Torque Vectoring Control
Brake Based Torque Vectoring for Everyone

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Torque **Vectoring** Control

- Background
- The Problem
- Root Cause
- Solution Concepts
- Decision – Brake or Differential
- Principle & Benefits
- Conclusions & Outlook
Background

Torque Vectoring,

the ability to transfer torque around the driveline to where you want it, and ultimately, individually to each wheel,

is currently a popular theme in the vehicle dynamics and driveline areas.
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Background

A number of mechanical solutions (with clutches & gear sets) have been developed to achieve left/right torque transfer, e.g.:

– Mitsubishi (Lancer Evo IV upwards),
– Honda/Acura (SH-AWD system),
– BMW (X6 – Dynamic Performance Control) and
– Audi (quattro with Sport differential)

Torque Vectoring Control (TVC) has been developed to compete with such systems, but at a more efficient and affordable level.
FWD vehicles with a transverse mounted engine have emerged as the mainstream platform due to package, cost and low weight.

Major concept drawbacks, especially for performance derivatives, are:

- Power on understeer
- Reduced traction performance

Vehicle weight is a very sensitive theme in the current fuel economy conscious climate.
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Root Cause – Load Transfer

Vehicle cornering forces lead to reduced inner wheel vertical load.

In front wheel driven vehicles with high performance engines this may lead to the inner drive wheel slip when accelerating out of a turn.
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Vehicle Acceleration in a Turn

Friction circle limits applicable tractive force

Friction circle defined by vertical load

Torque balance limits turn outer tractive force

Remaining tire potential is wasted

$F_y$ needed for cornering
$F_x$ limited by friction circle
$F_x$ limited by torque balance
Wasted tire potential
Assuming in a left turn the gearbox delivers 3000 Nm drive torque and the curve inside wheel can transfer 1000 Nm.

**Solution Concepts – An Example**

**TC**
- Engine torque is reduced to deliver 1000 Nm to each wheel

**TVC**
- Engine torque is not reduced
- Brake absorbs 500 Nm to prevent the wheel slipping

**TV Differential**
- Engine torque is not reduced
- Multiplate clutch packs and gear sets can transfer the torque asymmetrically
The Decision – Brake or Differential?

Pro Differential

• During system activation the energy loss in the clutches is lower than in the brakes
  – Lower fuel consumption increase when in use
  – Possibly better acceleration in low gears
• Differential actuation is less intrusive
  – No change in longitudinal acceleration during activation and modulation
  – Specialised system is easier to control with less hysteresis and smoother application
The Decision – Brake or Differential?

**Pro Brake**

- No weight increase
  - No fuel consumption increase when not in use
  - No acceleration deficit due to power to weight ratio
  - No increase of front load distribution for FWD vehicles
- TVC can be modulated over a wide range
- Simple integration / harmonization with existing ESP system
- Slight reduction of engine power available for acceleration when active, but increases the ability to get available power on the road
- Lever arm to steering axis is smaller than for driveshaft forces, resulting in less steering disturbance
- Cost efficient solution – software only
TVC Working Principle

- TVC prevents excessive wheel spin during high / wide open throttle manoeuvres, before ESP thresholds are reached.
- It controls the speed of the curve inside wheel so that it doesn't slip, but doesn't brake the wheel hard enough to create negative drive forces at the tyre contact patch.
- During Power on TVC increases traction and agility compared to uncontrolled vehicles or engine torque truncation.
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Performance Benefits

• Improved cornering agility – improved turn-in and self-steer behaviour
• Driver assistance in mid to close-to-limit handling manoeuvres
• Later ESP intervention (an active yaw increase is provided before the ESP activation limit is reached) → comfort improvement
• Improved traction during cornering (and turn-in)
• Engine torque can be maintained longer in curves during sporty driving – less annoying TCS interventions
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Performance Benefits

- Provides small tyre life improvement for the sporty driver

![Graph showing performance benefits with and without TVC](image-url)
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Other Effects / Benefits

• A better compromise between traction and torque steer than with a limited slip differential.

• Minimises the slip in the curve inside wheel, possible to maintain the lateral grip capacity of the tyre

• Makes the car feels smaller – it reacts faster to driver steering inputs, cornering agility is increased and path following is improved.

• Increases power-off stability "at the limit" (reduced slip angle overshoot)

• Strongly reduced power-on understeer (especially in FWD vehicles)

• More consistent cornering behaviour, especially in power-on/off transitions (lower roll angle change, smaller slip angle change)
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**Simulations with C-Car**

- TVC-Off
- TVC-On

**Torque Vectoring Control**

- Vehicle Speed [km/h]
- Simulation Time [s] 17.520
- Steering wheel Angle [deg]
Conclusions & Outlook

• TVC brings its maximum advantage for vehicles with higher levels of power and torque, but is still beneficial for lower powered vehicles, especially in lower grip conditions (e.g. on wet roads).

• Slip based control works well for FWD, but has some limitations for AWD – addition of a yaw based controller could improve performance even further
Q&A