QwikSEER+ Theory of Operation and Retrofit Potential

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Introduction

Three motor types are primarily used in residential air handlers: permanent split capacitor (PSC), X-13, and electrically commutated motor (ECM). If selected properly, all three are capable of delivering the required airflow. However, the three choices vary in price and energy consumption. The ECM motor is the most efficient and most expensive, while the PSC is the least efficient and least expensive.

The ECM and X-13 motors will indisputably decrease the electric bill when compared to a PSC motor that is providing the same airflow. However, an efficient blower motor that is providing more airflow than is required can waste more energy than a less efficient blower motor providing the correct lower airflow.

The two challenges addressed in this paper are first determining under which environmental conditions the fan speed can be lowered to reduce energy consumption, and second determining if the higher cost, increased complexity, and potentially lower reliability of the ECM or X-13 motor is worth the investment.

To understand the components involved in these challenges, the types of motors and thermostats used in residential air handlers are described in the next section, followed by a section that describes the environmental effects of conditioned airflow rate on efficiency. Finally, the last section shows how Mainstream's QwikSEER+ WattSaver control board can meet the challenge of providing the most efficient fan speed that can save money by changing with environmental conditions without the increased complexity of an expensive, continuously variable speed motor.

Motor Types

This section describes the three most commonly used motor types for residential air handlers: permanent split capacitor (PSC), X-13, and electrically commutated motor (ECM).

PSC Motors

A PSC motor is a fixed-speed, asynchronous motor that operates on alternating current power. PSC motors in residential air conditioning systems typically have between three and five speed taps. These speed taps are connection points for electrical power and determine the blower speed.

When installing a residential air conditioning system, the HVAC technician selects one of the possible blower speeds by connecting the power input to one of the speed taps. It is important to understand that although blower motor speed is constant, actual airflow, typically measured in Cubic Feet per Minute (CFM) is dependent on the pressure drop in the system. Clearly, the ideal blower speed selection for a given system is different for different installations due to differences in the pressure drop in the ductwork. The ideal flow rate also varies with environmental conditions.

A PSC blower motor is less efficient than ECM or X-13 motor. They are also the least expensive and most reliable motor due to their simplicity.

ECM Motor

An ECM motor is a brushless, direct current (DC) motor with an internal microprocessor that manages commutation, resulting in synchronous operation over a range of speeds. In addition to being more efficient than PSC motors, the variable-speed capability can be used on some systems to either deliver a constant airflow over a wide range of pressure drops in duct work or to provide a variable airflow based on environmental conditions (outdoor air temperature, return air temperature, return air humidity). An ECM motor can be programmed to deliver a constant airflow even while air filter configuration and cleanliness, or ducting geometries change.

Expensive and potentially unreliable electronics are required to maintain a constant airflow over a wide range of possible duct work pressure drops. Additional electronics are required to account for airflow optimization based on environmental conditions.

Constant Torque ECM Motor (AKA X-13 Motor)

The term X-13 motor originally referred to the high-efficiency motor developed by Regal-Beloit (General Electric) to help meet the 13 SEER mandate, but the name has become somewhat of a generic name for a class of less sophisticated ECM motors that provide constant torque (not constant air flow). These motors are high-efficiency, brushless DC motors, controlled by a 24 volt signal. The X-13 motor delivers constant torque, meaning the airflow still decreases as the pressure drop in the ductwork increases, but the change of air flow rate with pressure drop is far less dramatic than for the PSC motor.

X-13 motor efficiency is similar to ECM motor efficiency, but the X-13 motor has a less sophisticated electronic control and must be programmed with a torque value that provides sufficient airflow at the worst case external static pressure. Therefore, although the efficiency of the X-13 and ECM motors are similar, the X-13 motor will typically draw more energy than a continuously variable speed ECM motor that optimizes airflow. Like a conventional PSC motor, the X-13 motor usually moves more air than is required for certain environmental conditions. This type of blower motor does not optimize airflow based on outdoor or indoor air conditions.

Analog and Digital Thermostats

Although a few high-end air conditioning systems have digital thermostats that communicate with a digital data line and can control air handler airflow or compressor speed, conventional analog thermostats simply provide a 24 VDC signal to the contactor that activates the air handler or compressor.

Analog Thermostats

A conventional analog thermostat activates the G (green) wire so that 24 VAC between G and C (common) activates the evaporator blower contactor, 24 VAC across Y (yellow) and C activates the compressor contactor, 24 VAC across the W (white) and C activates the heat contactor, and 24 volts across either O (orange) or B (blue) to C actives the heat pump reversing valve. In addition, 24 VAC is continuously supplied to the thermostat, if needed, via R (red) and C wires.

Digital Thermostats

On a digital thermostat, 24 VAC is still supplied to the thermostat via the R (red) and C (common) wires; however, all commands from the thermostat to the system are via two or more digital lines. Such digital thermostats typically also control compressor speed and/or blower motor speed among other things. Examples of digital thermostats are the Carrier Infinity® Control, Lennox icomfort Touch®, and Goodman ComfortNet™. The ability to adjust the blower speed and compressor speed, provides a higher EER rating, however these systems are also more expensive.

Effects of Conditioned Air Flow Rate on Efficiency

To meet more stringent energy efficiency requirements for air conditioning systems, some manufacturers are trying to optimize the operation of air handler blower motors. An inefficient or oversized blower motor decreases system efficiency because this motor draws additional power and the power consumed by the blower motor heats the air that is being cooled. Unfortunately, optimal air handler airflow is affected by several factors, which can be divided into two categories, environmental effects (which can continuously vary throughout any given day) and installation-specific effects (which can vary from installation to installation or from technician to technician). Equipment manufacturers have focused most of their efforts on minimizing the negative effects of installation-specific variations so that their units operate properly, in spite of less-than-perfect installation conditions.

For PSC blower motors, manufacturers typically provide excess fan capacity to accommodate less than ideal ductwork systems that may have higher than normal pressure drops. Likewise, many technicians simply use the highest blower speed to assure that sufficient air is moving across the coil to avoid coil freeze-ups, and minimize callbacks. In addition to wasting energy, the higher flow rate will reduce humidity removal, due to the higher coil surface temperature and reduced residence time (the time the air is exposed to the coil surfaces).

Environmental Effects

The environmental effects are related to outdoor temperature, return air temperature, and return air humidity. This section describes the environmental conditions that would benefit from reduced airflow (and reduced energy consumption) if the air handler blower motor had the capability to adjust airflow. Although some high-end systems (high EER systems) with digital thermostats and continuously variable speed ECM motors already control evaporator blower airflow and/or compressor speed to improve the EER, typical systems using analog thermostats do not have this sophistication.

The heat removed by the evaporator will always match the heat carried from the air by the blower, the question is how to best adjust the mass flow rate of conditioned air, that is how to best adjust the blower motor speed. We have found that under certain situations, a lower blower shaft speed, which reduces air flow rate, and reduces heat transfer, also reduces overall power draw. For example, when the lift of the A/C unit is small, if reducing the air flow across the evaporator coil only increases the compressor lift by about a degree or less (i.e., lowers the evaporator temperature by 1 degree or less), then we have found that the savings in power consumption by the blower motor is greater than the increased power consumption of the compressor, the difference being the energy saved. This is in part because the motor power curve for the compressor is relatively flat, that is an unloaded compressor motor draws almost the same power as a loaded motor. This is why we see the most benefit at very low lift, which also happens to be the place where the typical A/C operates most.

The best way to illustrate this effect is with a specific case. For a 5 HP compressor motor, the electric motor is about 90% efficient at full load, but only about 30% efficient at 10% of full load. Therefore for a full load of 5 HP (3728 W), the motor power consumption is 4142 W (3728/0.90), but at 10% load (0.5 HP or 372.8 W), the power draw is 1,242 W (372.8/0.3). Increasing the load on the compressor by a factor of 10 (from 0.5 HP to 5 HP), only increased the power draw by a factor of 3.3 and not by a factor of 10. Therefore, increasing the compressor motor load a little (by reducing the fan speed and increasing the lift by only 1 degree) does not increase the compressor power draw very much (does not increase it linearly), but it reduces the blower motor power draw linearly (since different winding have been activated on the blower motor to keep the efficiency constant). The net result is a reduction in the total energy consumed by the A/C unit.

A high latent load (lots of humidity) in the conditioned air makes the positive effects of reducing the airflow even better, since a smaller fraction of the cooling is supplied by sensible air cooling. The lower airflow allows more residence time for the moisture to be removed from the air and the lower temperature coil, increases the moisture removal

Installation Effects

The installation-specific effects are related to the configuration of the supply ducts and the return air ducts, and the type of blower motor. The pressure drop in the supply air ducting can differ from installation to installation and can even change over time in a single installation because of changes to the supply register settings. Similarly, the pressure drop in the return air ducting can differ from installation to installation and can also change over time in a single installation because of changes in the pressure drop across the air filter (due to changes in the type and cleanliness of the air filter).

The type of blower motor affects how dramatically a change in pressure drop affects the evaporator airflow. Constant blower motor speed is not the same as constant airflow rate.

PSC Motors

Different PSC motor speed taps correlate to different motor speeds. Once a technician selects a speed tap, the PSC motor operates at a single speed. The resulting airflow that is achieved at a selected speed is greatly affected by the pressure drop in the ductwork. Therefore, the likelihood that the actual airflow achieved in a specific installation is the design airflow specified by the manufacturer is unlikely. This configuration cannot alter the airflow as the environmental effects change (outdoor air temperature, return air temperature, and humidity). To ensure adequate airflow in the worst environmental conditions, excess airflow is typically supplied.

Constant Torque ECM or X-13-type Motors

Constant torque ECM or X-13-type motors have multiple torque settings instead of speed settings. These motors are typically operated at a single torque setting, and as a result, can provide a relatively constant airflow even as installation conditions change. Besides being more efficient than PSC motors, the actual airflow achieved in an installation is more likely to be the design airflow specified by the manufacturer. Unfortunately, like the PSC configuration, this configuration cannot alter the airflow as the environmental effects change. Therefore, sometimes excess airflow is provided, thus wasting energy and lowering the system efficiency.

Continuously Variable Speed ECM motors

Continuously variable speed ECM motors are just as efficient as other ECM or X-13 motors (and more efficient than PSC motors), while having the additional benefit of providing constant, manufacturer-specified airflow, independent of reasonable variations in installation and operational conditions. However, the typical variable-speed ECM motor does not optimize the evaporator airflow for environmental changes (changes in outdoor temperature, or return air temperature or humidity).

A further performance improvement can be achieved if these continuously variable speed ECM motors also adjust the airflow to changing environmental conditions. Normally, if this were to occur, the ECM blower motor would be controlled by a digital thermostat, and the airflow could be adjusted to better match the environmental conditions. Such a configuration would typically be the most efficient because the motor type is the most efficient and the blower motor is only supplying the airflow that is needed.

Variable-Speed PSC Motor

A Variable-Speed PSC Motor capability is achieved when the QwikSEER+ WattSaver control board controls a traditional PSC motor. Although only three speeds are available instead of the continuously variable speeds of an ECM motor and the PSC motor is less efficient than an ECM motor, this configuration has the advantage of matching the airflow to both the environmental and installation conditions of the conditioned space.

Not only does this system provide airflow rate adjustment similar to the best continuously variable speed ECM motor control, the control provided by the QwikSEER+ control board allows the motor to operate on a conventional analog thermostat.

Another opportunity is that the low-cost QwikSEER+ WattSaver board and a low-cost PSC motor can be used together to replace any expensive ECM or X-13 blower motor and controller, as long as a contactor can be activated by the 24 VAC to the G (green) and C (common) wires to supply either 120 VAC or 240 VAC from that contactor to the input side of the QwikSEER+ control board. The QwikSEER+ board then determines the best of three possible operating speeds and supplies power to the proper PSC motor speed tap.

QwikSEER+ Benefits

On air conditioning or heat pump systems with traditional analog thermostats, the HVAC technician selects the blower speed (PSC motor), blower torque (X-13 motor), or constant airflow setting (ECM motor) by selecting a power input port or programming the motor.

Unfortunately, HVAC installers do not perform efficiency optimization tests when selecting the appropriate airflow rate, so there is no way to know if the blower is operating at the conditions that optimize system performance.

Even if HVAC technicians could perform a system efficiency optimization test when selecting the blower setting, the optimal blower airflow can change over time because of environmental changes. For PSC blower motors, changes in the system pressure drop, caused by such things as a dirty air filter, will make a more dramatic change to the airflow.

Unlike typical digital thermostat variable speed system installations, which have complicated and costly ECM motor power electronics, Mainstream's QwikSEER+ blower control module automatically accounts for changing installation and environmental conditions each time the cooling mode is activated and does so with a lower-cost PSC motor configuration.

Mainstream's patent-pending QwikSEER+ WattSaver control board uses simple relays to turn a reliable, inexpensive fixed-speed PSC motor into a three-speed motor, yielding much of the benefit provided by a variable-speed ECM motor (which optimizes airflow with environmental changes) at a fraction of the cost and with potentially improved reliability.

When the system starts in cooling mode, QwikSEER+ operates the PSC blower motor in different speeds, compares system operating conditions for the different fan speeds, and determines the optimal fan speed to maximize performance. This flexibility allows QwikSEER+ to optimize air handler blower speed while accounting for all system conditions: outdoor air temperature, indoor air temperature and humidity, supply ducting restrictions, and air filter type and status.

Independent laboratory testing was conducted by Intertek (Plano, Texas) following the ANSI/ASHRAE 37 test protocol. Running a residential 14 SEER air handler and condensing unit (80 °F indoor, 97 °F outdoor temperatures) with a QwikSEER+ installed resulted in an EER improvement of 7.4%. Using the same condensing unit and temperature conditions with a residential furnace unit (with QwikSEER+ installed), the EER improved by 10.5%. On cooler days, (82 °F outdoor temperature), the EER improvements for air conditioning and furnace units with the QwikSEER+ installed increased to 10.9% and 12.9%, respectively. These results are displayed in Figure 1. To view the Intertek EER test report, go to www.Qwik.com.

Lower airflow rates also improve humidity removal. When a residential SEER 14 air conditioner with the QwikSEER+ installed was tested for the ability to remove humidity (with the return air at 80 °F, and 51% relative humidity), the QwikSEER+ WattSaver improved humidity removal rates by up to 566%, as shown in Figure 2. This increased moisture removal can significantly improve indoor comfort while also inhibiting the formation of mold, thus improving indoor air quality. By connecting the optional humidity sensor (QT6001), the QwikSEER+ control board will also optimize the system for the fastest humidity removal during high-humidity situations. The Intertek Humidity Removal test report is also at www.Qwik.com.

Unlike a variable-speed ECM motor with a digital thermostat, QwikSEER+ does not have complicated digital control electronics or complicated power electronics, which can increase cost and potentially lower the reliability. QwikSEER+ can be installed in an existing system with a PSC motor and analog thermostat to enhance efficiency and humidity removal. QwikSEER+ along with a PSC motor can also be installed in any system with a failed ECM or X-13 motor that uses an analog thermostat.

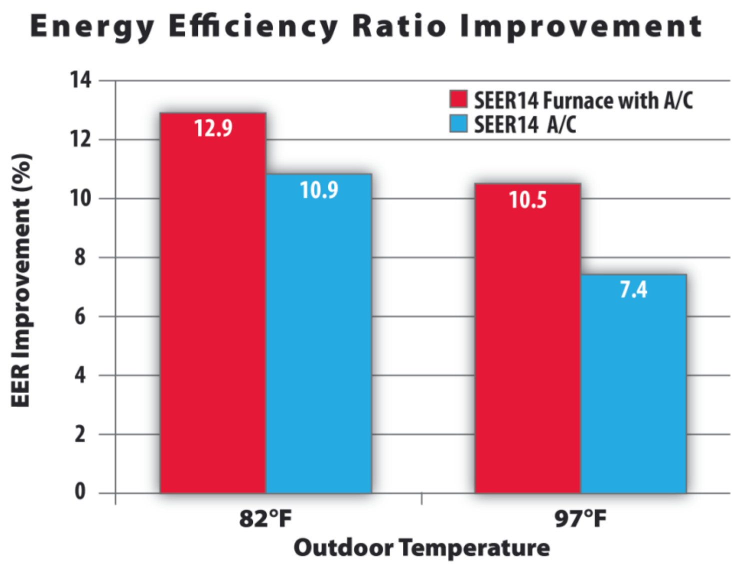

Figure 1. Percentage improvement in EER with QwikSEER+ control board (using 14 SEER Straight Cool and 14 SEER combined AC–furnace, return air: 80 °F, 51% RH)

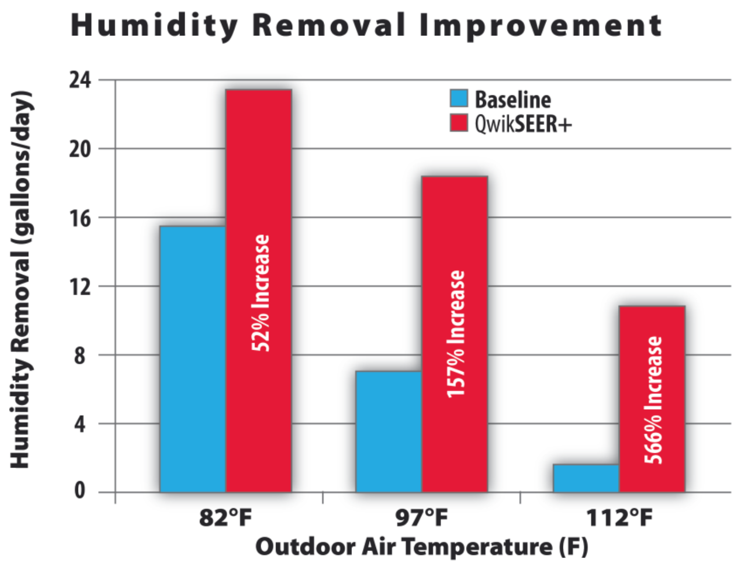

Figure 2. Increase in humidity removal (using 14 SEER combined AC–furnace, return air: 80 °F, 51% RH)