Making Power Windows safe

Delphi Electronics & Safety is developing power window controls with TargetLink

At its Mexico Technical Center, Delphi Electronics & Safety is developing new algorithms for power window functions. The goal is to provide maximum protection against power window injuries. Delphi is simulating, implementing, and testing the new functions with the help of dSPACE prototyping systems and the TargetLink production code generator.

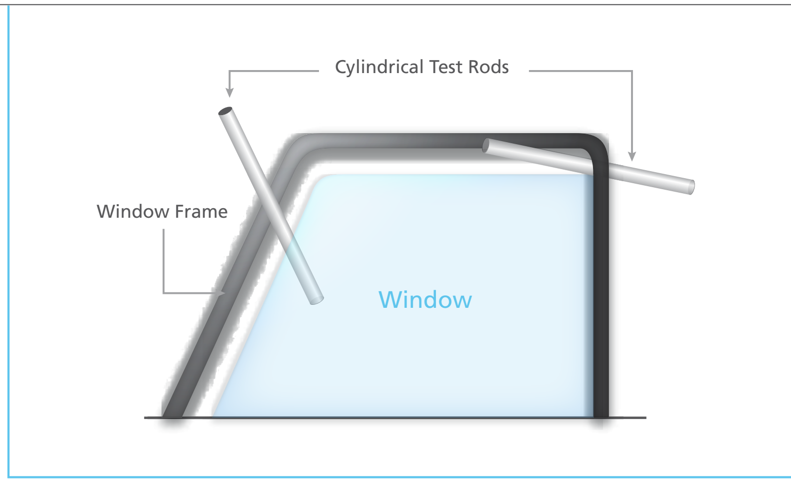


Figure 1: Test method for anti-pinch technology. Test rods are inserted to measure the actual closing forces that occur.

Safety Issues in Power Windows

Like other vehicle domains, vehicle interiors have a constantly increasing number of electronic functions. And comfort functions also have safety issues that must never be neglected. A power window can cause serious, or in some cases fatal, injury to passengers. Strong countermeasures are needed to prevent this happening.

Anti-Pinch Technology Standards

The anti-pinch technology of a power window has to meet standards issued by the EU and the United States. Test methods are available for this (figure 1). For example, the maximum force a power window is allowed to exert on any object is 100 N. Compliance with this limit must be monitored and enforced in a range of 4 mm to 100 mm from the top window frame. It is also important to deactivate the anti-pinch mechanism immediately before the window seal is reached, so that the window can close tightly. In addition, to avoid damage to the window motor, blocking must not last too long. The anti-pinch algorithm used in this project is based on the "Method for Monitoring Movable Elements" patented by Delphi. The method monitors the Hall effect feedback signal of the power window motor to detect if an object has been pinched.

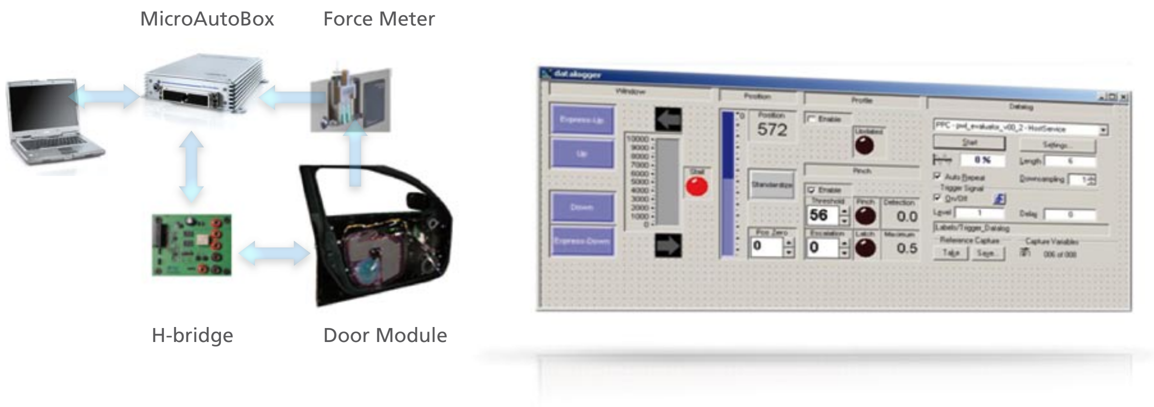


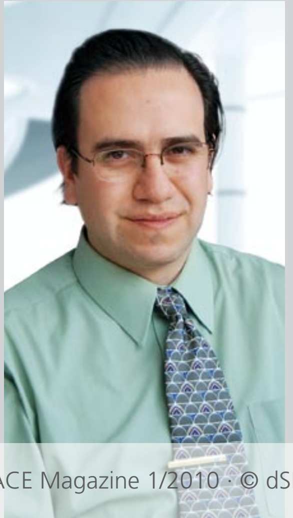
Figure 2: Left: Test bench for algorithm validation with MicroAutoBox. Right: ControlDesk experiment layout.

The Development Environment

Delphi developed the algorithm in Simulink®/TargetLink and validated the concept with a dSPACE MicroAutoBox and ControlDesk (figure 2). ControlDesk was used not only to adjust the algorithm parameters, but also to record the signals to provide test vectors for simulation runs later in Simulink/TargetLink. As well as performing test bench validation, the developers also created a Simulink/TargetLink environment for closed loop simulations, so that they could use model-in-the-loop (MIL) and software-in-the-loop (SIL) simulations to develop algorithms for the overall system.

Left: Ernesto Wiebe-Quintana
Advanced Analysis Engineer
Ernesto Wiebe-Quintana is an advanced analysis engineer working on advanced development projects for Controls and Security Applications at Delphi.

Right: Salvador Canales
Electrical Analysis Engineer
Salvador Canales is an electrical analysis engineer, responsible for advanced development projects for Controls and Security Applications at Delphi.



> "The code generated by TargetLink is efficient, well-structured, and very readable."
>
> *Salvador Canales, Delphi Electronics & Safety Mexico, Technical Center*

The relevant power window behavior was represented by a state-space model of a DC motor and by look-up tables. The wave form of the Hall effect was superimposed on the motor model's position signal.

Anti-Pinch Algorithms

The algorithms are subdivided in several function blocks, two of them are described here: position control and stall detection. The position control provides information on the current window position and the last direction of motion before blocking occurred. To set the lower and upper position limits of the window (home indexing), the window is lifted from the lower pinch position to the upper one in an initial operating state before the position control is switched to the normal operating mode. In this mode, the position control sums all the window position changes across its entire lifetime to determine the current window position. The aging on the window seal is also estimated from the number of complete closures performed by the window. The position control is triggered by the edges of the Hall signal and is predominantly modeled in Stateflow® (figure 3).

The stall detection has a dual purpose: it prevents injuries from power window crushing, and stops the motor overheating at the window's lower and upper position limits. The algorithm for stall detection essentially compares the current value of a timer with a threshold value. The timer is restarted each time a Hall signal edge is detected, and a blockage is diagnosed if the timer's value exceeds the threshold value. The latter is not constant,

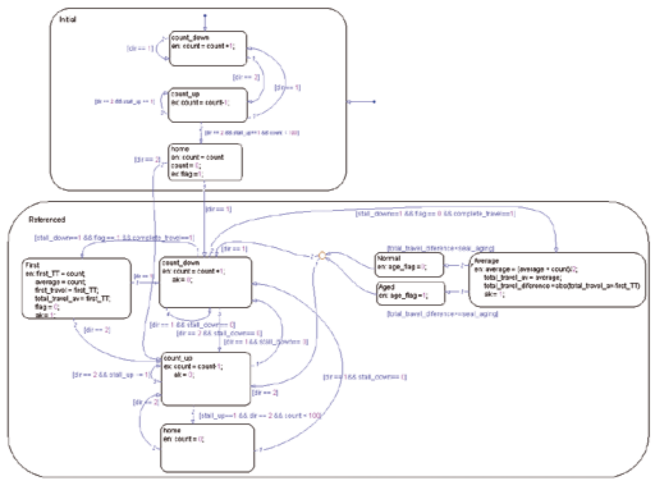


Figure 3: Excerpt from the algorithm for position control in normal operating mode.

Outlook

The individual functions have all been implemented. The next tasks will be to integrate the overall functionality in a door ECU and validate the system under all the specified operating conditions. Finally, aging test verification has to be performed to calibrate and validate some of the algorithm parameters in conjunction with the side door.

but is computed as a function of battery voltage and temperature.

TargetLink in Action

The entire functionality of the power window control was designed in Simulink/TargetLink and then autocoded with TargetLink. The generated code was highly efficient and clearly structured. Moreover, simulation in MIL and SIL modes proved extremely useful in advancing controller design and fixed-point software development. For offline simulation, signals recorded in rapid control prototyping were reused, and additional test vectors were also developed (figure 4). To specify the position control's software interfaces, the TargetLink Property Manager was used frequently to convert the Stateflow sections of the anti-pinch protection into production-ready C code. TargetLink's ability to flexibly generate code for look-up tables was harnessed to autocode the stall detection, making it possible to use different types of search and interpolation routines, to partition the code into different files, etc. ▪

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Figure 4: Simulation environment in Simulink/TargetLink.