Technical Article

Understanding Flap Actuators and What Drives Them in Automotive HVAC Systems

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Whether it's hot or cold outside, passengers inside a car are comfortable thanks to automotive heating and cooling systems. These heating, ventilation and air conditioning (HVAC) systems vary in complexity and level of automation depending on the vehicle class. While an economy car requires that a driver manually turn knobs to control the temperature, a higher-end vehicle uses sensors to automatically control not only the temperature but also the humidity and quality of air inside the cabin.

Moving the Air

Regardless of vehicle class, an automotive HVAC system is all about moving the air from here to there. It conditions the air as well, modifying its temperature, humidity and quality while moving it.

Let's look at simply moving the air for a second. The air could be drawn into the system from outside or inside the cabin. It could also be routed inside the HVAC system through the evaporator or heat exchanger for conditioning; that conditioned air is distributed throughout the cabin, whether it is to keep passengers' feet warm or prevent the windshield from fogging.

The number of ways that the air can flow is remarkable: from outside to the evaporator to the windshield, or from inside to the heat exchanger to the vent in the footwell. So how does an HVAC system control which way the air goes?

Figure 1 is a side view of an HVAC system. Numbers mark the key components, while arrows show the direction of air distribution. Components 4 through 8 in Figure 1 show the flap actuators. The orange dotted lines represent the area where the flaps are moving, and the solid orange lines represent the flaps. The number of flap actuators in an HVAC system depends on the overall complexity of the system – if it has single or multiple-zone HVACs.

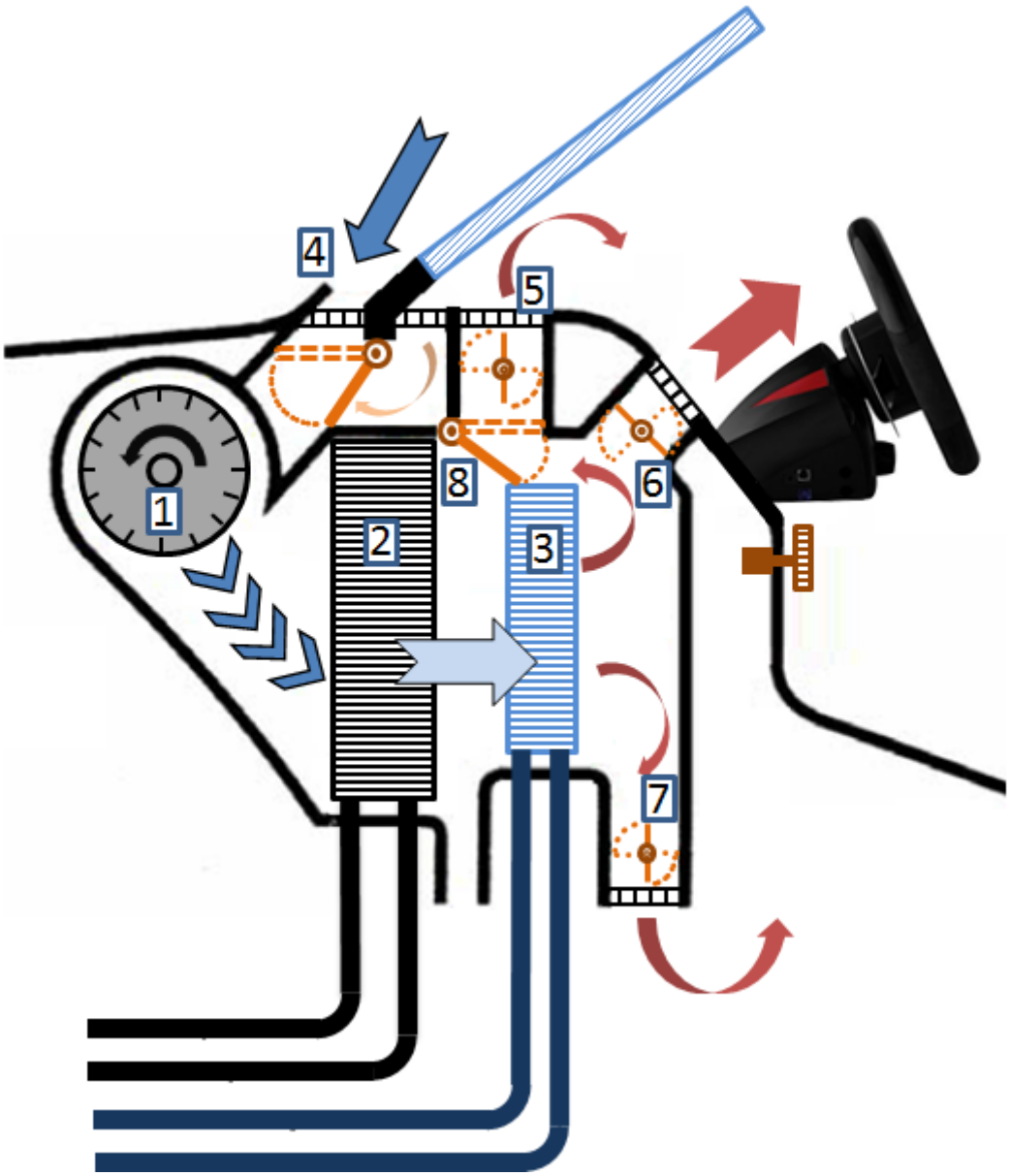

Figure 1. A Car HVAC with Eight Components: 1 = Blower, 2 = Evaporator, 3 = Heater, 4 = Intake Air Flap, 5, 6 and 7 = Air-distribution Flap, 8 = Air-mixing Flap

Flap Actuators

The air flows in an HVAC system through ducts or pipes; a flap is used to open or close, either fully or partially, certain portions of the duct in order to control which way the air goes. A flap actuator, also called a damper, is simply an electrical machine that moves the flap.

There are three types of flap actuators in an automotive HVAC system:

- Intake air-flap actuator (component 4 in Figure 1): This flap actuator controls whether the source of air for conditioning will be outside air or recirculated cabin air. This flap actuator position is controllable by the driver using the recirculate button, or by the HVAC system using data from in-cabin air-quality sensors.
- Air-mixing flap actuator (component 8 in Figure 1): This flap actuator mixes the warm (heat exchanger) and cool (evaporator) air in order to achieve the desired air temperature.
- Air distribution flap actuator (components 5, 6 and 7 in Figure 1): These flap actuators, which could vary in number based on the vehicle class, distribute the air inside the cabin.

DC Motor

What electrical machine moves the flap? Just as there are choices for controlling the flow of air, automakers have choices for the electrical machines that move the flaps. Potential choices include brushed DC motors with potentiometers to sense the position of the flap, three-phase brushless DC (BLDC) motors that use back electromotive force (back EMF) to measure positions or stepper motors that count the number of steps to measure the positions. These DC motors drive the flap through gears of varying sizes.

More Choices

Having chosen the motor, HVAC systems engineers also have a choice of architectures for driving the motor. As I've mentioned, flap actuators can be controlled locally or remotely. The motor driver, electronics, and motor location are in a single housing when using local motor control. Communication protocols, such as Local Interconnect Network (LIN), command the electronics to drive the flap to a particular position. For remote control, the electronics that control the motor are located on the HVAC control unit (Figure 2 and Figure 3), which is away from the flap actuator. Communication between the motor driver and the microcontroller on an HVAC control unit could be realized with a serial peripheral interface (SPI) (Figure 4) or more straightforward with a parallel digital control interface (Figure 5). Texas Instruments' DRV8912-Q1 is an example of a device that interfaces with the microcontroller via SPI and can drive the flap actuator.

Figure 2 and Figure 3 illustrate the two possible architectures. The architecture in Figure 2 is more complex than the one in Figure 3; however, the architecture in Figure 2 offers more design scalability and flexibility.

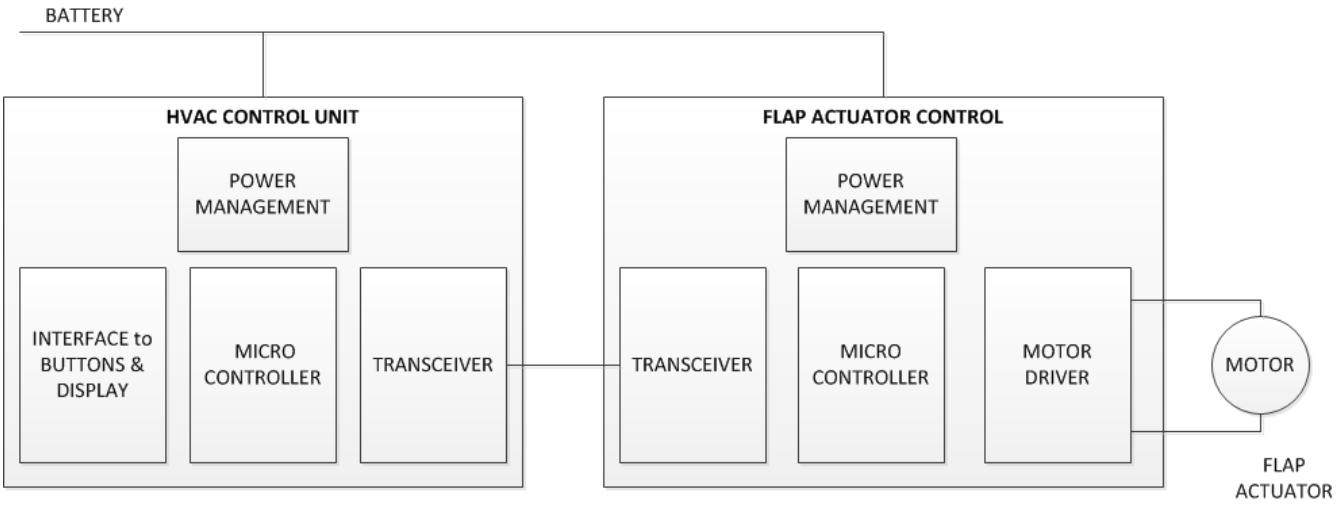

Figure 2. Remote Control of Flap Actuator Motor

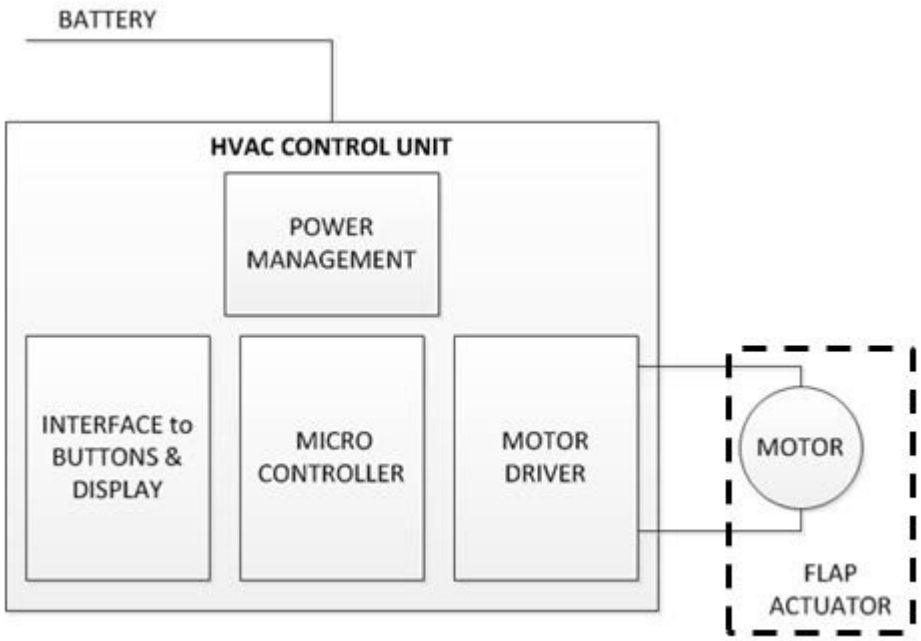

Figure 3. Integrated Motor Driver for Flap Actuator

Even More Choices

Let's talk about the connection between the microcontroller and the motor driver control integrated circuit. HVAC system designers have choices regarding this connection as well. The microcontroller can connect to the motor driver using a digital communication interface such as SPI or can directly connect to the motor driver using control lines. Figure 4 and Figure 5 illustrate these choices.

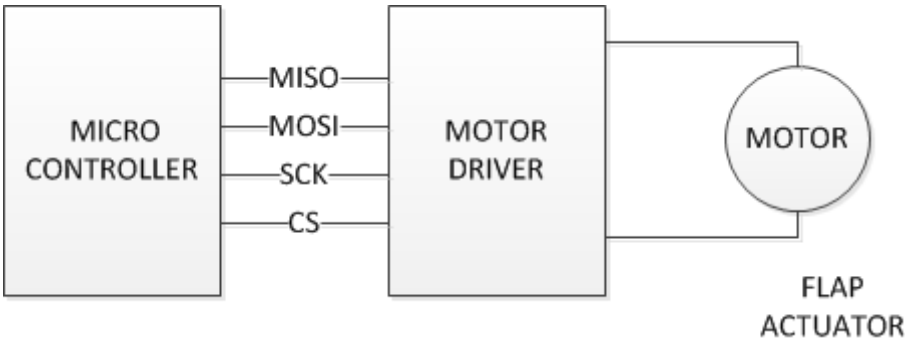

Figure 4. A Microcontroller Communicating with the Motor Driver Using SPI

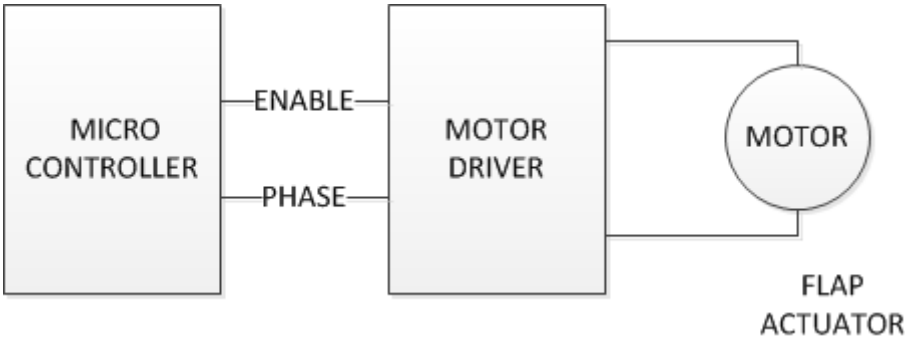

Figure 5. A Microcontroller Controlling the Motor Driver Directly

Keeping It Simple

The driver electronics used to drive a flap using a brushed DC motor is simple and found across multiple system configurations. If you choose to use brushed DC motors for moving the flaps, using a motor driver that directly drives the flap motor has a clear advantage – it is simpler in both hardware and software.

For HVAC systems, using a brushed DC motor driver that directly drives multiple flap motors in forward and reverse direction in a single integrated circuit reduces system size, cost, complexity, and thermal performance. An example of these drivers is DRV8912-Q1 device family. To learn more about the DRV8912-Q1 device family, read blog Driving HVAC system's flaps with an integrated, multichannel motor driver check out the DRV8912-Q1 datasheet, or evaluate the DRV8912-Q1EVM.

Additional Resources to Help You Design Automotive HVAC Subsystems:

- Learn how to connect and control multiple flap motors with the automotive HVAC control reference design with HMI.
- For DC motor designs, check out the automotive 12V 200W (20A) BLDC motor drive reference design and the automotive 2-axis power seat brushed DC motor drive reference design.
- Check out TI's body electronics and lighting portal for more related reference designs.

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