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Application Engineering Europe

REFRIGERATION – CONTROLLING COPELAND® DISCUS 3D DIGITAL

1 Introduction

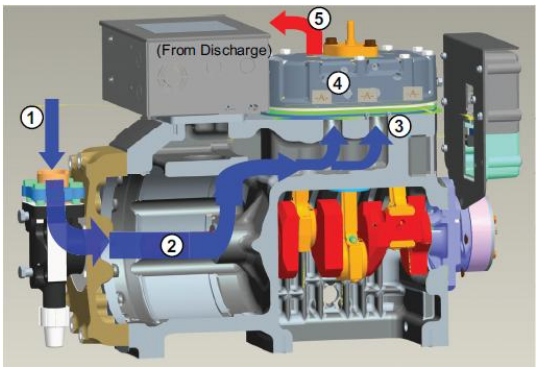
In refrigeration applications where the load may vary over a wide range, some means of cooling capacity modulation is often desirable for optimum system performance and control. In addition, compressor capacity modulation can reduce power and energy consumption, reduce compressor cycling, and decrease the starting electrical load. In order to achieve the above objectives, Emerson Climate Technologies has developed Digital technology, a method for variable capacity in semi-hermetic compressors. Digital technology will permit digital modulation of semi-hermetic compressors for high, medium and low temperature applications.

2 How Digital works

2.1 Theory of operation

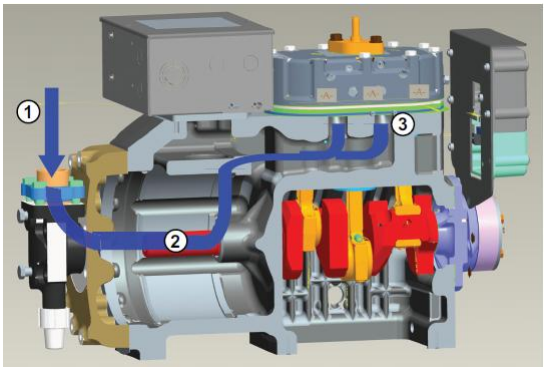
Digital capacity control is achieved by using a proven internal unloading method, based on blocking gas to the valve plate suction area. Cooling capacity between 10 and 100% can be achieved by varying the percentage of duty cycle when the compressor is loaded and unloaded. During blocked suction operation, the flow of suction gas is blocked to all cylinders; therefore there is no gas to compress and the power consumption is significantly lower. The unloader piston mechanism that controls the flow of suction gas into the cylinders is driven by a solenoid valve. See the descriptions and figures below for the unloaded and loaded states for Copeland® 3D Digital operation.

Loaded



1. Gas enters compressor
2. passes through body
3. into valve plate
4. Compressed gas
5. exits compressor

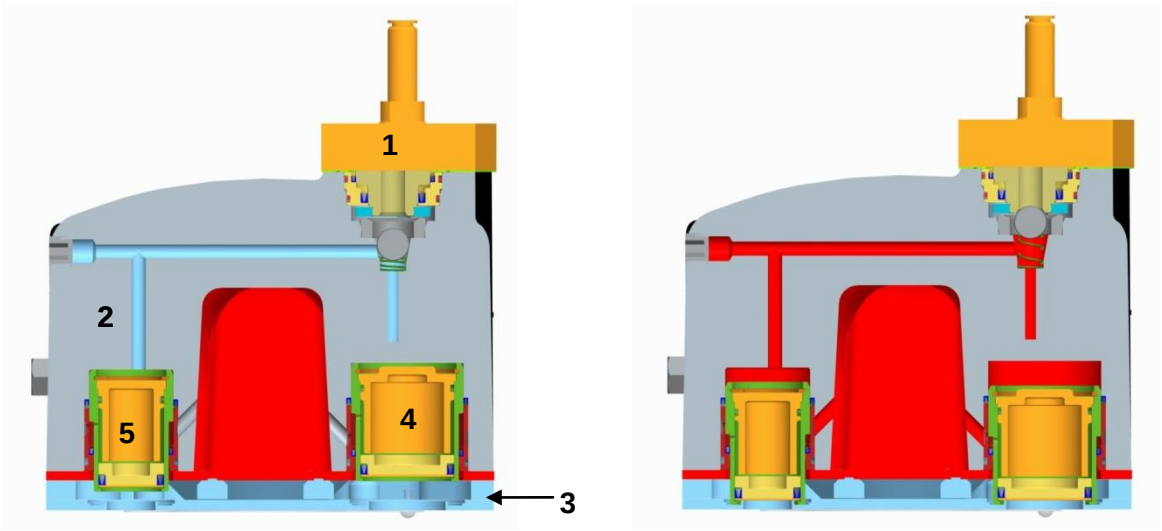
Unloaded



1. Gas enters compressor
2. passes through body
3. Unloader mechanism blocks gas before entering valve plate

Figure 1: Gas flow

Loaded – Valve de-energized (100% capacity) **Unloaded – Valve energized (0% capacity)**



1 = Solenoid valve **2 =** Cylinder head **3 =** Valve plate **4 & 5 =** Unloading piston

Figure 2: Cutaway view of the Digital cylinder head loaded and unloaded

2.2 Pulse Width Modulation (PWM)

Capacity modulation is achieved by energizing and de-energizing the solenoid valve. When the solenoid valve is de-energized, the capacity is 100%. When the solenoid valve is energized, the capacity is zero. Therefore, the capacity achieved is the time average capacity.

Example: In a 20-second cycle, if the solenoid is de-energized for 16 seconds, and then energized for 4 seconds, the resulting capacity will be approximately 80%.

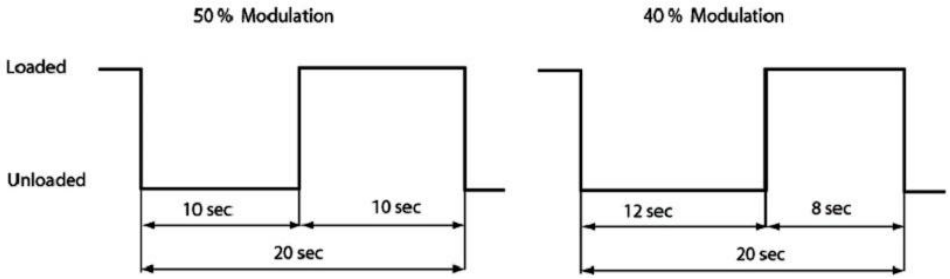
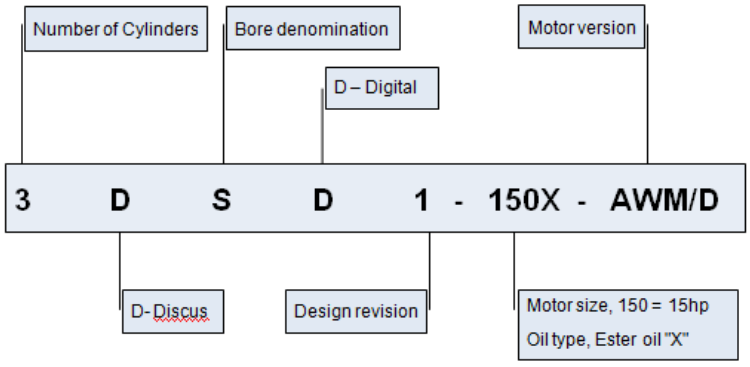


Figure 3: The digital signal from the controller activates the unloading

3 Components for Digital control

3.1 Compressor

3D Digital models are designated by the letter "**D**" in the 4th character of the nomenclature. Please refer to Copeland® brand products Selection Software for available models.



3.1.1 Operating envelopes – R404A

D3DAD1-75X, D3DCD1-100X, D3DSD1-150X

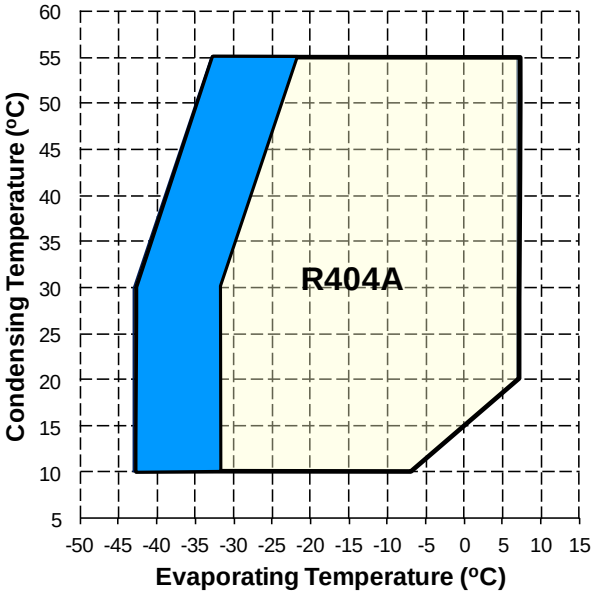


Figure 4: Medium and high temp with R404A

D3DAD1-50X, D3DCD1-75X, D3DSD1-100X

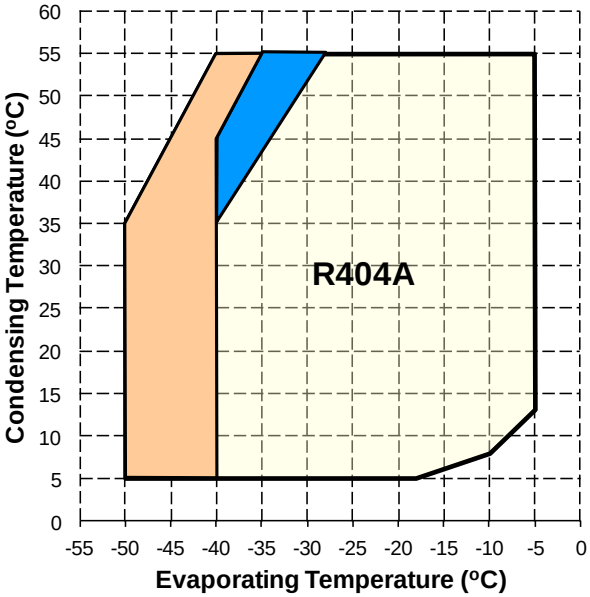
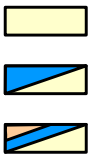


Figure 5: Low and medium temp with R404A

25ºC Suction Gas Return

25ºC Suction Gas Return w fan



25ºC Suction Gas Return

0ºC Suction Gas Return

0ºC Suction Gas Return w fan

3.1.2 Operating envelopes – R134a

D3DAD1-75X, D3DCD1-100X, D3DSD1-150X

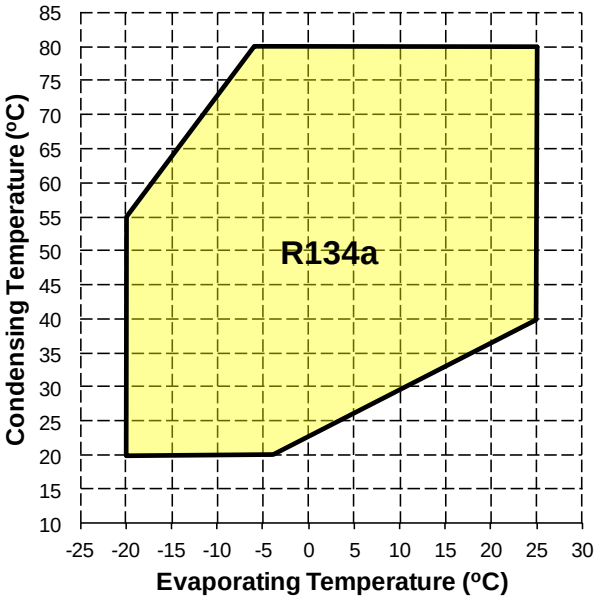


Figure 6: High temp with R134a

D3DAD1-50X, D3DCD1-75X, D3DSD1-100X

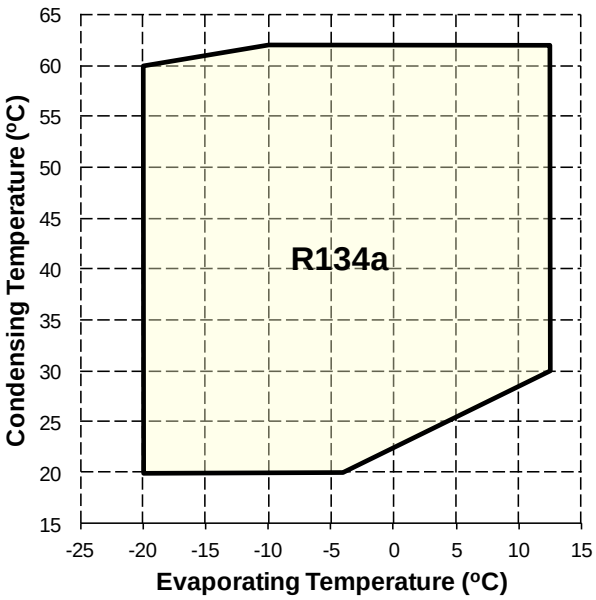


Figure 7: Medium and high temp with R134a

20K Suction Superheat

25ºC Suction Gas Return

NOTE: **Application envelopes with other refrigerants are available on request.**

3.2 Solenoid valve

Due to the high life cycle requirements in a hot gas environment, a special valve has been developed. Due to reliability requirements, only Emerson® solenoid valves may be used. All compressor warranties are null and void if the Emerson valve is not used. Digital compressors are **originally delivered with the 220-240V solenoid coil**.

The solenoid coil is also available for voltages 24V and 120V as a variation.

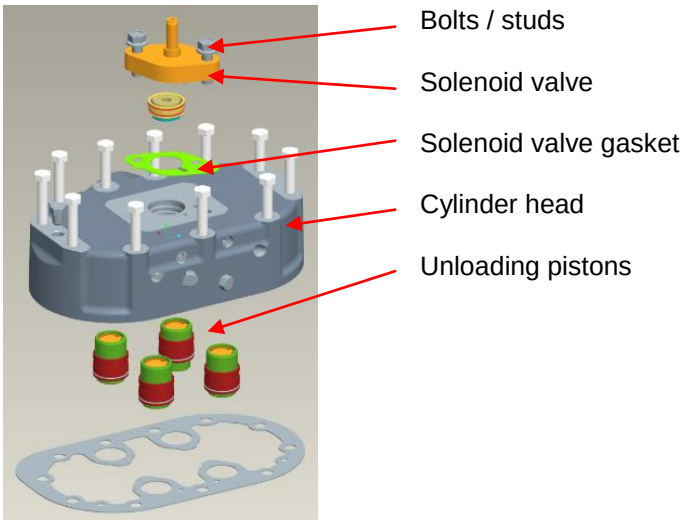


Figure 8: Configuration of Digital

Furthermore, 3D Digital compressors use special head and valve plate gaskets which have modifications to ensure gas flow for proper digital modulation. Only Emerson gaskets may be used. All compressor warranties are null and void if Emerson gaskets are not used for servicing.

3.3 Control components

Components required for control are an electronic controller and a suction pressure transmitter. The electronic controller sends the PWM signal modified in accordance with the pressure deviation from the set point using a built-in algorithm.

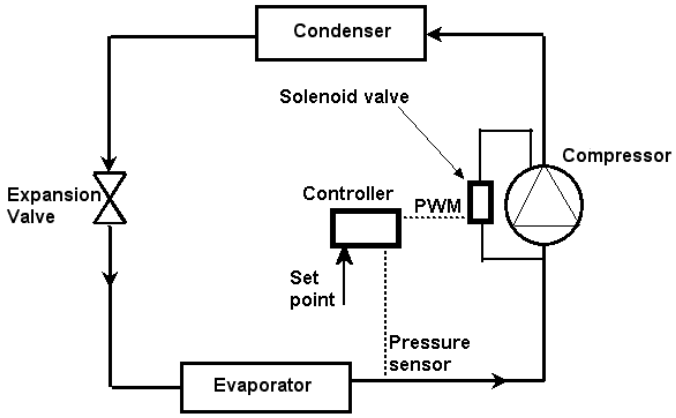


Figure 9: Control principle

4 Controlling 3D Digital compressors

The Emerson controllers EC2 and EC3 are specifically designed for Copeland Digital compressors.

Kits containing all the necessary components can be supplied by Emerson Climate Technologies. Other controllers can be used but require confirmation of their compatibility by Emerson Climate Technologies.

4.1 Controllers

4.1.1 EC3–D13 Driver

The EC3-D13 receives an input signal from an existing system controller (0…10V, 1 … 6V or 4…20mA) and activates the Copeland Digital 3-cylinder semi-hermetic solenoid valve.

An input allows to monitor the discharge temperature or the compressor DLT signal and to send an alarm signal if the specified temperature is exceeded.

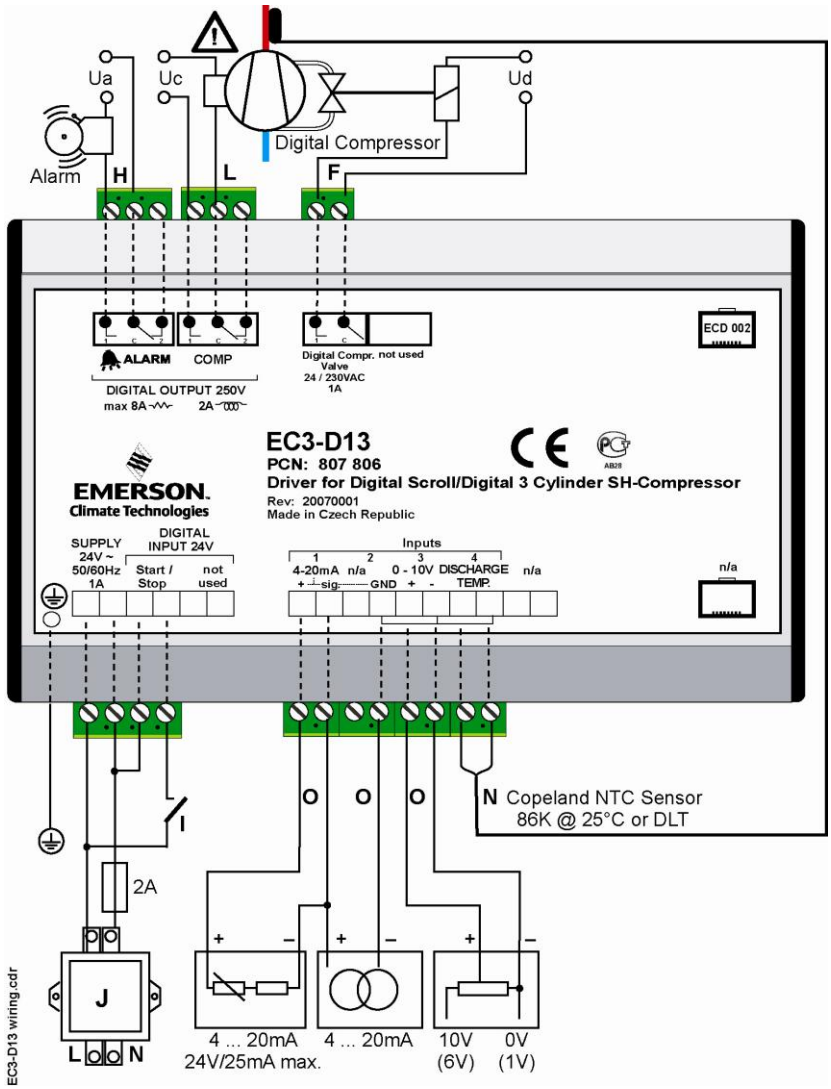
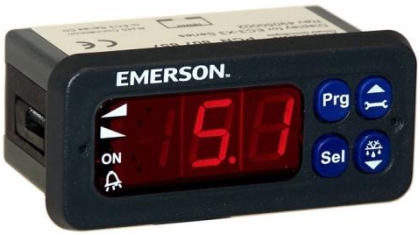


Figure 10: Wiring diagram for EC3-D13 Driver



An ECD-002 display module is available as an option; it displays system temperatures, indicates system status and enables parameters to be modified.

Figure 11: ECD-002 Display module

The EC3**–**D13 controller is a controller with built-in synchronization control for 3D Digital compressors of the refrigeration circuit.

The list of parameters can be found in “EC3-D13 Digital Driver and ECD-00 Keypad / Display Unit” - Operating Instructions, available on www.emersonclimate.eu

4.1.2 EC2 –552 Controller – Up to 2 compressors

Emerson controller EC2-552 is designed for a single Digital or two-compressor operation where one would be a 3D Digital and the other one a standard 3D compressor.

Based on the suction pressure, the EC2-552 will control the running operation of the compressors. The Digital compressor is programmed to be first in and last out (FILO), operation via a PWM output. The modulation cycle time can be set between 10 and 20 seconds and the capacity time can be adjusted down to 2 seconds (10% minimum) through the parameters of the controller. With two identical capacity compressors this will allow modulation down to 5% capacity. As illustrated in **Figure 15**, the logic is for the Digital to “fine tune” the system capacity between 5% - 100% as required. The fixed-capacity compressor is switched On when the Digital exceeds its maximum and Off with its minimum modulation depending on the system capacity requirements.

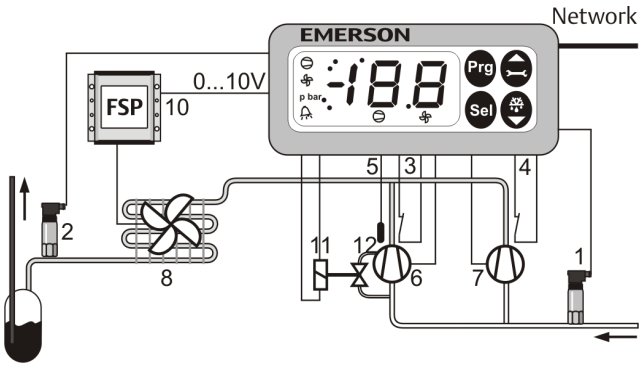


Figure 12: EC2-552 controls two compressors on one system

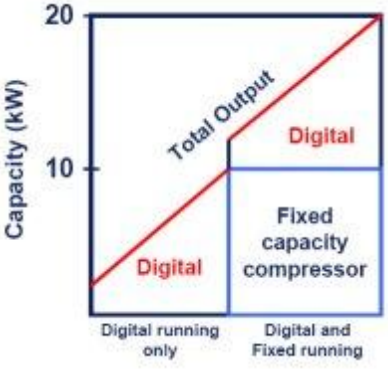


Figure 13: Total output 5 – 100% with two compressors

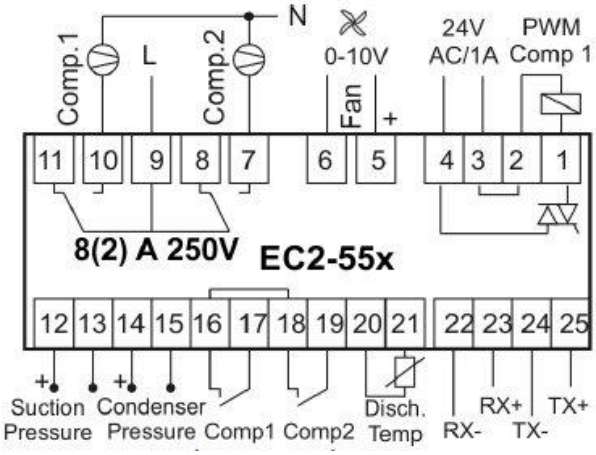


Figure 14: Wiring diagram for the EC2-55X controller

The input from the LP pressure transmitter is the reference parameter for the output signal to the compressors, and HP transmitter input is used to control fan speed via a 0 -10V output. It is possible to control up to 2 fans. The Emerson EC2-552 controller also has TCP/IP Ethernet communication capability.

The PWM output is in 24V AC, so the Digital solenoid coil rating has to be 24V. The compressor contacts should be controlled with relays having gold plated contacts to ensure longevity.

To aid selection and provide application support to manufacturers and users, an EC2 kit is available containing the controller and its accessories. For full details see the Quick Ordering Guide below.

4.1.3 Rack controllers for 3D Digital compressors

Emerson Climate Technologies can supply compressor rack controllers where a larger number of fixed standard capacity compressors plus one 3D Digital compressor can be applied to provide complete modulated control for larger systems. As with the EC2 controller, control is based on suction pressure. The pack controller models are:

EC3–65X Controller – 1 Digital plus a maximum of 7 standard D3D compressors
Networking capability:
EC3-651 LON (open communication standard)
EC3-652 TCP/IP Ethernet

ECD–000 Display module
Available as an option; it displays system temperatures, indicates system status and enables parameters to be modified.

Figure 15: EC3-6XX Controller

Figure 16: ECD-000 Display

The EC3-65X series component schematic, wiring inputs/outputs are shown below:

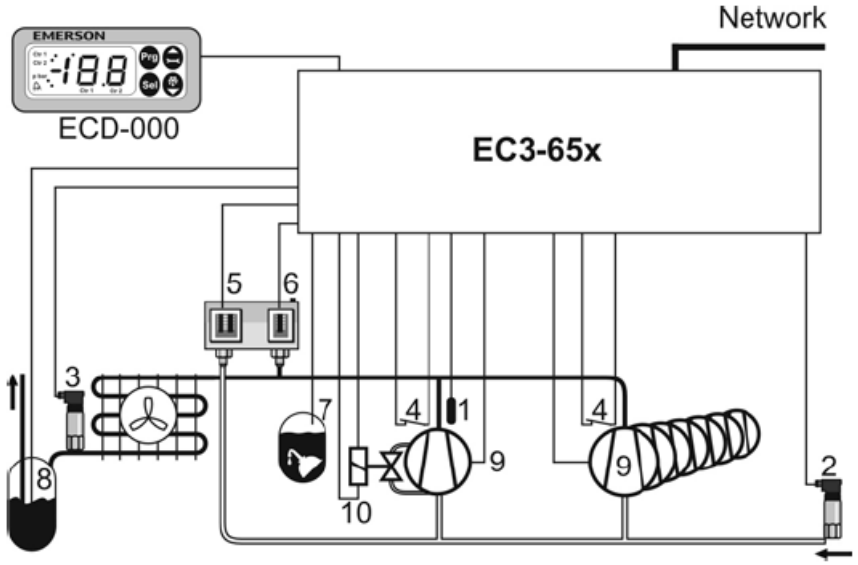


Figure 17: Schematic for the controller

KEY	
Inputs:	***Outputs:***
1. Compressors discharge temperatures 2. Suction pressure 3. Discharge pressure 4. Serial alarm inputs for compressors 5. Low pressure alarm 6. High pressure alarm 7. Oil level alarm 8. Refrigerant level alarm	9. Up to 8 compressors EC3-65X 10. Capacity control for D3D Digital

Input/Output configuration for the EC3 Controller		
Description	**I/O Specification**	**EC3-65X**
Pressure sensor inputs	24V DC, 4…20 mA	2
Compressor output relays	SPDT contacts, AgCdO Inductive (AC 15) 250 V / 2A Heating (AC 1) 250 V / 8A	8
Digital compressor control (Triac output)	Digital semi-conductor switch, 24 VAC/230 VAC	1
Alarm output (Triac)	Digital semi-conductor switch, 24 VAC/230 VAC	1
Serial alarm inputs for compressors	Digital input contacts, 24 VAC/DC or 230 VAC, two input voltage ratings provided	4
	Digital input contacts 24 VAC/DC or 230 VAC	
Dedicated alarm inputs for LP / HP, oil level and refrigerant level switches	Digital input contacts, 24 VAC/DC or 230 VAC, two input voltage ratings provided	4
Temperature 1 ambient Temperature input discharge (1) Temperature input discharge (2, 3, 4)	NTC 10 kΩ @ 25°C, -50°C…+50°C NTC 86 Ω @ 25°C, -40°C…+180°C 1 MΩ @ 25°C, +50°C…+150°C	1 1 3

Table 1

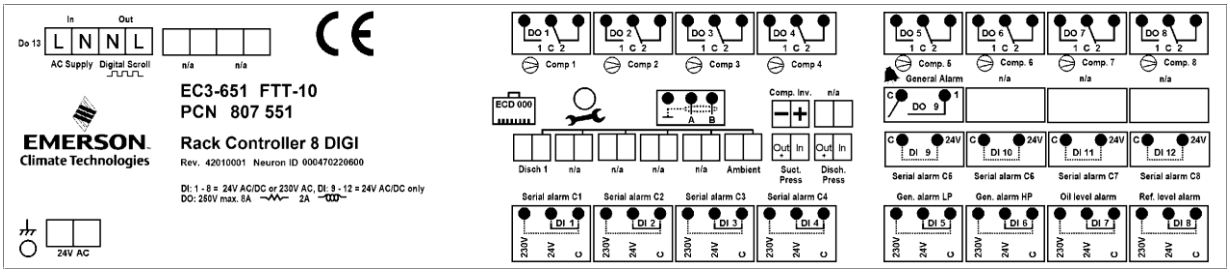


Figure 18: Wiring diagram for the EC3-651 controller

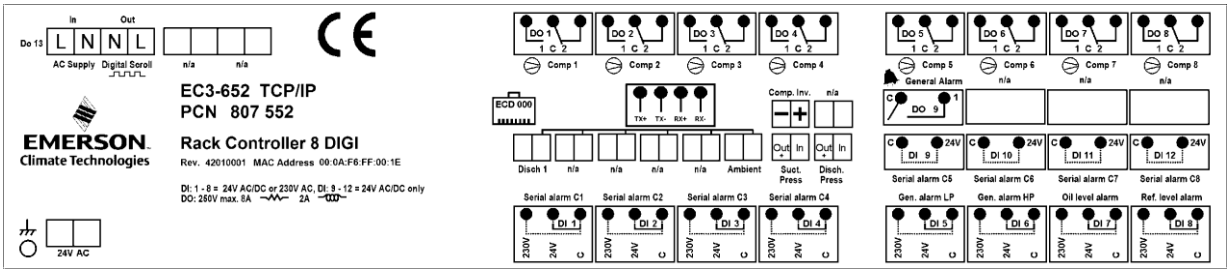


Figure 19: Wiring diagram for the EC3-652 controller

5 Quick ordering guide

Emerson Climate Technologies has compiled complete kits in order to facilitate the integration of the Digital technology. Details of kit components are listed below.

5.1 EC3–D13 Driver

Copeland kit N° 8405187 or variation N°5405815

Description	Type	Qty
Kit EC3-D13 Digital driver		1
EC3-D13 Driver	EC3-D13	1
Display	ECD-002	1
Cable EC3 to ECD, 1m	ECC-N10	1
Terminal kit	K03-331	1
Transformer 24V, 25VA	ECT-323	1

Copeland kit driver + terminal = N° 3187306 or variation N°5405804

5.2 EC2–552 Kit

Copeland kit N° 8557704

Description	Type	Qty
Kit EC2-552 Digital Control		1
EC2-552 Controller	EC2-552	1
Terminal kit	K02-540	1
Pressure transmitter, 7 bar	PT4-07M	1
Pressure transmitter, 30 bar	PT4-*30M	1
Cable assembly 3m	PT4-M30	2
Transformer 24V, 20A, DIN Rail	ECT-323	1

5.3 EC3–652 Kit

Description	Type	Qty
Kit EC3-652 Digital Control		
EC3-652 Controller	EC3-652	1
Terminal kit	K03-110	1
Pressure transmitter, 7 bar	PT4-07M	1
Pressure transmitter, 30 bar	PT4-*30M	1
Cable assembly 6m	PT4-M30	2
Transformer 24V, 20A, DIN Rail	ECT-623	1
Discharge sensor	ECN-H60	4

5.4 Display kits

OEM's that require the display and cable can order the accessories through Emerson Climate Technologies.

Display for EC3-D13

Description	Type	Copeland Ident	Qty
Display ECD-002 + cable		3187328	
Display	ECD-002	8403318	1
Display cable	ECC-N10	8557782	1

Display for EC3-652

Description	Type	Copeland Ident	Qty
Display for EC3-652	ECD-000	8557771	1
Display cable	ECC-N10	8557782	1

6 Parallel operation

The single compressor with its maximum refrigeration capacity has a limited use. For larger refrigeration capacities the parallel compressor installation can be used. Parallel operation is when several compressors are operating on one common refrigeration system. These installations require a special design to achieve maximum operating capacity and reliability.

Extensive testing has shown that passive paralleling is not working with 3D Digital compressors.

Active oil management system is a must to keep warranty rights in parallel applications.

The usage of an oil level regulating system is advocated when paralleling a 3D Digital compressor with a standard 3D.

The regulating system is composed of an oil level regulator fitted to each compressor at the sight glass location. The regulator is fed from an oil reservoir which is itself fed from an oil separator. Filters can be installed in the oil feeding line. The reservoir allows variations in oil quantity in the system to be accommodated. Oil carried over from the compressor to the system is replaced when insufficient oil is being returned.

6.1 Low pressure oil reservoir

The oil reservoir is maintained at a pressure slightly above the compressor sump pressure; this limits the amount of refrigerant dissolved in the oil in the reservoir. The pressure drop is low when the oil enters the compressor and the amount of flash gas formed in the sump is small.

Float switches or other devices can be used as regulators. It is recommended that the regulator has an electrical output which can be wired into the control circuit and can stop the compressor if the oil level falls and remains below the minimum level for a period of time (maximum 2 minutes). This protects against failure of the oil supply to the individual compressor. A level switch in the reservoir will only protect against insufficient oil in the receiver, but not against loss of oil supply to an individual compressor or against a fault on an individual regulator.

Regulators currently on the market which meet these requirements include ALCO OM3 TraxOil and the AC&R S9040. The TraxOil requires the oil reservoir to be pressurized to 3.5 bar above suction pressure for reliable operation.

When using a regulator care must be taken to set the oil level in the upper half of the sight glass. If an adapter is used to connect the regulator this may have a smaller internal diameter than the glass and this could give rise to a false oil level reading.

Proper oil pressure safety control with an approved switch is a condition of warranty!

When commissioning these systems it is important to allow sufficient time for equilibrium running conditions to be attained.

Model	Oil level control
Functions: - Oil fill - Alarm - Compressor lockout	 Yes Yes Yes
Supply voltage current	24V AC, 50/60 Hz, 0.7A
Level control	40% – 60% of sight glass height
Switch/Relay release time	120 sec
Reset mode Time delay filling Time delay alarm	Auto 10 sec 20 sec
Oil connection	Screw adapter ¾" – 14 NPTF
Maximum working pressure	450 psi / 31 bar
Solenoid valve MOPD	305 psi / 21 bar
Alarm contact	3A, 230 V
Solenoid coil	Alco ASC 24V AC 50/60 Hz: 8VA

Table 2: OM3 TraxOil properties

Figure 20: TraxOil

6.2 High-pressure oil reservoir

The need for a separate oil receiver may be avoided if a combined separator/receiver is used, but in this case the oil will be stored at discharge pressure. It will therefore cause much more disturbance and foaming when it enters the compressor sump. For this reason it is advisable to limit the quantity of oil entering the sump when the valve opens. The Alco OM3 TraxOil is suitable for this type of application and has been proven to operate satisfactorily with a high-pressure oil supply.

7 Check valve

For standard applications a check valve is not needed

A check valve is needed in racks where pressures are unstable.

A check valve can be needed at partial load (10%) depending on the pressure ratio.

8 Additional fan

When an additional fan is needed (see operating envelopes in Chapter 3.1.1) the fan kit is the same as for D3D compressors with Moduload.

The fan kit ident number can be found in the compressor spare part lists.

9 Unloaded start

The Digital system on 3D compressors can operate as unloaded start when the solenoid valve is energized.