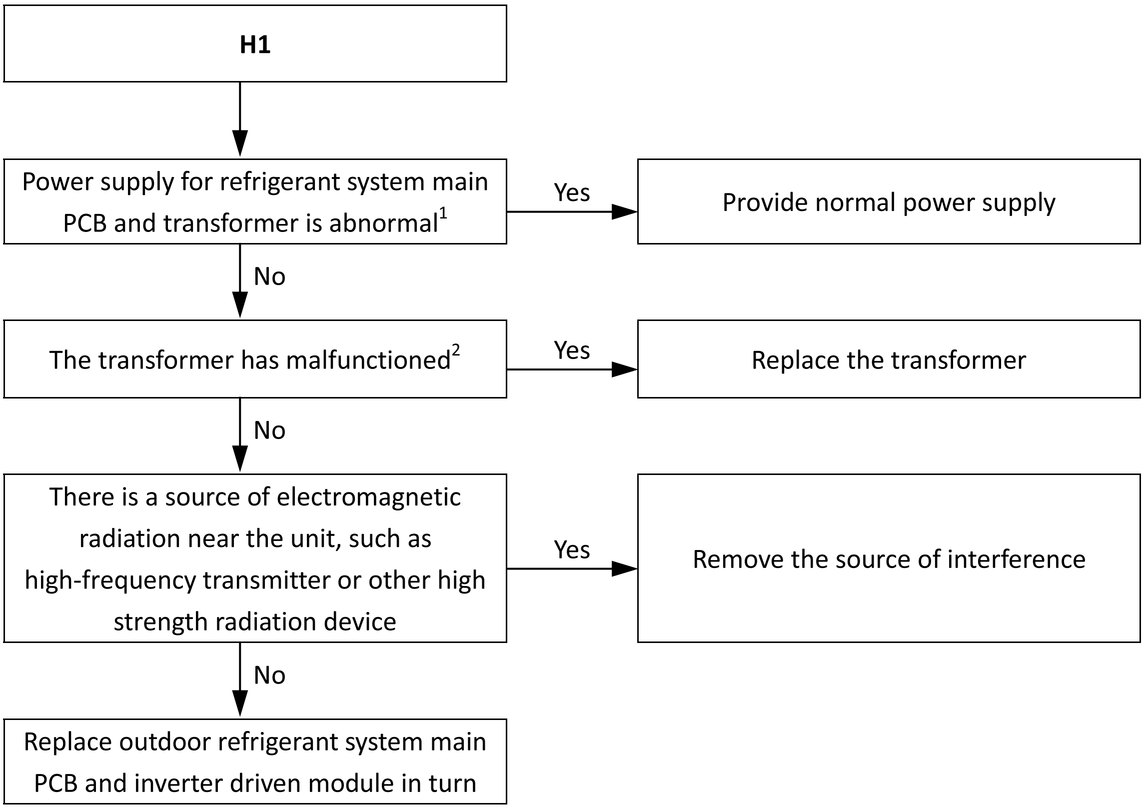
4.10.2 Description

- Communication error between refrigerant system main control chip and the inverter driver chip.
- M-Thermal Mono stops running.
- Error code H1 is displayed on refrigerant system main PCB and user interface.

4.10.3 Possible causes

- Power supply abnormal.
- Transformer malfunction.
- Interference from a source of electromagnetic radiation.
- Refrigerant system main PCB or inverter driven module damaged.

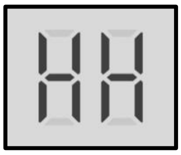
4.10.4 Procedure



Notes:
1. Measure the voltages of transformer input port and on the main PCB. The normal voltage between transformer input port terminals is 220V, between GND and 18V is 18V. If one or more of the voltages are not normal, the power supply for main PCB and transformer is abnormal.
2. Measure the voltages of transformer output port ports. If the voltages are not normal, the transformer has malfunctioned.

4.11 H6, HH Troubleshooting

4.11.1 Digital display output



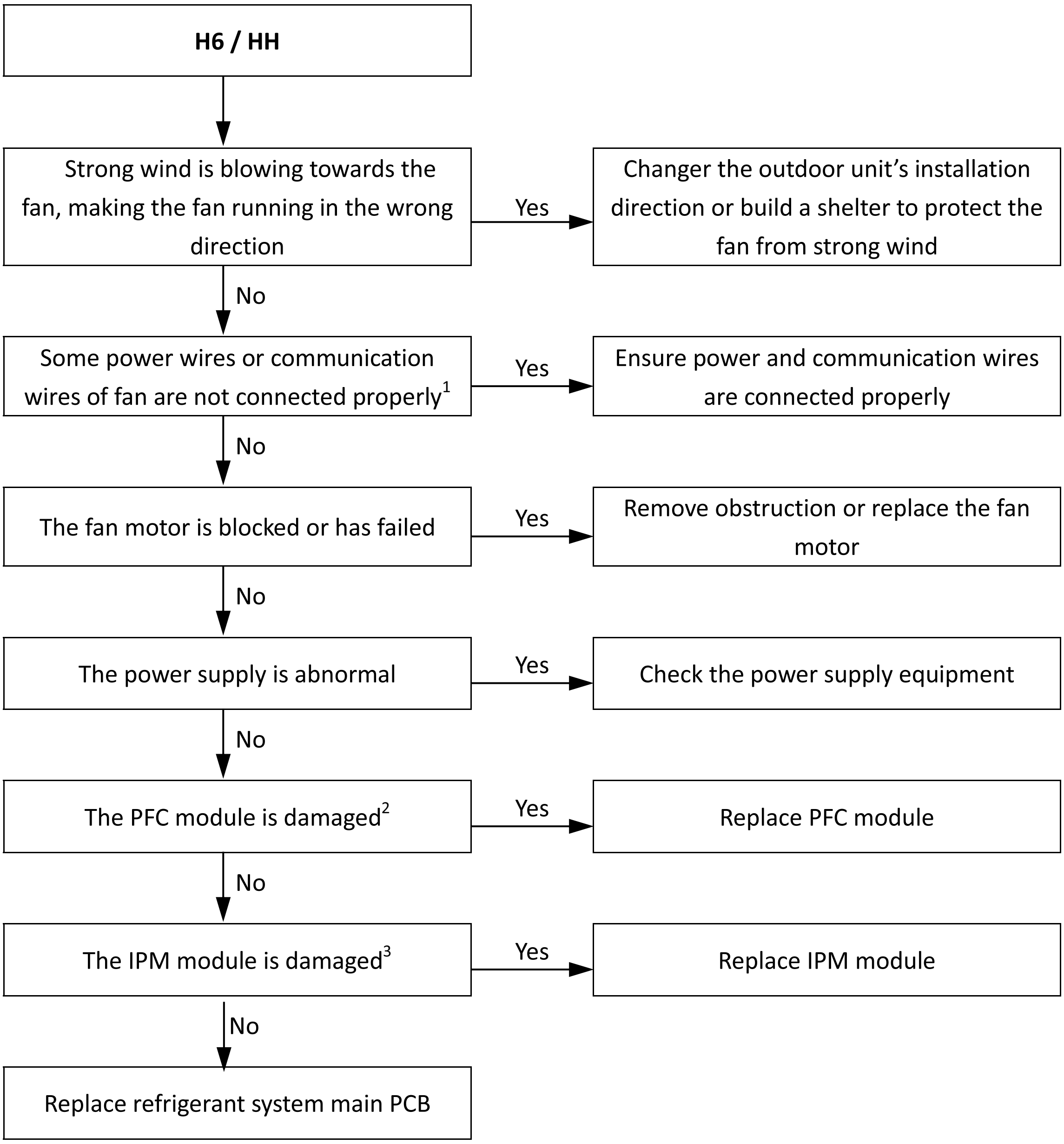
4.11.2 Description

- H6 indicates a DC fan error.
- HH indicates that H6 protection has occurred 10 times in 2 hours. When an HH error occurs, a manual system restart is required before the system can resume operation. The cause of an HH error should be addressed promptly in order to avoid system damage.
- M-Thermal Mono stops running.
- Error code is displayed on refrigerant system main PCB and user interface.

4.11.3 Possible causes

- Power or communication wires not connected properly.
- High wind speed.
- Fan motor blocked or has failed.
- Power supply abnormal.
- PFC module damaged.
- IPM module damaged.
- Main PCB damaged.

4.11.4 Procedure



Notes:

1. Refer to Figures 4-1.1 to 4-1.7 in Part 4, 1 "Outdoor Unit Electric Control Box Layout" and to the M-Thermal Mono Engineering Data Book, Part 2, 5 "Wiring Diagrams".
2. Only applies to single-phase power supply models. Check the voltage between "+" and "-" terminals on the PFC module on the inverter module. The normal range is 277V to 354V. If the voltage is outside this range, the PFC module is damaged.
3. Measure the voltage between the DC fan motor power supply's white and black wires. The normal voltage is 15V when the unit is in standby. If the voltage is significantly different from 15V, the IPM module on the inverter module is damaged. The fan connections on each type of refrigerant system main PCB are labelled in Figures 4-2.2, 4-2.4 and 4-2.6 in Part 4, 2.3 "Main PCBs for Refrigerant System, Inverter Modules and Filter Boards".

4.12 H7 Troubleshooting

4.12.1 Digital display output

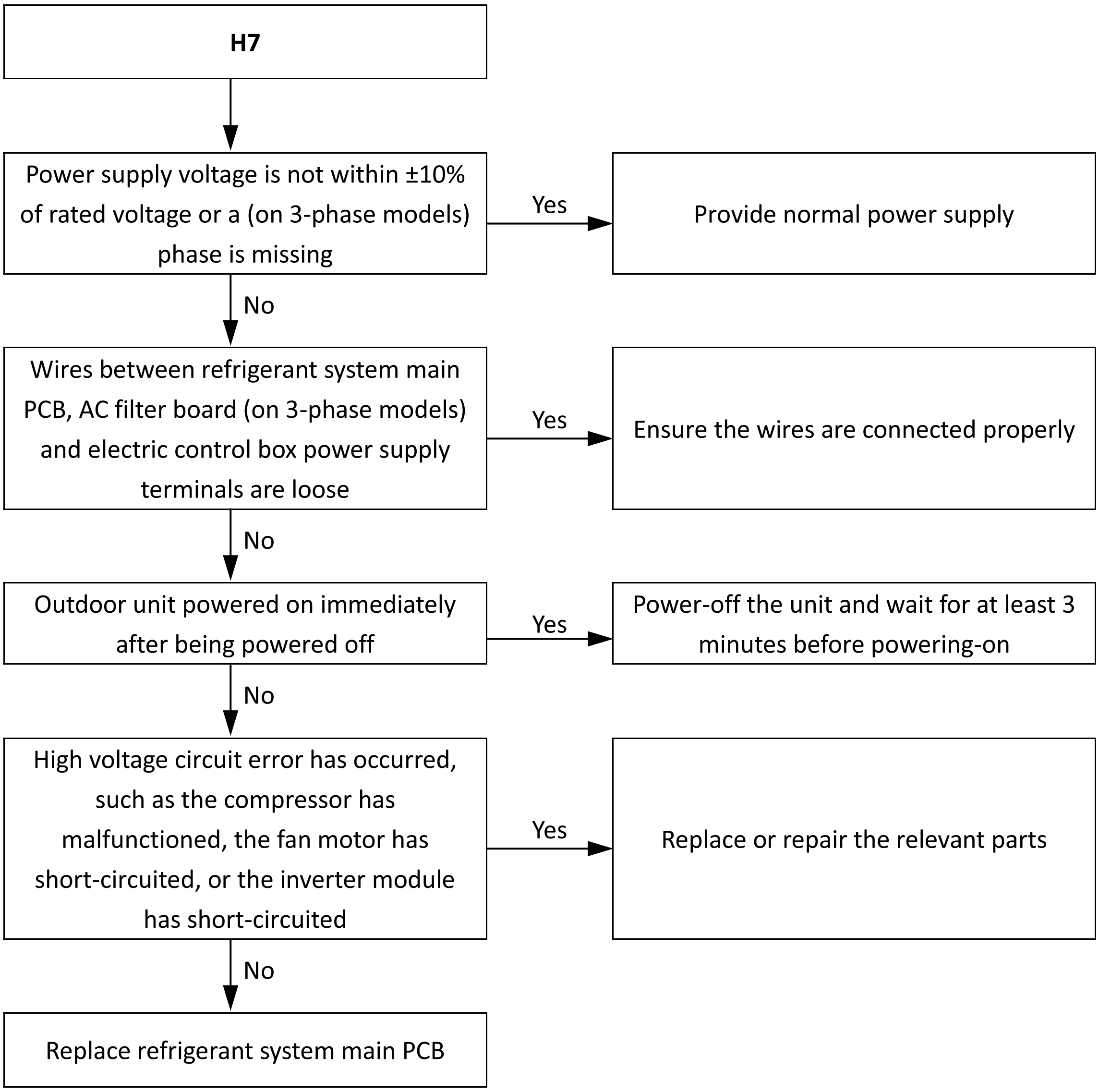
4.12.2 Description

- Abnormal main circuit voltage.
- M-Thermal Mono stops running.
- Error code is displayed on refrigerant system main PCB and user interface.

4.12.3 Possible causes

- Power supply voltage not within ±10% of rated voltage or a phase is missing.
- Outdoor unit powered on immediately after being powered off.
- Loosened wiring within electric control box.
- High voltage circuit error.
- Main PCB damaged.

4.12.4 Procedure



4.13 H8 Troubleshooting

4.13.1 Digital display output

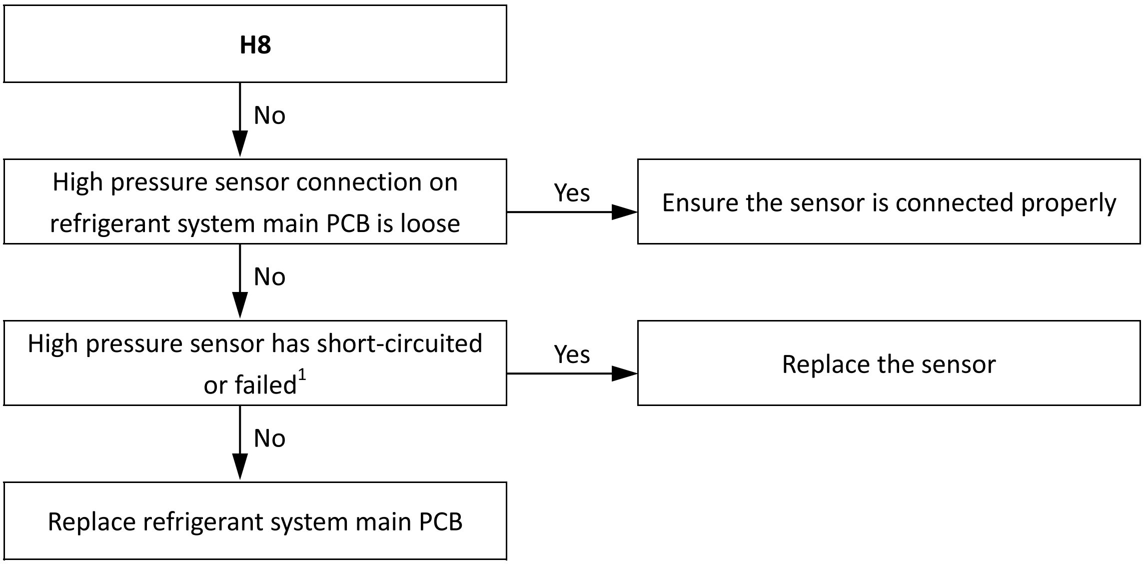
4.13.2 Description

- Pressure sensor error.
- M-Thermal Mono stops running.
- Error code is displayed on refrigerant system main PCB and user interface.

4.13.3 Possible causes

- Pressure sensor not connected properly or has malfunctioned.
- Refrigerant system main PCB damaged.

4.13.4 Procedure



Notes:

1. Measure the resistance among the three terminals of the pressure sensor. If the resistance is of the order of mega Ohms or infinite, the pressure sensor has failed. The pressure sensor connection on each type of refrigerant system main PCB is labelled in Figures 4-2.2, 4-2.4 and 4-2.6 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”. Refer also to Part 2, 1 “Layout of Functional Components”.

4.14 P0, HP Troubleshooting

4.14.1 Digital display output

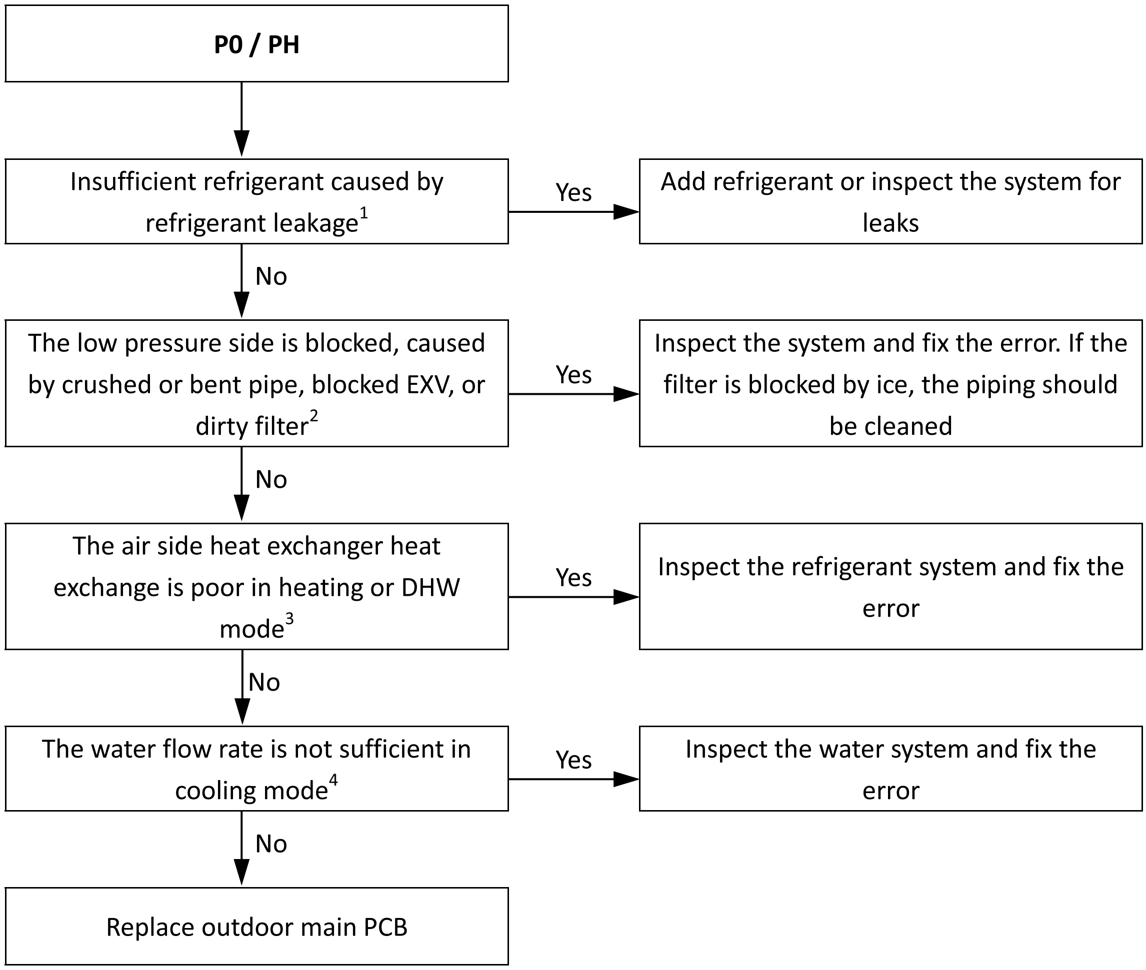
4.14.2 Description

- P0 indicates suction pipe low pressure protection. When the suction pressure falls below 0.05MPa, the system displays P0 protection and M-Thermal Mono stops running. When the pressure rises above 0.15MPa, P0 is removed and normal operation resumes.
- HP indicates P0 protection has occurred 3 times in 60 minutes. When an HP error occurs, a manual system restart is required before the system can resume operation.
- Error code is displayed on refrigerant system main PCB and user interface.

4.14.3 Possible causes

- Low pressure switch not connected properly or has malfunctioned.
- Insufficient refrigerant.
- Low pressure side blockage.
- Poor evaporator heat exchange in heating mode or DHW mode.
- Insufficient water flow in cooling mode.
- Main PCB damaged.

4.14.4 Procedure



Notes:

1. To check for insufficient refrigerant:
   - An insufficiency of refrigerant causes compressor discharge temperature to be higher than normal, discharge and suction pressures to be lower than normal and compressor current to be lower than normal, and may cause frosting to occur on the suction pipe. These issues disappear once sufficient refrigerant has been charged into the system.
2. A low pressure side blockage causes compressor discharge temperature to be higher than normal, suction pressure to be lower than normal and compressor current to be lower than normal, and may cause frosting to occur on the suction pipe. For normal system parameters.
3. Check air side heat exchanger, fan(s) and air outlets for dirt/blockages.
4. Check water side heat exchanger, water piping, circulator pumps and water flow switch for dirt/blockages.

4.15 P1 Troubleshooting

4.15.1 Digital display output

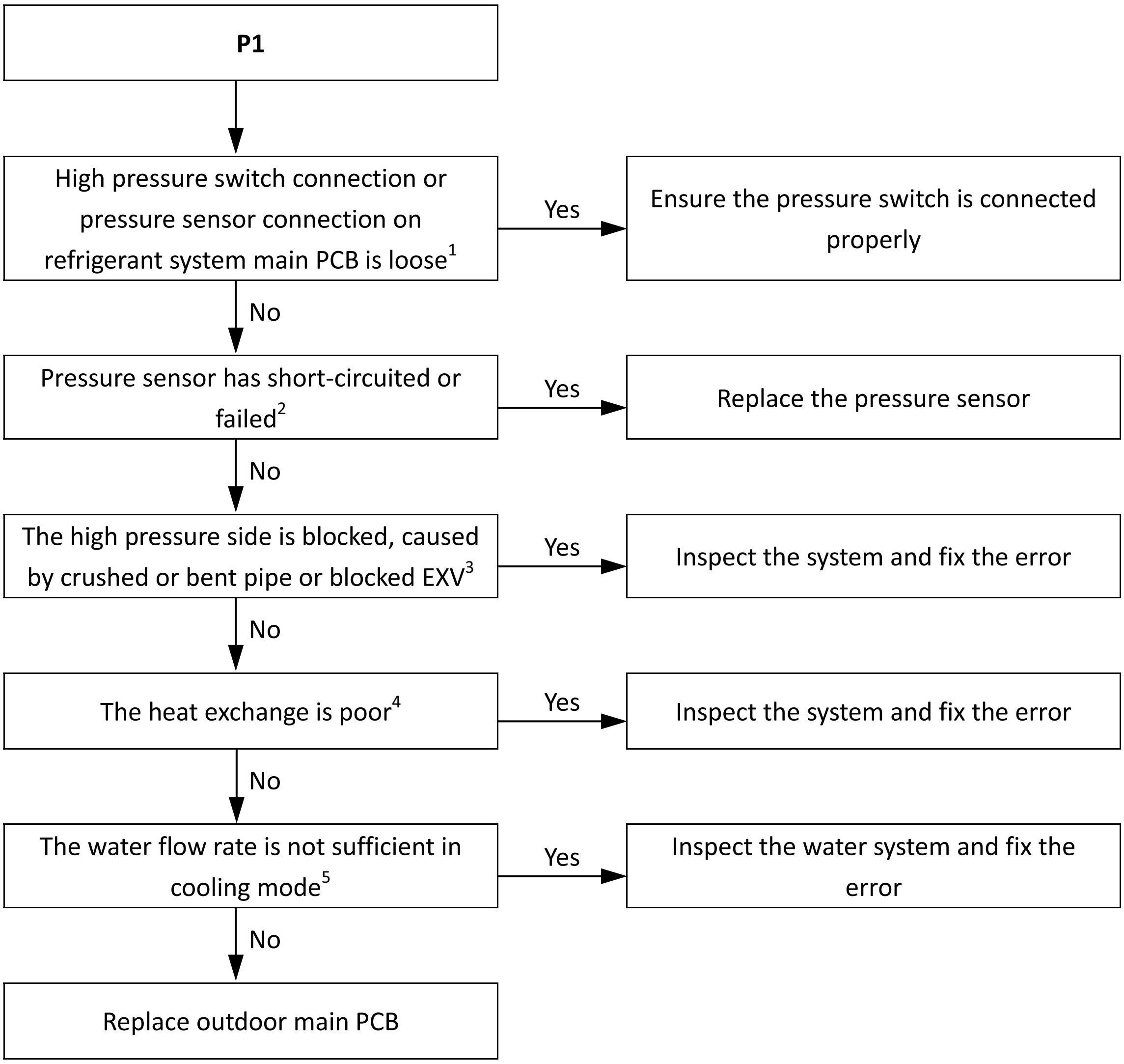
4.15.2 Description

- Discharge pipe high pressure protection. When the discharge pressure rises above 4.4MPa, the system displays P1 protection and M-Thermal Mono stops running. When the discharge pressure falls below 3.2MPa, P1 is removed and normal operation resumes.
- Error code is displayed on refrigerant system main PCB and user interface.

4.15.3 Possible causes

- Pressure sensor/switch not connected properly or has malfunctioned.
- Excess refrigerant.
- System contains air or nitrogen.
- High pressure side blockage.
- Poor condenser heat exchange.
- Main PCB damaged.

4.15.4 Procedure



Notes:

1. High pressure switch connection is port CN13 on the models 5 and 7kW refrigerant system main PCB (labeled 9 in Figure 4-2.2 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”), port CN12 on the models 10 to 16kW (1Ph) refrigerant system main PCB (labeled 1 in Figure 4-2.4 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”) and port CN6 on the models 10 to 16kW (3Ph) refrigerant system main PCB (labeled 6 in Figure 4-2.6 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”). Pressure sensor connection is port CN14 on the models 5 and 7kW refrigerant system main PCB (labeled 11 in Figure 4-2.2 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”), port CN28 on the models 10 to 16kW (1Ph) refrigerant system main PCB (labeled 2 in Figure 4-2.4 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”) and port CN36 on the models 10 to 16kW (3Ph) refrigerant system main PCB (labeled 2 in Figure 4-2.6 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”).
2. Measure the resistance among the three terminals of the pressure sensor. If the resistance is of the order of mega Ohms or infinite, the pressure sensor has failed.
3. High pressure side blockage causes discharge temperature to be higher than normal, discharge pressure to be higher than normal and suction pressure to be lower than normal.
4. In heating mode check water side heat exchanger, water piping, circulator pumps and water flow switch for dirt/blockages. In cooling mode check air side heat exchanger, fan(s) and air outlets for dirt/blockages.
5. Check water pressure on the manometer. If the water pressure is not > 1 bar, water flow is insufficient. Refer to Figure 2-1.2 and 2-1.6 in Part 2, 1 “Layout of Functional Components”.

4.16 P3 Troubleshooting

4.16.1 Digital display output

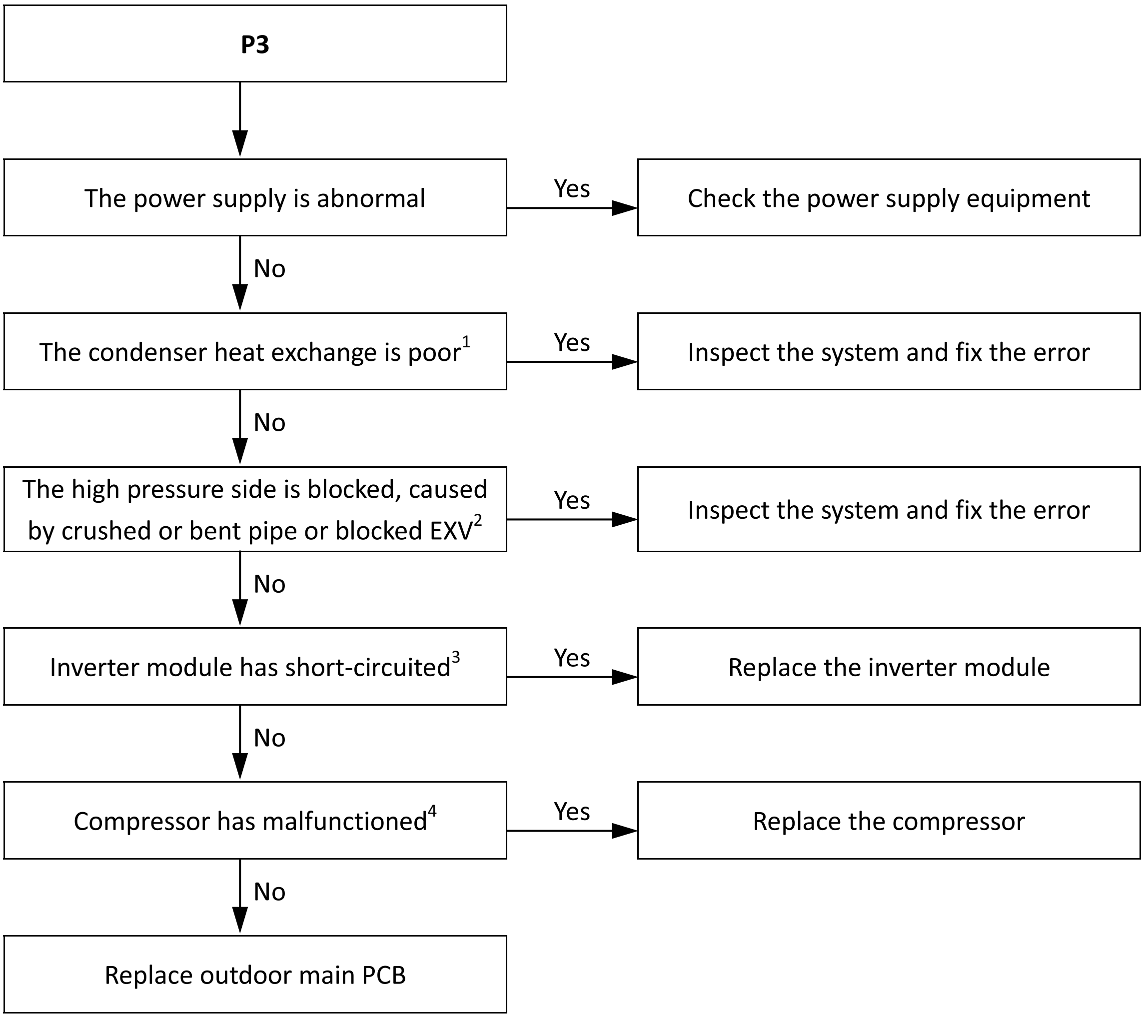
4.16.2 Description

- Compressor current protection.
- When the compressor current rises above the protection value (Single phase 5/7kW models 20A, single phase 10 to 16kW models 31A, three phase models 15A), the system displays P3 protection and M-Thermal Mono stops running. When the current returns to the normal range, P3 is removed and normal operation resumes.
- Error code is displayed on refrigerant system main PCB and user interface.

4.16.3 Possible causes

- Power supply abnormal.
- Poor condenser heat exchange.
- High pressure side blockage.
- Inverter module damaged.
- Compressor damaged.
- Main PCB damaged.

4.16.4 Procedure



Notes:

1. In heating mode check water side heat exchanger, water piping, circulator pumps and water flow switch for dirt/blockages. In cooling mode check air side heat exchanger, fan(s) and air outlets for dirt/blockages.
2. High pressure side blockage causes discharge temperature to be higher than normal, discharge pressure to be higher than normal and suction pressure to be lower than normal.
3. Set a multi-meter to buzzer mode and test any two terminals of P N and U V W of the inverter module. If the buzzer sounds, the inverter module has short-circuited.
4. The normal resistances of the inverter compressor are 0.7-1.5Ω among U V W and infinite between each of U V W and ground. If any of the resistances differ from these specifications, the compressor has malfunctioned.

4.17 P4 Troubleshooting

4.17.1 Digital display output

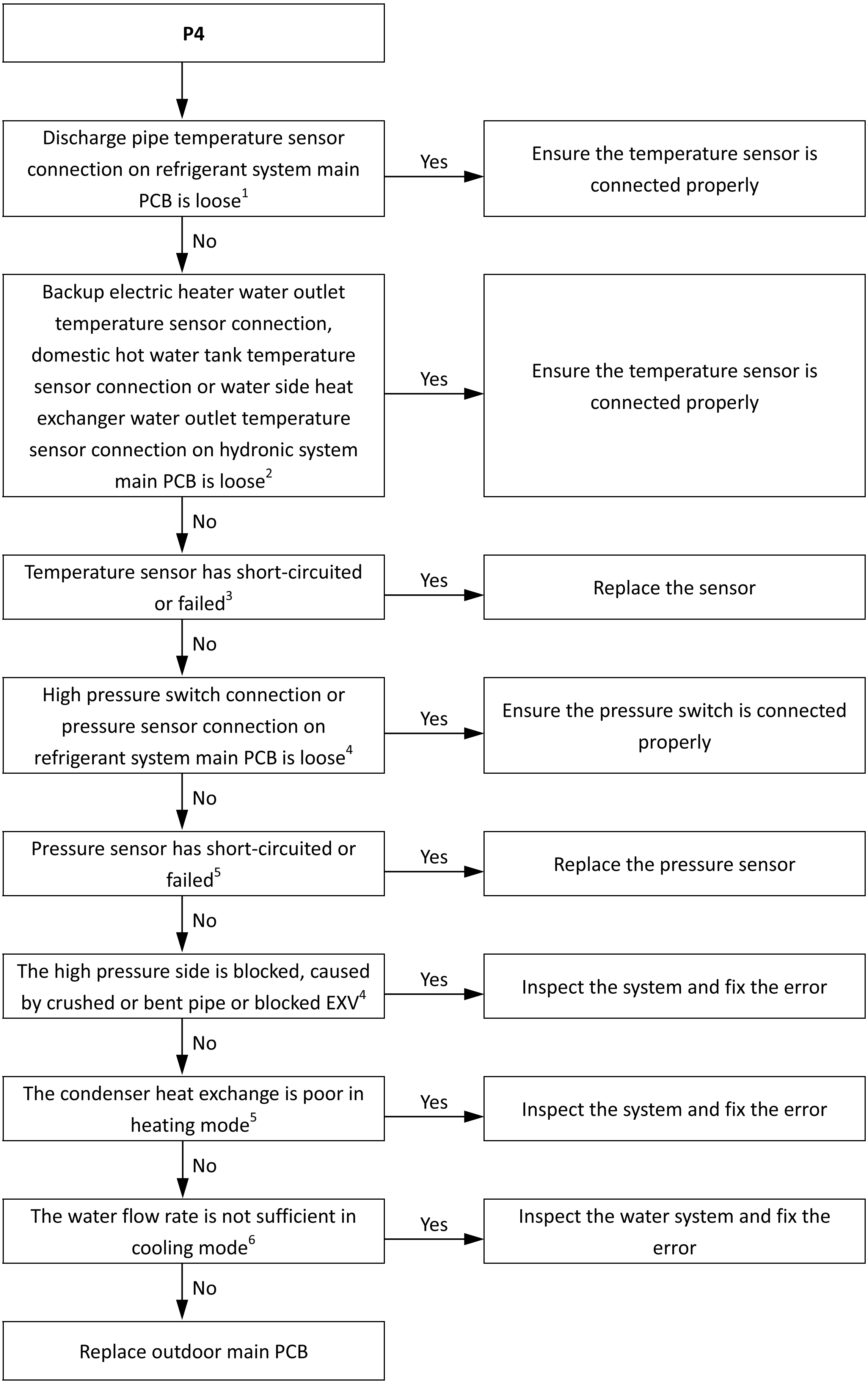
4.17.2 Description

- Discharge temperature protection.
- When the compressor the discharge temperature rises above 115°C, the system displays P4 protection and M-Thermal Mono stops running. When the discharge temperature falls below 83°C, P4 is removed and normal operation resumes.
- Error code is displayed on refrigerant system main PCB and user interface.

4.17.3 Possible causes

- Temperature sensor error
- High pressure side blockage.
- Poor condenser heat exchange.
- Main PCB damaged.

4.17.4 Procedure



Notes:

1. Discharge pipe temperature sensor connection is port CN8 on the refrigerant system main PCBs (labeled 8 in Figure 4-2.2 and labelled 4 in Figures 4-2.4

and 4-2.6 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”).

2. Backup electric heater water outlet temperature sensor and water side heat exchanger water outlet temperature sensor connections are port CN6 on the hydronic system main PCB (labeled 8 in Figure 4-2.1 in Part 4, 2.2 “Main PCB for Hydronic System”). Domestic hot water tank temperature sensor connection is port CN13 on the hydronic system main PCB (labeled 9 in Figure 4-2.1 in Part 4, 2.2 “Main PCB for Hydronic System”).
3. Measure sensor resistance. If the resistance is too low, the sensor has short-circuited. If the resistance is not consistent with the sensor’s resistance characteristics table, the sensor has failed. Refer to Part 2, 1 “Layout of Functional Components” and to Table 5-5.1 or 5-5.2 in Part 5, 5.1 “Temperature Sensor Resistance Characteristics”.
4. High pressure switch connection is port CN13 on the models 5 and 7kW refrigerant system main PCB (labeled 9 in Figure 4-2.2 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”), port CN12 on the models 10 to 16kW (1Ph) refrigerant system main PCB (labeled 1 in Figure 4-2.4 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”) and port CN6 on the models 10 to 16kW (3Ph) refrigerant system main PCB (labeled 6 in Figure 4-2.6 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”). Pressure sensor connection is Pressure sensor connection is port CN14 on the models 5 to 7kW refrigerant system main PCB (labeled 11 in Figure 4-2.2 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”), port CN28 on the models 10 to 16kW (1Ph) refrigerant system main PCB (labeled 2 in Figure 4-2.4 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”) and port CN36 on the models 10 to 16kW (3Ph) refrigerant system main PCB (labeled 2 in Figure 4-2.6 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”).
5. Measure the resistance among the three terminals of the pressure sensor. If the resistance is of the order of mega Ohms or infinite, the pressure sensor has failed.
6. High pressure side blockage causes discharge temperature to be higher than normal, discharge pressure to be higher than normal and suction pressure to be lower than normal.
7. Check air side heat exchanger, fan(s) and air outlets for dirt/blockages.
8. Check the water side heat exchanger, water piping, circulator pumps and water flow switch for dirt/blockages.

4.18 P5 Troubleshooting

4.18.1 Digital display output

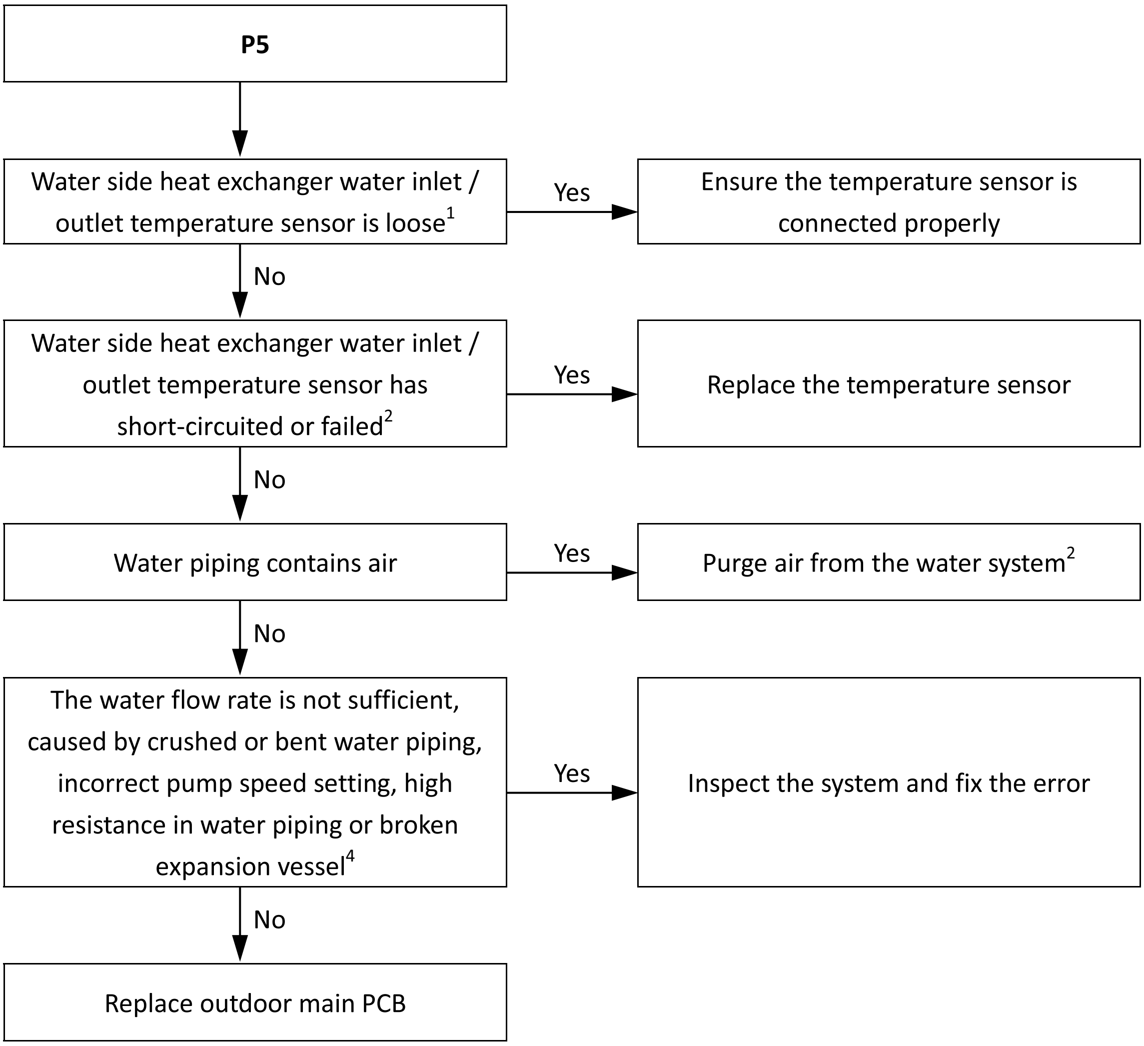
4.18.2 Description

- High temperature difference between water side heat exchanger water inlet and water outlet temperatures protection.
- M-Thermal Mono stops running.
- Error code is displayed on hydronic system main PCB and user interface.

4.18.3 Possible causes

- Temperature sensor not connected properly or has malfunctioned.
- Water piping contains air.
- Insufficient water flow.
- Hydronic system main PCB damaged.

4.18.4 Procedure



Notes:

1. Water side heat exchanger water inlet temperature sensor and water side heat exchanger water outlet temperature sensor connections are port CN6 on the hydronic system main PCB (labeled 8 in Figure 4-2.1 in Part 4, 2.2 “Main PCB for Hydronic System”).
2. Measure sensor resistance. If the resistance is too low, the sensor has short-circuited. If the resistance is not consistent with the sensor’s resistance characteristics table, the sensor has failed. Refer to Part 2, 1 “Layout of Functional Components” and to Table 5-5.3 in Part 5, 5.1 “Temperature Sensor Resistance Characteristics”.
3. Refer to the M-Thermal Mono Engineering Data Book, Part 5, 15 “SPECIAL FUNCTIONS”.
4. Check water pressure on the manometer. If the water pressure is not > 1 bar, water flow is insufficient. Refer to Figures 2-1.2 and 2-1.6 in Part 2, 1 “Layout of Functional Components”.

4.19 P6 Troubleshooting for single-phase models

4.19.1 Digital display output

4.19.2 Description

- Inverter module protection.
- M-Thermal Mono stops running.
- Error code P6 is displayed on the user interface. Specific error code L0, L1, L2, L4, L5, L7, L8 or L9 is displayed on the refrigerant system main PCB.

4.19.3 Possible causes

- Inverter module protection.
- DC bus low or high voltage protection.
- MCE error.
- Zero speed protection.
- Phase sequence error.
- Excessive compressor frequency variation.
- Actual compressor frequency differs from target frequency.

4.19.4 Specific error codes for P6 inverter module protection

If a P6 error code is displayed on the user interface, one of the following specific error codes is displayed on the refrigerant system main PCB: L0, L1, L2, L4, L5, L7, L8, L9. Refer to Table 4-4.1.

Table 4-4.1: Specific error codes for error P6

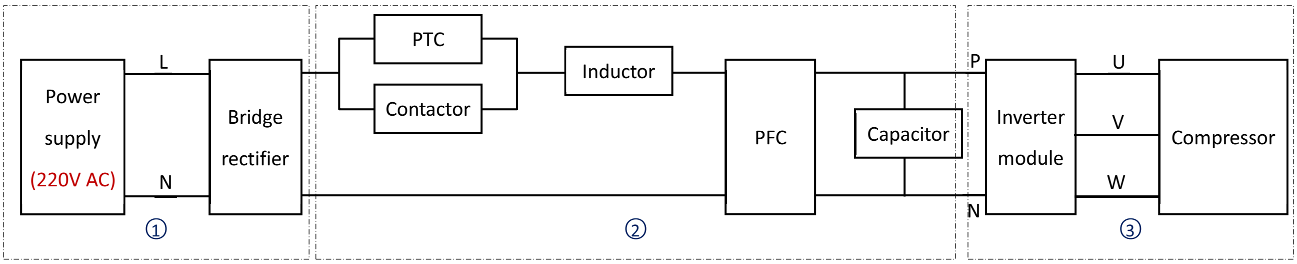
Specific error code	Content
L0	Inverter module protection
L1	DC bus low voltage protection
L2	DC bus high voltage protection
L4	MCE error
L5	Zero speed protection
L7	Phase sequence error
L8	Compressor frequency variation greater than 15Hz within one second protection
L9	Actual compressor frequency differs from target frequency by more than 15Hz protection

The specific error codes can also be obtained from the LED indicators LED1/LED2 on the inverter module. Refer to Table 4-4.2 and Figure 4-2.3 or 4-2.5 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Module and Filter Boards”.

Table 4-4.2: Errors indicated on LED1/2

LED1/2 flashing pattern	Corresponding error
Flashes 8 times and stops for 1 second, then repeats	L0 - Inverter module protection
Flashes 9 times and stops for 1 second, then repeats	L1 - DC bus low voltage protection
Flashes 10 times and stops for 1 second, then repeats	L2 - DC bus high voltage protection
Flashes 12 times and stops for 1 second, then repeats	L4 - MCE error
Flashes 13 times and stops for 1 second, then repeats	L5 - Zero speed protection
Flashes 15 times and stops for 1 second, then repeats	L7 - Phase sequence error
Flashes 16 times and stops for 1 second, then repeats	L8 - Compressor frequency variation greater than 15Hz within one second protection
Flashes 17 times and stops for 1 second, then repeats	L9 - Actual compressor frequency differs from target frequency by more than 15Hz protection

4.19.5 Principle of DC inverter



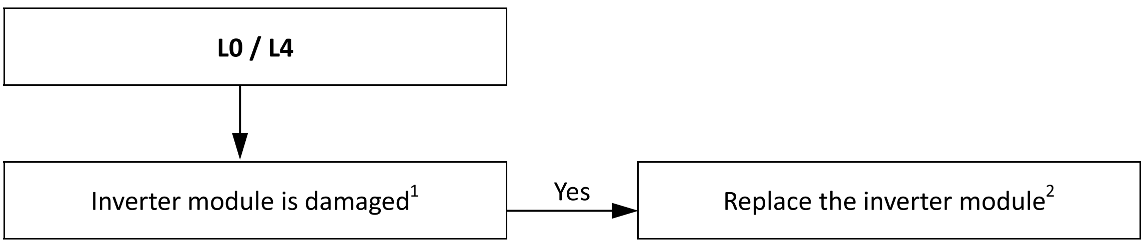
① 220V AC power supply change to DC power supply after bridge rectifier.

② Contactor is open, the current across the PTC to charge capacitor, after 5 seconds the contactor closed.

③The capacitor output steady power supply for inverter module P N terminals. In standby the voltage between P and N terminal on inverter module is 310V DC. When the fan motor is running, the voltage between P and N terminal on inverter module is 380V DC.

4.19.6 L0/L4 troubleshooting

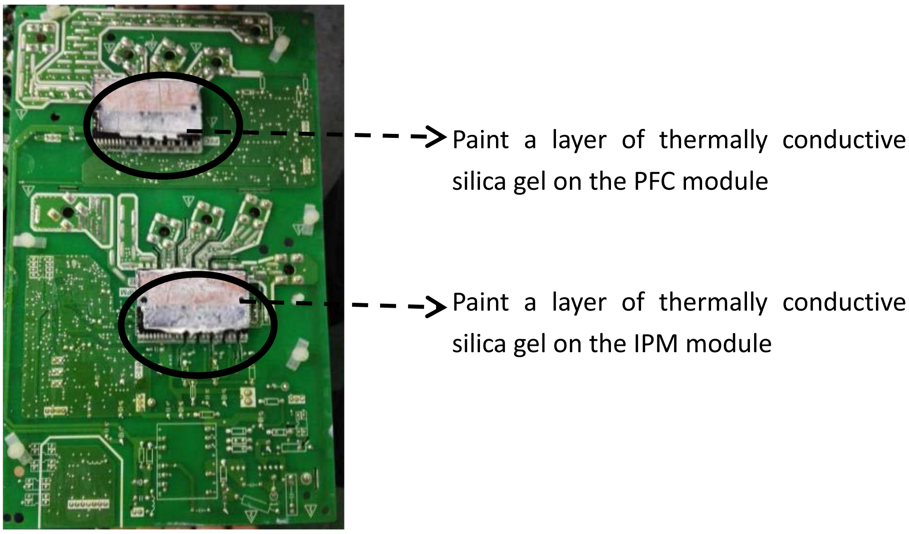
Situation 1: L0 or L4 error appears immediately after the outdoor unit is powered-on



Notes:

1. Measure the resistance between each of U, V and W and each of P and N on the inverter module. All the resistances should be infinite. If any of them are not infinite, the inverter module is damaged and should be replaced. Refer to Figure 4-2.3 or 4-2.5 in Part 4, 2.3 "Main PCBs for Refrigerant System, Inverter Module and Filter Boards".
2. When replacing an inverter module, a layer of thermally conductive silica gel should be painted on the PFC and IPM modules (on the reverse side of the inverter module PCB). Refer to Figure 4-4.1.

Figure 4-4.1: Replacing an inverter module



Situation 2: L0 or L4 error appears immediately after the compressor starts up

L0 / L4

↓

U V W wire between inverter module and compressor is not connected properly[1] — Yes → Ensure U V W wire is connected properly

↓ No

Inverter module is damaged[2] — Yes → Replace the inverter module[3]

↓ No

Compressor has malfunctioned[4] — Yes → Replace the compressor

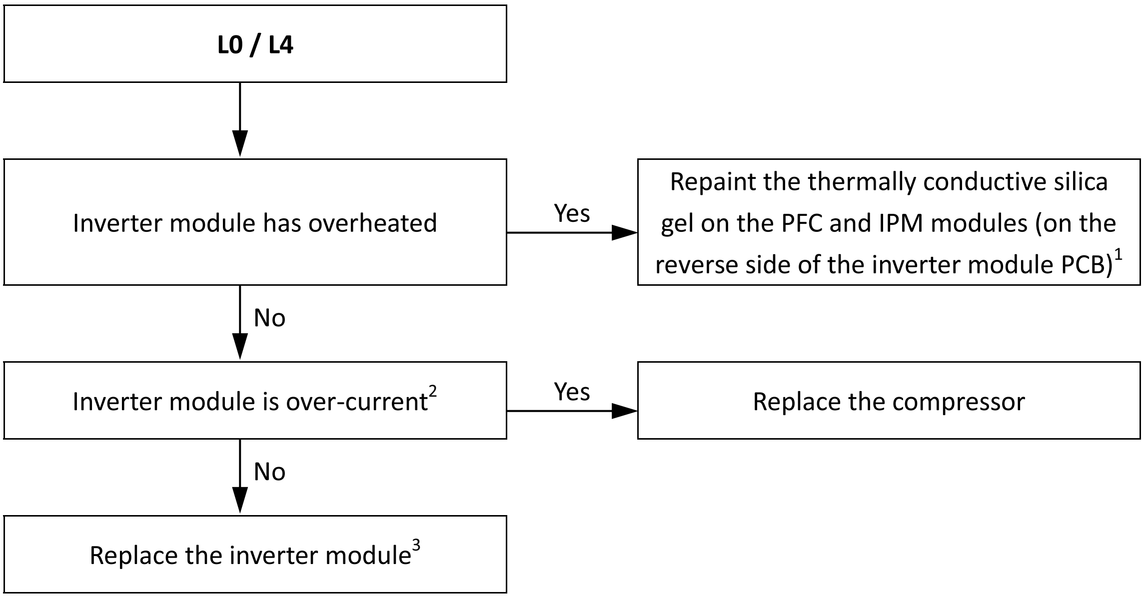
↓ No

Replace the refrigerant system main PCB

Notes:

1. Connect the U V W wire from the inverter module to the correct compressor terminals, as indicated by the labels on the compressor.
2. Measure the resistance between each of U, V and W and each of P and N on the inverter module. All the resistances should be infinite. If any of them are not infinite, the inverter module is damaged and should be replaced. Refer to Figure 4-2.3 or 4-2.5 in Part 4, 2.3 "Main PCBs for Refrigerant System, Inverter Module and Filter Boards".
3. When replacing an inverter module, a layer of thermally conductive silica gel should be painted on the PFC and IPM modules (on the reverse side of the inverter module PCB). Refer to Figure 4-4.1.
4. The normal resistances of the inverter compressor are 0.7-1.5Ω among U V W and infinite between each of U V W and ground. If any of the resistances differ from these specifications, the compressor has malfunctioned.

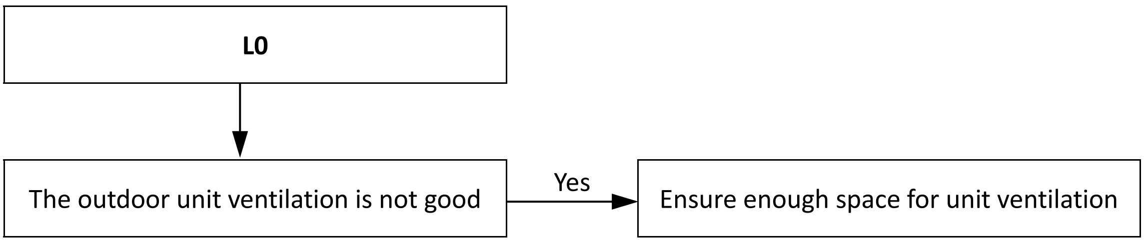
Situation 3: L0 or L4 error appears after the compressor has been running for a period of time and the compressor speed is over 60rps



Notes:

1. Refer to Figure 4-4.1.
2. Use clip-on ammeter to measure the compressor current, if the current is normal indicates the inverter module is failed, if the current is abnormal indicates the compressor is failed.
3. When replacing an inverter module, a layer of thermally conductive silica gel should be painted on the PFC and IPM modules (on the reverse side of the inverter module PCB). Refer to Figure 4-4.1.

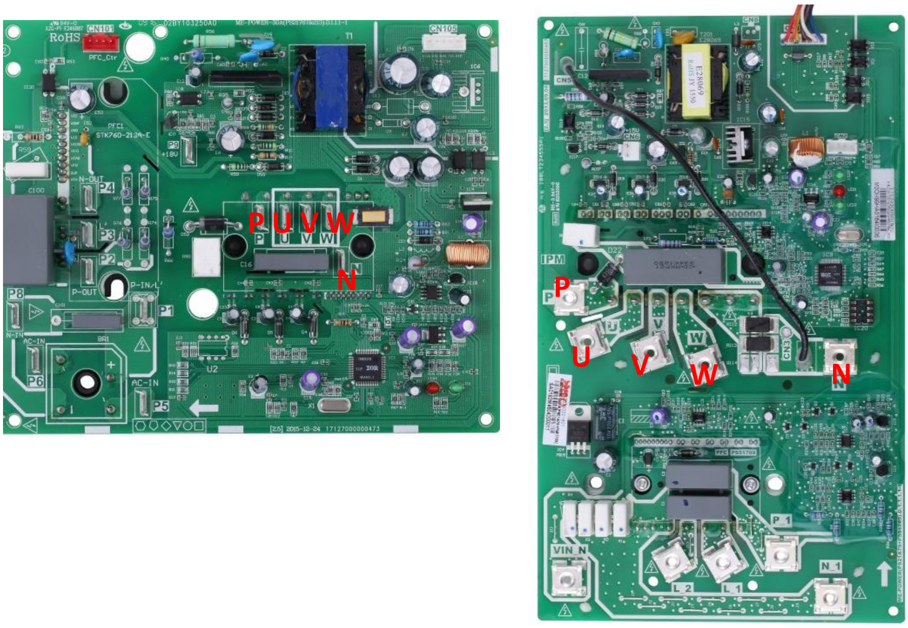
Situation 4: L0 error appears occasionally/irregularly



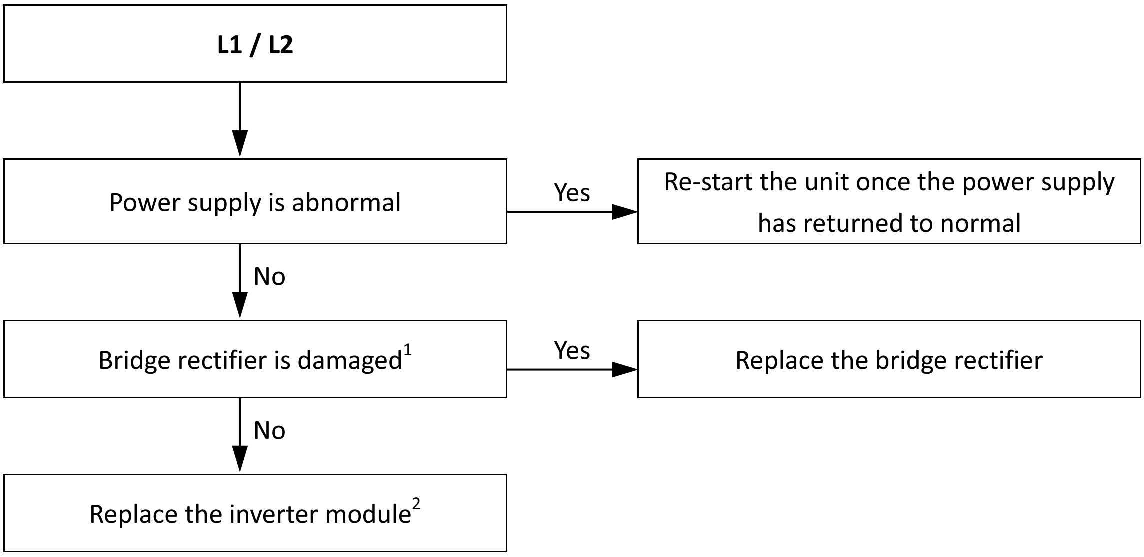
4.19.7 L1/L2 troubleshooting

The normal DC voltage between terminals P and N on inverter module is 310V in standby and 380V when the fan motor is running. If the voltage is lower or higher than the normal voltage, the unit displays an L1 or L2 error.

Figure 4-4.2: Inverter module terminals



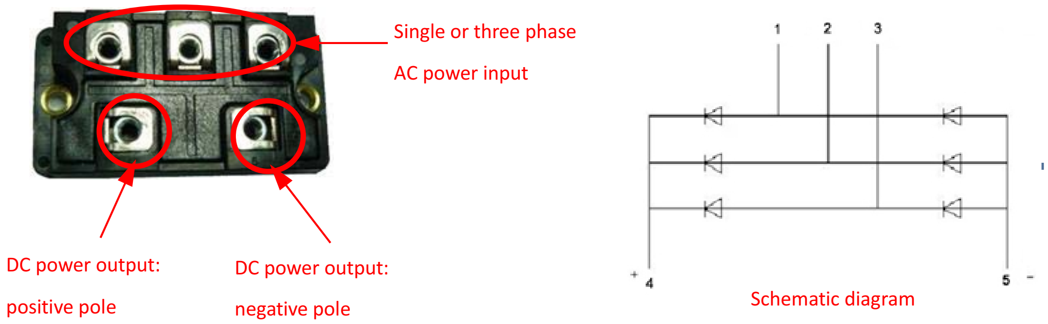
Situation 1: L1 or L2 error appears immediately after the outdoor unit is powered-on



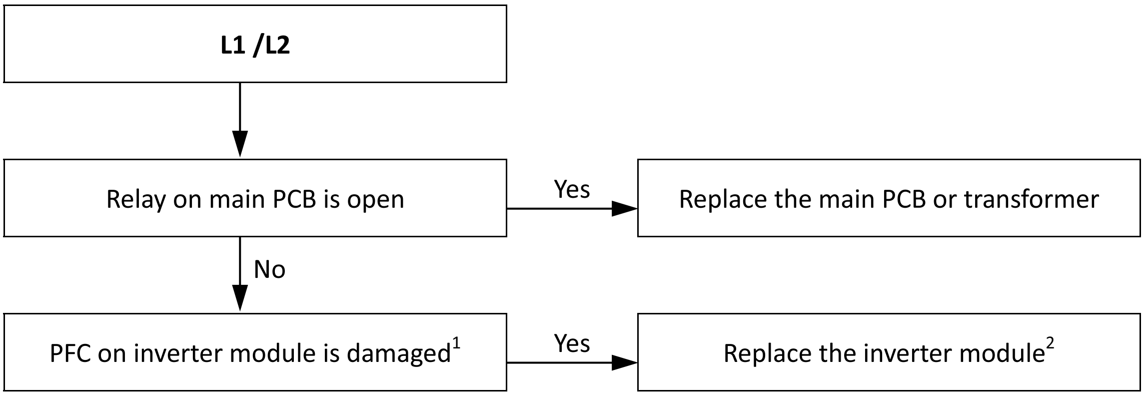
Notes:

1. Check the bridge rectifier using one of the following two methods (refer to Figure 4-4.3):
   - Method 1: measure the resistance between any two of the 5 bridge rectifier terminals. If any of the resistances is close to zero, the bridge rectifier has failed.
   - Method 2: dial a multimeter to the diode setting:
     - Put the red probe on the DC power output negative terminal (terminal 5) and put the black probe onto each of the AC power input terminals (terminals 1, 2 and 3) in turn. The voltage between terminal 5 and each of terminals 1, 2 and 3 should be around 0.378V. If the voltage is 0, the bridge rectifier has failed.
     - Put the red probe on the DC power output positive terminal (terminal 4), then put black probe onto each of the AC power input terminals (terminals 1, 2 and 3) in turn. The voltage between terminal 4 and each of terminals 1, 2 and 3 should be infinite. If the voltage is 0, the bridge rectifier has failed.
2. When replacing an inverter module, a layer of thermally conductive silica gel should be painted on the PFC and IPM modules (on the reverse side of the inverter module PCB). Refer to Figure 4-4.1.

Figure 4-4.3: Bridge rectifier



Situation 2: L1 or L2 error appears after the compressor has been running for a period of time and the compressor speed is over 20rps



Notes:

1. If the fan motor is running and the DC voltage between terminals P and N on inverter module is not 380V, the PFC is damaged.
2. When replacing an inverter module, a layer of thermally conductive silica gel should be painted on the PFC and IPM modules (on the reverse side of the inverter module PCB). Refer to Figure 4-4.1.

4.20 P6 Troubleshooting for three-phase models

4.20.1 Digital display output

4.20.2 Description

- Inverter module protection.
- M-Thermal Mono stops running.
- Error code P6 is displayed on the user interface. Specific error code L0, L1, L2, L4, L5, L7, L8 or L9 is displayed on the refrigerant system main PCB.

4.20.3 Possible causes

- Inverter module protection.
- DC bus low or high voltage protection.
- MCE error.
- Zero speed protection.
- Phase sequence error.
- Excessive compressor frequency variation.
- Actual compressor frequency differs from target frequency.

4.20.4 Specific error codes for P6 inverter module protection

If a P6 error code is displayed on the user interface, one of the following specific error codes is displayed on the refrigerant system main PCB: L0, L1, L2, L4, L5, L7, L8, L9. Refer to Table 4-4.3.

Table 4-4.3: Specific error codes for error P6

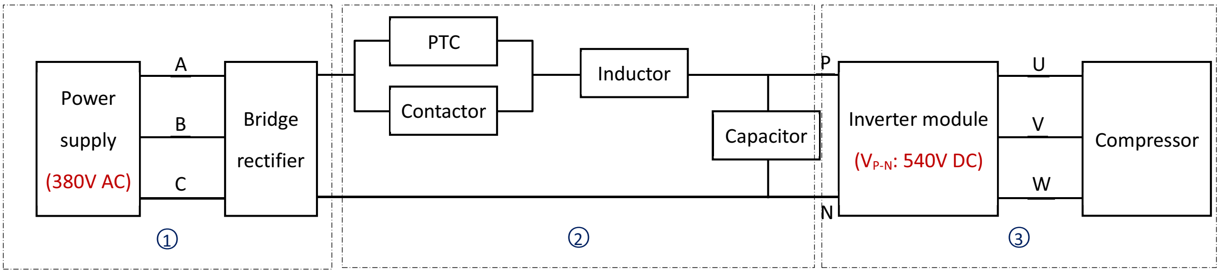
Specific error code	Content
L0	Inverter module protection
L1	DC bus low voltage protection
L2	DC bus high voltage protection
L4	MCE error
L5	Zero speed protection
L7	Phase sequence error
L8	Compressor frequency variation greater than 15Hz within one second protection
L9	Actual compressor frequency differs from target frequency by more than 15Hz protection

The specific error codes can also be obtained from the LED indicators LED1/LED2 on the refrigerant system main PCB. Refer to Figure 4-2.6 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Module and Filter Boards”.

Table 4-4.4: Errors indicated on LED1/2

LED1/2 flashing pattern	Corresponding error
Flashes 8 times and stops for 1 second, then repeats	L0 - Inverter module protection
Flashes 9 times and stops for 1 second, then repeats	L1 - DC bus low voltage protection
Flashes 10 times and stops for 1 second, then repeats	L2 - DC bus high voltage protection
Flashes 12 times and stops for 1 second, then repeats	L4 - MCE error
Flashes 13 times and stops for 1 second, then repeats	L5 - Zero speed protection
Flashes 15 times and stops for 1 second, then repeats	L7 - Phase sequence error
Flashes 16 times and stops for 1 second, then repeats	L8 - Compressor frequency variation greater than 15Hz within one second protection
Flashes 17 times and stops for 1 second, then repeats	L9 - Actual compressor frequency differs from target frequency by more than 15Hz protection

4.20.5 Principle of DC inverter



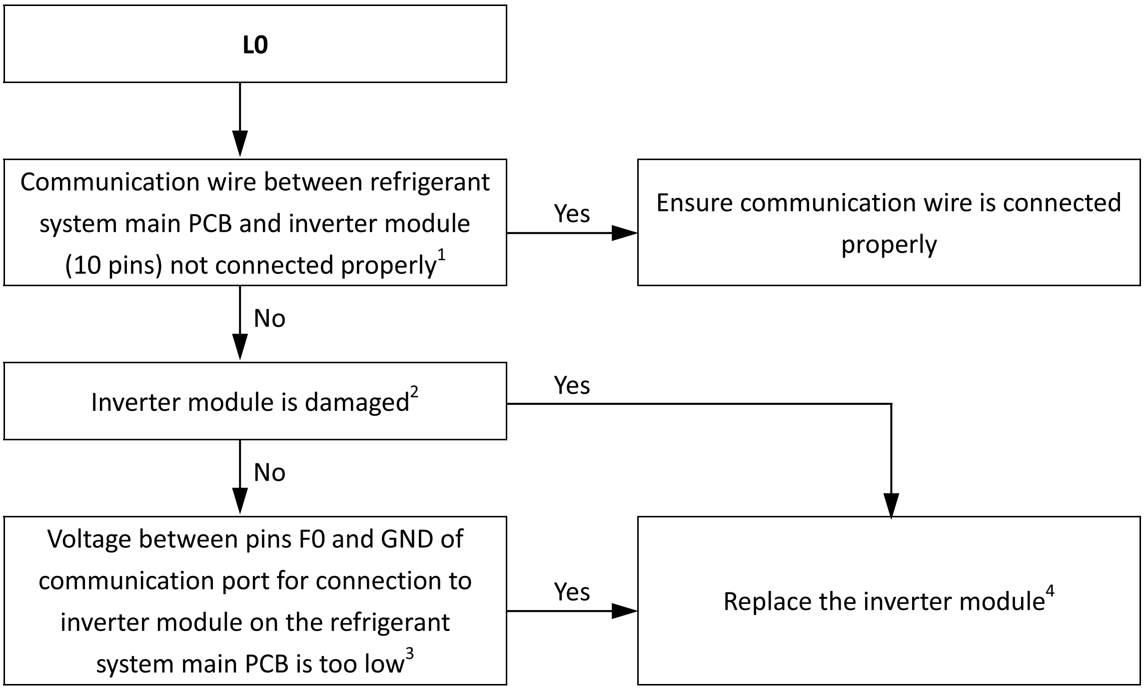
① 380-415V AC power supply change to DC power supply after bridge rectifier.

② Contactor is open the current across the PTC to charge capacitor, after 5 seconds the contactor closed.

③ The capacitor output steady 540V DC power supply for inverter module P N terminals.

4.20.6 L0 troubleshooting

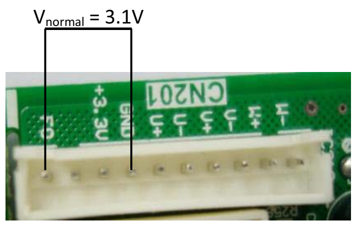
Situation 1: L0 error appears immediately after the outdoor unit is powered-on



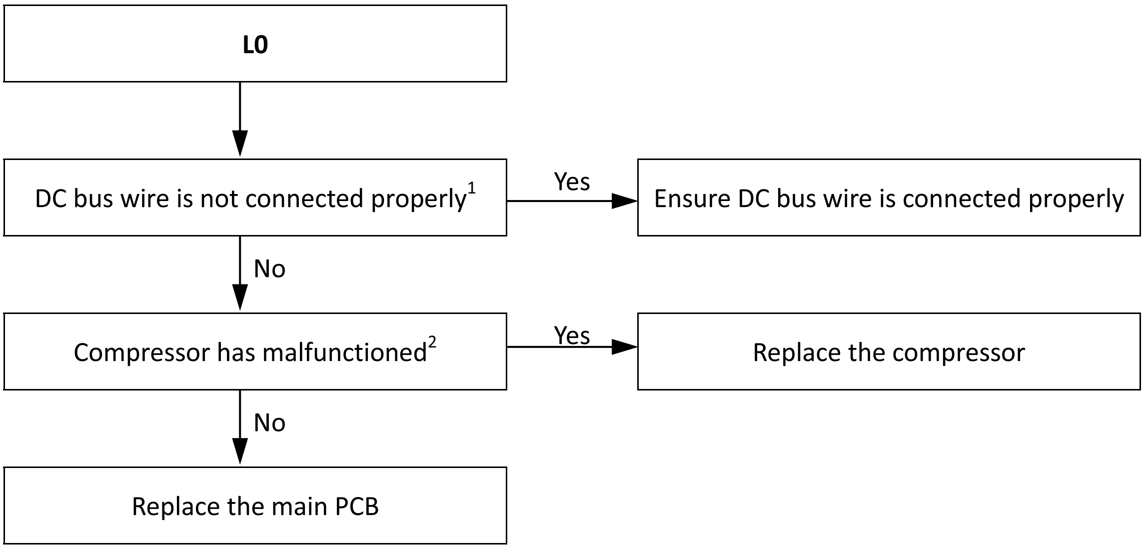
Notes:

1. The communication port between refrigerant system main PCB and inverter module is port CN201 on refrigerant system main PCB and port CN1 on inverter module.
2. Measure the resistance between each of U, V and W and each of P and N on the inverter module. All the resistances should be infinite. If any of them are not infinite, the inverter module is damaged and should be replaced. Refer to Figure 4-2.3 or 4-2.5 in Part 4, 2.3 "Main PCBs for Refrigerant System, Inverter Module and Filter Boards".
3. The normal voltage between F0 and GND is 3.1V. Refer to Figure 4-4.4.
4. When replacing an inverter module, a layer of thermally conductive silica gel should be painted on the IPM module (on the reverse side of the inverter module PCB).

Figure 4-4.4: F0 and GND voltage on CN201



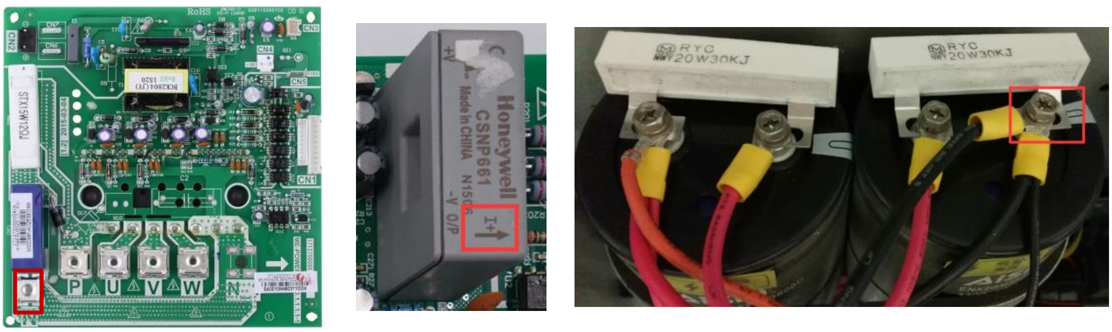
Situation 2: L0 error appears immediately after the compressor starts up



Notes:

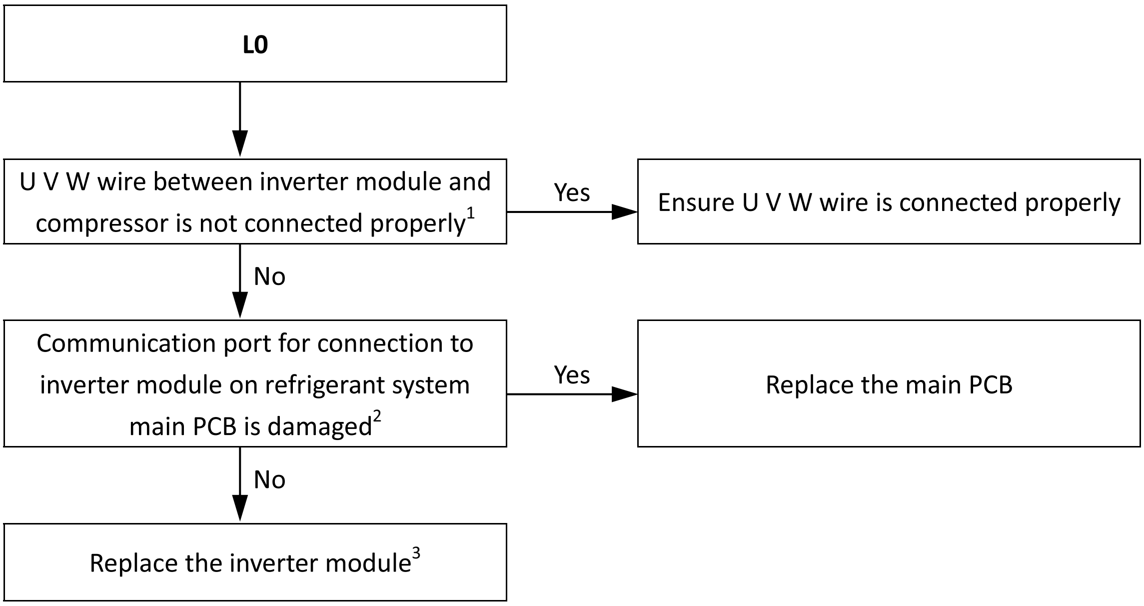
1. The DC bus wire should run from the N terminal on the inverter module, through the current sensor (in the direction indicated by the arrow on the current sensor), and end at the N terminal of capacitor. Refer to Figure 4-4.5.

Figure 4-4.5: DC bus wire connection



2. The normal resistances of the inverter compressor are 0.7-1.5Ω among U V W and infinite between each of U V W and ground. If any of the resistances differ from these specifications, the compressor has malfunctioned.

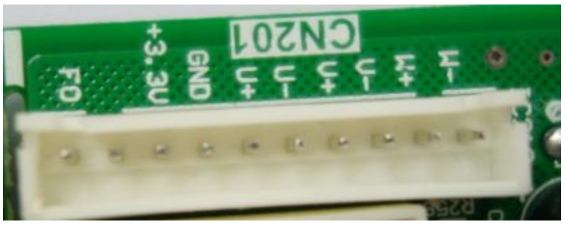
Situation 3: L0 error appears within 2 seconds of compressor start-up



Notes:

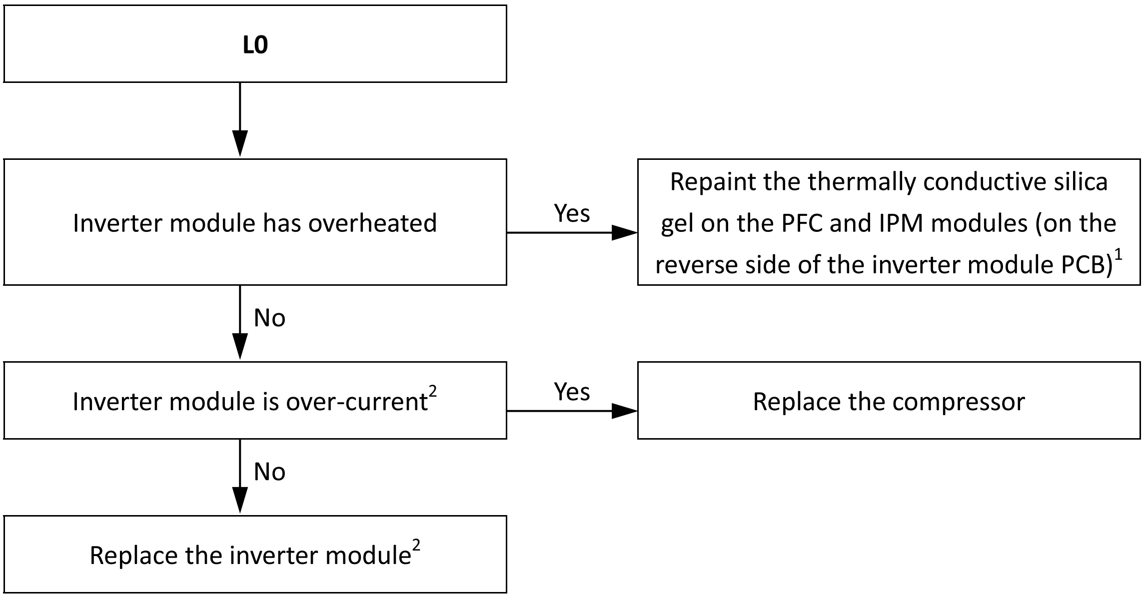
1. Connect the U V W wire from the inverter module to the correct compressor terminals, as indicated by the labels on the compressor.
2. Measure the voltage between each of W-, W+, V-, V+, U-, U+ and GND when the unit is in standby. The normal voltage should be 2.5V-4V and the six voltages should be same, otherwise the communication terminal has failed. Refer to Figure4-4.6.

Figure 4-4.6: Connection port for inverter module



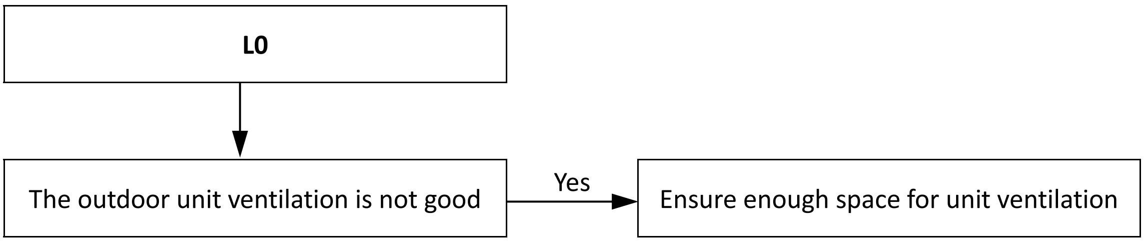
3. When replacing an inverter module, a layer of thermally conductive silica gel should be painted on the IPM module (on the reverse side of the inverter module PCB).

Condition 4: L0 error appears after the compressor has been running for a period of time and the compressor speed is over 60rps



Notes:
1. When replacing an inverter module, a layer of thermally conductive silica gel should be painted on the IPM module (on the reverse side of the inverter module PCB).
2. Use clip-on ammeter to measure the compressor current, if the current is normal indicates the inverter module is failed, if the current is abnormal indicates the compressor has failed.

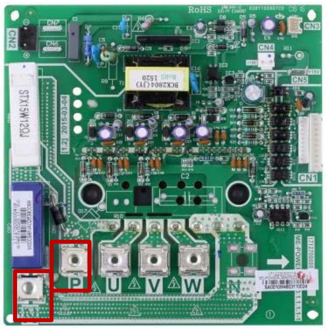
Situation 5: L0 error appears occasionally/irregularly



4.20.7 L1/L2 troubleshooting

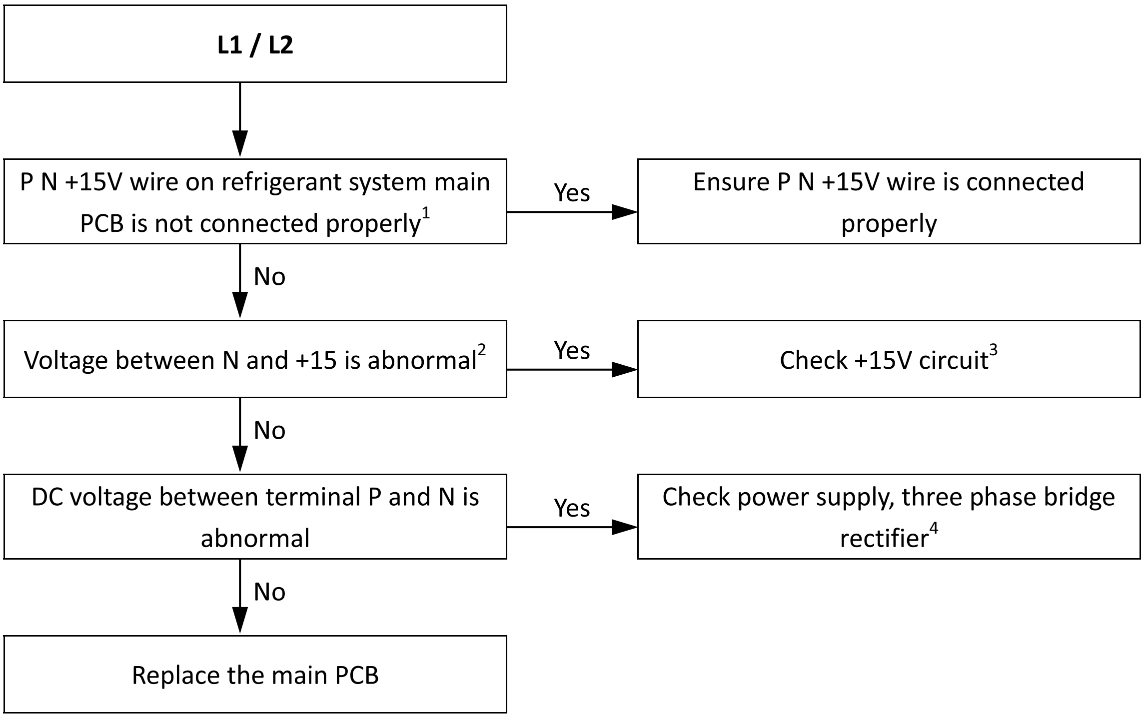
The normal DC voltage between terminals P and N on inverter module is 540V. If the voltage is lower than 300V, the unit displays an L1 error; if the voltage is higher than 800V, the unit displays an L2 error. Refer to Figure4-4.7.

Figure 4-4.7: P, N terminals voltage



V_{normal} = 540V DC

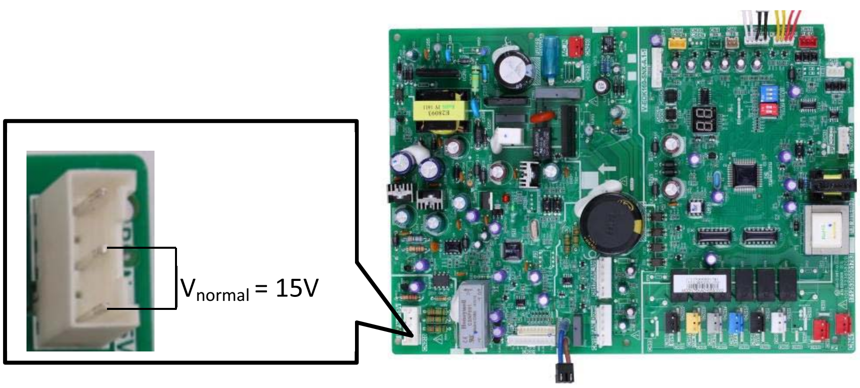
Situation 1: L1 or L2 error appears immediately after the outdoor unit is powered-on



Notes:

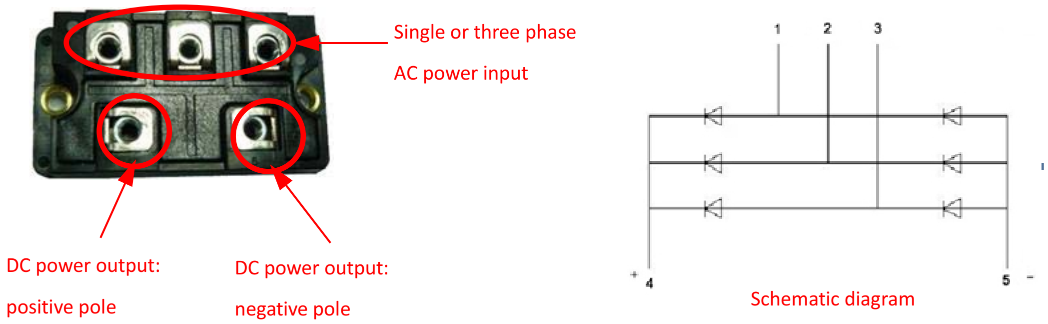
1. P N +15V terminal on refrigerant system main PCB. Refer to Figure4-4.7.
2. Voltage between N and +15. Refer to Figure4-4.8

Figure 4-4.8: P N +15V terminal

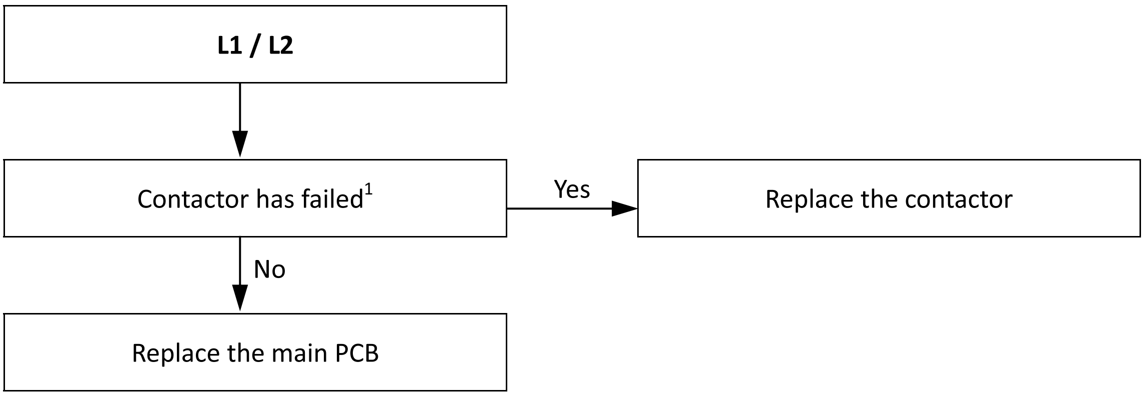


3. Check the +15V circuit according to corresponding wiring diagram. If CN5 on inverter module output voltage is not +15V means the inverter module is failed. If voltage output of inverter module is +15V means main PCB is failed.
4. Check the bridge rectifier using one of the following two methods (refer to Figure 4-4.9):
   - Method 1: measure the resistance between any two of the 5 bridge rectifier terminals. If any of the resistances is close to zero, the bridge rectifier has failed.
   - Method 2: dial a multimeter to the diode setting:
     - Put the red probe on the DC power output negative terminal (terminal 5) and put the black probe onto each of the AC power input terminals (terminals 1, 2 and 3) in turn. The voltage between terminal 5 and each of terminals 1, 2 and 3 should be around 0.378V. If the voltage is 0, the bridge rectifier has failed.
     - Put the red probe on the DC power output positive terminal (terminal 4), then put black probe onto each of the AC power input terminals (terminals 1, 2 and 3) in turn. The voltage between terminal 4 and each of terminals 1, 2 and 3 should be infinite. If the voltage is 0, the bridge rectifier has failed.

Figure 4-4.9: Bridge rectifier



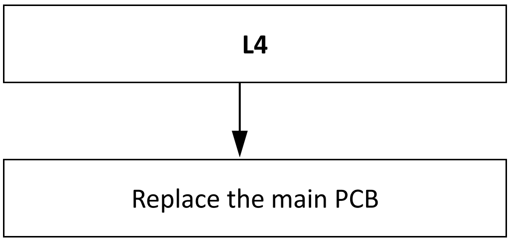
Situation 2: L1 or L2 error appears after the compressor has been running for a period of time and the compressor speed is 20 - 30 rps



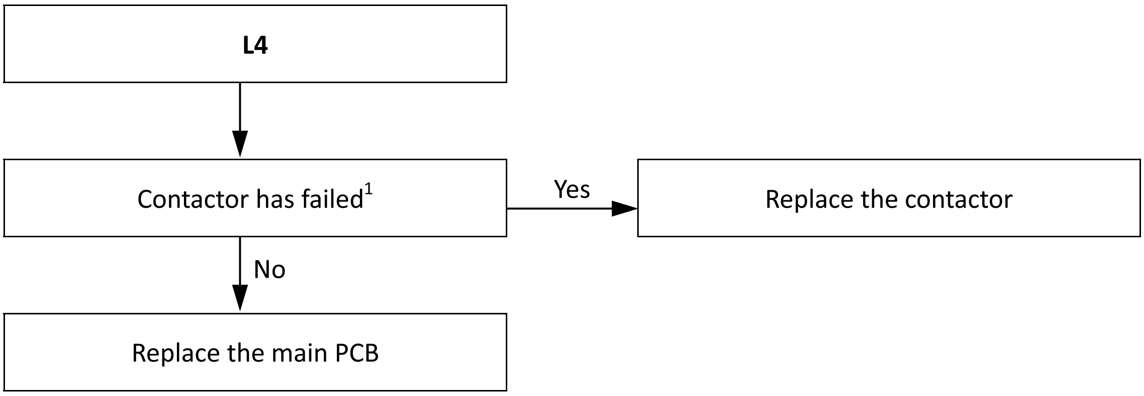
Notes:
1. Check the voltage between the two wires which connect the contactor with the refrigerant system main PCB. If the voltage is 220V AC and the contactor is open, the contactor has failed.

4.20.8 L4 troubleshooting

Situation 1: L4 error appears immediately after the outdoor unit is powered-on



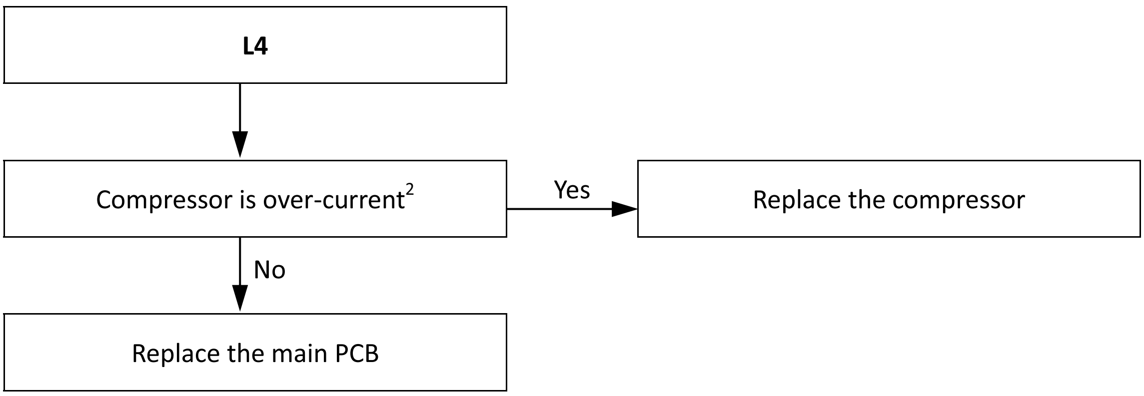
Situation 2: L4 error appears after the compressor has been running for a period of time and the compressor speed is 20 - 30 rps



Notes:

1. Check the voltage between the two wires which connect the contactor with the refrigerant system main PCB. If the voltage is 220V AC and the contactor is open, the contactor has failed.

Condition 3: L4 error appears after the compressor has been running for a period of time and the compressor speed is over 60rps



Notes:

1. Re-start the unit, use clip-on ammeter to measure the compressor current, if the current is normal indicates the compressor is failed, if the current is abnormal indicates the main PCB is failed.

4.21 Pb Troubleshooting

4.21.1 Digital display output

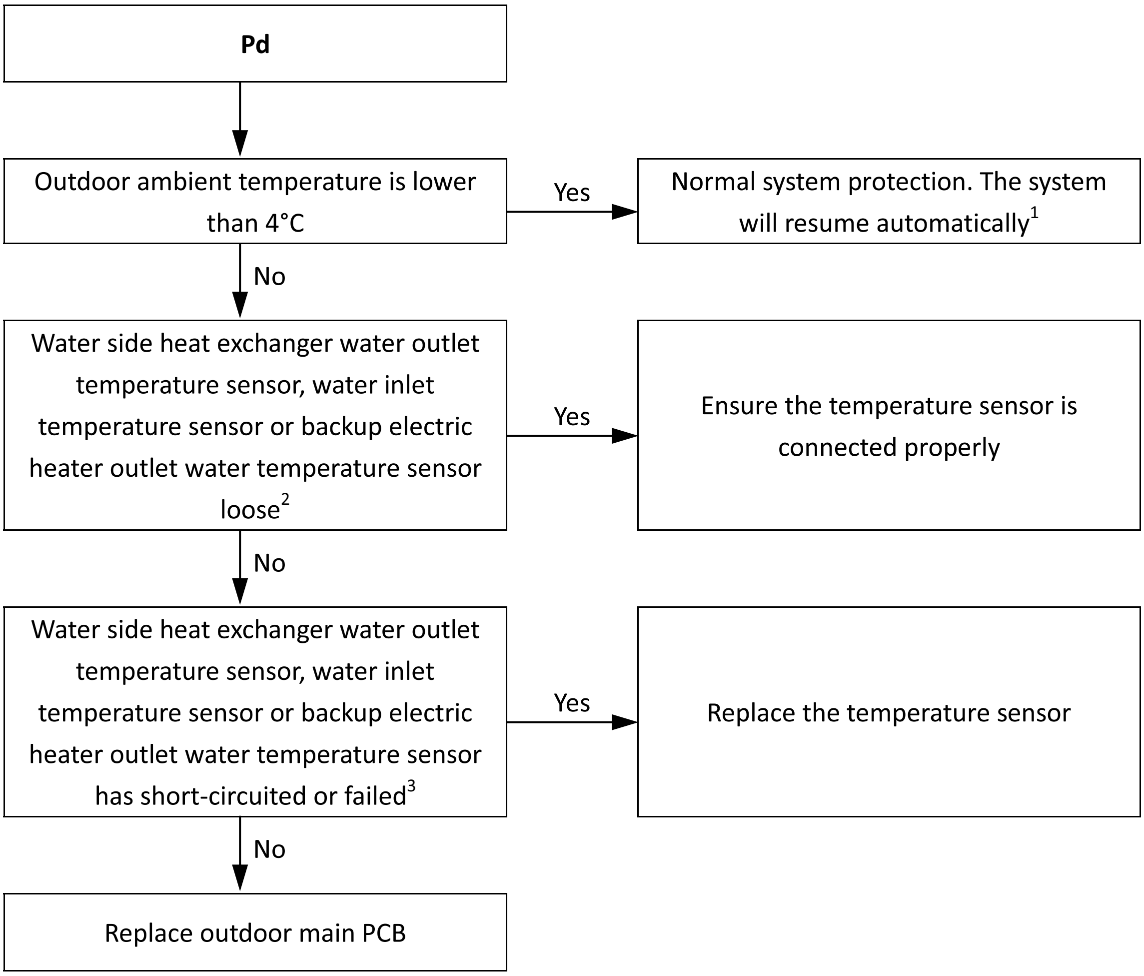
4.21.2 Description

- Water side heat exchanger anti-freeze protection.
- M-Thermal Mono stops running.
- Error code is displayed on refrigerant system main PCB and **ANTI.FREEZE** icon is displayed on user interface.

4.21.3 Possible causes

- Normal system protection.
- Temperature sensor not connected properly or has malfunctioned.
- Hydronic system main PCB damaged.

4.21.4 Procedure



Notes:

1. Refer to Part 3, 5.7 "Water Side Heat Exchanger Anti-freeze Protection Control".
2. Backup electric heater water outlet temperature sensor, water side heat exchanger water inlet temperature sensor and water side heat exchanger water outlet temperature sensor connections are port CN6 on the hydronic system main PCB (labeled 8 in Figure 4-2.1 in Part 4, 2.2 "Main PCB for Hydronic System").
3. Measure sensor resistance. If the resistance is too low, the sensor has short-circuited. If the resistance is not consistent with the sensor's resistance characteristics table, the sensor has failed. Refer to Part 2, 1 "Layout of Functional Components" and to Table 4-5.3 in Part 4, 5.1 "Temperature Sensor Resistance Characteristics".

4.22 Pd Troubleshooting

4.22.1 Digital display output

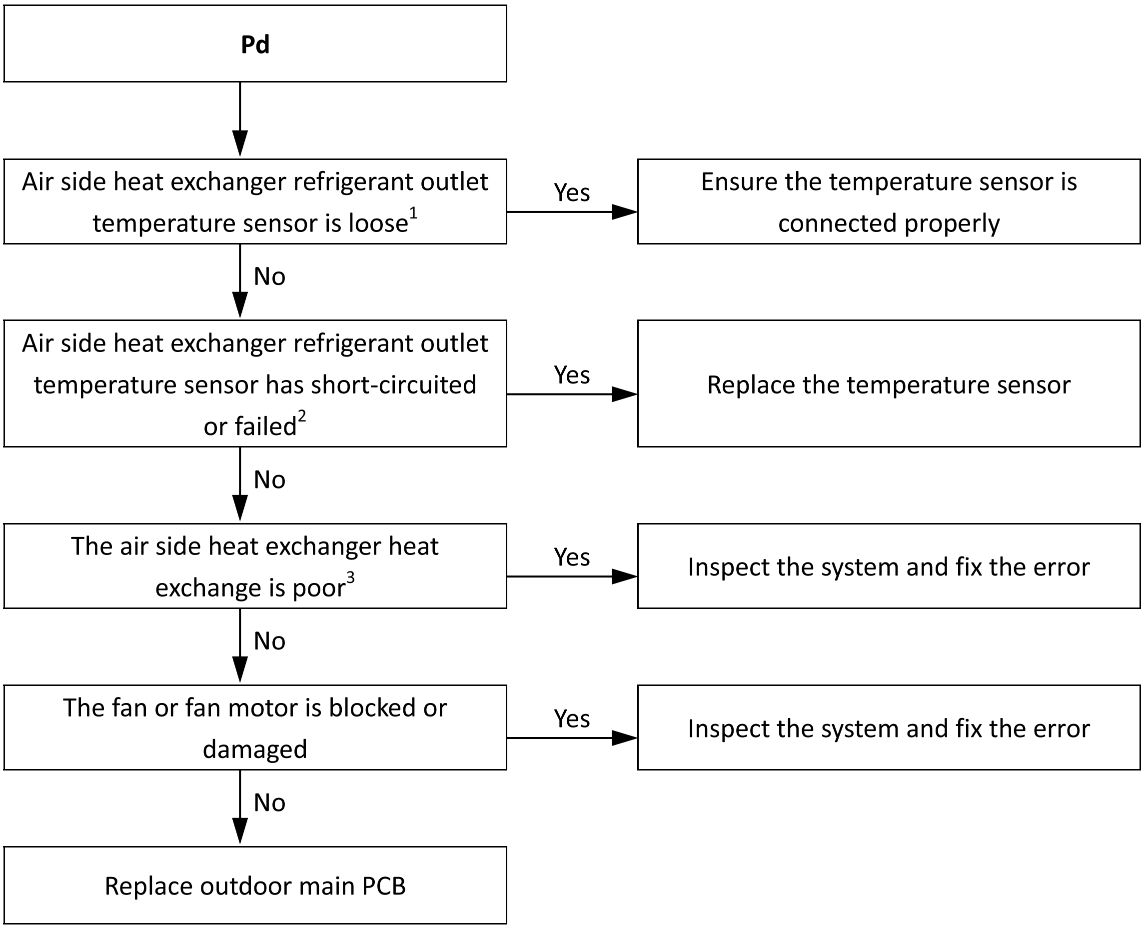
4.22.2 Description

- High temperature protection of air side heat exchanger refrigerant outlet in cooling mode. When the air side heat exchanger refrigerant outlet temperature is higher than 62°C for more than 3 seconds, the system displays Pd protection and M-Thermal Mono stops running. When the air side heat exchanger refrigerant outlet temperature returns drops below 52°C, Pd is removed and normal operation resumes.
- M-Thermal Mono stops running.
- Error code is displayed on refrigerant system main PCB and user interface.

4.22.3 Possible causes

- Temperature sensor not connected properly or has malfunctioned.
- Poor condenser heat exchange.
- Fan motor damaged.
- Hydronic system main PCB damaged.

4.22.4 Procedure



Notes:

1. Air side heat exchanger refrigerant outlet temperature sensor and outdoor ambient temperature sensor connection port is CN9 on the refrigerant system main PCB (labeled 7 in Figure 4-2.2 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”, (labeled 5 in Figure 4-2.4 and Figure 4-2.6 in Part 4, 2.3 “Main PCBs for Refrigerant System, Inverter Modules and Filter Boards”).
2. Measure sensor resistance. If the resistance is too low, the sensor has short-circuited. If the resistance is not consistent with the sensor’s resistance characteristics table, the sensor has failed. Refer to Part 2, 1 “Layout of Functional Components” and to Table 4-5.1 in Part 4, 5.1 “Temperature Sensor Resistance Characteristics”.
3. Check air side heat exchanger, fan(s) and air outlets for dirt/blockages.

4.23 PP Troubleshooting

4.23.1 Digital display output

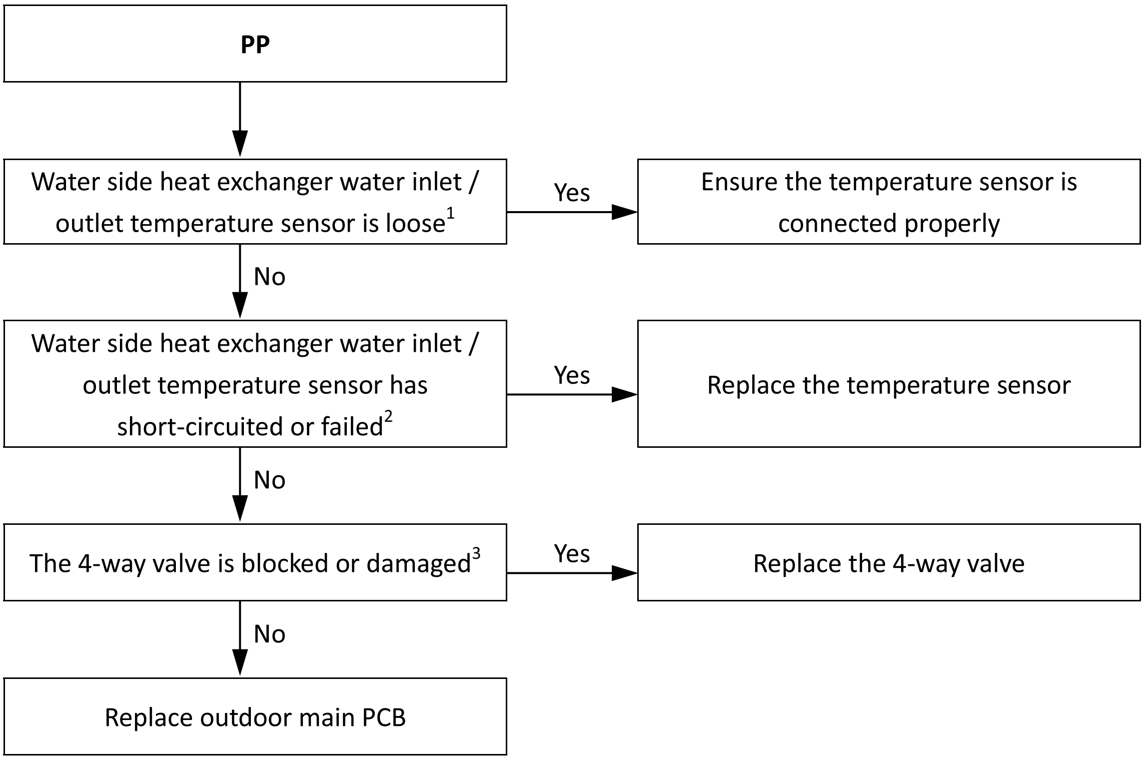
4.23.2 Description

- Water side heat exchanger inlet temperature is higher than outlet temperature in heating mode.
- M-Thermal Mono stops running.
- Error code is displayed on hydronic system main PCB and user interface.

4.23.3 Possible causes

- Temperature sensor not connected properly or has malfunctioned.
- 4-way valve is blocked or damaged.
- Hydronic system main PCB damaged.

4.23.4 Procedure



Notes:

1. water side heat exchanger water inlet temperature sensor and water side heat exchanger water outlet temperature sensor connections are port CN6 on the hydronic system main PCB (labeled 8 in Figure 4-2.1 in Part 4, 2.2 "Min PCB for Hydronic System").
2. Measure sensor resistance. If the resistance is too low, the sensor has short-circuited. If the resistance is not consistent with the sensor's resistance characteristics table, the sensor has failed. Refer to Part 2, 1 "Layout of Functional Components" and to Table 4-5.1 to 4-5.2 in Part 4, 5.1 "Temperature Sensor Resistance Characteristics".
3. Restart the unit in cooling mode to change the refrigerant flow direction. If the unit does not operate normally, the 4-way valve is blocked or damaged.

5 Appendix to Part 4

5.1 Temperature Sensor Resistance Characteristics

Table 4-5.1: Outdoor ambient temperature sensor, water side heat exchanger refrigerant inlet / outlet (liquid / gas pipe) temperature sensor, air side heat exchanger refrigerant out temperature sensor and suction pipe temperature sensor resistance characteristics

Temperature (°C)	Resistance (kΩ)	Temperature (°C)	Resistance (kΩ)	Temperature (°C)	Resistance (kΩ)	Temperature (°C)	Resistance (kΩ)
-20	115.3	**20**	12.64	**60**	2.358	**100**	0.6297
-19	108.1	**21**	12.06	**61**	2.272	**101**	0.6115
-18	101.5	**22**	11.50	**62**	2.191	**102**	0.5939
-17	96.34	**23**	10.97	**63**	2.112	**103**	0.5768
-16	89.59	**24**	10.47	**64**	2.037	**104**	0.5604
-15	84.22	**25**	10.00	**65**	1.965	**105**	0.5445
-14	79.31	**26**	9.551	**66**	1.896	**106**	0.5291
-13	74.54	**27**	9.124	**67**	1.830	**107**	0.5143
-12	70.17	**28**	8.720	**68**	1.766	**108**	0.4999
-11	66.09	**29**	8.336	**69**	1.705	**109**	0.4860
-10	62.28	**30**	7.971	**70**	1.647	**110**	0.4726
-9	58.71	**31**	7.624	**71**	1.591	**111**	0.4596
-8	56.37	**32**	7.295	**72**	1.537	**112**	0.4470
-7	52.24	**33**	6.981	**73**	1.485	**113**	0.4348
-6	49.32	**34**	6.684	**74**	1.435	**114**	0.4230
-5	46.57	**35**	6.400	**75**	1.387	**115**	0.4116
-4	44.00	**36**	6.131	**76**	1.341	**116**	0.4006
-3	41.59	**37**	5.874	**77**	1.291	**117**	0.3899
-2	39.82	**38**	5.630	**78**	1.254	**118**	0.3796
-1	37.20	**39**	5.397	**79**	1.2133	**119**	0.3695
0	35.20	**40**	5.175	**80**	1.174	**120**	0.3598
1	33.33	**41**	4.964	**81**	1.136	**121**	0.3504
2	31.56	**42**	4.763	**82**	1.100	**122**	0.3413
3	29.91	**43**	4.571	**83**	1.064	**123**	0.3325
4	28.35	**44**	4.387	**84**	1.031	**124**	0.3239
5	26.88	**45**	4.213	**85**	0.9982	**125**	0.3156
6	25.50	**46**	4.046	**86**	0.9668	**126**	0.3075
7	24.19	**47**	3.887	**87**	0.9366	**127**	0.2997
8	22.57	**48**	3.735	**88**	0.9075	**128**	0.2922
9	21.81	**49**	3.590	**89**	0.8795	**129**	0.2848
10	20.72	**50**	3.451	**90**	0.8525	**130**	0.2777
11	19.69	**51**	3.318	**91**	0.8264	**131**	0.2708
12	18.72	**52**	3.192	**92**	0.8013	**132**	0.2641
13	17.80	**53**	3.071	**93**	0.7771	**133**	0.2576
14	16.93	**54**	2.959	**94**	0.7537	**134**	0.2513
15	16.12	**55**	2.844	**95**	0.7312	**135**	0.2451
16	15.34	**56**	2.738	**96**	0.7094	**136**	0.2392
17	14.62	**57**	2.637	**97**	0.6884	**137**	0.2334
18	13.92	**58**	2.540	**98**	0.6682	**138**	0.2278
19	13.26	**59**	2.447	**99**	0.6486	**139**	0.2223

Table 4-5.2: Compressor discharge pipe temperature sensor resistance characteristics

Temperature (°C)	Resistance (kΩ)	Temperature (°C)	Resistance (kΩ)	Temperature (°C)	Resistance (kΩ)	Temperature (°C)	Resistance (kΩ)
-20	542.7	**20**	68.66	**60**	13.59	**100**	3.702
-19	511.9	**21**	65.62	**61**	13.11	**101**	3.595
-18	483.0	**22**	62.73	**62**	12.65	**102**	3.492
-17	455.9	**23**	59.98	**63**	12.21	**103**	3.392
-16	430.5	**24**	57.37	**64**	11.79	**104**	3.296
-15	406.7	**25**	54.89	**65**	11.38	**105**	3.203
-14	384.3	**26**	52.53	**66**	10.99	**106**	3.113
-13	363.3	**27**	50.28	**67**	10.61	**107**	3.025
-12	343.6	**28**	48.14	**68**	10.25	**108**	2.941
-11	325.1	**29**	46.11	**69**	9.902	**109**	2.860
-10	307.7	**30**	44.17	**70**	9.569	**110**	2.781
-9	291.3	**31**	42.33	**71**	9.248	**111**	2.704
-8	275.9	**32**	40.57	**72**	8.940	**112**	2.630
-7	261.4	**33**	38.89	**73**	8.643	**113**	2.559
-6	247.8	**34**	37.30	**74**	8.358	**114**	2.489
-5	234.9	**35**	35.78	**75**	8.084	**115**	2.422
-4	222.8	**36**	34.32	**76**	7.820	**116**	2.357
-3	211.4	**37**	32.94	**77**	7.566	**117**	2.294
-2	200.7	**38**	31.62	**78**	7.321	**118**	2.233
-1	190.5	**39**	30.36	**79**	7.086	**119**	2.174
0	180.9	**40**	29.15	**80**	6.859	**120**	2.117
1	171.9	**41**	28.00	**81**	6.641	**121**	2.061
2	163.3	**42**	26.90	**82**	6.430	**122**	2.007
3	155.2	**43**	25.86	**83**	6.228	**123**	1.955
4	147.6	**44**	24.85	**84**	6.033	**124**	1.905
5	140.4	**45**	23.89	**85**	5.844	**125**	1.856
6	133.5	**46**	22.89	**86**	5.663	**126**	1.808
7	127.1	**47**	22.10	**87**	5.488	**127**	1.762
8	121.0	**48**	21.26	**88**	5.320	**128**	1.717
9	115.2	**49**	20.46	**89**	5.157	**129**	1.674
10	109.8	**50**	19.69	**90**	5.000	**130**	1.632
11	104.6	**51**	18.96	**91**	4.849		
12	99.69	**52**	18.26	**92**	4.703		
13	95.05	**53**	17.58	**93**	4.562		
14	90.66	**54**	16.94	**94**	4.426		
15	86.49	**55**	16.32	**95**	4.294		
16	82.54	**56**	15.73	**96**	4.167		
17	78.79	**57**	15.16	**97**	4.045		
18	75.24	**58**	14.62	**98**	3.927		
19	71.86	**59**	14.09	**99**	3.812		

Table 4-5.3: Water side *heat exchanger water inlet / outlet temperature sensor, backup heater exchanger outlet water temperature sensor and DHW temperature sensor resistance characteristics*

Temperature (°C)	Resistance (kΩ)	Temperature (°C)	Resistance (kΩ)	Temperature (°C)	Resistance (kΩ)	Temperature (°C)	Resistance (kΩ)
-30	867.29	**10**	98.227	**50**	17.600	**90**	4.4381
-29	815.80	**11**	93.634	**51**	16.943	**91**	4.3022
-28	767.68	**12**	89.278	**52**	16.315	**92**	4.1711
-27	722.68	**13**	85.146	**53**	15.713	**93**	4.0446
-26	680.54	**14**	81.225	**54**	15.136	**94**	3.9225
-25	641.07	**15**	77.504	**55**	14.583	**95**	3.8046
-24	604.08	**16**	73.972	**56**	14.054	**96**	3.6908
-23	569.39	**17**	70.619	**57**	13.546	**97**	3.5810
-22	536.85	**18**	67.434	**58**	13.059	**98**	3.4748
-21	506.33	**19**	64.409	**59**	12.592	**99**	3.3724
-20	477.69	**20**	61.535	**60**	12.144	**100**	3.2734
-19	450.81	**21**	58.804	**61**	11.715	**101**	3.1777
-18	425.59	**22**	56.209	**62**	11.302	**102**	3.0853
-17	401.91	**23**	53.742	**63**	10.906	**103**	2.9960
-16	379.69	**24**	51.396	**64**	10.526	**104**	2.9096
-15	358.83	**25**	49.165	**65**	10.161	**105**	2.8262
-14	339.24	**26**	47.043	**66**	9.8105		
-13	320.85	**27**	45.025	**67**	9.4736		
-12	303.56	**28**	43.104	**68**	9.1498		
-11	287.33	**29**	41.276	**69**	8.8387		
-10	272.06	**30**	39.535	**70**	8.5396		
-9	257.71	**31**	37.878	**71**	8.2520		
-8	244.21	**32**	36.299	**72**	7.9755		
-7	231.51	**33**	34.796	**73**	7.7094		
-6	219.55	**34**	33.363	**74**	7.4536		
-5	208.28	**35**	31.977	**75**	7.2073		
-4	197.67	**36**	30.695	**76**	6.9704		
-3	187.66	**37**	29.453	**77**	6.7423		
-2	178.22	**38**	28.269	**78**	6.5228		
-1	168.31	**39**	27.139	**79**	6.3114		
0	160.90	**40**	26.061	**80**	6.1078		
1	152.96	**41**	25.031	**81**	5.9117		
2	145.45	**42**	24.048	**82**	5.7228		
3	138.35	**43**	23.109	**83**	5.5409		
4	131.64	**44**	22.212	**84**	5.3655		
5	125.28	**45**	21.355	**85**	5.1965		
6	119.27	**46**	20.536	**86**	5.0336		
7	113.58	**47**	19.752	**87**	4.8765		
8	108.18	**48**	19.003	**88**	4.7251		
9	103.07	**49**	18.286	**89**	4.5790		

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