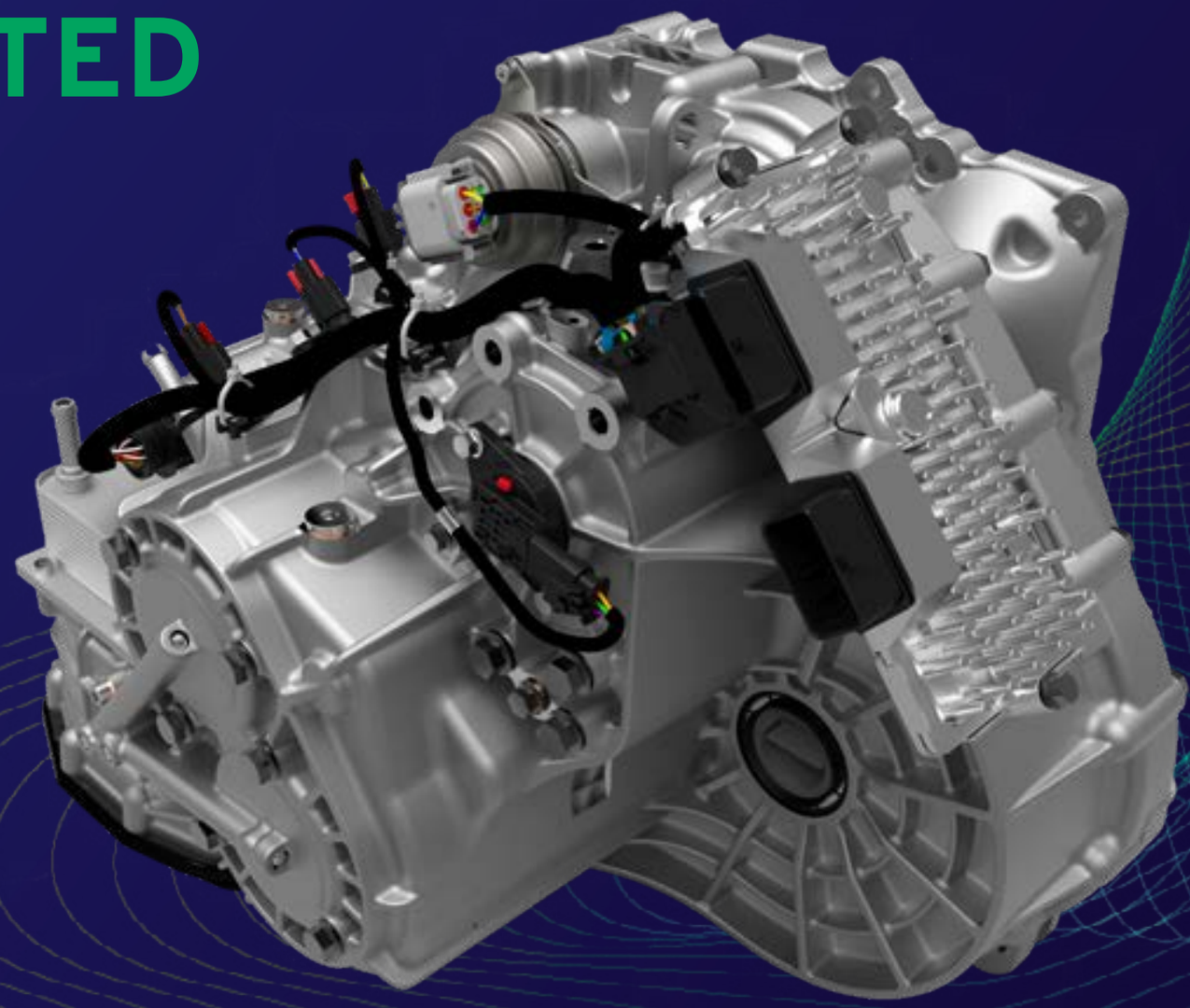
punch powertrain

Gear up for the future

DCT REINVENTED

Single layshaft DCT,
meeting the needs of
global market platforms



INTRODUCTION

Single layshaft DCT, performing at the level of an automatic transmission, at a reduced cost level

The global market is showing a gradual and clear move towards automated transmissions, driven by changing customer demands and the need to combine automation with hybridization. This is also increasingly the case for emerging markets and compact car segments.

In order to transition from MT to a ‘similar feel’ automated transmission, various options are available, such as AMT, 4,6 or 8AT and DCT.
When selecting the appropriate technology, however, OEMs are faced with a tradeoff between higher price or reduced functionality.
The patented “single lay shaft DCT” seeks to improve this tradeoff and offer an advantageous alternative for global platforms.

This paper further describes the requirements, which were taken into account for the design; the particularities of the design concept and benchmarks the technology against alternatives.

A study by:

Punch Powertrain offers a full range of fuel efficient drivetrains, ranging from automated powertrains (CVTs and DCTs) to mild hybrids, plug-in hybrids and full electric propulsion systems with integrated e-motor and power electronics.

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1. MOVE TO AUTOMATED TRANSMISSIONS

Inspired by changing customer demands and the need to hybridize and automate

In anticipation of full electrification, at least up to 2030, most cars, equipped with an ICE, are in need of a very efficient, often hybridized automated transmission.

Below graph illustrates the evolution of rising automated transmission market shares. The adoption rate on different markets, however, varies based on regional technological legacy and customer preferences. DCT proves to be the strongest grower, as it is the most versatile option, able to meet most of the needs of global markets.

Market trend:

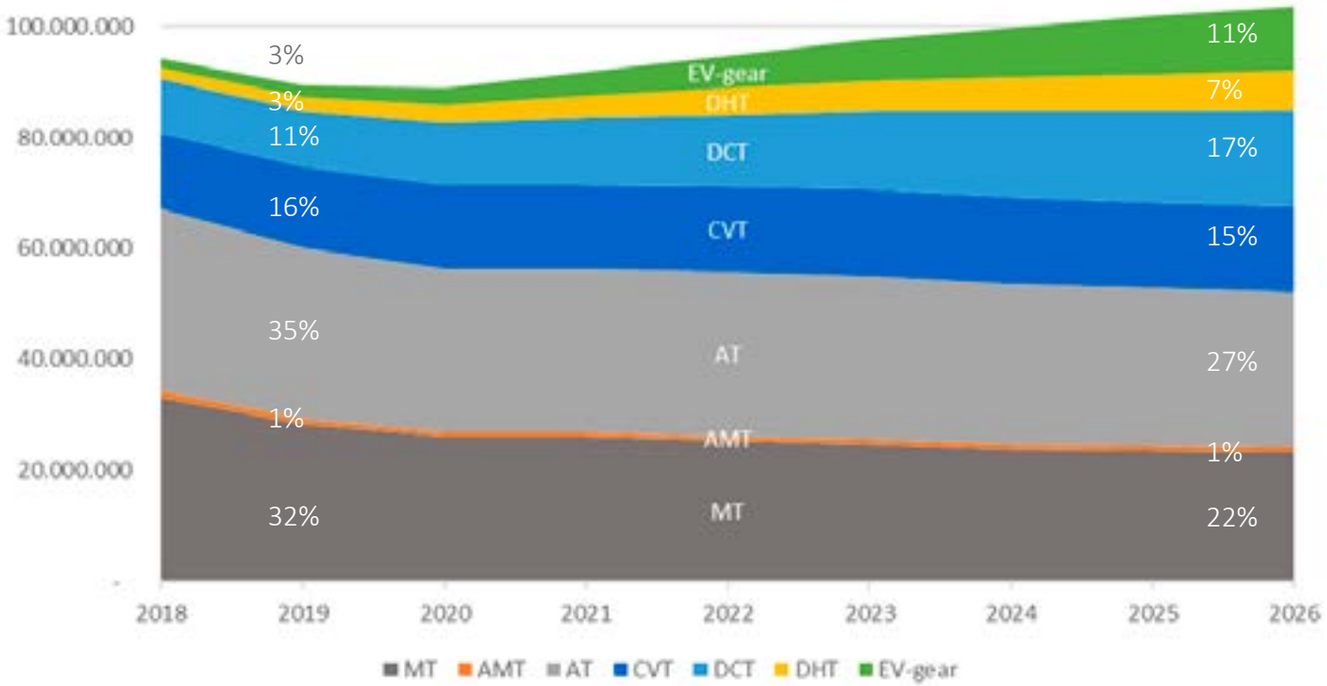
Change in global market share per transmission type from 2018 to 2026:

-10% Manual Transmission

-8% Automatic Transmission

+6% Dual Clutch Transmission

Transmission forecast by type - global market



Source: IHS Transmission forecast (data September 2019)

End-user trends & preferences

- Urbanization & stop-and-go traffic
- Increased desire for driving comfort
- Increased automation & hybridization
- Rise in fuel efficiency awareness
- Awareness of TCO and desire for long maintenance intervals

Global market legacy & preferences

- Legacy in torque converter
- Smooth shifting AT
- Subconcious P-RND-L

- Busy traffic
- Large vehicles
- Low ICE power requires automatic transmission

- Legacy in MT driving experience
- Legacy in synchro/gear production technology

- Cost-focused MT driving
- Seek automated transmissions at low premium & equal fuel economy

2.1 CONCEPT DEFINITION

Combining advantages of alternatives

When seeking the most appropriate automated transmission, the OEM is faced with a series of trade-offs. Every automated transmission has its merits, but faces compromises in other aspects.

Below table illustrates the features of various types of automated transmissions in the global compact car segment and their technical attributes. These transmissions were used as a benchmark. The strongest feature of each was identified as a target for the design process.

Benchmark targets:

- Cost effectiveness ≥ DCT, AT
- Durability at high thermal loading > AMT
- Fuel efficiency > AMT
- Large ratio coverage > 7DCT
- Compactness/ weight > 4AT

Attribute	5AMT	4AT	7DCT	Top benchmark
Dimensions	Bulky actuators, slim end	Fits, but bulky end	Fits, but bulky end	**Fits and slim end**
Weight	~ 55 kg (incl. dry clutch)	~ 60 kg (incl. TqC)	~ 70 kg	**~ 60 kg**
Thermal performance	Passive cooling	Active cooling + TqC	Active cooling	**Active cooling + low 1st**
Fuel efficiency	Same as 5MT	Worse than 5MT	Same/ better than 5MT	**Better than 5MT**
Cost effectiveness	Low cost	High cost	High cost	**Moderate cost**
Ratio coverage	~ 5	~ 4- 5	~ 7	**~ 8**
Torque shift	Interrupted	Perceivable slow shifts	Good	**Good**

2.2 TECHNICAL REQUIREMENTS

Driver requirements:

- Comfortable automated shifting
- Strong launch performance
- Value for money

- Favorable TCO through:
  - › fuel efficiency
  - › long maintenance intervals

- Consistently strong performance:
  - › on inclined or uneven roads
  - › in high ambient temperatures
  - › in slow and stop-and-go traffic

Translating market needs into technical specifications

The design seeks to cover the needs of the global market in the compact car segment. This implies the need for a compact and cost effective transmission. Additionally, it needs to ensures optimal functioning and smooth acceleration in congested traffic (stop-and-go traffic and driving at low speed) and inclined or uneven roads, while operating in high ambient temperatures.
With increasing importance of TCO to the end-user, it must demonstrate both favorable fuel consumption and long maintenance intervals.

Based on these criteria, below technical specifications have been achieved.

Technical specifications

Orientation:	Front Transversal
Max. Input Torque:	200 Nm
Max. / Peak Input Speed:	6.500 / 7.000 rpm
Gears:	7 Speeds + R
1st Gear Ratio:	1:18
Ratio Spread:	8,2
Shift Mechanism / Shifter:	Electric Shift Drum / SbW RND (P, S, L, M optional)
Park Lock:	Electrically Actuated
Clutches:	Wet Plate Clutch & Brake
Oil Pump:	Mechanical Dual Port Vane Pump
Installation Length (min. / max.):	320/378 mm
Center Distance:	180,5 mm
Weight (dry):	59 kg
Oil:	5,7 l

3.1 SINGLE LAYSHAFT DCT PRINCIPLE

Creating additional transmission ratios through mechanical pre-reduction

This unique DCT principle is created based on components, seen in both DCT and automatic transmissions (AT). The adjacent graphic describes the functioning of the principle on vehicle level.

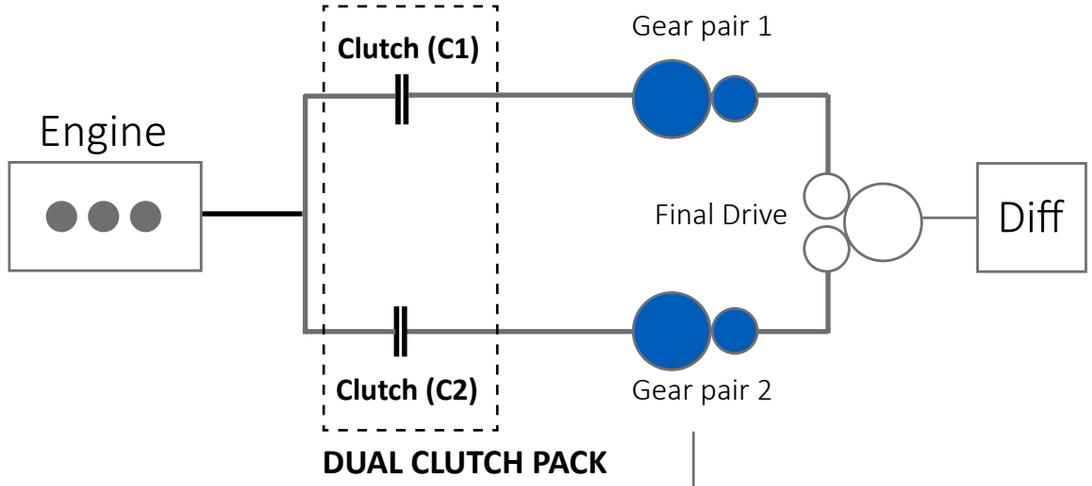
The second clutch in this new DCT is a normal multiplate clutch, while the first clutch represents an additional planetary gear set ratio, that can be engaged between the engine and the transmission.
This results in a shiftable pre-reduction, which allows to use one gear pair for more than one transmission ratio and hence, remove a large portion of the gear sets.

The functioning of the concept on transmission level, as well as the role of key components are illustrated on the next pages.

Design feature contributes to:

- ✓ Compactness
- ✓ Cost effectiveness
- Fuel efficiency
- ✓ Durability
- Functionality

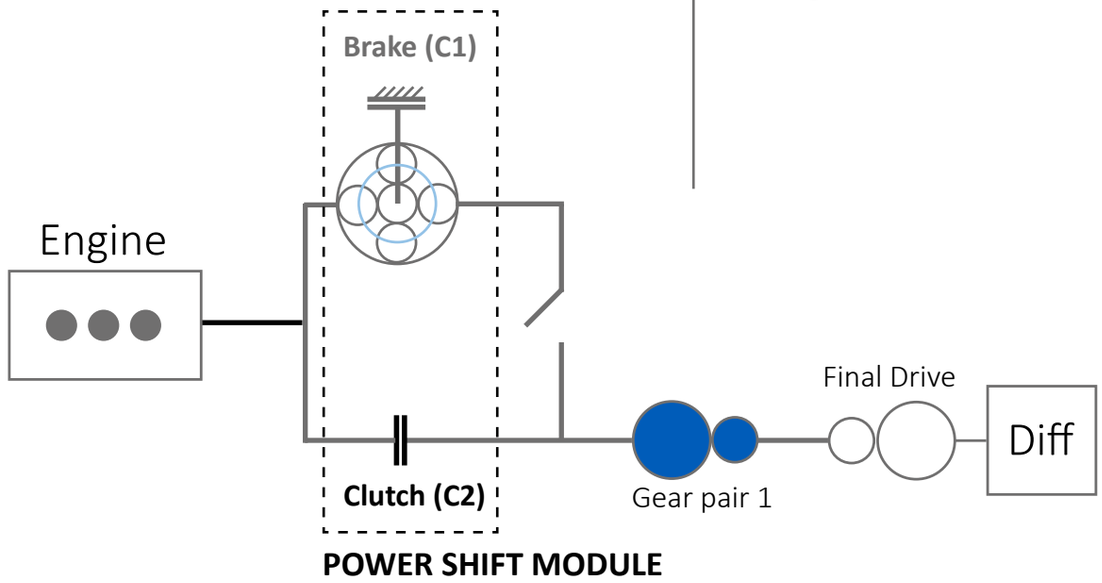
Traditional DCT principle



1 GEAR PAIR REPLACES 2

- strongly reduced amount of gears and shafts

New DCT principle



3.2 TRANSMISSION CONCEPT

Strongly reduced number of (rotating) parts and packaging size

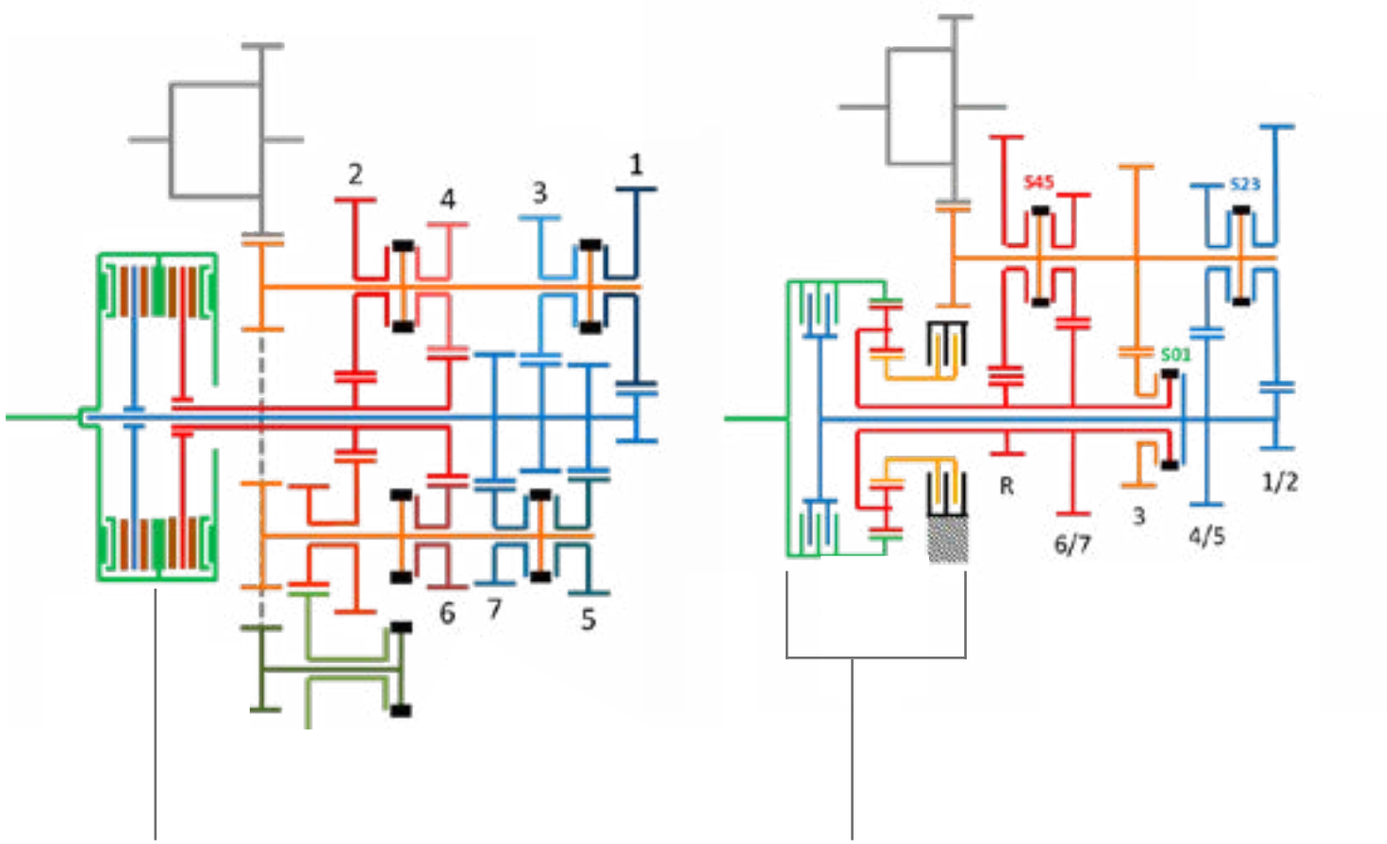
When compared to the traditional 7DCT, it becomes clear which effect the introduction of a powershift module has on the overall transmission layout of the new 7DT1. As a second range of ratios is now created by the powershift module, many components, as summarized in the table, become obsolete.

The strongly reduced amount of components lead to a cascade of benefits, such as reduced packaging, weight and cost, as well as increased durability, thanks to a reduced amount of rotating parts.

Design feature contributes to:

- ✓ Compactness
- ✓ Cost effectiveness
- ✓ Fuel efficiency
- ✓ Durability
- Functionality

Comparison of traditional 7DCT with the new DCT principle (7DT1)



DUAL CLUTCH UNIT

POWERSHIFT MODULE
WITH PLANETARY PRE-REDUCTION

	7DCT	7DT1
Shafts	4	2
Synchronizer sets	5	3
Synchronizers	8	6
Gear wheels	20 (14 fwd, 2 rev, 4 fd)	13 (8 fwd, 3 rev, 2 fd)
Shift forks	5	3
Shift actuation	10 hyd-valves or 2 shift drums	1 shift e-drum

3.3 KEY COMPONENTS

Modular design, allowing flexibility and upgrading

The transmission is equipped with only 1 shift drum, which provides sufficient functionality in this car segment. The drum is mechatronically actuated, in order to adhere to the lower price segment.

For the same reason the hydraulics are actuated by the means of a mechanic pump, which can be interchanged with an e-pump without substantial design changes.

Although the package is already sufficiently small to fit under the side member, additional design flexibility is achieved by allowing the TCU to be placed on or near the transmission.

Overall, the design allows interchanging components to suit specific customer needs, as well as to make the transmission hybridization ready (see section 3.7).

Design feature contributes to:

- ✓ Compactness
- ✓ Cost effectiveness
- Fuel efficiency
- Durability
- Functionality

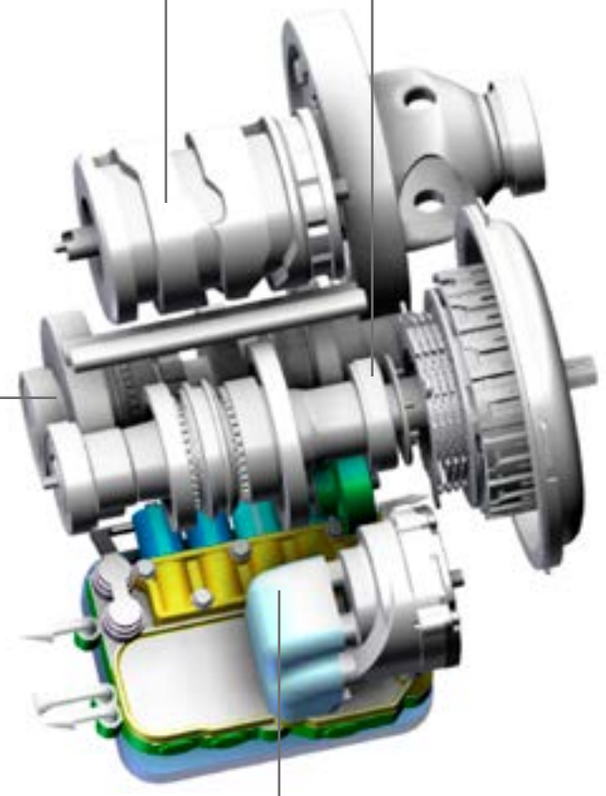
POWERSHIFT MODULE

- PSM creates 2 ratios
- in combination with 4 gear box ratios total design enables 8 ratios (7 chosen)

- ⊕ realizing DCT functionality
- ⊕ allows to strongly reduce the number of parts
- ⊕ increased durability

MECHATRONIC GEAR SHIFT DRUM

- shift-by-wire
- only 1 shift drum
- reduced amount of synchronizers



TCU

- can be placed at or near transmission to allow design flexibility

- ⊕ design flexibility

COMPACT SINGLE LAYSHAFT

- cluster of 4 + R gear sets
- 2 layshafts removed

MODULAR HYDRAULIC SOLUTION

- PSM actuation, cooling, lubrication
- pump relocated to side-driven location
- mechanic pump can be replaced by e-pump without change to the hydraulic block

- ⊕ allows for tighter packaging, and design flexibility
- ⊕ hybridization ready design

3.4 POWERSHIFT MODULE

Creating additional gear ratios, while highly improving durability

The traditional dual wet clutch pack is replaced by a powershift module, consisting of a clutch and a Planetary Gear set, that is controlled by a wet brake.

The friction elements are positioned at a certain distance from each other, created by the planetary gearset between them. This leads to both friction elements having an independent cooling flow and never receiving each other's heated oil.

In addition, the brake is firmly mechanically connected to the housing, which further contributes to more effective heat rejection. This allows to use the brake as a more robust launching element.

All the measures together contribute greatly to the thermal stability and thus the functional robustness and consistency of the transmission.

CASCADED CLUTCH & BRAKE POSITION

- no heat exchange between both friction elements through oil or metal
- 100% independent & proportional cooling control

⊕ increased cooling performance

⊕ increased robustness

⊕ enables pre-reduction

WET BRAKE

- firm mechanical connection to the housing, enabling additional heat rejection
- used as a launching element for first gear, creep, etc.

⊕ no separate launching element needed

PLANETARY GEAR SET

- defines input gear ratio and enables a mechanical pre-reduction
- exceptionally high first gear ratio
- creates distance between the 2 friction elements

⊕ improved launch performance

⊕ decreased slippage, leading to a decrease in heat generation and wear

Design feature contributes to:

- ✓ Compactness
- Cost effectiveness
- Fuel efficiency
- ✓ Durability
- Functionality

3.5 GEAR SPREAD

Exceptionally wide ratio spread (8.2) achieved with only 4 gear pairs

The gear train contains 4 forward gear pairs. Each gear pair can be activated either via the clutch or via the brake/planetary, resulting in 2 different ratios. In principle, this could create 8 forward gear ratios. However, to obtain an optimal gear sequence, an optimized design with 7 gear ratios was developed.

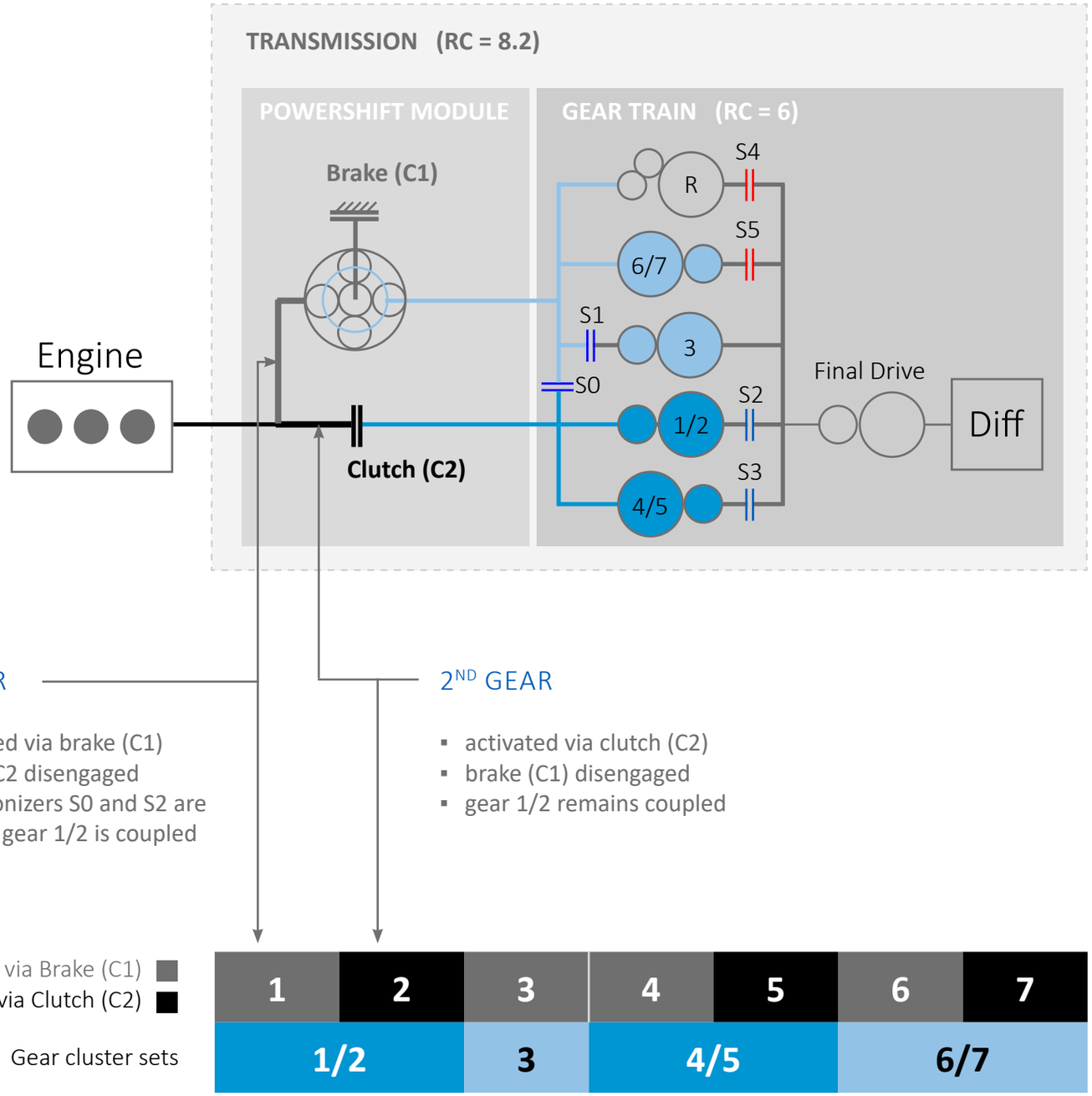
While the cluster of 4 gear pairs achieves a ratio coverage of 6, in combination with the powershift module, the transmission in total achieves an exceptionally wide ratio coverage of 8.2.

As can be observed, the third gear is the only set that is engaged exclusively by C1 (brake/planetary). As the 4th gear is also engaged by using C1, shifting from 3rd to 4th gear is done by shortly sliding clutch C2 at 5th gear. This provides time to engage synchronizer S01 from S1 towards S0 and then powershift to 4th gear by engaging C1 (brake) and releasing C2.
Through sophisticated controls, this is unnoticeable for shifts at low to medium power.

Design feature contributes to:

- ✓ Compactness
- Cost effectiveness
- Fuel efficiency
- Durability
- ✓ Functionality

Schematic of the transmission functioning



3.6 RATIO SEQUENCE

Optimal sequence of 7 speeds, resulting in fuel economy and superior driver experience

Achieving 7 ratios through a planetary gear set (PSG), in combination with 4 gear pairs, could give the impression of limited flexibility. However, by meticulously defining the optimal PSG ratio and shifting patterns, a very balanced ratio distribution is achieved.

The adjacent graphic compares the emerging 7 gear ratio sequence with a typical 5AMT (an alternative within the same market segment), illustrating its merits:

- ⊕ 3-5% fuel economy improvement over 5AMT
- ⊕ improved driving comfort and experience at both low and high speeds

Design feature contributes to:

- Compactness
- Cost effectiveness
- ✓ Fuel efficiency
- ✓ Durability
- ✓ Functionality

1ST AND 2ND GEAR

- extra wide 1st gear ratio of > 1:18
- small ratio step 1st >2nd gear of > 40%
- relaunches at low speed in 2nd gear

- ⊕ increased (hill) launch performance
- ⊕ increased low speed and stop-and-go (city) driving performance
- ⊕ decreased slippage, decreased wear on clutch mechanism

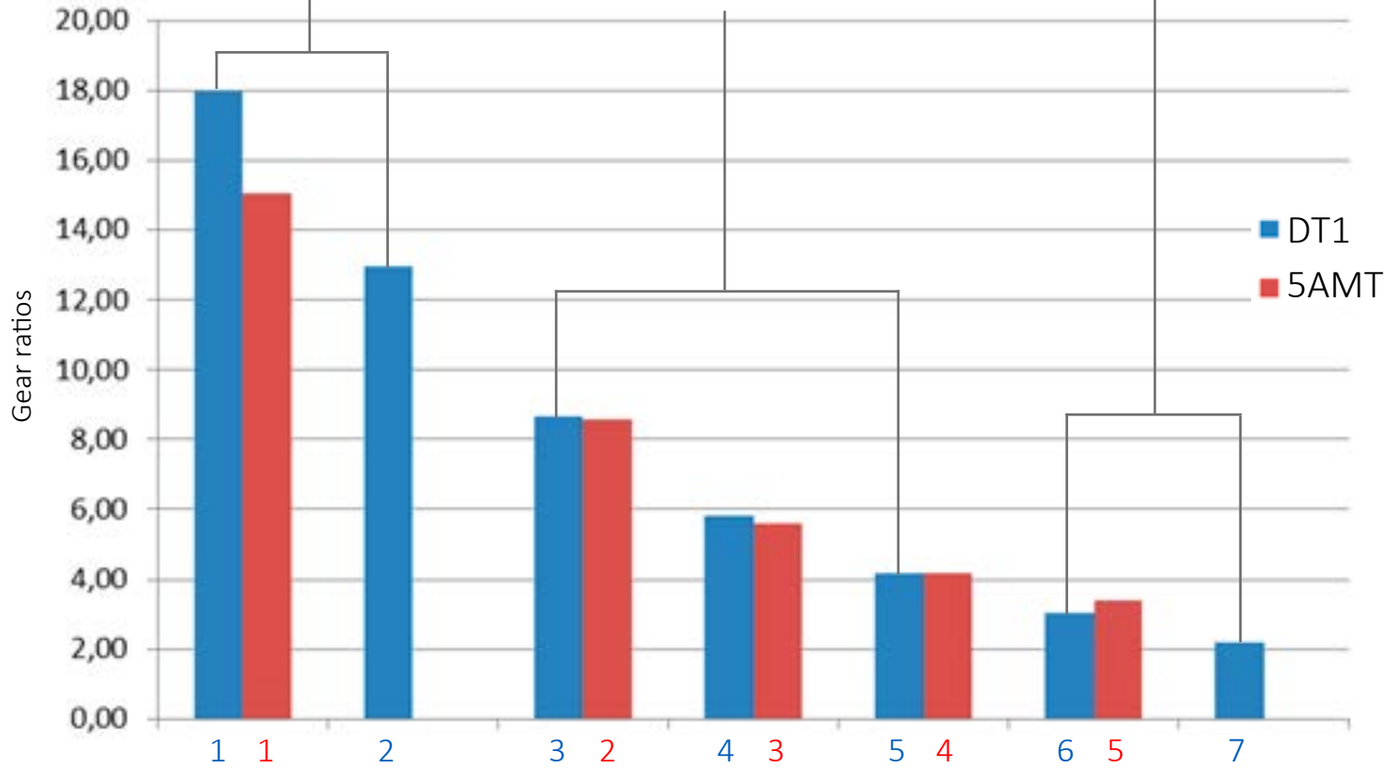
6TH AND 7TH GEAR

- additional step for top speeds

- ⊕ silent and comfortable cruising
- ⊕ increased fuel efficiency at higher speeds

3RD , 4TH AND 5TH GEAR

- Roughly overlapping 2nd to 4th gear



3.7 HYBRID DCT FAMILY

Flexible fleet hybridization for global platforms

The exceptionally compact design creates space for integration of an off-axis (side) mounted electric machine in P2 arrangement, unique in the hybrid DCT segment.

Harvesting this benefit, a higher torque hybrid DCT (DT2) range has been introduced, available in 48V, high voltage or conventional variants. This automated transmission with a common design base can be fitted in the OEM's entire front-transverse platform program, regardless of the (continuously adjusting) mix in mild, full or plug-in hybrids.

This is a logical choice for regions, already having a strong legacy in MT/DCT adoption (such as EU, China, India and South America).

MHEV (STANDARD)

- hybrid first design, with derived variants
- integrated electric machine and inverter
- on-axis C0 clutch can decouple the engine and allow the hybrid transmission to propel/regen the vehicle on its own

⊕ hybrid DCT, fitting in packaging space of regular DCT

⊕ operation with e-motor alone is possible at low speeds or moderate driver demands

CONVENTIONAL VARIANT

- derivate from MHEV
- e-machine removed

(P)HEV VARIANT

- powerful e-machine is integrated in the design space
- high voltage inverter is placed on top of hybrid transmission

⊕ common design base allows for a constant adjustment of the fleet hybridization mix with minimal efforts

⊕ applicable in full front transversal fleet, leading to cost effectiveness

	Conventional	MHEV	PHEV
Weight (incl. oil):	77 kg	97 kg	105 kg
Nominal E-Motor Voltage:	-	48 V	320 V
E-Motor Power (mot. / gen.):	-	21 kW / 24 kW	93 kW / 93 kW

Native hybrid DCT

DT2 is identified as a native hybrid DCT and is unique to Punch Powertrain.
It has been developed as a 48V hybrid first and can be converted into a conventional or a (P)HEV variant, by simply removing the 48V motor or adding a high voltage motor, with minimal design changes and efforts.

In contrast to the dedicated hybrid DCT, the native hybrid DCT remains fully functional as a conventional DCT, when the e-motor is removed.

CONCLUSION

1. Unique single layshaft DCT design

This DCT concept introduces a new way of realizing the dual clutch principle. By linking a planetary gearset to one of the two clutches, a shiftable pre-reduction in front of transmission gearsets emerges.
This allows to **remove a large portion of the components**, leading to a cascade of benefits.

OEM benefits:

- Compact and flexible packaging
- Light weight
- Cost effective
- Fuel efficient
- Robust
- High level of functionality

Driver benefits:

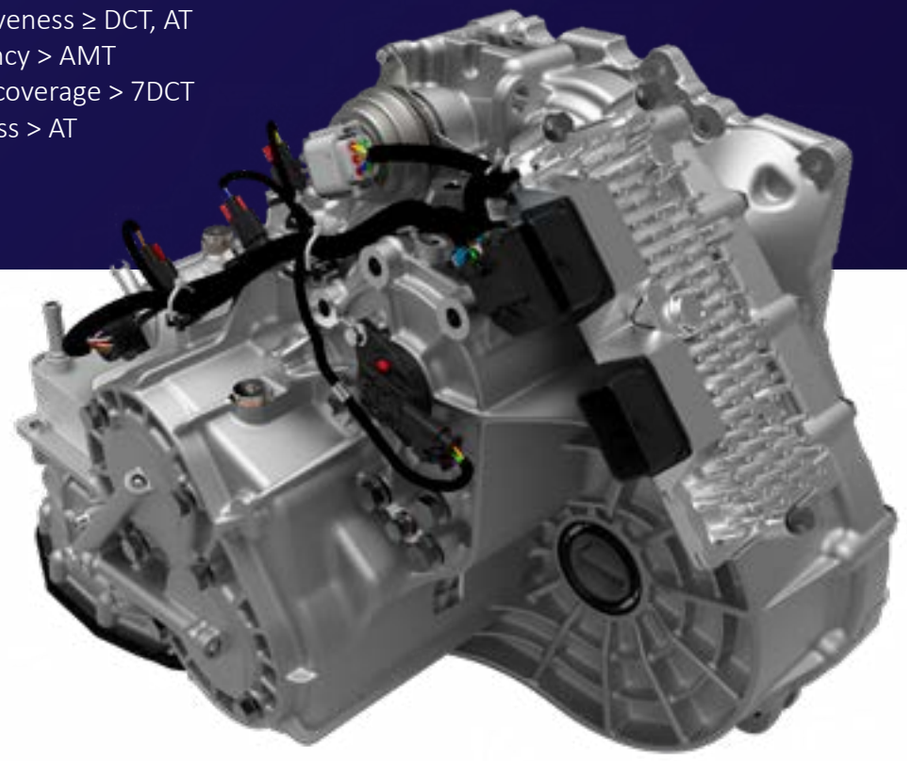
- Increased driver comfort (in shifting behavior and sound)
- Favorable TCO, in terms of:
  - purchase price
  - fuel consumption
  - maintenance cost

2. Outperforming benchmark technologies on global markets

This DCT is a very suitable solution for OEMs seeking a robust, compact and cost effective automated transmission, especially for smaller car segments and emerging markets. DT1 combines the merits of, and therefore provides a more **favorable alternative to: 5AMT, 4 and 6 AT.** It also delivers comparable performance to contemporary 7DCTs, at a lower cost level.

Performance compared to alternatives:

- Durability at high thermal loading > AMT
- Cost effectiveness ≥ DCT, AT
- Fuel efficiency > AMT
- Large ratio coverage > 7DCT
- Compactness > AT



3. Hybrid DCT range

This innovation allows to integrate a cost effective off-axis e-machine, while occupying the packaging space of a regular DCT.
Building on this merit, a **range of “native hybrid” DCTs** has been developed, with the standard being a 48V 7DCT, while the conventional or (P)HEV variants can be derived with minimal efforts and design adjustments.
This allows OEMs to **constantly adjust their fleet hybridization mix**, as CO_2 compliancy need arises.

CONTACT US

Are you curious how our range of compact DCTs could fit in your application?

Our specialists will help define the most suited solution for you!

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ABOUT US

Punch Powertrain is an independent full system supplier of fuel efficient powertrains. With over 45 years of experience in the production of CVTs, Punch Powertrain also offers propulsion systems for New Energy Vehicles, such as Hybrids (48V &PHEVs) and Electric Vehicles (EVs), as well as DCTs.

Punch Powertrain is an international player, with a strong presence in Europe and China and with full in-house capabilities and know-how from concept to industrialization. With 30% of all employees being active in one of the 6 globally spread R&D centers, product innovation is hardwired into the company's DNA.

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