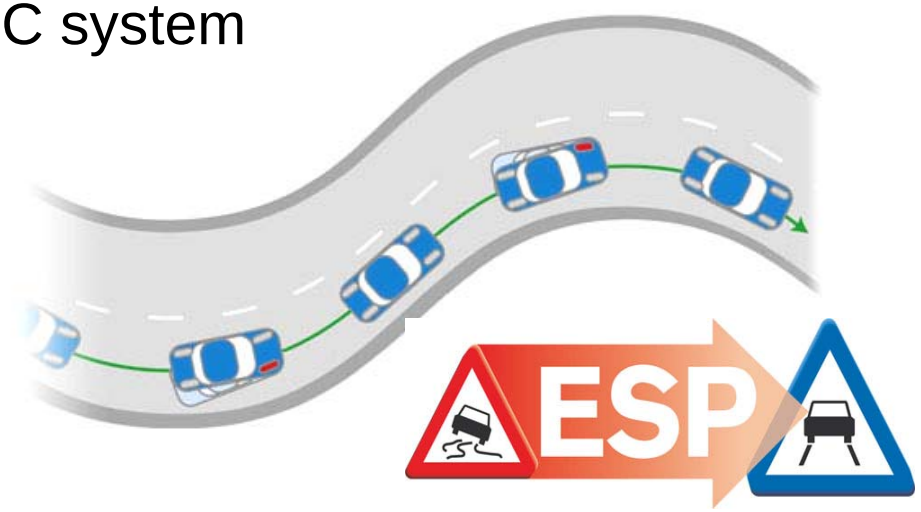
Testing and evaluation

- Test procedure – how to evaluate an ESC system
- System Integration – cooperation with VM‘s and system tuning
- NHTSA Test – asses an ESC system



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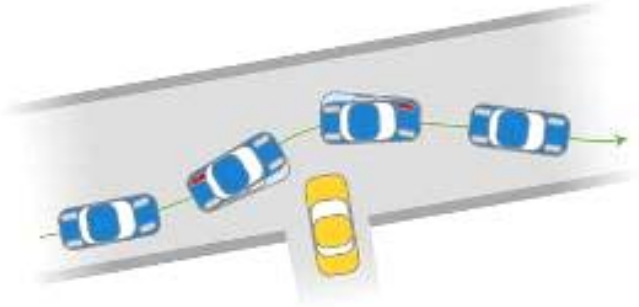
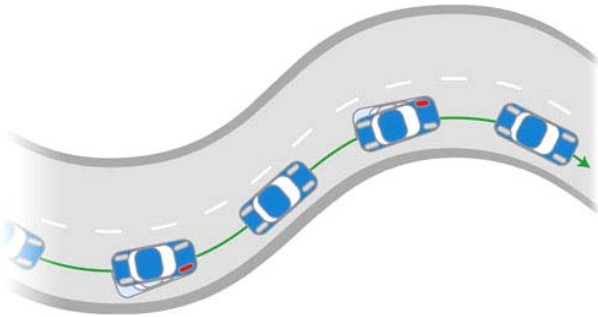
Examples of ESC Functionality

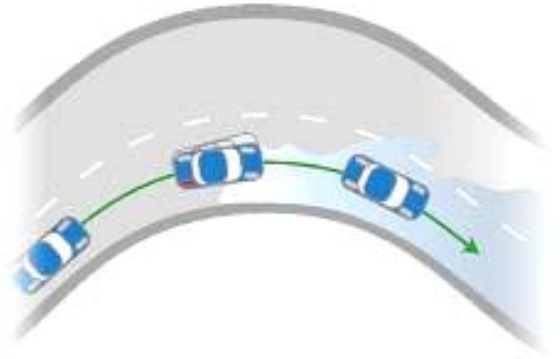
- **Avoiding an obstacle**
  Vehicle smoothly follows steering-wheel input, oversteering tendency during reverse steering prevented



- **Cornering at the limit**
  Oversteering after heavy steering inputs removed



- **Driving on varying road surfaces**
  Understeering because of excessive vehicle velocity at the beginning of a bend mitigated



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Calibration Procedure 1

During calibration period (about 12-18 months, dependent e.g. on complexity and number of variants), about 1000 - 1500 driving tests are carried out

- on different test tracks and
- on various public roads (robustness tests)

to cover the infinite variety of everyday road conditions and to ensure a reliable effectiveness in all real-world situations.

Example: Test Maneuver Catalogue for System Release

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Meeting with Thatcham, 29.03.2006

Test Maneuver Catalogue for System Release (>500 tests)

	A	B	C	D	E	F	G
1	Application:				Systemdevelopment:		
2	Person in charge:		Date:		Person in charge:		
3							
4	Proving ground:		Measurement directoy:				
5							
6	Official Software ESP:						
7							
8	>> Add Measurement Names to Sheet <<	>> Start UNIVIEW with specified Measurement <<			Remarks:		
9	Maneuver for Test SW-Release (Category 5)			Front wheel			
10	No.	Description	Test of module group / function	Manual	Automatic	CVT	ASG
133	064	G: Doppelter Spurwechsel Antriebsfall auf Asphalt E: Double lane change with constant throttle position on asphalt	ASR[F] FZR[F]	AND / AND	AND / OR	AND / OR	AND / OR
134		Measurement name->					
135	065	G: Doppelter Spurwechsel ABS-gebremst auf Schnee oder Basalt E: Double lane change, ABS spike brake apply on snow or basalt	Backup-ABS[B] FZR[F] EHB(EHB-ASG)[E]	OR / OR	OR / OR	OR / OR	OR / OR
136		Measurement name->					
137	066	G: Doppelter Spurwechsel gebremst im Teilbremsbereich auf Schnee oder Basalt E: Double lane change, partial brake apply on snow or basalt	Backup-ABS[B] EHB(EHB-ASG)[E]	OR / OR	OR / OR	OR / OR	OR / OR
138		Measurement name->					
139	067	G: Doppelter Spurwechsel Freilauf auf Schnee oder Basalt E: Double lane change, free rolling on snow or basalt	FZR[F] EHB(EHB-ASG)[E]	OR / OR	OR / OR	OR / OR	OR / OR
140		Measurement name->					
141	068	G: Doppelter Spurwechsel Antriebsfall auf Schnee oder Basalt E: Double lane change with constant throttle position on snow or basalt	ASR[F] FZR[F] HIM[F]	AND / AND	AND / OR	AND / OR	AND / OR
142		Measurement name->					

Subjective assessments
(most of the performance tests)

Objective Criteria
- Software Functions
- Performance Test (e.g.Stability based on side slip angle)

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Calibration Procedure 2

The great number of tests include

- **numerous driving maneuvers and road profiles** (obstacle avoidance, slalom, bends, straight line, inclined road with positive and negative superelevation, off-road, mountain pass, unfortified country roads, open-loop, closed-loop-tests ...),
- **on different surfaces** (different types of dry/wet asphalt, snow, ice, split-mue, gravel, rock-crawl, inhomogeneous surfaces, ...),
- **with all control conditions** (free rolling, acceleration, lift-off, partial and full braking, ...) and in
- **multiple vehicle configurations** (tires type and pressure, loading, air spring, ...).

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Cooperation and tuning

The cooperation with the VM depends on the different customers.

- Complete development and calibration done by RB. Joint tests with VM at different milestones during project
- Close cooperation during development and calibration. Calibration partly done by customer

The tuning proceeds in different steps

- Adaption to the properties of the specific vehicle
- Configuration of the different function setups
- Tuning the parameters to fulfill the VM‘s requirements

Cooperation and tuning

Different possible tunings during development

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Test and evaluation

Handling is much too complex and can not completely be covered by a few objective measures (e.g. how to seize harmony inside the driver-vehicle control loop in all conceivable driving situations and any environmental conditions possible?)

The necessary size of tests clarifies that a significant overall ESC assessment by some objective tests is not at all possible!

But: Test(s) needed to prove essential ESC effectiveness for customer information

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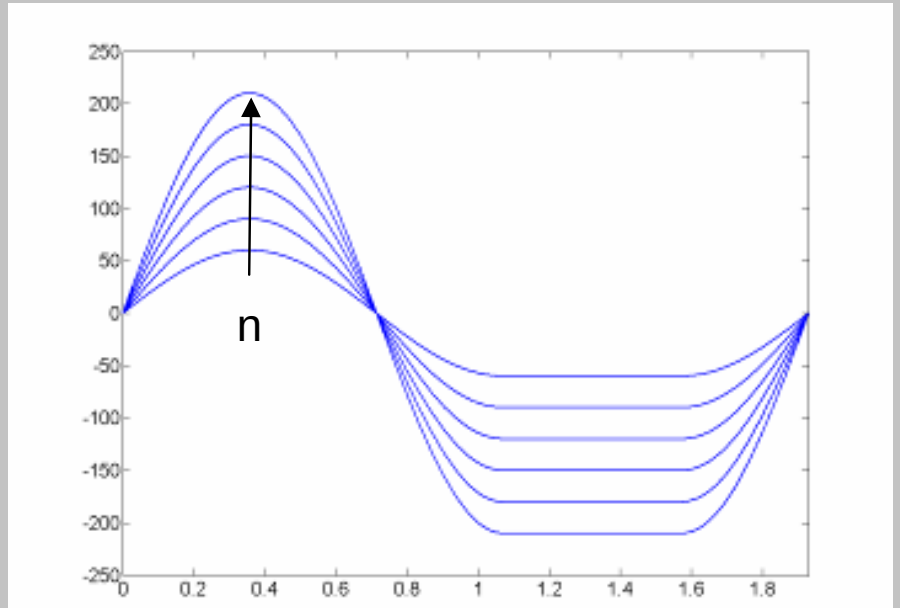
Search for an Objective Handling Test

Test requirements:

- Significance concerning main ESC functionality (side slip angle limitation in order to prevent vehicle spin)
- Excellent repeatability (open-loop maneuver, use of steering robot)
- Detailed test procedure description (test setup, environmental conditions etc.)
- Appropriate effort for maneuver realization
- Objective multi-criteria assessment (e.g. stability and responsiveness)
- Comprehensible and efficient evaluation

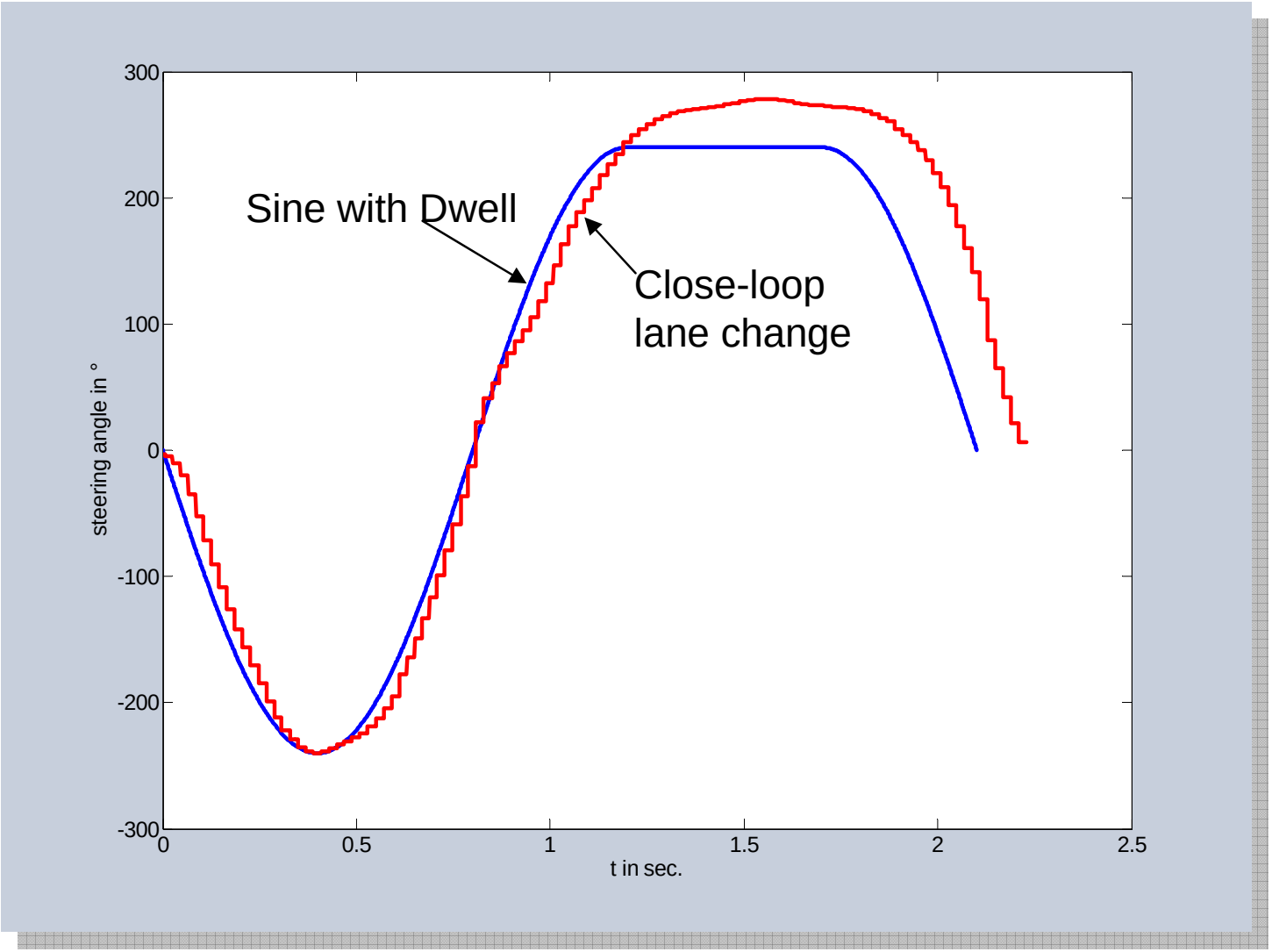
NHTSA ESC Effectiveness Test

- Maneuver: open-loop „0.7 Hz Sine with Dwell“



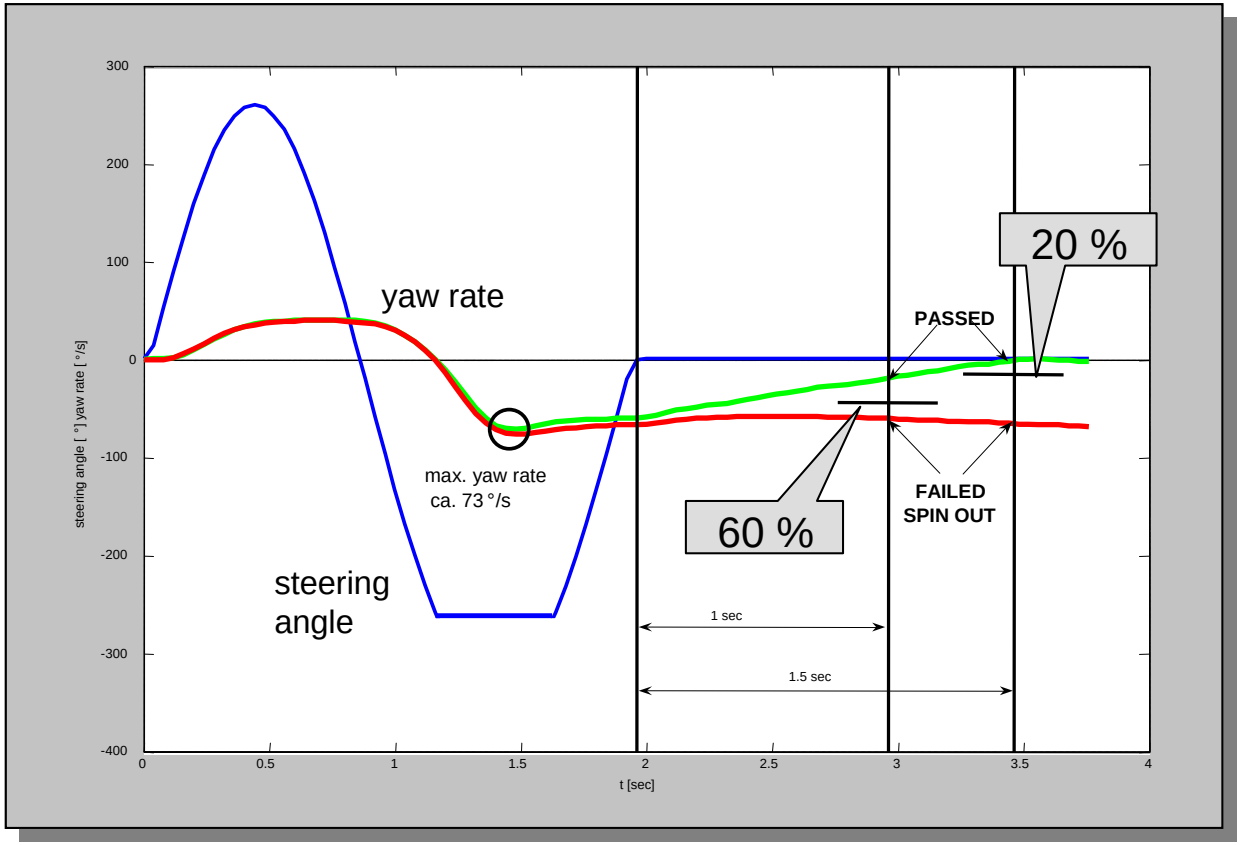
- n*A@0.3g (n = 2...7)
- 80 km/h

Comparison with Closed-Loop Obstacle Avoidance



NHTSA Proposal for ESC Test

- Metrics:
  - "Spinout" criterion: sufficient yaw rate decay



Stability
&
Responsiveness

  - Minimum lateral displacement: 12 ft (= 3,65 m)

NHTSA Proposal for ESC Test

Yaw rate crit. (NHTSA) :

0,25% ✓

11% ✓

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Drawback of NHTSA Test

Test can be passed by vehicle even with “Dummy ESP” !

- An open-loop control based on steering input information only is sufficient to pass the test criterion because vehicle behavior is excited essentially by the predefined steering robot input
- Lateral motion (characterized by yaw rate and lateral acceleration) in test maneuver is not independent enough from steering input
- With simple control system, bad side-effects during real-world driving situations are possible
- No benefit of Dummy ESC on traffic safety shown (as for ESC by accident statistics analysis)

Possible remedy:
Complete NHTSA test with additional exclusion test
stimulating vehicle’s lateral motion independently of steering input

Conclusion

- Handling is much too complex and can not completely be covered by a few objective measures.
- ESC can be tuned for different setups regarding the VM's requirements.
- ESC prevents spin-outs in basic tuning within physical limits.
- The NHTSA maneuver "Sine with Dwell" generates a strong lateral dynamic input to the vehicle.
- The NHTSA criteria detects spin-outs.
- Multi-criteria assessment is necessary (Stability & Responsiveness).

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ESP

Thank you for your attention.

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