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INTRODUCTION

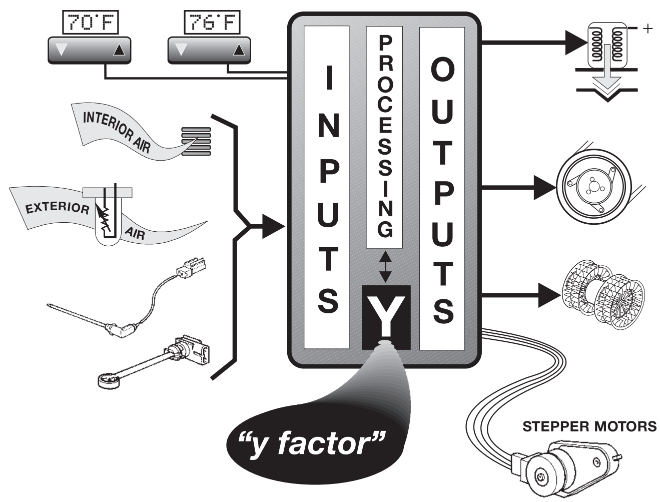
Several general system operation concepts apply to both the IHKR and IHKA Climate Control Systems. These concepts should be familiar to you **before** you begin to learn about the specifics of the IHKR and IHKA systems.

The general system operation concepts are:

- Inputs, Processing, Outputs (IPO)
- Temperature Sensor Monitoring
- The “Y-Factor”
- Stepper Motor Operation

INPUTS, PROCESSING, OUTPUTS

All modern, microprocessor-controlled systems use various sensors, switches, voltage signal circuits, ground signal circuits, etc. to **provide information to a system control module.** These sensors, switches, and other components are known as the **input devices**; the information or signals they provide are known simply as the **inputs**. Typically, each input has its own, dedicated terminal or pin at the control module.

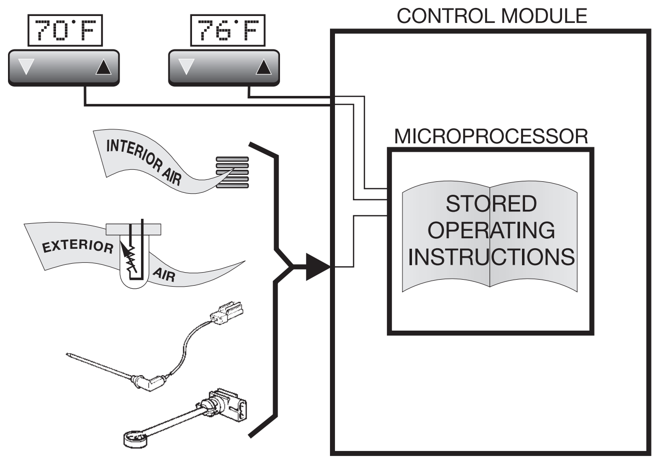


Some examples of inputs to the climate control system control module are:

- heater core temperatures (from the heater core temperature sensors)
- evaporator temperature (from the evaporator temperature sensor)
- refrigerant pressure (from the compound pressure switch on the receiver/dryer)
- stratified air thumbwheel position (from the thumbwheel potentiometer)
- vehicle speed (from the vehicle speed sensor)
- A/C compressor request (from the A/C compressor “snowflake” button)
- the start signal, Kl. 50 (from the ignition switch).

The system control module repetitively accepts all the inputs (many times each second) and **processes** them.

Engineers and researchers thought about how the module should respond to specific inputs, combinations of inputs, or even missing inputs, and then programmed the control module microprocessor to perform in each case.



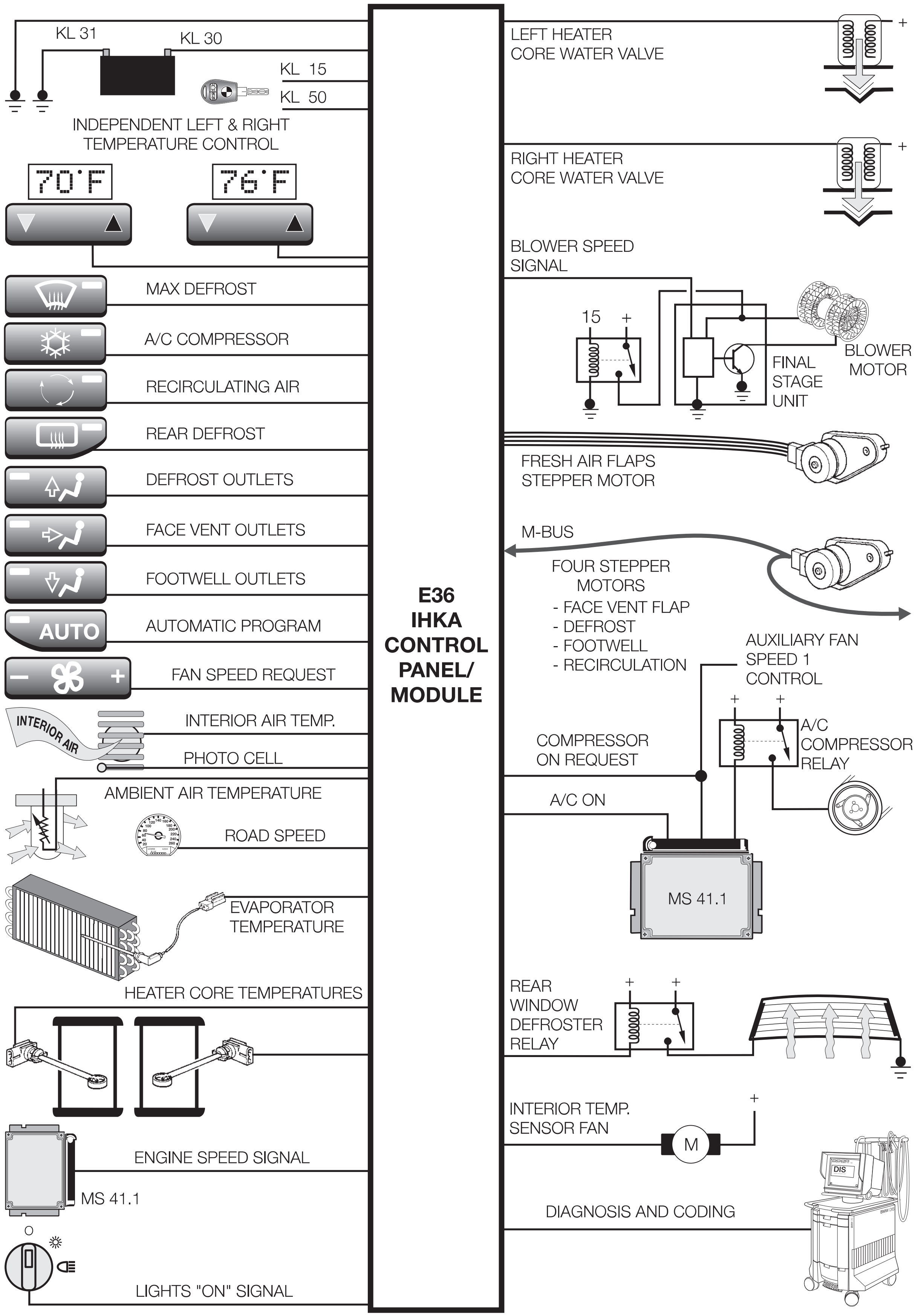
Each time the control module **processes** the inputs, it provides power or ground circuits to operate solenoids, stepper motors, relays, lamps, etc., or it may send signals to other control modules. The signals or power/ground circuits provided by the control module are known as its **outputs**. The actual component operated (relay, solenoid, motor, etc.) is referred to as the output device.

As an example, the IHKA climate module operates both the blower motor and the water valves.

- The **input** used to request blower speed is the blower speed knob, which goes to the processing area for blower speed control. If the input device is faulty, or the circuit is broken, the blower control processing area does not receive all the information necessary, and will operate the blower speed based on a substitute value.
- The water valve control processing, however, which does not use the blower speed knob input, will continue to function normally.

To perform diagnosis efficiently, it's important to understand which inputs are used to control a specific output. Or perhaps more importantly, which inputs will not affect a specific output.

BMW uses Inputs, Processing, Outputs diagrams (IPOs) to provide a quick view of the important features of microprocessor controlled systems. Typically (as shown in the previous graphics), inputs are shown on the left side of the IPO, the processor (control module) is shown in the middle, and the outputs are shown on the right.

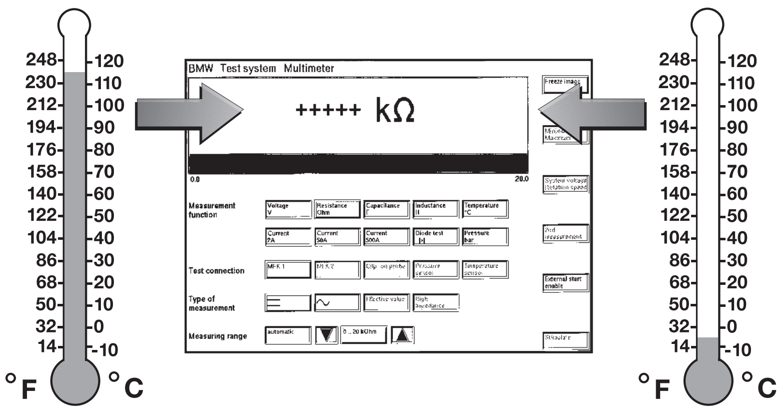


KL 31
KL 30
KL 15
KL 50
INDEPENDENT LEFT & RIGHT TEMPERATURE CONTROL
70˚F
76˚F
MAX DEFROST
A/C COMPRESSOR
RECIRCULATING AIR
REAR DEFROST
DEFROST OUTLETS
FACE VENT OUTLETS
FOOTWELL OUTLETS
AUTO
AUTOMATIC PROGRAM
FAN SPEED REQUEST
INTERIOR AIR
INTERIOR AIR TEMP.
PHOTO CELL
AMBIENT AIR TEMPERATURE
ROAD SPEED
EVAPORATOR TEMPERATURE
HEATER CORE TEMPERATURES
ENGINE SPEED SIGNAL
MS 41.1
LIGHTS "ON" SIGNAL
E36 IHKA CONTROL PANEL/ MODULE
LEFT HEATER CORE WATER VALVE
RIGHT HEATER CORE WATER VALVE
BLOWER SPEED SIGNAL
15
FINAL STAGE UNIT
BLOWER MOTOR
FRESH AIR FLAPS STEPPER MOTOR
M-BUS
FOUR STEPPER MOTORS
- FACE VENT FLAP
- DEFROST
- FOOTWELL
- RECIRCULATION
AUXILIARY FAN SPEED 1 CONTROL
A/C COMPRESSOR RELAY
COMPRESSOR ON REQUEST
A/C ON
MS 41.1
REAR WINDOW DEFROSTER RELAY
INTERIOR TEMP. SENSOR FAN
M
DIAGNOSIS AND CODING
DIS

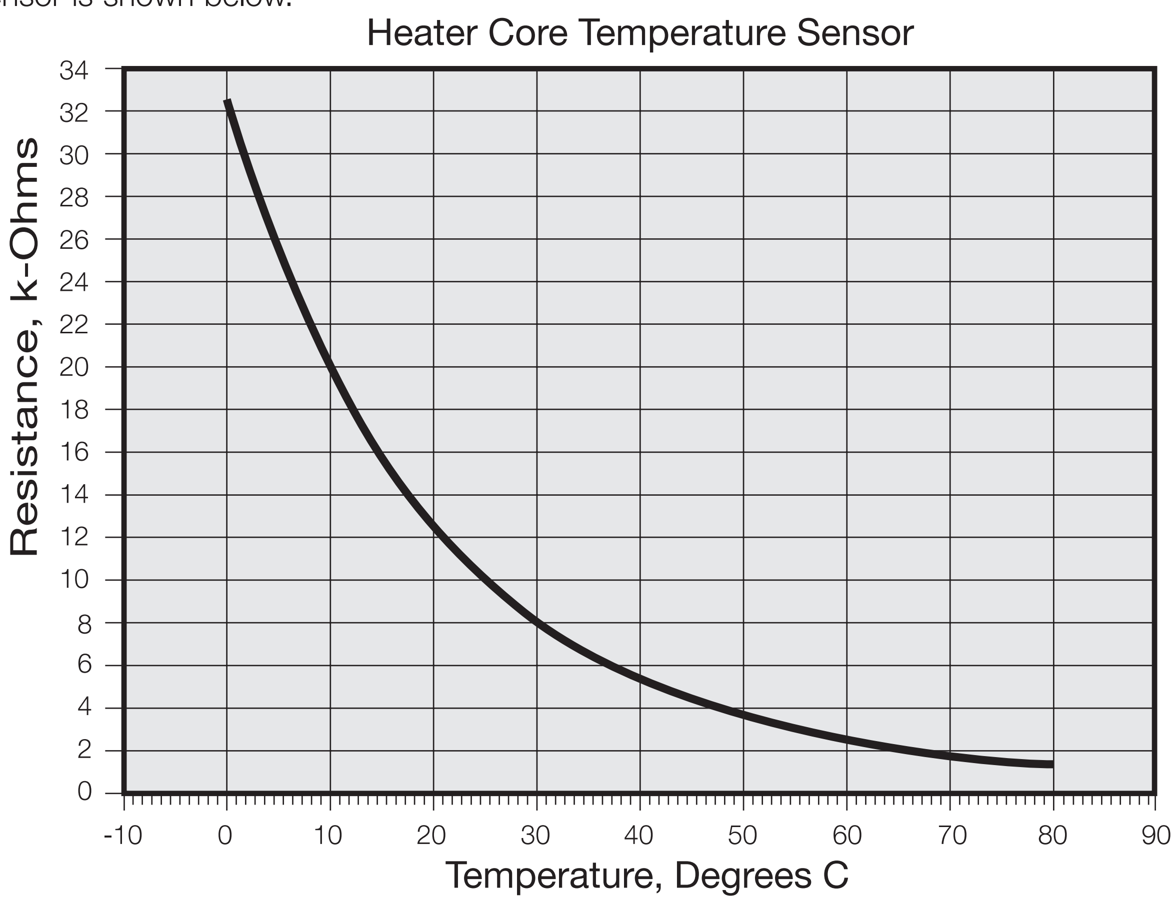
TEMPERATURE SENSOR MONITORING

Several different temperature sensors provide inputs to the climate control module. These Negative Temperature Coefficient (NTC) are resistors which are sensitive to changes in temperature.

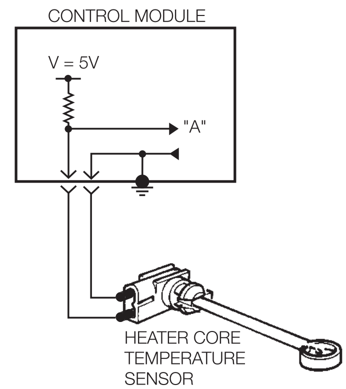
The NTC sensors used on the IHKR and IHKA Climate Control Systems have the property that their **resistance decreases with increasing temperature**.



The resistance "curve" (a plot of temperature vs. resistance) for the heater core temperature sensor is shown below.

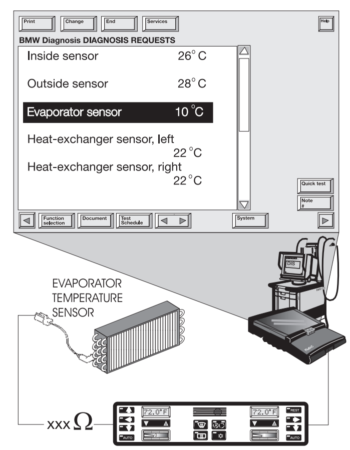


The control module applies a reference voltage (approx. 5 volts DC) to each sensor circuit, as shown here, and monitors the voltage present on the sensor signal circuit. In the example shown, the sensor signal voltage is monitored by the control module at point “A” in the circuit.



The resistor shown inside the control module has a “fixed” resistance (its resistance does NOT change with temperature). It is added to the temperature sensor circuit in order to drop the supply voltage from battery down to a 5 volt reference that will be influenced by sensor resistance.

The heater core example shown above can be redrawn as a simple schematic, placing a **volt meter** at the point where the control module would be measuring sensor voltage.

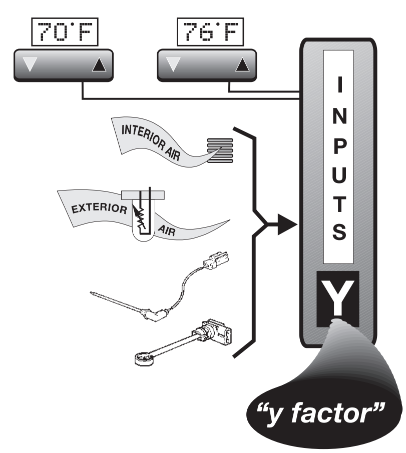


The control module is programmed to voltage values that are reasonable for each signal circuit. If the module receives a voltage signal that is much too high or much too low for a particular sensor, it assumes that the sensor is defective and disregards the signal.

The module will then store a fault code in memory and begin using a “substitute” value in place of the actual sensor signal. This allows the climate control system to function until the faulty component can be replaced.

THE “Y-FACTOR”

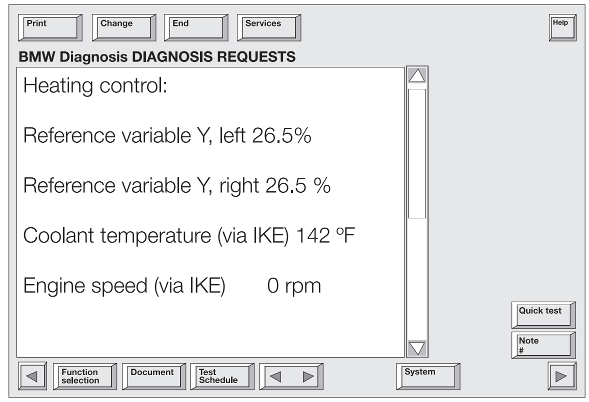
Y-Factor is the term used to describe how much **heating effort or cooling effort** (expressed as a percentage) is required by the microprocessor-controlled climate control system (IHKR/IHKA) for it to achieve the desired passenger compartment temperature. The terms **“adjusting factor,” “master controller,”** and **“guide control”** are sometimes used in place of Y-Factor.



The climate control system control module computes the Y-Factor (actually two Y-Factors, one for the driver’s side of the vehicle, Y_L, and one for the passenger’s side, Y_R), using the information it receives from some of the inputs.

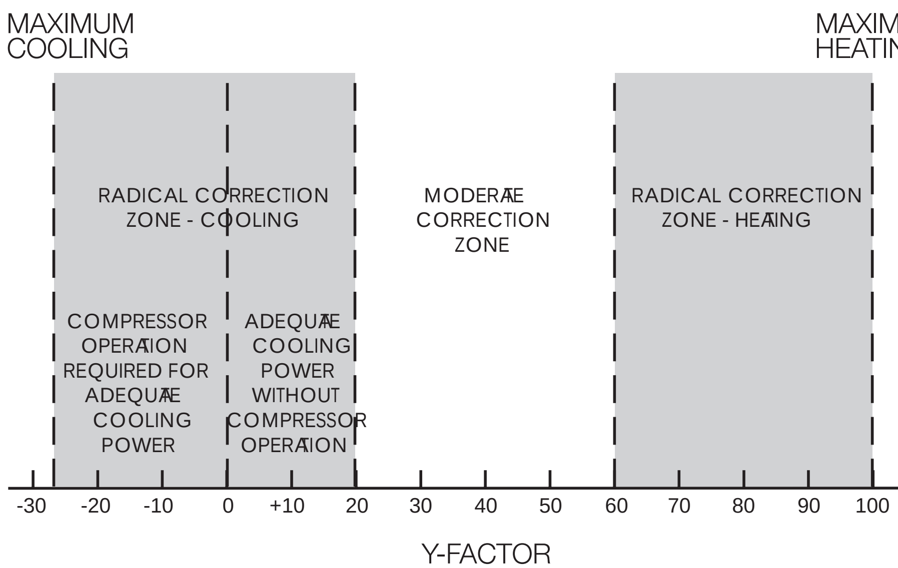
- Left Desired Temperature
- Interior Temperature
- Left Heater Core Temp.
- Right Desired Temperature
- Ambient Temperature
- Right Heater Core Temp.

The Y-Factors (left & right) computed from these inputs have numerical values ranging from -27.5% to +100% and **can be displayed on the DIS for diagnostic purposes.** (Except E46)



Values between -27.5% and 20% indicate that the system is working to cool the interior; values from about 20% to 100% indicate that it is warming the interior.

The lower the Y-factor number, the harder the system is working to **cool down** the interior; the higher the number, the harder the system is working to **warm up** the interior. In the middle region, the system is working to **maintain** the existing interior temperature.



The desired temperatures (left and right) and interior temperature are the primary inputs used to compute the Y-factor. (The control module monitors the temperatures that the passengers want, monitors the existing interior temperature, and controls outputs to make the two match.) The left desired temperature input has priority over the right, when the left input is set to the minimum or maximum values.

For a given Y-Factor, the control module can perform the following actions to achieve the desired interior temperatures:

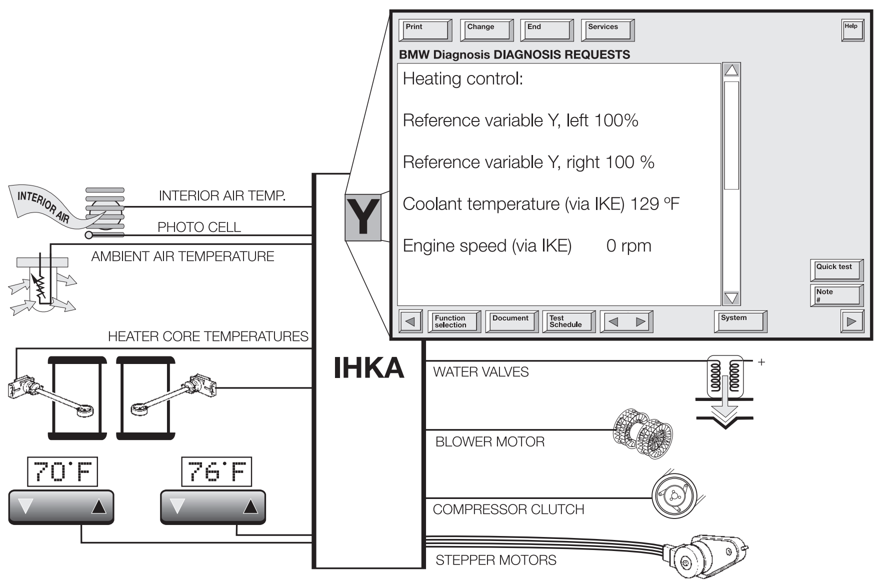
- pulse a coolant flow control valve to regulate left heater core temperature
- pulse a coolant flow control valve to regulate right heater core temperature
- operate a relay to turn an electric coolant pump on and off (except E36 & E46)
- operate stepper motors to **recirculate** interior air, instead of using outside air
- operate stepper motors to control air discharge location (IHKA only)
- boost blower speed to decrease interior cool down or warm up time (IHKA only)

Some sample temperature readings with approximate Y-factor values appear below and on the following page.

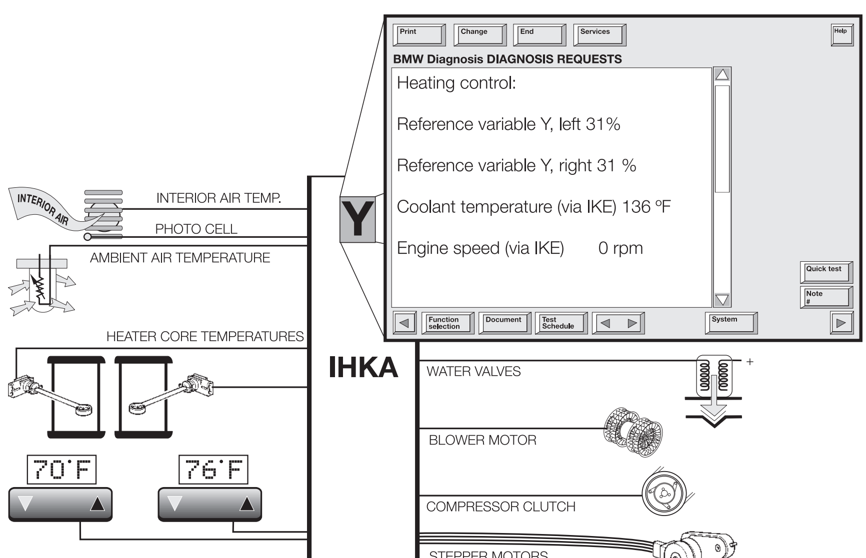
With the large difference between the desired and interior temperatures, Y-Factors of 100% should be expected since the system will work as hard as possible to increase interior temperature.

As the interior warms up, the Y-Factors drop steadily to avoid grossly “overshooting” the desired temperatures. Coolant valves, initially held “wide open,” are pulsed more frequently to reduce coolant flow (and heater core temperatures). Due to the extremely low ambient temperature, the control module will “boost” (or in the case shown above, “create”) a difference between interior and desired temperatures to offset rapid heat loss to the atmosphere.

Despite the “match” between interior and desired temperatures, the Y-Factors will still be 100% due to the low heater core temperature. The control module initially keeps the coolant valves wide open to utilize all heat available from the engine. As soon as the heater cores begin to warm up, though, the Y-Factors will drop rapidly since sufficient heat can be obtained with very low flow through the cores.

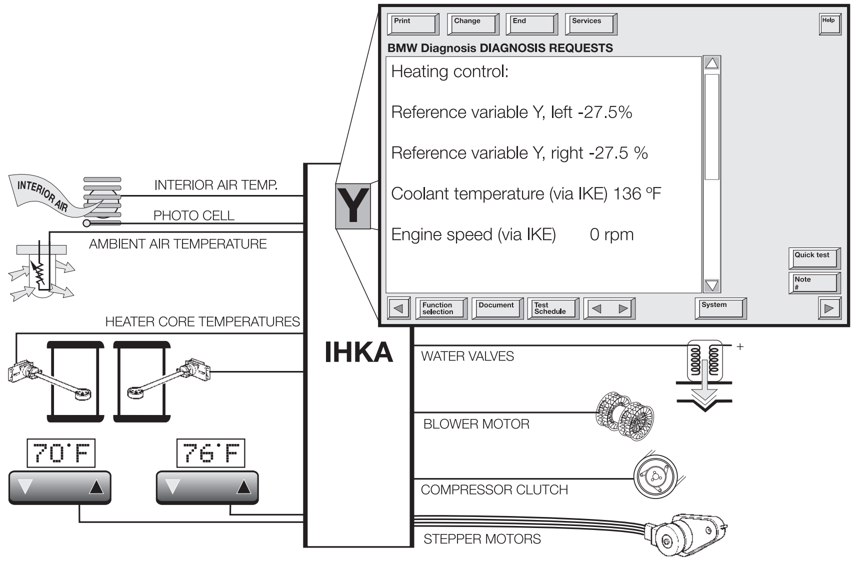


With the engine warmed-up, the climate control system expends very little effort to maintain interior temperature. The coolant valves are seldom opened, maintaining heater core temperatures just above the desired temperatures.



With such a large difference between the interior and desired temperatures, maximum cooling power is required. Heater core temperatures will drop rapidly since the coolant valves will be kept closed. The module will activate recirculation.

Although the interior temperature is approaching stabilization, the system must continue to work hard due to the high ambient temperature.



The heater cores are now nearly at evaporator temperature since they are placed directly in the flow of cold air and the coolant valves are kept closed. Once interior temperature drops a few more degrees, recirc. mode will be discontinued and the system will draw in only fresh air.

STEPPER MOTOR OPERATION

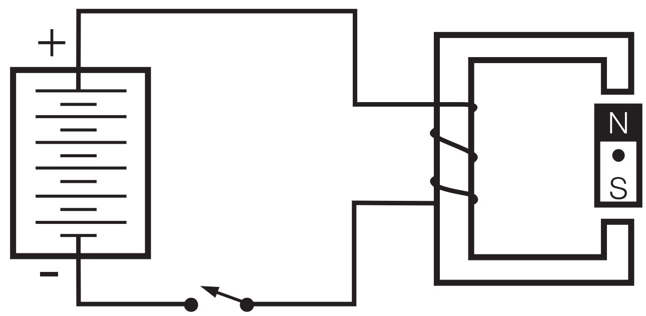
BMW IHKR and IHKA Climate Control Systems use 12 volt DC electric stepper motors to operate many of the air inlet, air distribution and temperature mixing flaps. While different types of stepper motors are used on different vehicles, they all share many desirable characteristics:

- lower power consumption
- operate in both directions
- can be started and stopped in any position
- provide quick movement
- move in precise increments
- does not require feedback potentiometers to determine position
- remain in position when shut off
- have long service life

Unlike a “normal” 12 volt DC motor (for example, a blower motor) in which the rotor spins through many revolutions per second when the motor receives power a stepper motor rotor rotates through only a small angle when it receives power and then it stops.

"CONVENTIONAL" STEPPER MOTOR

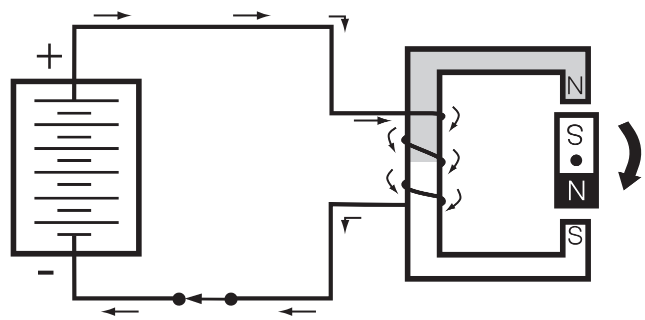
An extremely simple stepper motor circuit is shown to the right; it consists of a bar shaped permanent magnet which can rotate about its center, a "C" shaped piece of soft iron, a length of insulated copper wire (wrapped around the piece of soft iron), a switch, and a battery.



With the switch open, the bar magnet will rotate to position itself with the soft iron as shown and it will stay there.

When the switch is closed, current flows through the wire creating a magnetic field. With the wire wrapped around the soft iron in the direction shown here, the magnetic field North pole will be located at the top.

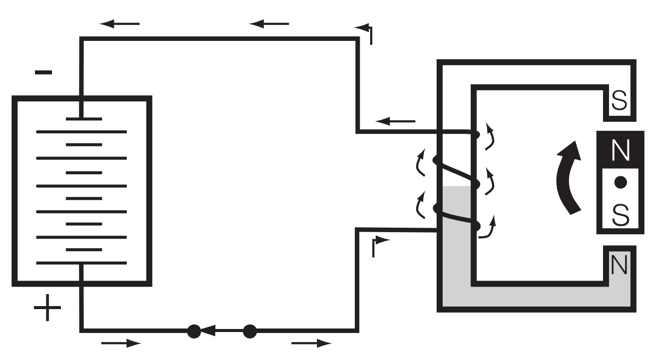
Since **"like" poles repel and opposites attract**, the permanent magnet rotor will turn 180 degrees to align itself with the new magnetic field and then it will stop there.



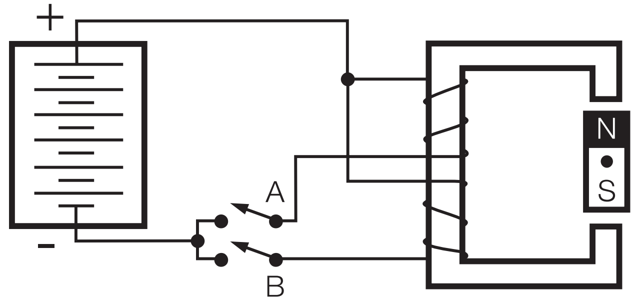
NOTE: In this simple motor, the rotor can turn in either direction to reach its new position.

Opening the switch will cause the magnetic field to collapse, but the rotor will remain in its new position.

By reversing battery polarity, though, and closing the switch, a new magnetic field is created. One that has its North pole located at the bottom of the "C." The rotor moves again, this time back to its original position.

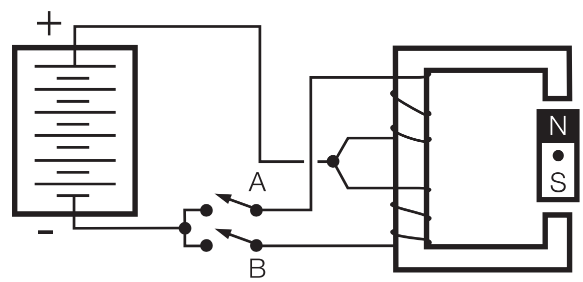


Using this information, we can again redraw the parts of the circuit in a slightly different way to get a stepper motor that is closer to the ones found on BMW vehicles.



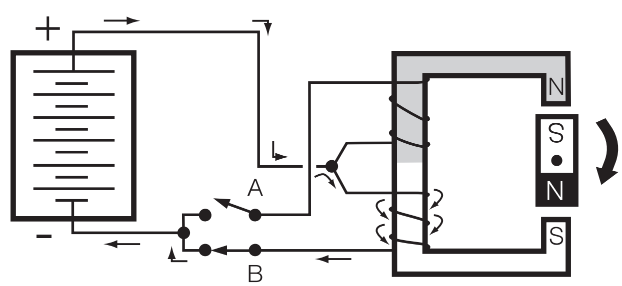
All we've done is wrap **two coils** around the soft iron core (one wound in each direction to give opposite polarities), and use two switches so **each coil can be energized independently**.

Rearranging some parts of this circuit just one more time puts the beginning of both coils at the middle of the "C" (for manufacturing reasons) so we have to wind the top coil in the other direction to have its polarity stay the same.



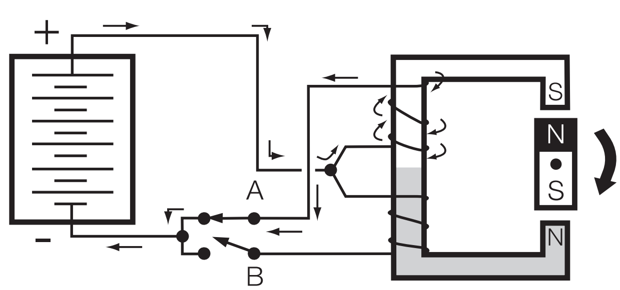
The bottom coil is unchanged.

Now, momentarily closing switch "B" energizes the bottom coil, a magnetic field forms with its North pole at the top, and the rotor turns 180 degrees to align with the field.



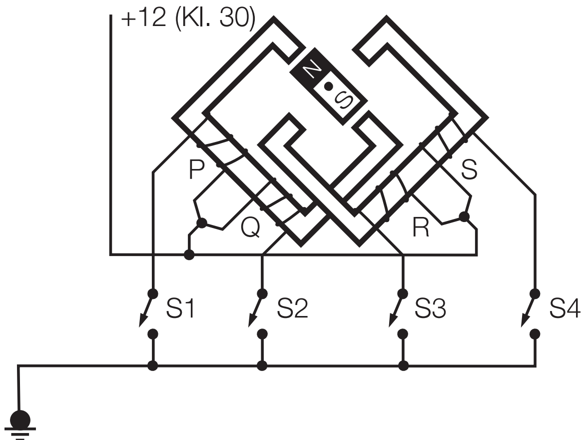
The rotor then stops there.

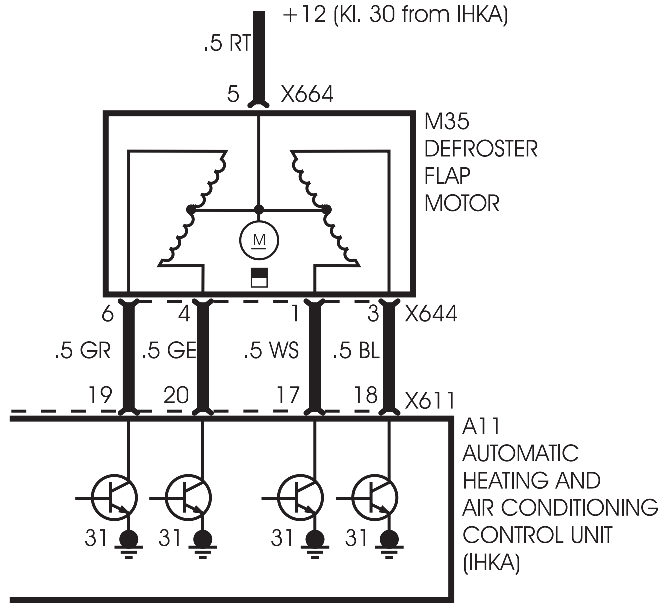
Momentarily closing switch "A" energizes the top coil, a magnetic field forms with its North pole at the bottom, and the rotor turns 180 degrees again to align with the new field.



Alternately closing switches "A" and "B" toggles the magnetic field polarity, causing the rotor to rotate in 180 degree steps

Compare our "generic" 90 ° stepper motor to a BMW climate control system stepper motor as shown in an Electrical Troubleshooting Manual (ETM) and note the similarities.

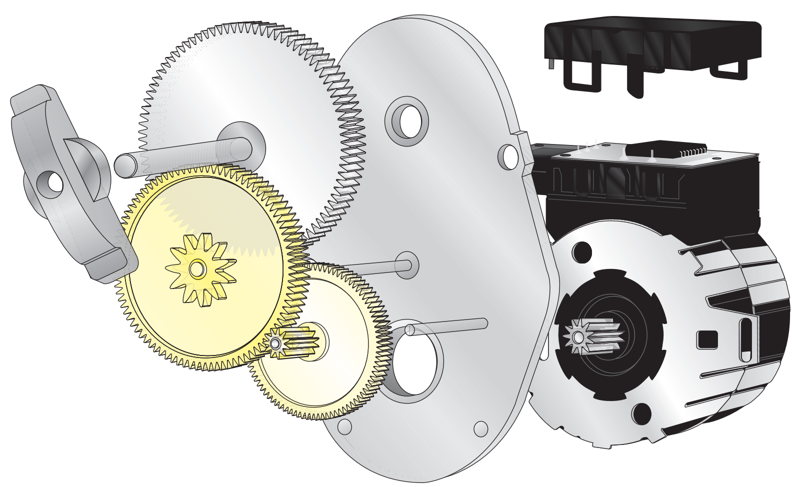




They both:

- have 4 coils arranged around a permanent magnet rotor
- have the 4 coils receiving power directly from the battery
- energize the coils individually using ground switches (transistors inside the control module for the ETM version)

Another important difference for the actual BMW part is that it is mounted on a high reduction gearbox. In fact, on the typical stepper motor, the stepper motor rotor must rotate about 300 revolutions (that's 7200 separate rotor steps) for the gearbox output shaft to rotate through just a single revolution.



This high-reduction gear box allows a relatively **low power motor** to operate the flaps against the **substantial suction and pressure forces** generated by the blower motor.

Taking another look at an "actual" BMW stepper motor, notice that it requires 5 connections:

- power (to all 4 coils)
- ground (control) to coil "S1"
- ground (control) to coil "S2"
- ground (control) to coil "S3"
- ground (control) to coil "S4"

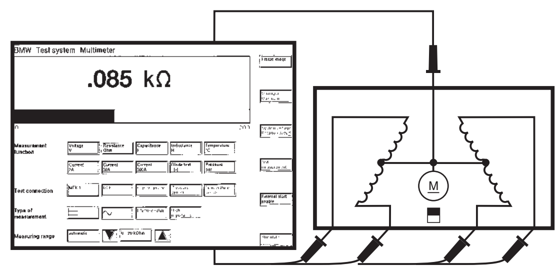
These connections are important for diagnostic purposes, since it is impractical to run a stepper motor once it has been disconnected from the control module.

One way to test for a faulty stepper motor is to measure coil resistance.

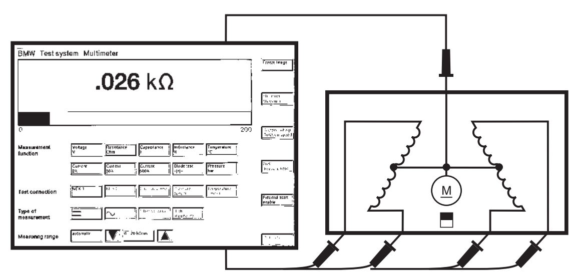
On E31, E32, and E34 stepper motors **except the fresh air flap motor**, each of the motor's 4 field coils has a resistance of about **85 ohms**.

For the fresh air flap motor **only** on E31, E32, and E34 vehicles, each of the 4 field coils has a resistance of about **26 ohms**.

The fresh air flap motor is designed to operate **faster** in the "close flap" direction than in the "open flap" direction, so it has different characteristics. It's easy to distinguish the fresh air flap stepper motor from the other motors because it has a different color identification label; typically red or blue, depending on production date.



All Except Fresh Air Flap Motor



Fresh Air Flap Motor Only

"SMART" STEPPER MOTORS

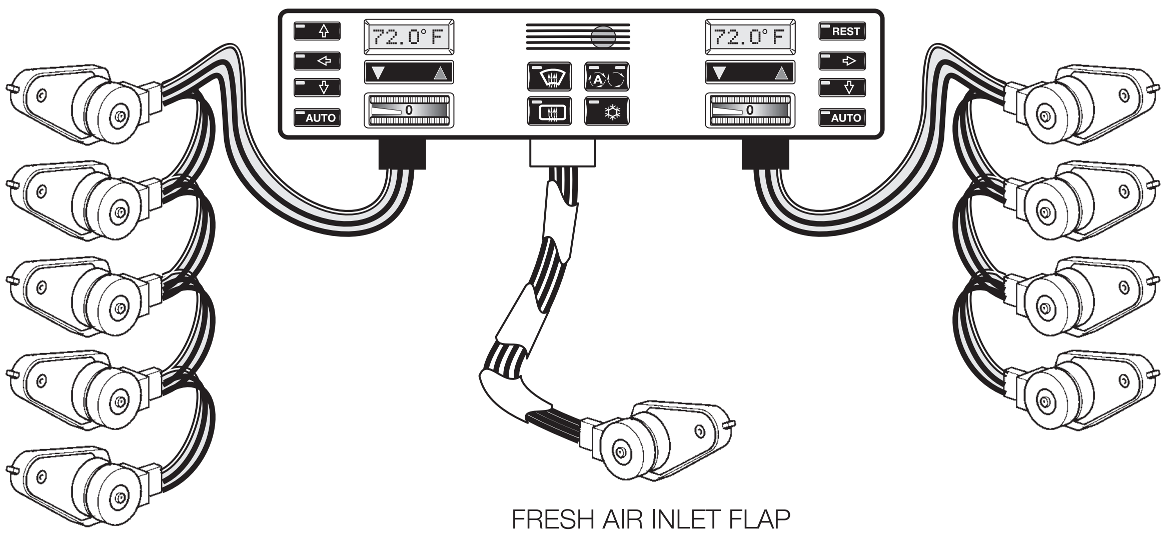
Until the E38 was introduced, the stepper motors used in IHKR and IHKA climate control systems did not contain electronic components, and only 3 part numbers were needed to service all the motor assemblies. As described earlier in this Handout, the motors consisted of copper wire coils wrapped around iron cores (pole pieces), and permanent magnet rotors, all attached to a high-reduction mechanical gearbox. The system electronic control components were located inside the climate control module assembly.

Starting with the E38 climate control system, **some of the control module electronics were moved into the stepper motors**, making the E38 motors (except the fresh air flaps motor) substantially different from the "conventional" stepper motors we've already discussed.

The circuits feeding these new "smart" stepper motors also changed -- for one thing, there are only **three circuits**:

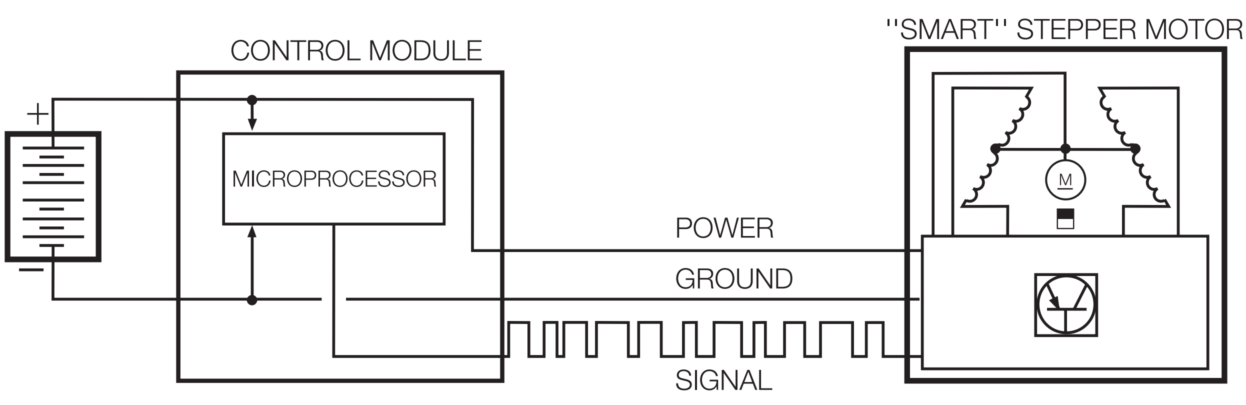
- power
- ground
- signal

Also, all 9 smart stepper motors used on the E38 system share the **same** set of power, ground, and signal circuits. (Left and right branches are connected **inside** the control module.) The fresh air flaps "conventional" stepper motor has its own separate circuits.



These stepper motors have the same type gear box, permanent magnet rotor, and 4 field coils as a "conventional" stepper motor. Plus, it still receives operating signals from the system control module.

An E38/E39/E46 stepper motor constantly receives **power and ground** on two of the terminals, and **operating instructions** on the third.



The operating instructions are digital signals which "tell" the stepper motor whether to open or close a flap. The microprocessor inside the stepper motor receives the instructions and converts them into pulses to operate the permanent magnet rotor.

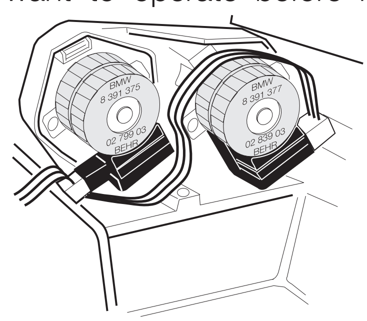
Notice that this 3-wire arrangement (referred to as the **M-Bus**) allows the control module to operate the motor using only 1 **signal** circuit instead of the 4 control circuits used previously.

And, since all 9 smart stepper motors are connected to the same signal circuit, a total of 35 separate circuits between the control module and the motors can be eliminated.

But how can the system operate with just one signal circuit for all 9 motors?

- Each of the 9 stepper motors is different (and has its own part number).
- The control module identifies which motor it want to operate before it issues the commands.

The part number is clearly marked on every stepper motor, and every stepper motor must be installed in the correct location on the climate control housing.

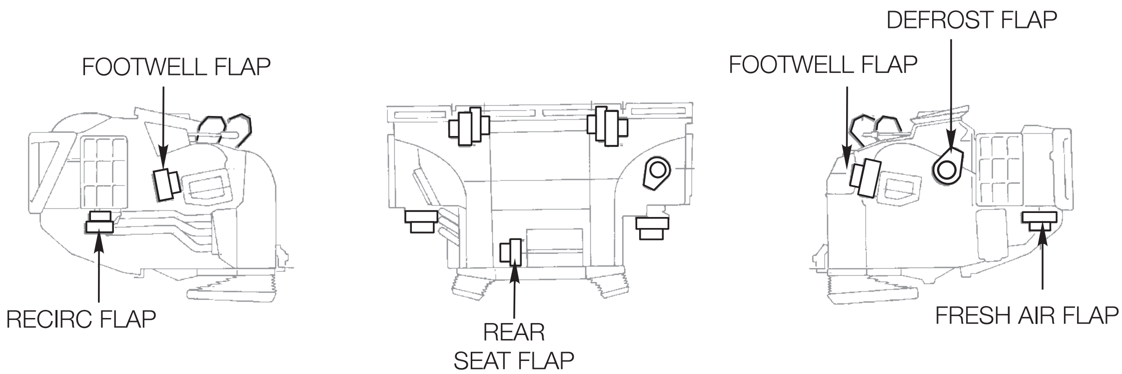


The operating instructions issued to the smart stepper motors by the control module are much more sophisticated than with conventional stepper motors. The sequence of events appears below:

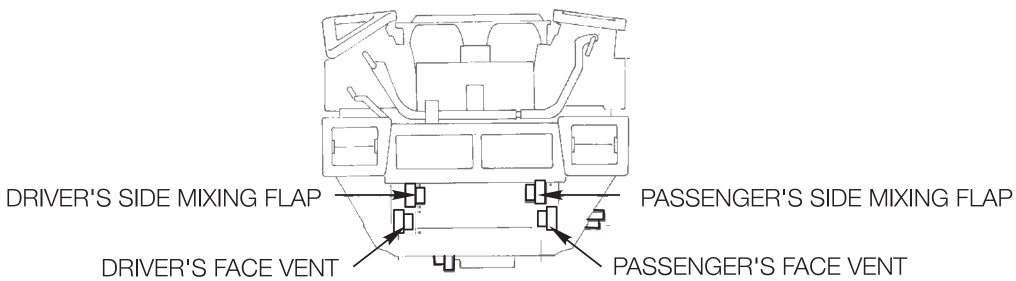
- The control module determines that a flap position must change
- It issues a "wake-up call" to alert the stepper motors that a command is coming
- It "names" the motor that is to respond to the command
- It issues the command signal, e.g. "move 15 steps clockwise"
- All the stepper motors "hear" the command
- Only the stepper motor that "hears its name" follows the command
- The "named" stepper motor then informs the control module that it has carried out the command

STEPPER MOTOR LOCATIONS

Air distribution of the IHKA E38 (for example) is regulated using stepper motors. There are 10 stepper motors used for air distribution including:



DRIVER'S SIDE **REAR VIEW** **PASSENGER'S SIDE**



TOP VIEW

Of these 10 stepper motors, the Fresh Air Flap stepper motor is operated as on previous systems. It has four circuits that control the motor rotation with a 500 Hz signal at each circuit as needed.

The remaining 9 stepper motors each contain a microprocessor that monitors operating signals on the M-Bus. When a specific signal is “heard” on the M-Bus the motor is activated by the microprocessor to carry out its function. Therefore, correct location by part number is critical.

CALIBRATION RUN

If the battery is disconnected, IHKA control module memory is cleared and the module loses its information about where the flaps are positioned. Therefore, when power is restored, the control module performs a calibration run, whether the IHKA system is turned "On" or "Off".

The control module runs all the stepper motors at maximum speed to fully close the flaps, and then continues to run the motors for a few seconds more than the normal endstop-to-endstop time, in order to ensure the flaps are closed.

The calibration run takes about 40 seconds. During that time, soft "ticking" or "scratching" noises can be heard, as the flaps reach their endstops but continue to be pulsed.

The control module also monitors system voltage. A sudden surge or dropout causes the control module to automatically perform the calibration run.