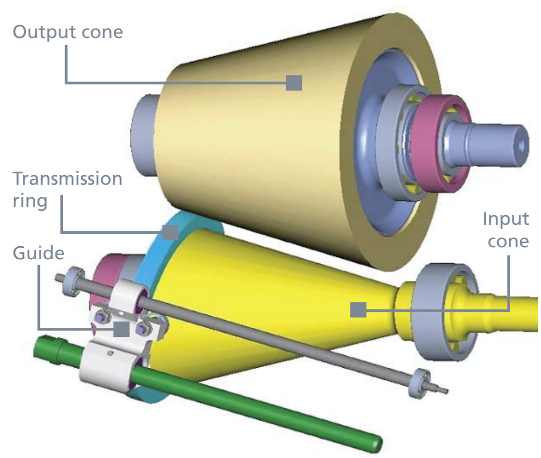
Continuously Variable Transmission in Formula Racing Cars

- Ecurie Aix – The Formula Student Team at the RWTH Aachen University
- A controller for a continuously variable transmission developed with MicroAutoBox
- Transmission parameters optimized by means of ControlDesk

Formula SAE and Formula Student are international design competitions for engineering students. The students design, build, and drive small formula-type racing cars according to fixed rules. The members of Ecurie Aix, the Formula Student team at the RWTH Aachen University in Germany, have given their car an innovative continuously variable transmission. They used a MicroAutoBox from dSPACE to develop the controller for it.

We, that is the Ecurie Aix team, built the EAC 02 formula racing car for the 2004 season. The vehicle has a unique continuously variable transmission (CVT). It was developed by six of our team members in cooperation with GIF mbH (Gesellschaft für Industrieforschung), a company that does industrial research in Aachen. The transmission allows an infinite number of gear ratios – so there is an infinite number of possible gear shifts. Its particularly advantage is that the optimum engine speed, the nominal speed, can be reached and held. This means that the engine always runs at its maximum performance.



▲ *An infinite number of gear shifts: With a CVT, the engine runs at its maximum performance.*

How the Transmission Works

The CVT consists of two cones with a transmission ring between them. The torque between the rotating cones is transmitted by a traction fluid. The axial position of the ring between the cones determines the transmission's gear ratio. To achieve the correct gear ratio, the ring must be deflected via a guide.

As the cones rotate, the ring in its guide runs with them, until the guide has reached the position computed by the transmission control. A servosystem is used to position the ring and lock the gear in place. We used a DC motor coupled with an incremental encoder to do this.

Unlike other CVTs, this one does not have a high power consumption, as the rotation of the cones and the oblique angle make it possible to change the gear ratio fast, applying very low forces. This means the formula-type racing car can accelerate rapidly. In addition, we also automated the clutch, to make the car easier to drive.

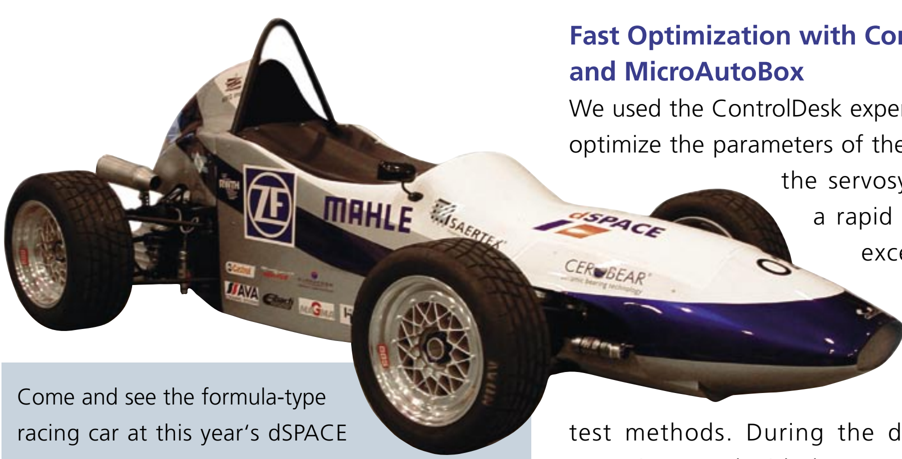
The History of the Formula SAE Series	
1981	Formula SAE is inaugurated as an engineering design competition for students, with the objective of building formula-type racing cars according to strict rules. The competition is run by the Formula SAE Consortium, consisting of representatives from Chrysler, General Motors, Ford, and the SAE.
1998	The first European competition, called Formula Student, is held in the UK.
2000	Formula SAE-A is set up. The first competition is held in Australia.
All three competitions take place annually.	

Rules of the Formula SAE Series (Excerpt)	
Vehicle	■ Open-cockpit, open-wheeled monoposto ■ Wheel base: at least 1525 mm ■ Complete ground clearance ■ Four-stroke piston engine not exceeding 610 cc ■ Engine can be naturally aspirated, turbo, or supercharger ■ Protection against frontal and side impact, and against rollover ■ Any transmission
Track Profile	Bend radius, straights, and chicanes defined
Cost	A maximum of $25,000 according to fixed costing rules
Judging Categories	■ Static events: Safety, engineering design, cost analysis, presentation ■ Dynamic events: Acceleration, skid-pad, autocross, fuel economy, endurance
For more information and the complete rules, see www.sae.org.	

The Team
Ecurie Aix was founded in 2000 and currently has 30 members from six different university courses.
The team competed for the first time in 2002, with the EAC 01.
Their greatest success with the car was 30th place in Formula Student 2002.
54 teams took part in this year's Formula Student (July 8-11, 2004). Ecurie Aix came 27th with the EAC 02.
For more information on Ecurie Aix, visit *www.ecurie-aix.rwth-aachen.de*

Developing the Prototype

To achieve a high degree of integration, we connected most of the electronic devices to a CAN bus. As the engine, also a prototype, was developed in parallel, the transmission has its own controller. To implement a prototype transmission of this kind, we needed a very flexible and powerful real-time system. MicroAutoBox is the ideal tool for our requirements.



Come and see the formula-type racing car at this year's dSPACE User Conference in Stuttgart, October 21-22. Further information: *www.dspace.de/goto?uc_stuttgart*

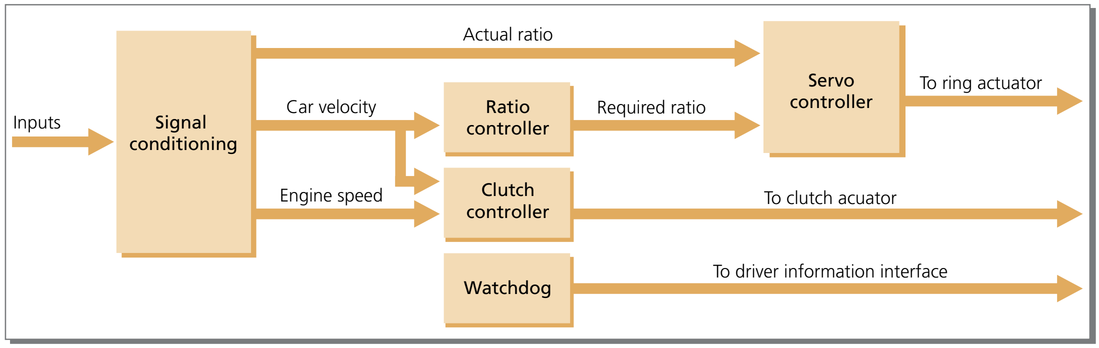
Four main tasks are implemented on the transmission controller:

- Processing and preparing signals
- Implementing a servosystem
- Triggering the clutch
- Monitoring and alarm system

We tested various algorithms and did the fine-tuning with MicroAutoBox. The signals (including CAN, sensor, and digital signals) were processed and prepared by simple Simulink® routines and filters.

Fast Optimization with ControlDesk and MicroAutoBox

We used the ControlDesk experiment software to optimize the parameters of the PID controller for the servosystem, to achieve a rapid response without exceeding maximum values. The settings were determined by means of simple test methods. During the development process, it was decided to replace the analog controller for engine control by a simple pulse width modulation (PWM) board to reduce both the



▲ *The transmission controller has four main tasks: processing and preparing signals, implementing a servosystem, and triggering the clutch, and as a monitoring and alarm system.*

cost and the weight. Using MicroAutoBox, we were able to carry out this change fairly effortlessly. The CVT transmission was then tested on a transmission test bench provided by GIF. MicroAutoBox's extensive I/O capabilities meant that diagnostic and monitoring routines could be implemented in conjunction with the test bench hardware. The algorithm for automating the clutch was implemented on a dynamic test bench at the ika (Institut für Kraftfahrwesen) institute of automotives in Aachen. Here too, ControlDesk enabled us to adjust the parameters with no problems. Additional monitoring routines control a variety of temperatures and transmission slip. When the values deviate from their reference values, an alarm is sent to the driver interface via the CAN bus.

Ready for the Competition

The entire powertrain of the EAC 02 is a prototype, so we needed a lot of time for extensive road tests. We used the data logging abilities of MicroAutoBox's Flight Recorder to detect errors in the model of the transmission. The resulting Simulink code was implemented on a commercially available microcontroller by means of TargetLink, the code generator from dSPACE.

Ecurie Aix Formula Student Team
RWTH Aachen
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◀ *During road tests, data was captured by MicroAutoBox's Flight Recorder, and later evaluated. This allowed errors in the controller model to be found.*