CONSTANT-AIRFLOW, VARIABLE-SPEED (OEM) INDOOR BLOWER ECMs

The constant-airflow (variable-speed) ECM was introduced in 1987 by GE (rebranded Genteq™ in 2009). It was the first and only indoor blower ECM until the introduction of the constant-torque ECM in 2006. The term “variable-speed motor” was coined in the late 1980s. By function it is a “constant-airflow motor.” Both of these terms define the type or style of ECM and how it is programmed to function.

Variable-speed motors are built in 1⁄8-, 1⁄2-, 3⁄4-, and 1-hp sizes, and only in direct-drive designs.

These motors have gone through many generational improvements in their more than 20 years of existence, including advances in reliability and communication formats, as well as changes in their physical appearance. This chapter covers only the current-generation motors.

The three main benefits of these motors over conventional induction (PSC) motors are:

- increased electrical efficiency
- more precise and unlimited airflow selection (the “variable-speed” feature)
properly maintained airflow during changes in system static pressure (the “constant-airflow” feature).

The ECMs shown in Figure 1 on the previous page are actually built as two separate components. The control module (motor control), with its own shell or housing, is attached to the back of the motor module (motor). The variable-speed motor control is programmed to provide constant airflow. This is accomplished by converting the desired cfm to a specific speed (rpm) and torque (current) delivered to the motor.

Each HVAC OEM (original equipment manufacturer) creates a special program unique to the model and size unit in which the variable-speed ECM will be used. This program provides multiple airflow and comfort options for each demand of the system in which the motor is installed, and any of the possible connected components.

To summarize: The variable-speed motor is operated by two programs. The HVAC OEM program determines the amount of airflow needed by demand, and the constant-airflow program makes sure that the selected airflow is maintained even if external static pressure changes. The constant-airflow programming is unique to each OEM by model and size of appliance. No two variable-speed motors are programmed alike.

**OPERATION**

The variable-speed ECM is a dual-voltage motor. The 120-V ac or 240-V ac single-phase power is supplied through the 5-pin connector to the motor at all times, even if there is no demand for airflow (see Figure 2). This power is what operates the internal electronics and drives the motor. The low-voltage or serial communication that is sent to the motor from the OEM control board through the 16-pin or 4-pin connector is a combination of the OEM programming, the installer’s selection of airflow and comfort settings, and the current demand of the HVAC system (heat, cool, fan, etc.). This is the information that the motor control (microprocessor) requires to determine how much torque and speed the motor will need in order to supply the proper airflow for each system demand.

During each demand, the motor control also monitors the actual speed in revolutions per minute (rpm) of the motor. There is only one combination of torque and speed that will create the proper cfm demanded at a specific total ESP (external static pressure) of the system. If the speed/torque relationship is incorrect for the required airflow, the motor control can increase or decrease the torque (current) to the motor. This, in turn, will increase or decrease the speed of the motor to maintain airflow. By constantly monitoring the actual speed of the motor, and maintaining the torque/speed relationship programmed by the HVAC OEM, the motor control is able to maintain the airflow selection per demand if the total ESP changes.

Figure 2. Electrical connections

Three very important points must be understood about this motor’s ability to maintain a constant airflow:
1. The motor requires more energy to maintain airflow when the total ESP is higher than the HVAC OEM recommendation, and the air noise of the system may be increased.

2. The motor requires less energy to maintain airflow when the total ESP is equal to or less than the HVAC OEM recommendation, and the air noise of the system will be decreased.

3. The motor has a programmed limit of operation to protect itself from damage, due to the energy (current) it must use to maintain airflow if the total ESP gets too high. Consult the HVAC OEM literature to find the recommended maximum total ESP. If the system exceeds the HVAC OEM recommendation, airflow may not be maintained—however, the motor will still try to deliver as much air as possible, without causing damage to itself.

**APPLICATION AND BENEFITS**

Variable-speed motors are typically found in two-stage, multi-stage, and modulating high-end furnaces (80+% and 90+% AFUE), air handlers, package systems, and geothermal systems.

*Constant airflow* is the ability of the variable-speed motor to maintain its programmed and field-selected airflow per demand, even when the total ESP is higher than recommended and/or changes during system operation. The total ESP (the resistance to the movement of air) is increased when ductwork is undersized, poorly constructed, and/or full of dirt or debris. The total ESP can increase during system operation when dirt builds up on the air distribution system components (especially the filter), and when customers close or block grilles and registers.

The variable-speed motor is programmed to maintain airflow during all of these situations, within the limits of the OEM programming and motor design. By contrast, torque (current) and airflow will decrease when the total ESP increases in PSC induction motor systems (see Figure 3).

![Figure 3. Airflow vs. total ESP](image)

When set up correctly, the benefits of the variable-speed motor system include:

- energy savings
- improved outlet air temperature for each system demand
- improved humidity control
- improved system capacity
- reduced space temperature swings
- reduced air noise with soft start/stop and gradual changes between airflow demands, delays, and/or profiles
- reduced constant fan air noise with low cfm settings, plus increased energy savings over normal system operation
- reduced repairs associated with continuous low-airflow operation.

**INSTALLATION AND SETUP**

After the system is installed, the technician must follow the HVAC OEM’s instructions in selecting the proper airflow and comfort settings to match the components and desired operation. These settings are typically selected by using jumper pins, dip switches, and/or multi-pin plugs on the OEM control board.
There are also some systems in which many of these selections can be adjusted at the user interface. (In these systems, the user interface replaces the thermostat as the communication center for the system.) If these selections are not set at the time of installation, there is a good chance that the system will not perform as expected and/or not produce the designed capacity. In addition, the system may be prone to problems and/or premature parts failures.

Figure 5 shows several examples of HVAC OEM airflow and comfort charts. The trim/adjust airflow chart allows the cooling airflow to be tweaked up or down to increase the sensible or latent capability of the cooling system. The climate/delay profile charts are designed to enhance the cooling cycle by climate for either more dehumidification or OFF-cycle cooling.

Another comfort option that greatly enhances dehumidification uses an external humidistat. The humidistat provides a demand to the HVAC system that is transferred to the motor to decrease the airflow during the cooling cycle. This type of on-demand dehumidification typically requires a separate humidistat or thermostat/humidistat combination, and a setting on the control board in the OEM system to initiate the feature.

It is recommended that the electrical connections on the ECM be facing downward, or between the 4 and 8 o-clock positions, and a drip loop formed out of the wiring harness leaving the motor (see Figure 6). This prevents any moisture or water that may get into the motor area from running into the connectors, where it could cause damage to the control. In most systems, the OEM installs the motor in the correct position and provides the drip loop. However, when multi-position systems are installed in a position other than the manufactured position, the motor may need to be turned and the drip loop rearranged.

The total ESP of the installed system should be measured and compared to the OEM charts. If it is above the maximum listed for that unit, improvements should be made to lower it. Any total ESP below the maximum is typically acceptable. However, system efficiency, noise levels, and potential service issues all will be improved when the total ESP is as close to the OEM recommendation as possible. The OEM’s installation manuals provide guidelines that should be followed per unit for best performance. Some important examples of the guidelines found in these manuals include filter-sizing charts, proper duct connections, and unit cutouts.

The temperature rise in fossil-fuel systems should always be measured and corrected if it is not within the OEM rating listed on the data plate of the given unit.

Note: Water damage is one of the most frequently recurring failures associated with electrical components. Always construct and size the condensate drains and traps according to OEM specifications.

**TROUBLESHOOTING**

Before troubleshooting any HVAC system, it’s a good practice to become familiar with the system components and wiring diagram. Check for and follow any on-board diagnostics (OEM system fault codes). When you’re working on a variable-speed
system, you should also check the airflow, comfort, and delay settings. Typically you will need to consult the HVAC OEM manuals for these settings. The manufacturer’s literature can also provide valuable sequence-of-operation and troubleshooting help.

If the motor is running but the system is noisy, shutting down on its limits or safeties, or the evaporator coil is freezing, there is a good chance that the problem is most likely external to the motor and the motor itself is good.

- **Check the airflow settings using the HVAC OEM guide.**

- **Check the air distribution system components for dirt load and closed dampers, registers, and grilles.**

- **Measure the total ESP and make the necessary repair(s) if it is above the maximum level recommended by the HVAC OEM.** Aftermarket filter sizing is a common issue.

Be aware, too, that thermostat (control) wiring is very important. HVAC equipment manufacturers have many different connection diagrams for the operation of multi-stage furnaces and air handlers with single-stage or multi-stage thermostats and outdoor units. Often there are circuit board settings that correspond to the type of connection and operation as installed. If the control wiring and

![Figure 5. Typical HVAC OEM airflow and comfort charts](https://example.com/figure5.png)

![Figure 6. Drip loop](https://example.com/figure6.png)
settings are not done properly, the system may run only in one stage and/or be operating at the wrong airflow per stage.

If the motor is not running, the following checks will help you diagnose whether it is operational. **Always disconnect the power to the HVAC system before disconnecting or reconnecting any connectors to the motor.** There are two inputs needed to operate this type of motor—a high-voltage constant power source, and the communication input that selects the airflow requirement per demand. All of the connectors/plugs used with the motor are keyed for proper orientation. If connected improperly, the motor may not operate properly and/or it may be damaged.

**Step 1. Check the high-voltage input**

First check the high-voltage input to the 5-pin connector. Depending on the system, there should be 120 V ac or 240 V ac at terminals 4 and 5 whenever there is power to the system, regardless of a demand call (see Figure 7). If there is no high-voltage input, fix the problem in the system before proceeding. For 120-V ac systems, make sure that the polarity of the power connected to the motor is correct. If the high-voltage reading is within ±15% of the rated voltage, move on to the next step. If the reading is higher or lower than ±15% of the rated voltage, fix the voltage problem first, then try to run the motor again. Always check for proper grounding and repair if needed.
**Note:** As shown in Figure 7, 120-V ac motors must have a jumper connected between terminals 1 and 2 for proper operation. To prevent damage, 240-V ac motors should *not* have this jumper.

**Step 2. Check the communication input**

To check the communication to the motor on the 16-pin or 4-pin connector, you will need to have the HVAC system’s OEM manual showing pin-by-pin what voltage/communication should be present per demand. Voltage may be ac, dc, and/or serial communication.

Some OEMs provide troubleshooting tools for use on their motors. For purposes of illustration, the following paragraphs will use the Genteq 16-pin and 4-pin variable-speed motors as examples. Genteq has a troubleshooting tool called the TECMate PRO that can simulate a communication signal to the motor (see Figure 8).

Begin setup with the TECMate PRO switch in the OFF position. The TECMate PRO has two wires with alligator clips for connecting to a 24-V ac power supply (they are not polarity-sensitive). The green LED on the TECMate PRO will light up when the device is properly connected to the 24-V ac power supply. The 16-pin connector from the TECMate PRO is connected to the motor in place of the OEM 16-pin harness or 4-pin harness with the provided adapter (see Figure 9). The 5-pin high-voltage connector must be connected to the motor with its power confirmed and the system power turned on (after all of these connections are completed) for this test.

If the motor runs when the TECMate PRO switch is turned on, the problem is not the motor—the problem is before the motor in the HVAC system. If the motor does *not* run with the TECMate PRO, then the motor control has failed and will need to be replaced. The motor itself, however, may still be good.

**Step 3. Check the motor module**

In order to check the motor separately from the motor control, turn off the main power and disconnect the high-voltage 5-pin connector and the communication 16-pin or 4-pin connector. *Allow at least 5 minutes to elapse between the time when the power was disconnected and the next step.* Remove the two ¼-in. hex head bolts from the end of the control module and carefully separate it from the motor module, as shown in Figure 10. Unplug the 3-pin connector.
between the control module and the motor. Perform the following ohm tests on the motor through the 3-pin connector:

- **Phase-to-phase test.** Ohm out the phases from one terminal to the other in the connector. Set your ohmmeter to the lowest scale. If the readings are all less than 20 Ω and within ±10% of each other, the motor passes this test (see Figure 11). If not, the motor has failed and must be replaced.

- **Winding test.** Ohm out the motor windings from each terminal in the connector to ground, using the endshield or unpainted brace as ground. Set your ohmmeter to the highest scale (no megohmmeters). If all of the readings are above 100,000 Ω, the motor is good (assuming it also passed the previous test). Typically a good motor will show all readings as infinity, which, depending on the meter, will display on the digital readout as “I,” “OL,” “Open,” or the symbol ∞ (see Figure 12). If any of the readings is below 100,000 Ω, the motor has failed and must be replaced.

### REPAIR

If only the motor control needs to be replaced (the motor has passed both of the ohm tests above), the motor can stay in its mount in the blower section. The new control can be installed simply by reversing the steps described in the previous section for removing the old one. If the entire motor (both motor control and motor module) must be replaced, it is easier to install the motor and control fully assembled. When installing the bellyband mounting brackets, make sure that they make contact only with the motor, not the motor control, and do not cover any motor vents.

The connectors should be facing down when the blower section is in the system and the wires leaving the motor should be formed into a drip loop, as
shown in Figure 6. If there is any sign of water damage on the old motor or control, the problem must be corrected.

The control module and the motor module have no field-repairable components. The variable-speed ECM has a unique program for each OEM model and size unit in which it is used. Replacement control modules and/or motor modules must be an exact match for the HVAC system from which they were removed, and are available only from the HVAC manufacturer of that system. There are no “universal” replacement controls or motors. Using the wrong parts voids all product warranties and may produce unexpected results. Always follow all instructions included with the replacement motor and/or control.

The variable-speed ECM may rock back and forth when it first turns on. This is normal operation for the control as it figures out the proper direction in which to operate the motor. Occasionally this rocking motion can last for more than a couple of seconds. In extreme cases, the rocking motion may continue until the motor turns itself off (typically within 5 seconds) and then turns back on again, which it may do until it finally achieves the proper rotation. This rare occurrence is typically caused by a loose-fitting bellyband, loose or weak mounting legs, or soft mounting grommets.

Always check the wiring, airflow settings, and proper operation of the entire system (including system safeguards) after all service and repair work. The temperature rise in fossil-fuel systems should always be measured and corrected if it is not within the OEM rating listed on the data plate of that unit.

Most fatal damage to the ECM motor control is typically related to water damage, voltage spikes (above the built-in protection of the motor), and/or operation at a total ESP above the maximum recommended by the HVAC system manufacturer. If voltage spikes are a common issue, consider adding

Figure 12. Winding test
higher protection to the HVAC system or to the home. If the total ESP is at or above the maximum rating specified by the HVAC OEM, be sure to correct the air distribution issue.

*Prevent repeat failures by investigating and correcting the cause of the failure.*

**POWER CHOKES**

Some 115-V ac systems with ¾-hp or 1-hp motors may have a *power choke* connected in series with the neutral wire to the motor. It looks like a transformer with a single coil. The most commonly used choke has an inductance of approximately 2 mH (millihenries) and is capable of handling around 12 A.

This device is designed to reduce the peak current drawn by the motor. It is not required on ½-hp or ½-hp 115-V ac motors or on any 230-V ac motors. Power chokes are very reliable components that rarely fail or cause the control to fail, unless there has been a large voltage spike. To ohm out this device, turn off the power to the system and disconnect the wires at the choke. Evaluate the choke as follows:

- **Measure the resistance across the choke:**
  - Good choke = low resistance (typically less than 1 Ω)
  - Bad choke = open or 0 Ω
  - Bad choke = resistance above 2 Ω

- **Measure the resistance from either terminal to ground:**
  - Good choke = infinite resistance (open circuit)
  - Bad choke = any resistance below 100,000 Ω (100 kΩ)

*Notes:* A digital meter, set to the lowest scale that can accurately read ohms below the decimal point, is necessary for measuring the resistance across the choke. If the choke is direct-shorted, the motor may still work. If the choke is open, the motor will not run.

**CONCLUSION**

Today's constant-airflow, variable-speed ECMs have undergone significant reliability improvements. The current generation of Genteq™ models discussed in this chapter are built with the following features:

- fully encapsulated electronics to protect against moisture damage
- improved EMI filters to provide protection against line transients (voltage spikes)
- speed limiting to prevent overcurrent operation due to extremely high ESPs
- 4 to 6-kVA surge protection
- more durable ball bearings.

With proper installation, setup, and annual system maintenance, these motors are providing proven reliability in today's high-end HVAC systems. The HVAC OEM has an almost limitless ability to choose the amount of airflow, ON/OFF delays, and comfort profiles for each demand of the system.

It is imperative for contractors to consult installation and service manuals in order to set up the system properly and take advantage of all of its capabilities. Attending OEM classes on variable-speed products, as with all products, is also highly recommended for service technicians.