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TECHNICAL NOTE

INTRODUCTION

The automotive HVAC market is mature, yet still subject to high-end innovation. Fuel economy, comfort and safety are the major drivers for change. In simple HVAC systems, a continuous inflow of fresh air is conditioned and brought into the cabin. This air leaves the car through some ventilation openings. Typically the driver can select, by means of a manual control function, whether the fresh air supply needs to be interrupted (recirculation) or not (fresh air open).

In recirculation mode, high-end HVAC systems monitor several cabin air parameters, recirculate the air through the air conditioning unit back into the cabin and limit the fresh air inlet to the minimum, while fulfilling the air parameters set by the driver and/or the system's specifications.

In theory [1], such automatic recirculation can reduce the fuel consumption of an HVAC system by 35%. Depending on the climatic conditions and driving cycles, an HVAC system can consume up to three litres of fuel per 100 km [1]. This indicates that large cars that are equipped with a low-end HVAC system will benefit the most from the addition of a small-and m with low C

emissions will also benefit from a smart already available will increasingly be reused in small cars and in cars with low-specification HVAC systems.

While the sensor aspect of the automatic recirculation function may have been solved, there is still some work needed to tackle the issues around flap motorization. This paper will focus on the recirculation function, system requirements, the air flap actuator and the driving of that actuator.

AIR RECIRCULATION SYSTEM

Climate control systems are one of the larger consumers of power in modern cars. In particular, the compressor consumes thousands of Watts when operational.

One of the ways to reduce the energy consumption of climate control systems is to improve compressor efficiency. However, a more important method for saving energy is to reduce the "active time" of the compressor. In order to do this, we need to look downstream at the compressed refrigerant flow and verify what really happens during compressor operation.

The efficiency of an HVAC system largely depends on the amount of refrigerant supplied to the evaporator. Replacing the mechanical expansion valve with an electromechanical valve controlled by a linear stepper motor has previously been proposed [2] to gain better control over the flow of the refrigerant. Alternatively, the average temperature of the airflow that runs over the evaporator could be decreased (if the evaporator is exposed to cooler airflow, then a smaller refrigerant flow is required, meaning reduced compressor activity). The lower temperature of air flowing over the

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evaporator can be accomplished by re-using, to a large extent, the cabin air that has already been cooled rather than the relatively warmer air from outside of the vehicle. This mixing of the correct amount of fresh air and cabin air can be performed by an automatic recirculation valve. This recirculation function is a key element in the overall energy efficiency of the HVAC system and special care has to be taken to assure correct and optimized operation over the lifetime of the car. Let us now look at the different system elements and important parameters and requirements for the recirculation function.

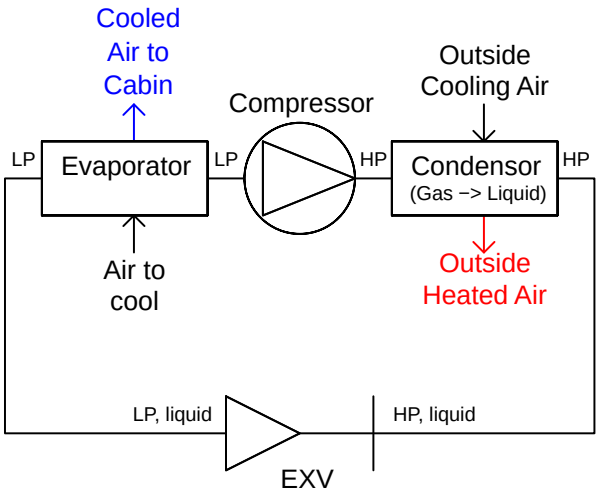

Figure 1. HVAC System

However, the software algorithm itself will require special attention because it is a matter of safety to ensure that the driver is supplied with the correct amount of fresh air under all circumstances.

Flap Actuator

The air recirculation flap actuator is a small motorized

TND416/D

STEPPER MOTOR DRIVER TECHNOLOGY

Advanced stepper motor drive technologies have been developed to optimize actuator operation in terms of factors such as acoustical and electrical noise production and long-term reliability. Compared to traditional architectures, new bipolar stepper motor actuator technologies offer a balanced solution: more system benefits (i.e. an optimized mix of features and quality) without overall system cost penalties.

Micro-Stepping

Basic movement of a stepper motor is accomplished by switching the windings, which energize the electromagnets, in an alternating on/off fashion. This is called a “full-step” movement because it aligns the rotor to the stator tooth-by-tooth or step-by step. This is a rough mode of operation and can cause the system to vibrate, contributing to increased acoustic noise during operation. Another possible effect is loss of steps, (i.e. steps are skipped). Without proper design this means that the system is no longer aware of the exact actuator position. These effects can be avoided or at least alleviated by operating the stepper motor in micro-stepping mode, meaning that the windings are energized together in such a way that the motor moves from step to step position via several sub-positions or micro-steps. Moving the motor in this more continuous way has a positive impact on the stability of the motor system and results in better performance in terms of acoustic noise and step-loss avoidance.

Sensorless, Closed-Loop Operation

guaranteeing error-free positioning. These algorithms allow speeds up to 1000 full steps per second.

Resonance Avoidance

The bemf signal proves to be very useful, not only for stall detection and adaptive speed control, but also for trouble-shooting resonance issues. A first difficulty with solving resonance issues is that a suitable sensor cannot be attached easily to the system. A second difficulty is that a mounted sensor should not change mass or friction of the motor-axis, as this alters the resonance behaviour being measured. Now this is solved easily if the resonance behaviour and related rotor-movement is observed through the “embedded virtual sensor”. Please refer to [3] for more information.

FLAP ACTUATOR TECHNOLOGIES SUMMARY

Table 1 summarizes the “fit for use” of the flap actuator technologies discussed. Both brush DC and unipolar stepper motors offer their advantages but also show weak points. The bipolar stepper motor technology seems to offer the best of both worlds and is compatible with all reviewed requirements.

Table 1. SUMMARY OF ACTUATOR TECHNOLOGIES

Actuator Characteristic	Brush DC	Unipolar Stepper

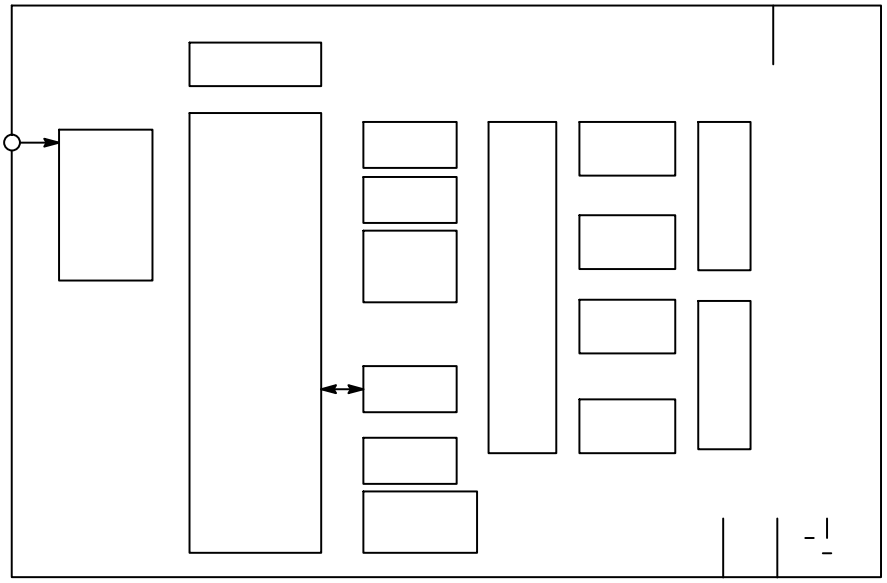

Figure 6. Bipolar Stepper Motor Driver IC (NCV70501) − Block Diagram

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[2] Bart De Cock: *"LIN Mechatronics Applied to HVAC Expansion Valves*", European Mechatronics Meeting, Paris, France, June 24 & 25 2009.

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GLOSSARY

HVAC:	Heating, Ventilation and Air-Conditioning
IAQ:	Interior Air Quality
IC:	Integrated Circuit
ECU:	Electronic Control Unit
UV:	Ultraviolet (light)
LED:	Light Emitting Diode
BDC:	Brush(ed) Direct Current (motor)
EMC:	Electro-Magnetic Compatibility
AC:	Alternating Current
Bemf:	Back-Electro-Mechanical Force
SPI:	Serial Peripheral Interface
EXV:	Expansion Valve
LP:	Low Pressure
HP:	High Pressure