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(71) Applicant(s):
Ford Global Technologies, LLC
(Incorporated in USA - Delaware)
Suite 800, Fairlane Plaza South,
330 Town Center Drive, Dearborn,
Michigan 48126, United States of America

(72) Inventor(s):
Paul Stephen A Bryan
Matt D Smith
William David Treharne
Susan Rebecca Cikanek

(74) Agent and/or Address for Service:
A Messulam & Co. Ltd
43-45 High Road, Bushey Heath, BUSHEY,
Herts, WD23 1EE, United Kingdom

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(56) Documents Cited:
EP 0565373 A2 **JP 2005238911 A**
US 6694764 B1 **US 20080034767 A1**

(58) Field of Search:
INT CL **B60H, F04B, F04D, G05B, G05D**
Other: **WPI; EPODOC.**

(54) Abstract Title: **A System and Method for Controlling a Compressor**

(57) A control system and method for controlling a compressor 20 that forms part of a climate control system 10; the control system/method comprises steps of assessing at least one temperature; generating a first compressor speed signal based on the assessed temperature; determining a pressure within the climate control system; generating a second compressor speed signal based on said pressure; accessing data held in a memory store corresponding to compressor speeds (maps/ look up tables); and generating an optimal compressor speed based on said first and second compressor speeds and said compressor speed data. Preferably, a vehicle's climate control system operation is achieved by optimal control of the operating speed of the compressor using temperature and pressure controllers 26, 36.

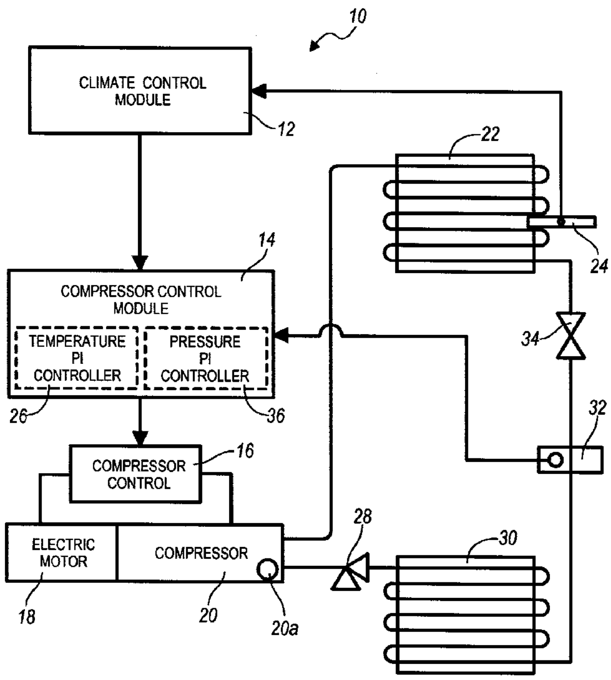

FIG. 1

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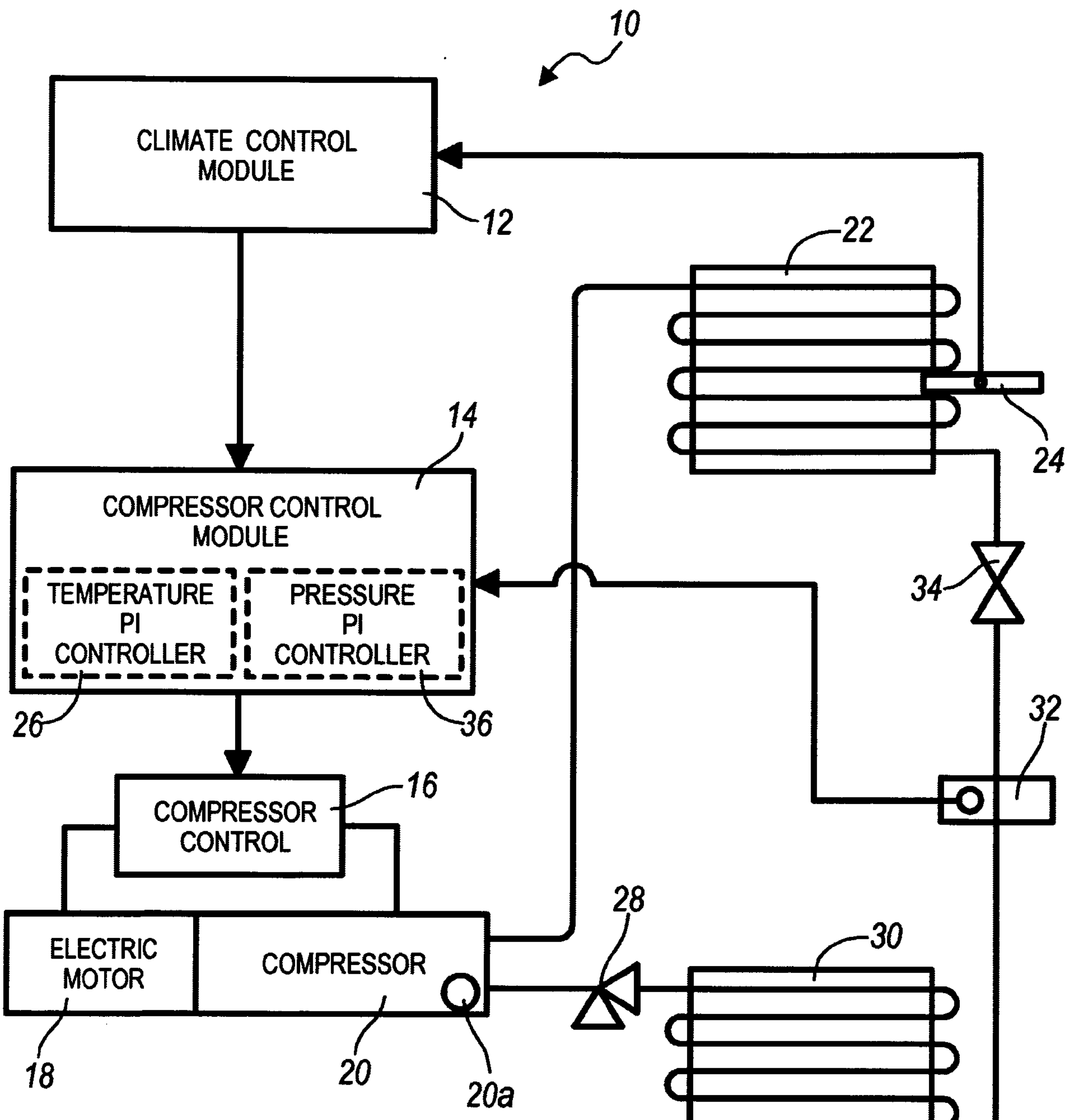
10
CLIMATE CONTROL MODULE
12
22
24
14
COMPRESSOR CONTROL MODULE
TEMPERATURE PI CONTROLLER
PRESSURE PI CONTROLLER
34
26
36
32
COMPRESSOR CONTROL
16
28
30
ELECTRIC MOTOR
COMPRESSOR
18
20
20a

FIG. 1

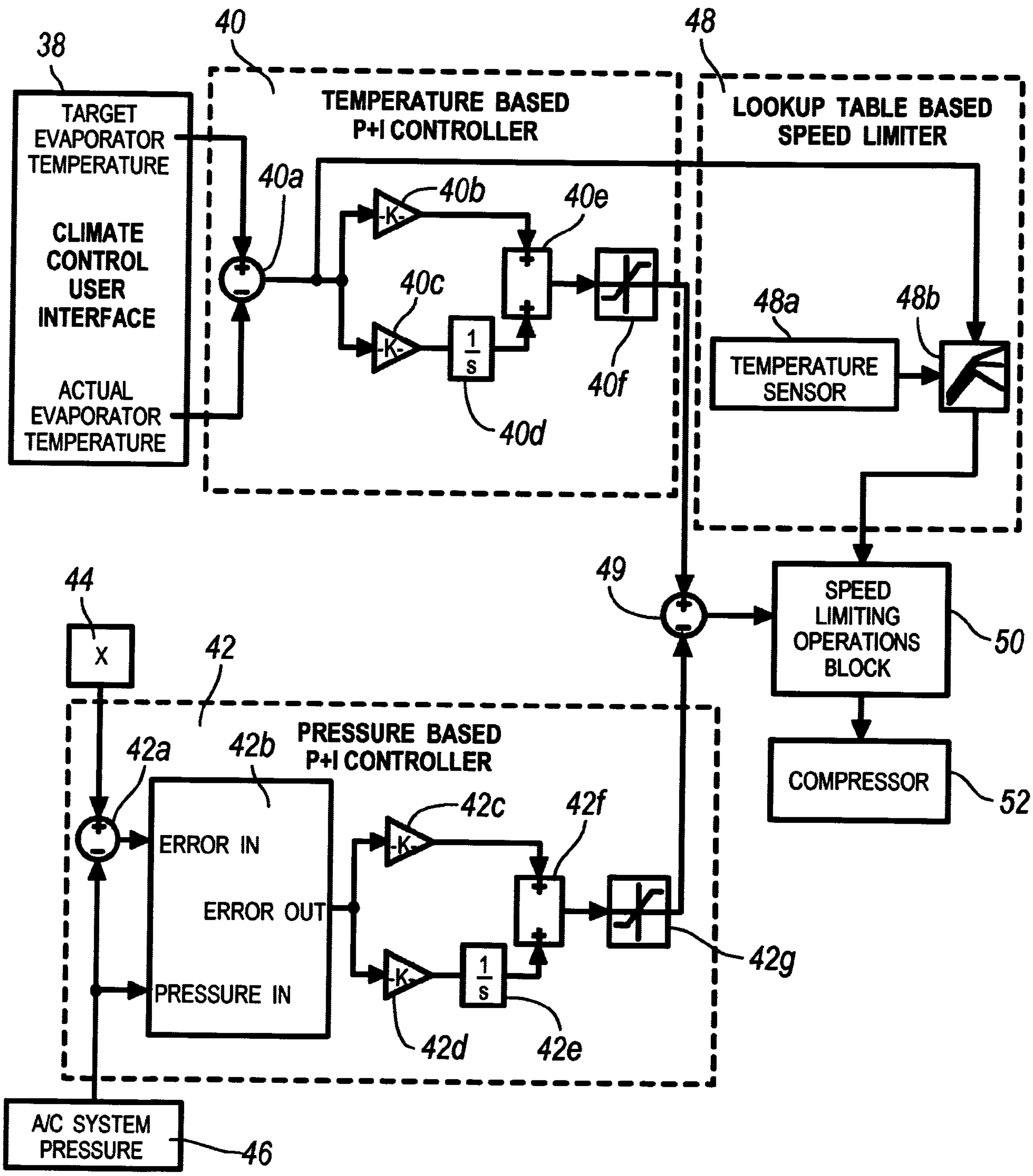
38
TARGET EVAPORATOR TEMPERATURE
CLIMATE CONTROL USER INTERFACE
ACTUAL EVAPORATOR TEMPERATURE
40
TEMPERATURE BASED P+I CONTROLLER
40a
40b
40c
40d
40e
40f
-K-
1/s
48
LOOKUP TABLE BASED SPEED LIMITER
48a
48b
TEMPERATURE SENSOR
49
SPEED LIMITING OPERATIONS BLOCK
50
COMPRESSOR
52
44
X
42
PRESSURE BASED P+I CONTROLLER
42a
42b
ERROR IN
ERROR OUT
PRESSURE IN
42c
42d
42e
42f
42g
A/C SYSTEM PRESSURE
46

FIG. 2

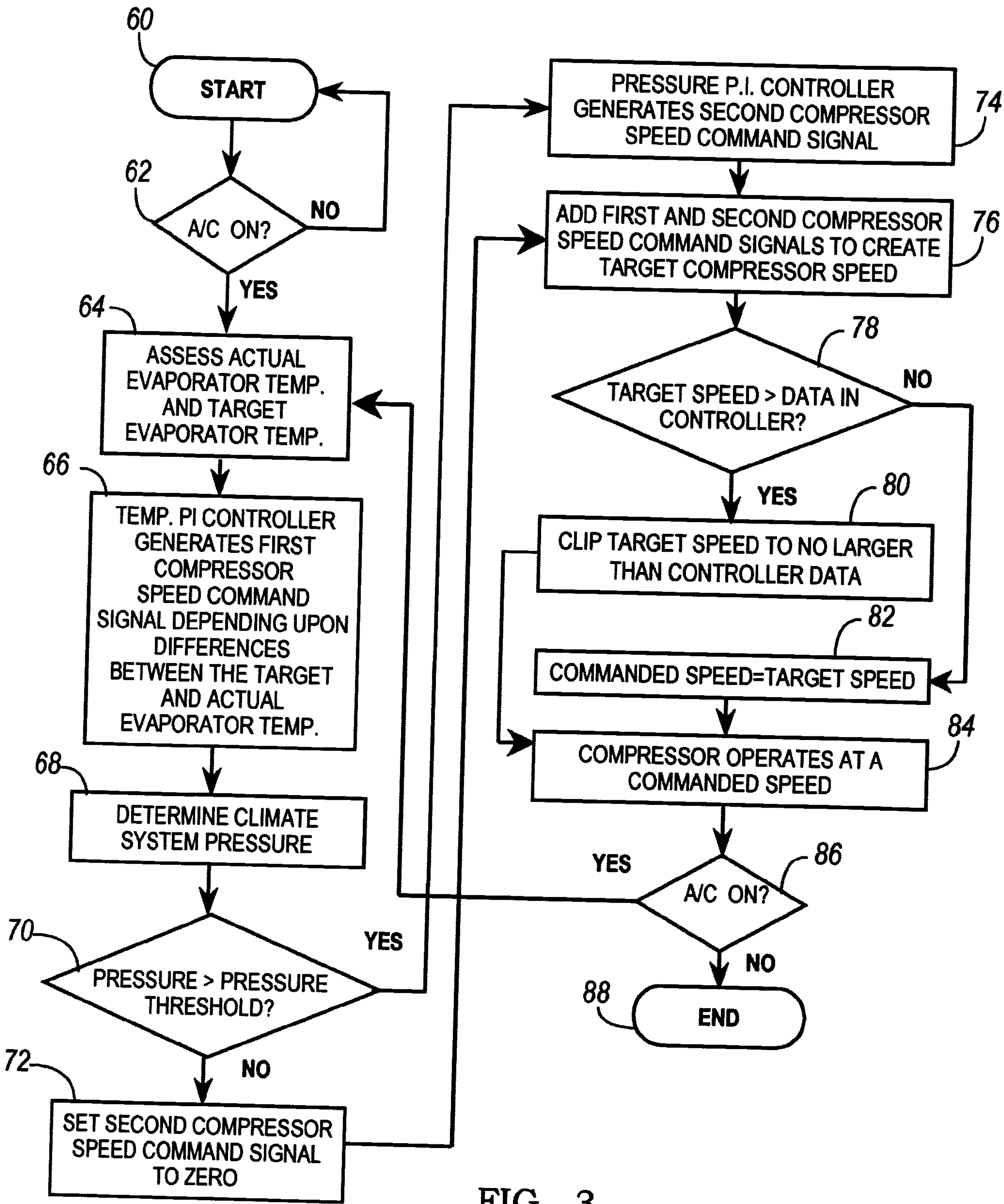
60
START
62
A/C ON?
NO
YES
64
ASSESS ACTUAL EVAPORATOR TEMP. AND TARGET EVAPORATOR TEMP.
66
TEMP. PI CONTROLLER GENERATES FIRST COMPRESSOR SPEED COMMAND SIGNAL DEPENDING UPON DIFFERENCES BETWEEN THE TARGET AND ACTUAL EVAPORATOR TEMP.
68
DETERMINE CLIMATE SYSTEM PRESSURE
70
PRESSURE > PRESSURE THRESHOLD?
YES
NO
72
SET SECOND COMPRESSOR SPEED COMMAND SIGNAL TO ZERO
PRESSURE P.I. CONTROLLER GENERATES SECOND COMPRESSOR SPEED COMMAND SIGNAL
74
ADD FIRST AND SECOND COMPRESSOR SPEED COMMAND SIGNALS TO CREATE TARGET COMPRESSOR SPEED
76
78
TARGET SPEED > DATA IN CONTROLLER?
NO
YES
80
CLIP TARGET SPEED TO NO LARGER THAN CONTROLLER DATA
82
COMMANDED SPEED=TARGET SPEED
84
COMPRESSOR OPERATES AT A COMMANDED SPEED
YES
86
A/C ON?
NO
88
END

FIG. 3

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A SYSTEM AND METHOD FOR CONTROLLING A COMPRESSOR

This invention relates to a system and method for controlling the speed of a compressor and in particular to the control of a compressor for a climate control system.

Climate control systems conventionally include a compressor that moves and pressurizes refrigerant flowing through the climate control system. Accordingly, these compressors operate at a particular speed to accommodate cooling demands.

In many conventional climate control systems, the compressor operates at either a full-on mode or a full-off mode. That is, the speed of the compressor cannot be varied from a designated compressor speed. Such compressors render the climate control system inefficient at meeting some cooling demands as some cooling demands require a compressor speed that differs from the designated compressor speed.

Alternatively, in some cases such as electric air conditioning compressors, the climate control system may vary the compressor speed. However, it is commonly known that these systems also possess operating inefficiencies.

It is an object of this invention to overcome the disadvantages associated with a conventional climate control system.

According to a first aspect of the invention there is provided a control system for a compressor that forms part of a climate control system, the system comprising a first control portion configured to assess an actual temperature and a target temperature and generate a first compressor speed command signal based on the actual temperature and the target temperature, a second control portion configured to determine a pressure of the climate control system and generate a second compressor speed command signal based on the pressure of the climate control system and a controller having a memory with data that corresponds to compressor speeds wherein the controller is operable to access the first compressor speed command signal, the second compressor speed command signal and the data and transmit a control signal to the compressor causing the compressor to operate at an optimal compressor speed.

The data that corresponds to compressor speeds may include data in the form of a look-up table.

The system may further comprise a temperature sensor for sensing a temperature and the controller is operable to receive temperature signals from the temperature sensor and transmit the control signal to the compressor based on the first compressor speed command signal, the second compressor speed command signal, the temperature signals and the data.

Transmitting a control signal to the compressor causing the compressor to operate at the target compressor speed may include transmitting a control signal that limits the compressor speed to a compressor speed that is no greater than the target compressor speed.

The first control portion may include a temperature proportional-integral (PI) controller.

The temperature PI controller may include a proportional gain, an integral gain and an integrator.

The second control portion may include a pressure proportional-integral (PI) controller.

The pressure PI controller may include a proportional gain, an integral gain and an integrator.

According to a second aspect of the invention there is provided a motor vehicle having a climate control system including a control system for a compressor constructed in accordance with said first aspect of the invention.

The first control portion of the control system may be a temperature proportional-integral (PI) controller configured to determine an actual temperature and a target temperature and generate a first compressor speed command signal based on the actual temperature and the target temperature, the second control portion may be a pressure proportional-integral (PI) controller configured to determine a pressure of the climate control system and generate a second compressor speed command signal based on the pressure of the climate control system, the system may include a temperature sensor for sensing a temperature and transmitting temperature signals, the memory may include the data in the form of a look-up table that corresponds to compressor speeds and the controller may be operable to determine an apparent temperature based on the temperature signals, determine a target compressor speed based on the apparent temperature, the first compressor speed command signal, the second compressor speed command signal and the data and transmit a control signal based on the target compressor speed causing the compressor to operate.

Assessing an actual temperature and a target temperature may include assessing an actual temperature and a target temperature of an evaporator that is operable with the climate control system.

According to a third aspect of the invention there is provided a method of controlling a compressor that forms part of a climate control system, the compressor being adapted to operate at multiple speeds wherein the method comprises assessing at least one temperature, generating a first compressor speed command signal based upon the at least one temperature, determining whether pressure within the climate control system is less than or greater than a pressure threshold, setting a second compressor speed command signal based on whether pressure within the climate control system is less than or greater than a pressure threshold, creating a target compressor speed based on the first and second compressor speed command signals, determining whether the target compressor speed is greater than compressor speed data and generating a control signal based on whether the target compressor speed is greater than compressor speed data causing operation of the compressor at an optimal speed.

Accessing at least one temperature may include assessing an actual evaporator temperature and assessing a target evaporator temperature.

Creating the target compressor speed based on the first and second compressor speed command signals may include creating the target compressor by summing the first and second compressor speed command signals.

The data that corresponds to the compressor speeds may include data stored in a memory of a controller device in the form of a look-up table.

Generating the control signal based on whether the target compressor speed is greater than compressor speed data may include clipping the target speed to a speed that is no greater than the speeds that correspond to the compressor speed data when the target speed is greater than the speeds that correspond to the compressor speed data and generating the control signal based upon clipping of the target speed.

Generating the control signal based on whether the target compressor speed is greater than compressor speed data may include setting the control signal equal to the target speed when the target speed is not greater than the compressor speed data and generating the control signal.

Setting a second compressor speed command signal based on whether pressure within the climate control system is less than or greater than the pressure threshold may include setting the second compressor speed command signal to zero when the pressure within the climate control system is less than a pressure threshold includes.

Setting a second compressor speed command signal based on whether pressure within the climate control system is less than or greater than the pressure threshold may include generating the second compressor speed command signal via a pressure proportional-integral (PI) controller.

The invention will now be described by way of example with reference to the accompanying drawing of which:-

Figure 1 illustrates a climate control system in accordance with an embodiment of the present invention;

Figure 2 provides a detailed illustration of a control system that is operable with the climate control system of Figure 1; and

Figure 3 illustrates a flow chart of a method for controlling a compressor in accordance with an embodiment of the present invention.

Referring to Figure 1, a climate control system 10 is shown that efficiently provides target cooling in response to cooling demands. The climate control system 10 may be installed in a vehicle. It is recognized, however, that climate control system 10 may be equally adapted for non-vehicular applications (e.g., buildings, homes, etc.).

As shown in Fig.1 the climate control system 10 includes a climate control module 12, a compressor control module 14, an electric motor 18, compressor controls 16, a compressor 20, an evaporator 22, a pressure relief valve 28, a condenser 30, a transducer 32, a thermal expansion valve (TXV) 34 and a temperature sensor 24.

The climate control module 12 and compressor control module 14 either individually or in combination may function as a controller device that processes signals received from various devices within climate control system 10 to effect or maintain a target temperature of an area.

The climate control module 12 has a microprocessor and is adapted to communicate with a climate control user interface (not shown). The user interface allows a user to select various temperature settings for climate control system 10. For example, the user interface may be used to control the climate control system or air conditioning system (e.g. turn it on or off, set a target temperature and the like).

To achieve various cooling demands in response to user interface settings, climate control system 10 utilizes a target evaporator temperature and an actual evaporator temperature. In one embodiment, climate control module 12 is preprogrammed with a target evaporator temperature that corresponds with various settings on the user interface. Additionally, the climate control module 12 communicates with the sensor 24 for a determination of the actual evaporator temperature. Upon selection of an air conditioning system setting (e.g., A/C on), climate control module 12 generates for compressor control module 14 signals that correspond to the target evaporator temperature and the actual evaporator temperature, and an air conditioning request signal.

As shown, compressor control module 14 includes a temperature proportional-integral (PI) controller 26 and a pressure PI controller 36. It will be appreciated that the Temperature PI controller 26 and the pressure PI controller 36 may be implemented in the form of a single controller or as multiple controllers. It will also be appreciated that although PI controllers are shown and described, alternative embodiments may utilize other types of controller such as a proportional-integral-differential (PID) controller.

Based on differences between the target evaporator temperature and the actual evaporator temperature, the climate control module 12 (i.e., temperature PI controller 26) generates compressor speed command signals for compressor control 16. Pressure PI controller 36 is also adapted to generate compressor speed command signals based on certain system pressures.

Transducer 32, which in this case is a pressure transducer, detects pressure within climate control system 10 and generates signals indicating the detected pressure. The compressor control module 14 receives the signals indicative of system pressure and determines whether the system pressure is higher than a predetermined pressure threshold. In one embodiment, the predetermined pressure threshold may be within a range of 2415 to 3100 kPa (350 psi to 450 psi). It is recognized, however, that alternative embodiments may have other pressure threshold ranges.

If the system pressure is greater than the pressure threshold, compressor control module 14 (via pressure PI controller 36) may generate the compressor speed command signals. In some instances, the compressor speed command signal generated by pressure PI controller 36 causes a reduction in system pressure.

The compressor control module 14 has a memory with data that corresponds to compressor speeds. In one embodiment, the data that corresponds to the compressor speeds may be data in the form of a look-up table. Depending upon the compressor speed command signals from temperature PI controller 26 and the pressure PI controller 36, compressor control module 14 identifies a target speed within the look-up table. The target compressor speed then operates as a limit or clip that prevents the generation of a control signal (also referred to as a commanded speed signal) that may cause the compressor to operate at an undesirable speed. The target compressor speed that limits the actual compressor speed is transmitted, in the form of electrical signals, to a compressor control 16.

Compressor control 16 may be implemented as a configuration of electric devices (e.g., transistors, diodes, micro-electronic chips, etc.) that enable the generation of control signals for compressor 20. In one embodiment, compressor control 16 may be implemented with compressor control module 14. As shown, compressor control 16 is operable with an electric motor 18 and compressor 20. As recognized by one of ordinary skill in the art, electric motor 18 may be directly coupled to and enable the operation of compressor 20.

Upon the receipt of the compressor command signals, compressor control 16 is adapted to generate the control signals for energizing compressor 20. That is, compressor 20 may be energized to suction low pressure gas or vapor from evaporator 22 and discharge high pressure gas or vapor, which is condensed into a high pressure liquid by condenser 30.

As shown, compressor 20 may also include a pressure relief valve 28 that opens in response to high pressure. Additionally, in this case, a high pressure relief valve 28 is disposed between compressor 20 and condenser 30. The relief valve 28 may also be designed to open when pressure between compressor 20 and condenser 30 exceeds a target pressure limit.

TXV 34 is disposed between condenser 30 and evaporator 22 and serves as a separating device that separates the high pressure side of climate control system 10 from the low pressure side. Accordingly, TXV 34 meters the flow of liquid refrigerant that flows from condenser 30 into evaporator 22.

Now, referring to Figure 2, a detailed schematic diagram of a temperature PI controller 40, a pressure PI controller 42 and a compressor speed limiter 48 is provided.

The controllers 40 and 42 may be integrated into a single electronic device or separately packaged as shown in Figure 1. The limiter 48 may be a separate controller or integrated with temperature PI controller 40 and/or pressure based controller 42.

User interface box 38 illustrates the generation of the target evaporator temperature and actual evaporator temperature signals. The signals that correspond to the target and actual evaporator temperatures are received at a summation point 40a. The resulting signal from summation point 40a may be referred to as a temperature error signal.

The temperature error signal may then be fed directly into a data look-up table 48b. The error signal is also fed into a proportional gain 40b and an integral gain 40c.

Once the error signal traverses proportional gain 40c it is received and integrated by an integrator 40d. The integrated signal is then summed along with a signal from proportional gain 40b at a device 40e. A limiting device 40f limits the range of authority of temperature based controller 40. That is, limiting device 40f prevents the temperature PI controller 40 from generating a compressor speed command signal that causes an undesirable compressor speed. The signal that is transmitted from limiting device 40f is received at a summation point 49.

As shown, pressure PI controller 42 initially receives a calibration value as indicated by block 44. The calibration value may be stored in a memory of controller 42 and serve as a target maximum system pressure. A transducer 46, which may be a pressure sensor, generates corresponding pressure signals that are fed into a summation point 42a along with the calibration value. The resulting signal from summation point 42a may be referred to as an actual pressure error signal. The actual pressure error signal is supplied to a device 42b. Device 42b may be a logic device or switch. As shown, device 42b also receives the pressure signal as detected by device 46.

Device 42b determines whether pressure PI controller 42 remains in an on state or an off state. Device 42b receives an "ERROR IN" signal, a "PRESSURE IN" signal and generates an "ERROR OUT" signal. If the "PRESSURE IN" signal, as received from transducer 46, is greater than the calibration value, then the "ERROR OUT" signal is equal to the "ERROR IN" signal. Alternatively, if the "PRESSURE IN" signal is less than the calibration value, then the "ERROR OUT" signal is zero. Thus, when the "PRESSURE IN" is less than the calibration value, the pressure PI controller does not generate a compressor speed command signal.

Alternatively, when the "ERROR OUT" signal equals the "ERROR IN" signal (i.e., the "PRESSURE IN" is greater than the calibration value), the "ERROR OUT" signal is received by a proportional gain device 42c and an integral gain device 42d. The signal received from integral gain device 42d is integrated by an integrator 42e. The signals from integrator 42e and proportional gain device 42c are summed together at a summing device 42f. Accordingly, limiting device 42g limits the range of authority of the pressure PI controller 42. That is, the device 42g calibrates the pressure PI controller 42 so as to not lower the compressor speed below a target speed.

The signal that is transmitted from device 42g may be referred to as a compressor speed command signal. The compressor speed command signal from device 40f and device 42g are summed at a summation point 49. As shown in limiter block 48, the look-up table 48b receives temperature signals from a temperature sensor 48a.

The signals from sensor 48a may indicate an ambient or an apparent temperature. It is recognized that the apparent temperature may include an ambient temperature plus considerations for sun load, humidity, interior temperature, etc. The look-up table, having received the temperature error signal from summation point 40a and the temperature signal from sensor 48a identifies the target compressor speed that corresponds to the signals received from summation point 40a and sensor 48a. The target compressor speed functions as limit to the actual compressor speed. Once a corresponding compressor speed is identified, a signal is generated and transmitted to a speed limiting operations block 50.

As shown, operation block 50 also receives the resulting signal from summation point 49. Operation block 50 clips the sum of output speeds of the temperature PI controller and the pressure PI controller to a speed that is no greater than the output of look-up table 48b.

Accordingly, a control signal (also referred to as a commanded speed signal), as generated by compressor control 16 (Figure 1) that includes operations block 50 is received at the compressor 52. In response to the control signal, compressor 52 operates at an optimal speed.

Now referring to Figure 3, a flow chart illustrates a method for controlling the speed of a compressor.

Block 60 is the starting point for the method. At block 62, the method includes determining whether the air conditioning system is on. It is recognized that block 62 also includes requests by the climate control system to energize the compressor. If the air conditioning system is not on, the method returns to block 60 but, if the air conditioning system is on, the method advances to block 64 where the actual and target evaporator temperatures are assessed.

Then, as shown in block 66, the temperature PI controller generates a first compressor speed command signal. This speed command signal may have a value that corresponds to the differences between the target and actual evaporator temperature.

At block 68, the method determines a pressure of the climate control system and, at block 70, the method includes determining whether the pressure of the climate control system is greater than a pressure threshold. If the pressure is greater than the threshold then the method advances to block 74 where the pressure P.I. controller sets a second compressor command speed but, if the pressure is not greater than the pressure threshold, the method proceeds to block 72 where the second compressor speed command signal is set to a value of zero. If the climate control system pressure is greater than the pressure threshold, at block 74, the pressure PI controller establishes and generates the second compressor speed command signal. Following block 74, block 76 occurs wherein the first and second compressor speed command signals are added to create the target compressor speed signal. Following block 76, the method continues to block 78.

The target compressor speed may then be compared with the data (e.g., compressor speed data) stored within the controller as shown by block 78. The compressor speed data corresponds includes data that corresponds with compressor operating speeds. If the target speed is greater than compressor speed data, block 80 is executed otherwise block 80 is skipped and block 82 is executed. In block 80, the target speed is clipped to a value that is no greater than the compressor speed data stored in the controller.

As shown in block 82 the commanded speed (being transmitted as the control signal) is set equal to the target speed and then, as shown by block 84, the compressor operates at the commanded speed. Following block 84, the method proceeds to block 86 as described below.

From block 80 the control signal (or commanded speed signal) is transmitted to compressor so as to cause the compressor to operate at the commanded speed in block 84.

At block 86, it is determined whether the air conditioning system remains on. If so, the method returns to block 64 otherwise the method ends at block 88.

CLAIMS

1. A control system for a compressor that forms part of a climate control system, the system comprising a first control portion configured to assess an actual temperature and a target temperature and generate a first compressor speed command signal based on the actual temperature and the target temperature, a second control portion configured to determine a pressure of the climate control system and generate a second compressor speed command signal based on the pressure of the climate control system and a controller having a memory with data that corresponds to compressor speeds wherein the controller is operable to access the first compressor speed command signal, the second compressor speed command signal and the data and transmit a control signal to the compressor causing the compressor to operate at an optimal compressor speed.

2. A system as claimed in claim 1 wherein the data that corresponds to compressor speeds includes data in the form of a look-up table.

3. A system as claimed in claim 1 or in claim 2 wherein the system further comprises a temperature sensor for sensing a temperature and the controller is operable to receive temperature signals from the temperature sensor and transmit the control signal to the compressor based on the first compressor speed command signal, the second compressor speed command signal, the temperature signals and the data.

4. A system as claimed in any of claims 1 to 3 wherein transmitting a control signal to the compressor causing the compressor to operate at the target compressor speed includes transmitting a control signal that limits the compressor speed to a compressor speed that is no greater than the target compressor speed.

5. A system as claimed in any of claims 1 to 4 wherein the first control portion includes a temperature proportional-integral (PI) controller.

6. A system as claimed in claim 5 wherein the temperature PI controller includes a proportional gain, an integral gain and an integrator.

7. A system as claimed in any of claims 1 to 6 wherein the second control portion includes a pressure proportional-integral (PI) controller.

8. A system as claimed in claim 7 wherein the pressure PI controller includes a proportional gain, an integral gain and an integrator.

9. A motor vehicle having a climate control system including a control system for a compressor as claimed in any of claims 1 to 8.

10. A method of controlling a compressor that forms part of a climate control system, the compressor being adapted to operate at multiple speeds wherein the method comprises assessing at least one temperature, generating a first compressor speed command signal based upon the at least one temperature, determining whether pressure within the climate control system is less than or greater than a pressure threshold, setting a second compressor speed command signal based on whether pressure within the climate control system is less than or greater than a pressure threshold, creating a target compressor speed based on the first and second compressor speed command signals, determining whether the target compressor speed is greater than compressor speed data and generating a control signal based on whether the target compressor speed is greater than compressor speed data causing operation of the compressor at an optimal speed.

11. A method as claimed in claim 10 wherein accessing at least one temperature includes assessing an actual evaporator temperature and assessing a target evaporator temperature.

12. A method as claimed in claim 10 or in claim 11 wherein creating the target compressor speed based on the first and second compressor speed command signals includes creating the target compressor by summing the first and second compressor speed command signals.

13. A method as claimed in any of claims 10 to 12 wherein generating the control signal based on whether the target compressor speed is greater than compressor speed data includes clipping the target speed to a speed that is no greater than the speeds that correspond to the compressor speed data when the target speed is greater than the speeds that correspond to the compressor speed data and generating the control signal based upon clipping of the target speed.

14. A method as claimed in any of claims 10 to 13 wherein generating the control signal based on whether the target compressor speed is greater than compressor speed data includes setting the control signal equal to the target speed when the target speed is not greater than the compressor speed data and generating the control signal.

15. The method of claim 14, wherein setting a second compressor speed command signal based on whether pressure within the climate control system is less than or greater than the pressure threshold includes setting the second compressor speed command signal to zero when the pressure within the climate control system is less than a pressure threshold includes.

16. The method of claim 15 wherein setting a second compressor speed command signal based on whether pressure within the climate control system is less than or greater than the pressure threshold includes generating the second compressor speed command signal via a pressure proportional-integral (PI) controller.

17. A control system for a compressor that forms part of a climate control system substantially as described herein with reference to the accompanying drawing.

18. A motor vehicle substantially as described herein with reference to the accompanying drawing.

19. A method of controlling a compressor that is operative with a climate control system substantially as described herein with reference to the accompanying drawing.

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Application No: GB0810275.8

Claims searched: 1-19

Examiner: Mr Tyrone Moore

Date of search: 4 September 2008

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	EP 0565373 A2 (INGERSOLL RAND CO) See whole document. Describes a method of controlling a variable speed compressor utilising a characteristic map of compressor speeds.
A	-	US 6694764 B1 (DELPHI TECH INC) See whole document. Describes a method of controlling a compressor associated with a climate control system.
A,P	-	US 2008/034767 A1 (GM GLOBAL TECHNOLOGY OPERATIONS INC) See whole document. Describes a method of controlling a compressor's speed for optimizing an air conditioning system of a vehicle.
A	-	JP 2005238911 A (KAWASAKI HEAVY IND LTD) See EPODOC, WPI abstracts and figures. AN-2005-587109 [60]. Describes a method of controlling a compressor speed based on temperature and pressure.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

B60H; F04B; F04D; G05B; G05D

The following online and other databases have been used in the preparation of this search report

WPI; EPODOC.

International Classification:

Subclass	Subgroup	Valid From
G05D	0013/00	01/01/2006

Subclass	Subgroup	Valid From
B60H	0001/00	01/01/2006
F04B	0049/06	01/01/2006
G05B	0013/02	01/01/2006