

E-Automat

Automatikgetriebe mit *Esprit*

- **Ausgangssituation im Getriebemarkt**
- **Weiterentwicklungen von Wandler-Automaten bis zum E-Automat**
- **Schalt- und Regelstrategie der E-Automaten**
- **Simulationen**
- **Bewertung**

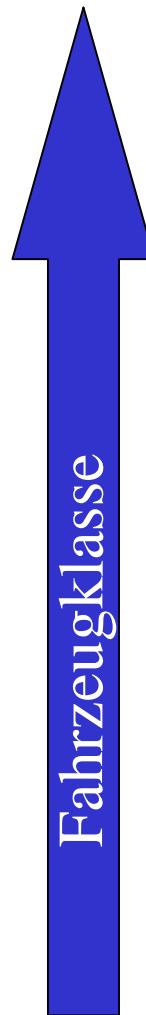


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Prof. Dr.
Peter Tenberge

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2



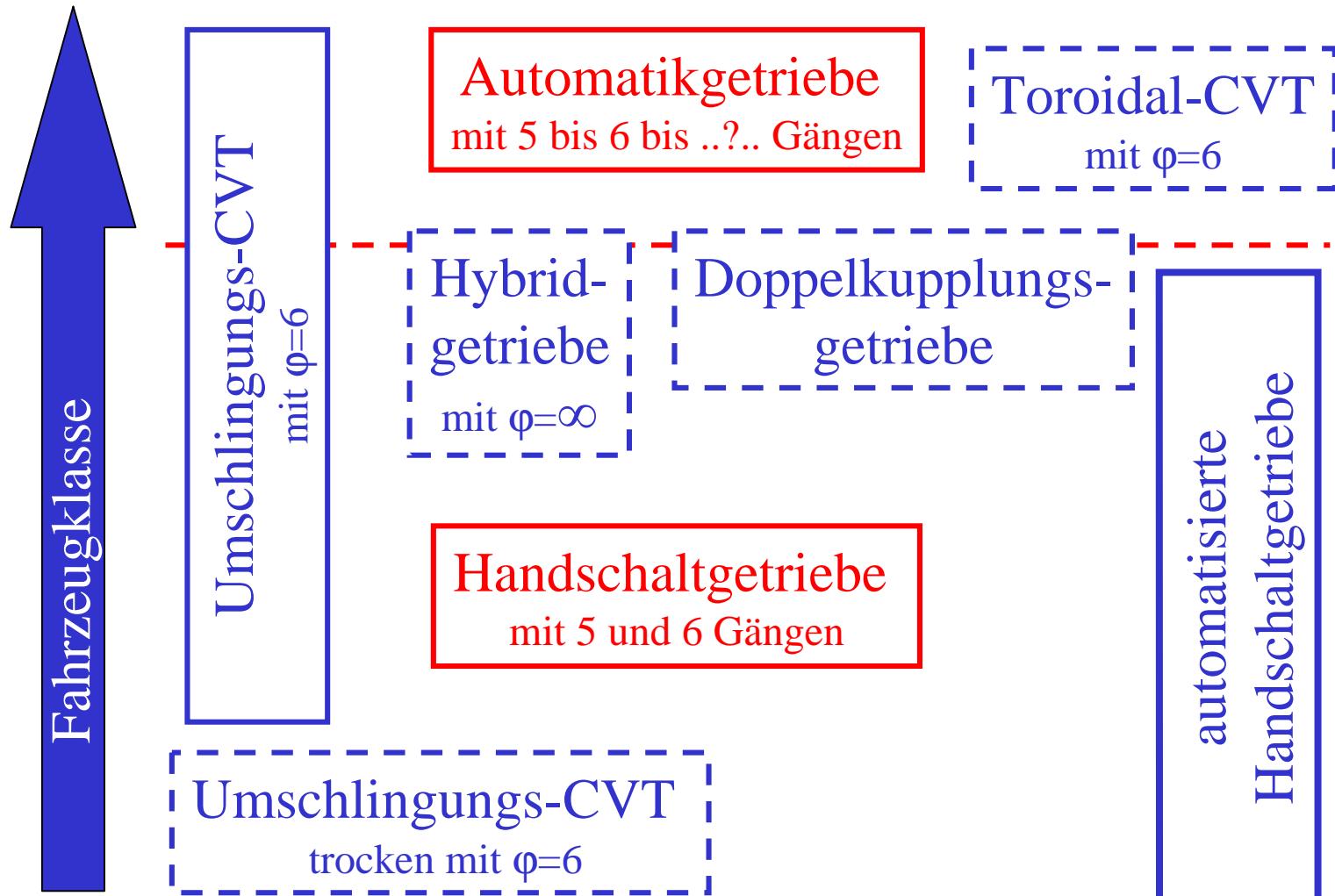
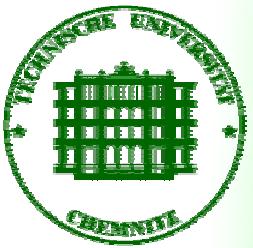
Automatikgetriebe
mit 4 und 5 Gängen

15%-20%

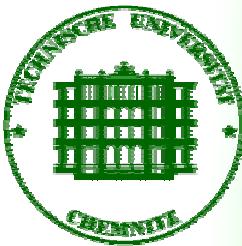
Handschaftgetriebe
mit 5 und 6 Gängen

80%-85%

Getriebemarkt
bis 1999 in Europa



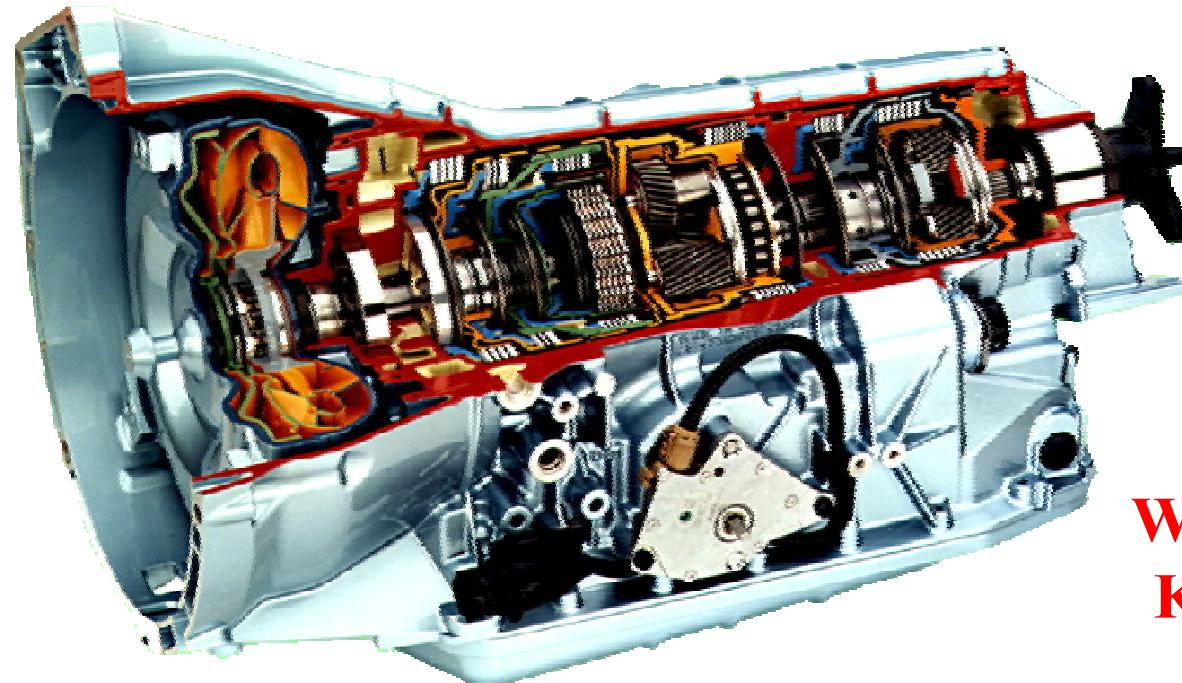
Getriebemarkt ab 2000 in Europa



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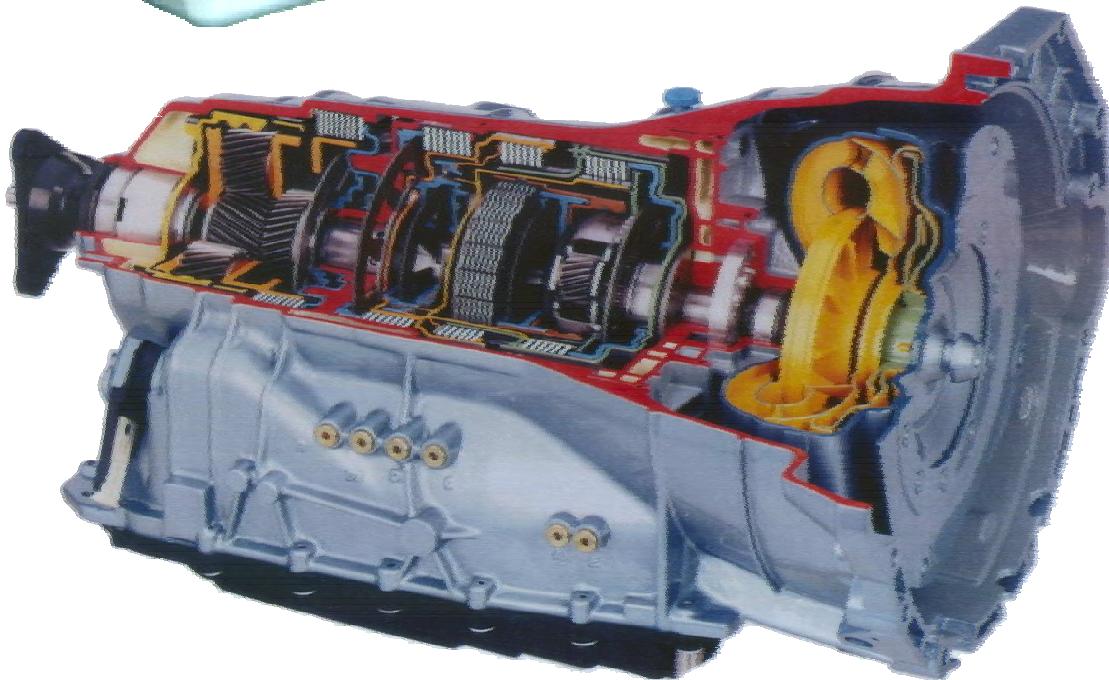
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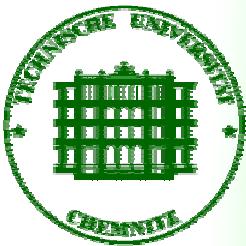


5-Gang-
Automat
von ZF

Weltstandard in
Komfortklasse

6-Gang-
Automat
von ZF

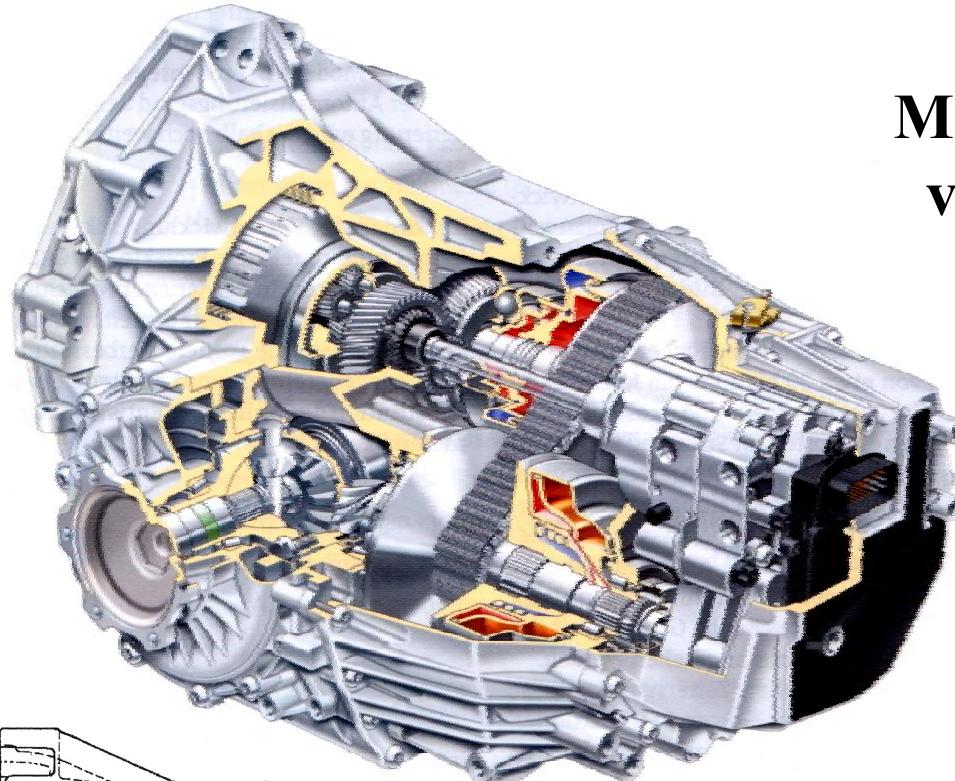




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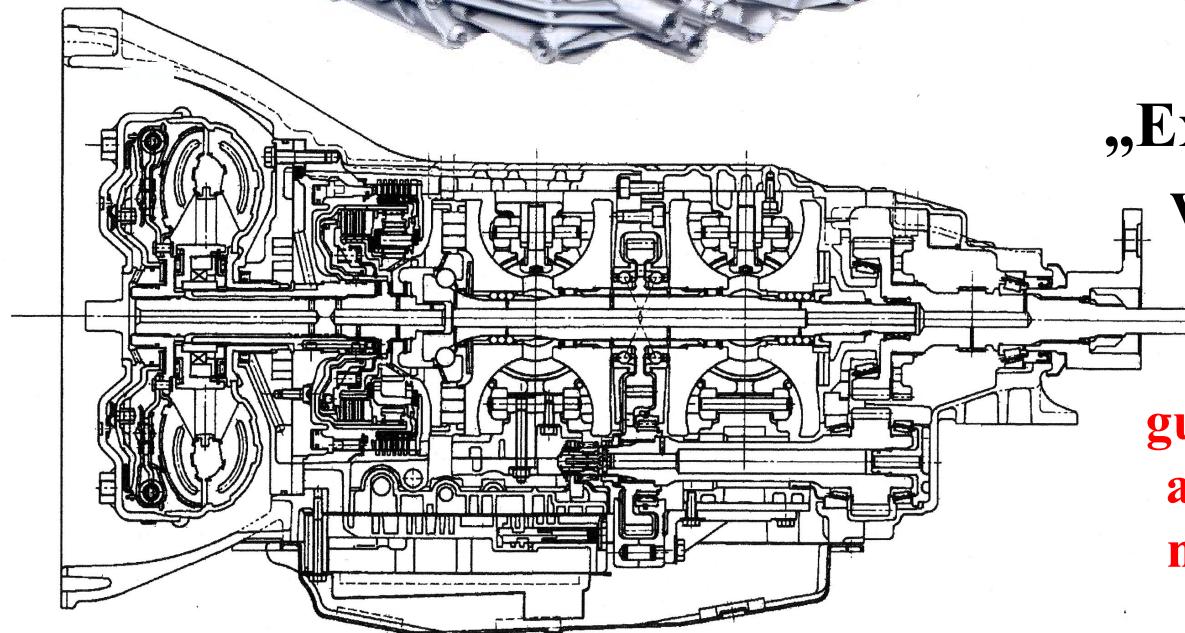
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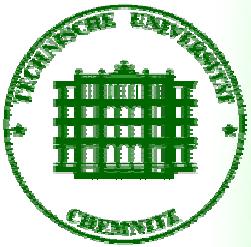
Multitronic
von Audi

„sehr gut,
aber noch zu
wenig Drehmoment“



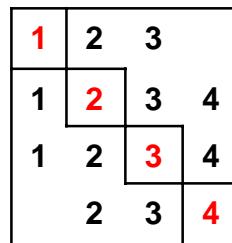
„Extroid“-CVT
von Nissan

gut, komfortabel,
aber sonst noch
nicht ausgereift

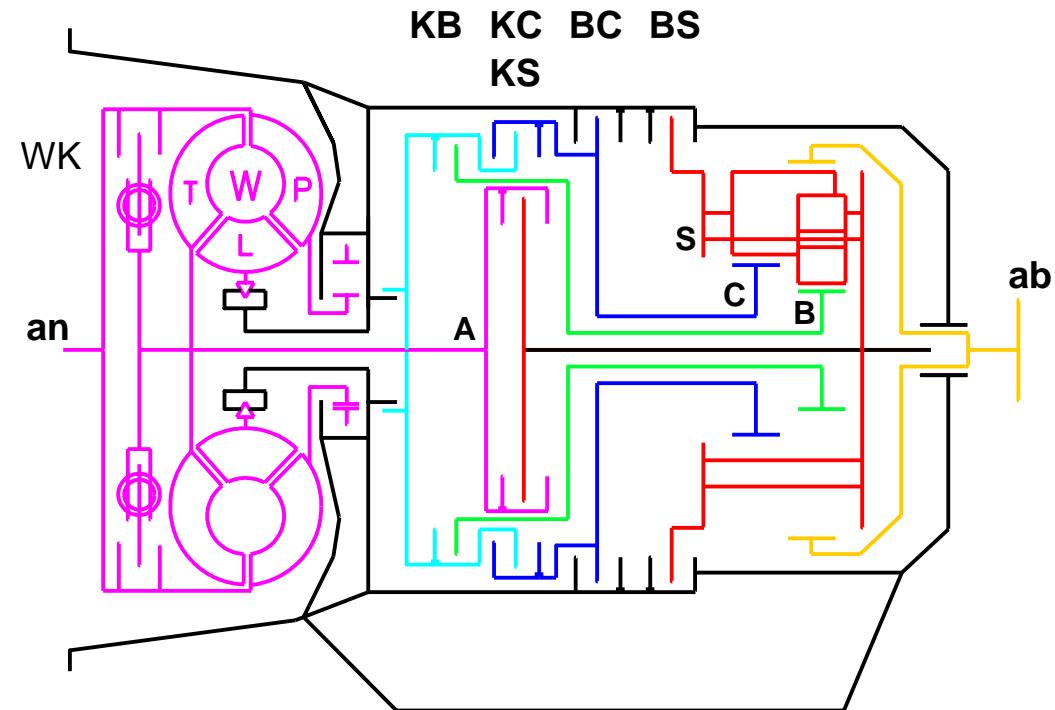


Zielsetzungen für verbesserte Fahrzeuggetriebe

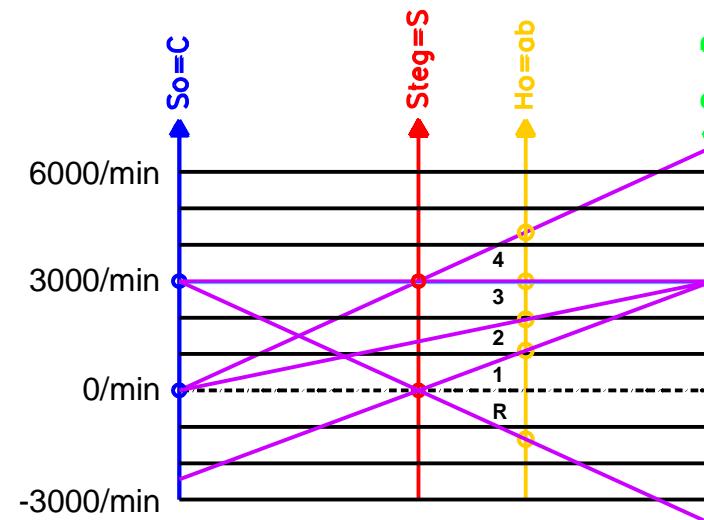
- **Beibehaltung der Kraftübertragung über gekoppelte Planetengetriebe**
 - hoher Wirkungsgrad
 - hohe Leistungsdichte
 - hohe Drehmomentkapazität
 - bekannte Technologie
 - vorhandene Fabriken
- **Erweiterung des Lepelletier-Konzeptes**
 - **6 bis 9 Gänge**
- **Ersetze Wandler durch Starter/Generator**
 - Start/Stopp-Funktionalität
 - Booster
 - Stufenlosigkeit
 - Energierekuperation
 - Kat.-vorheizung im rein elektrischen Fahrbetrieb

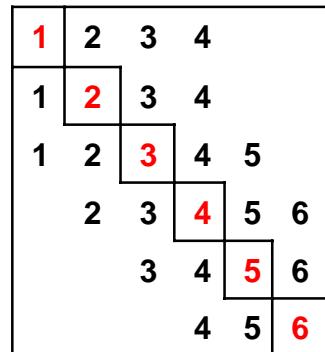
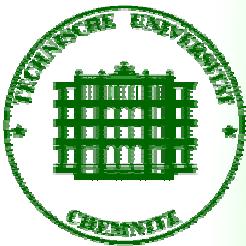


Gangsprünge mit einfachen Schaltungen

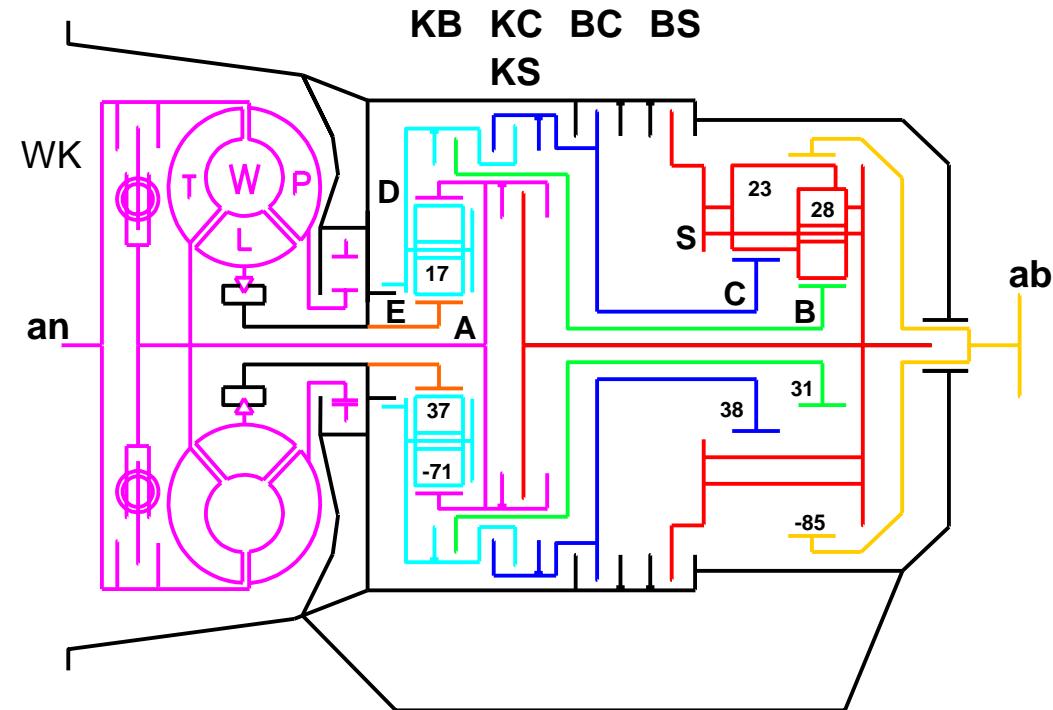


Gang	KC	KS	KB	BS	BC	i_{ges}
R						-2,55
N						
1						2,800
2						1,508
3						1,000
4						0,718

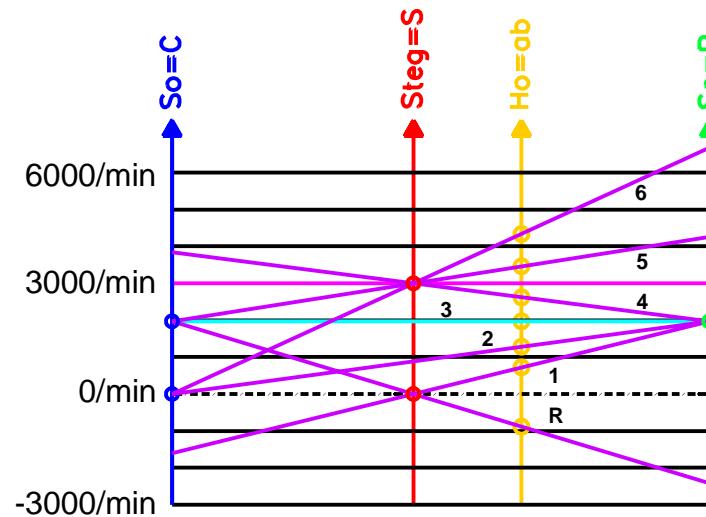


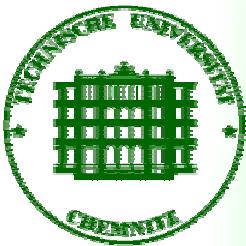


Gangsprünge
mit einfachen
Schaltungen

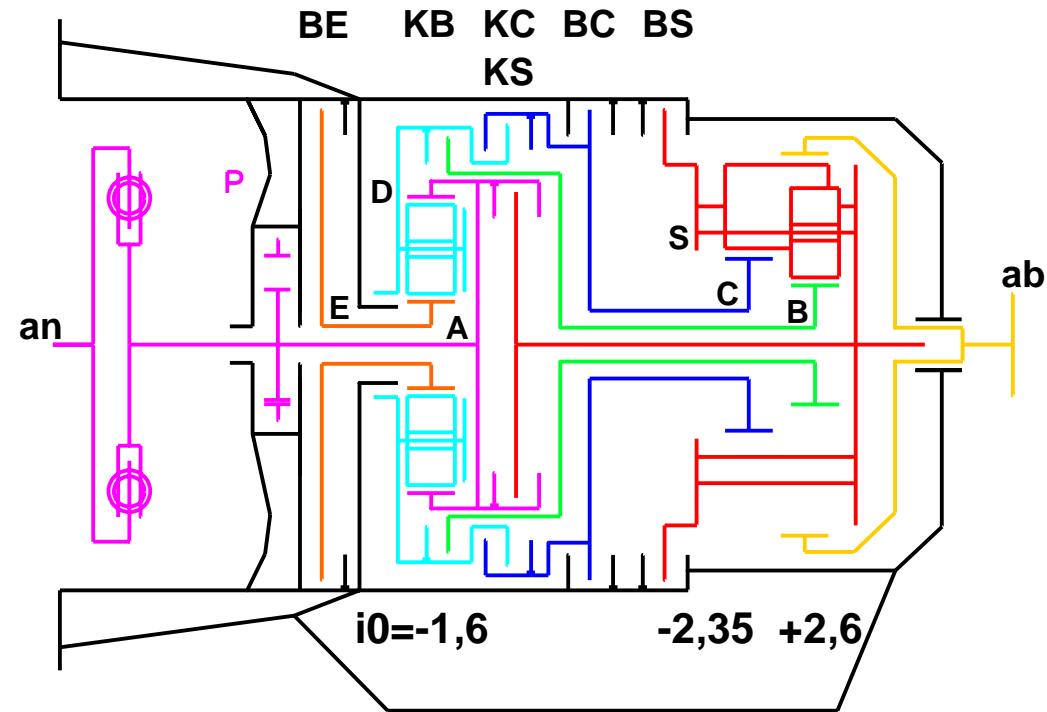
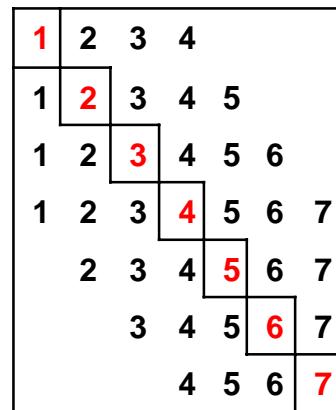


Gang	KC	KS	KB	BS	BC	i_{ges}
R						-3,40
N						
1						4,171
2						2,340
3						1,521
4						1,143
5						0,867
6						0,691

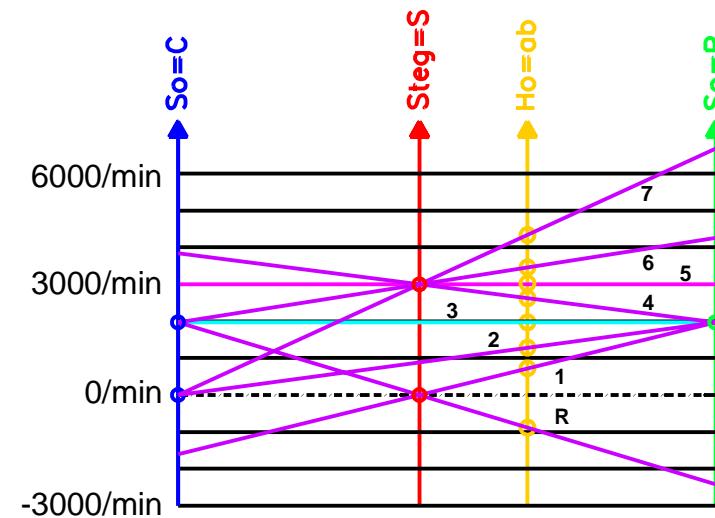




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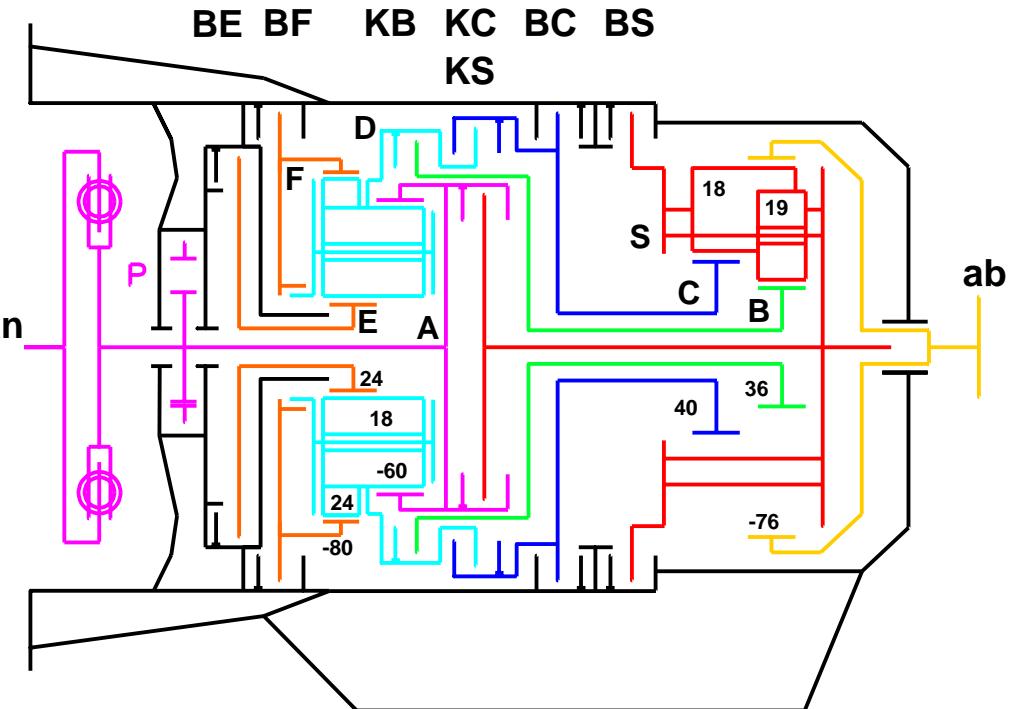
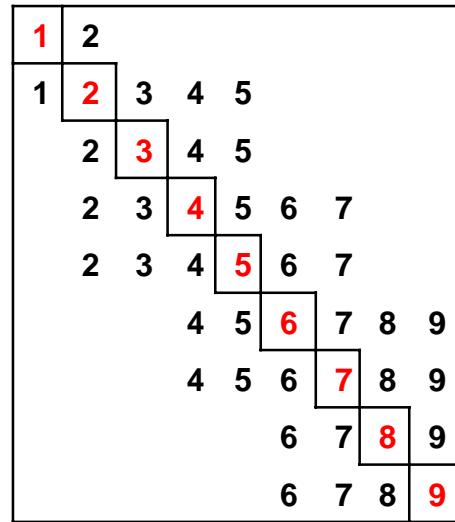


Gang	KC	KS	KB	BS	BC	BE	i_{ges}
R							-3,82
N							
1							4,225
2							2,401
3							1,625
4							1,174
5							1,000
6							0,859
7							0,701

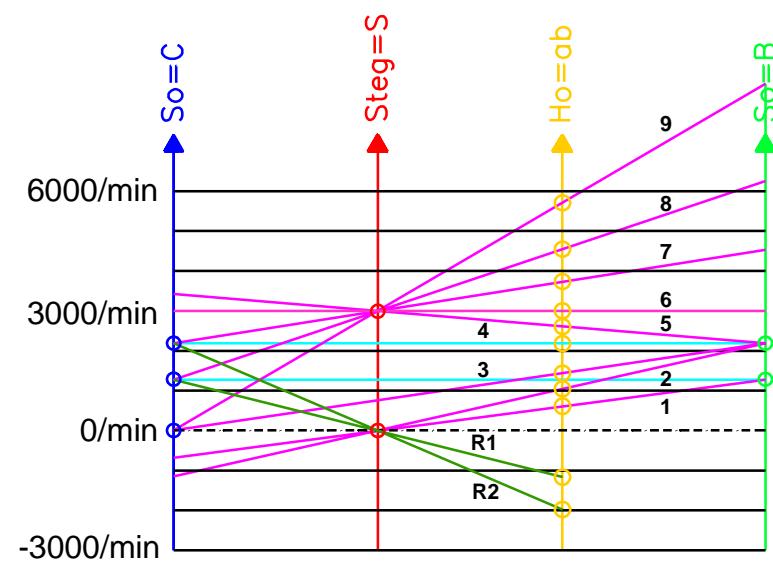




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Gang	KC	KS	KB	BS	BC	BE	BR	i_{ges}
R2								-2,660
R1								-4,433
N								
1								4,926
2								2,956
3								1,936
4								1,400
5								1,157
6								1,000
7								0,869
8								0,769
9								0,655

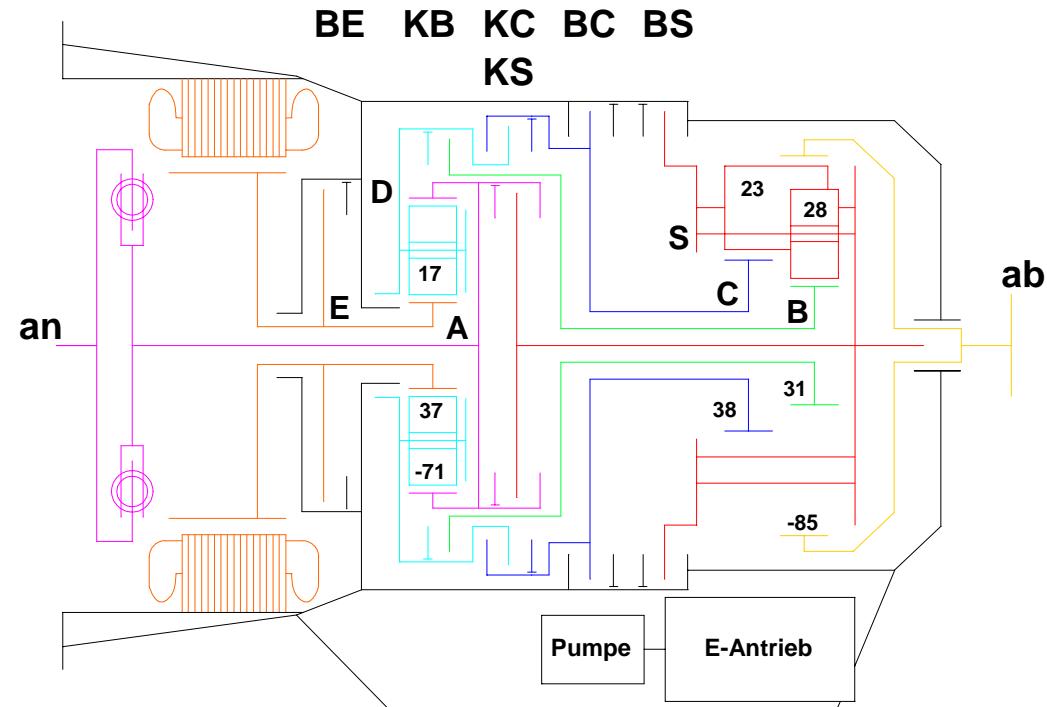
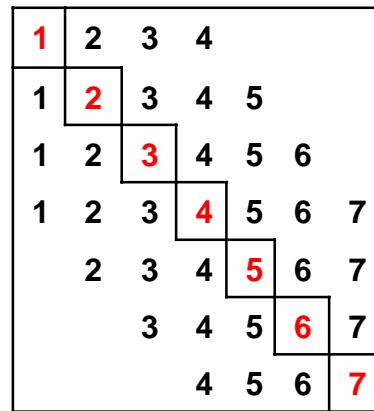




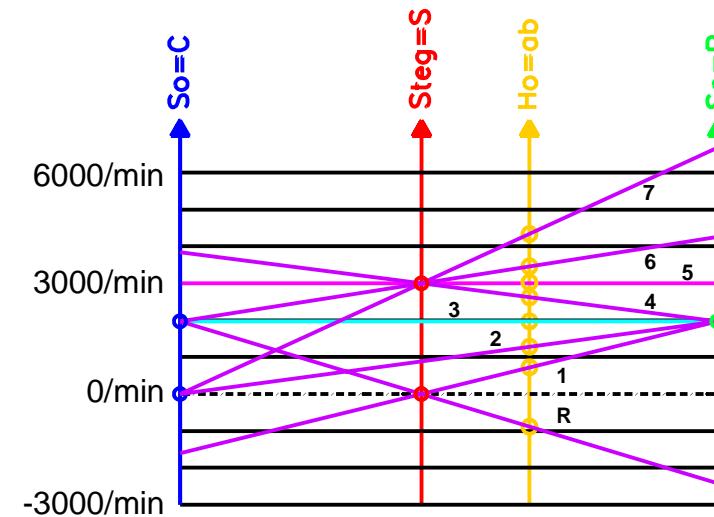
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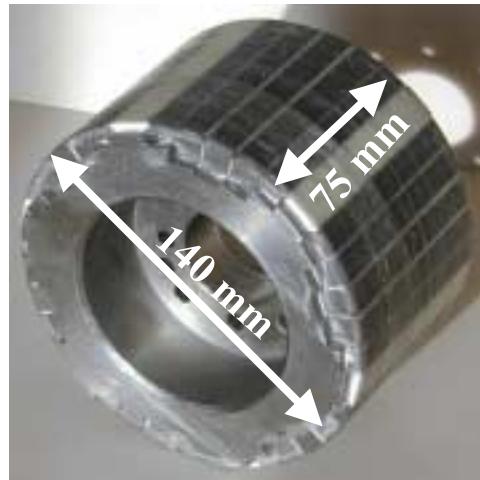
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Gang	KC	KS	KB	BS	BC	BE	i_{ges}
R							-3,40
N							
1							4,171
2							2,340
3							1,521
4							1,143
5							1,000
6							0,867
7							0,691





Rotor mit 3 Polpaaren

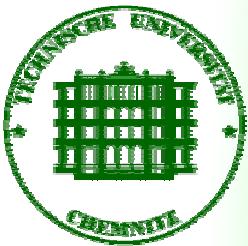


Stator mit Kühlmantel
Breite über Wickelköpfe = 115 mm

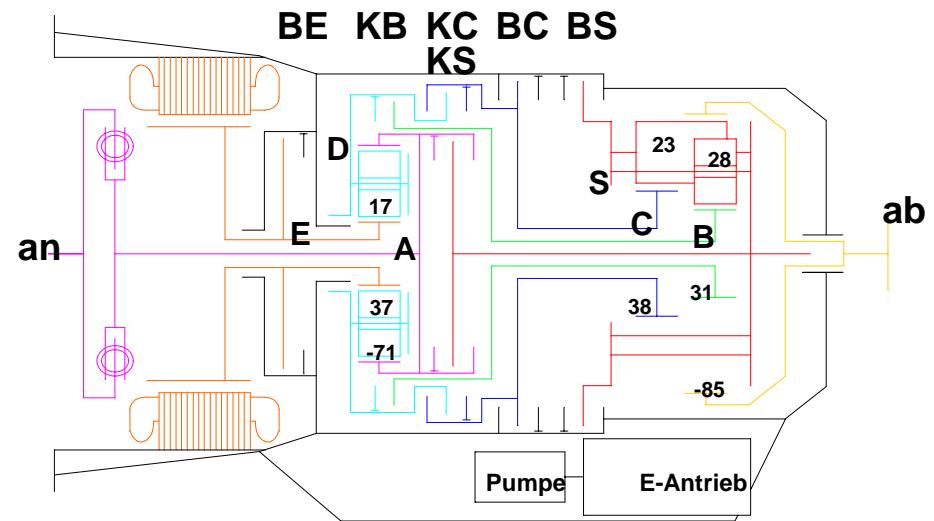
Gehäuse mit Wasserkühlung



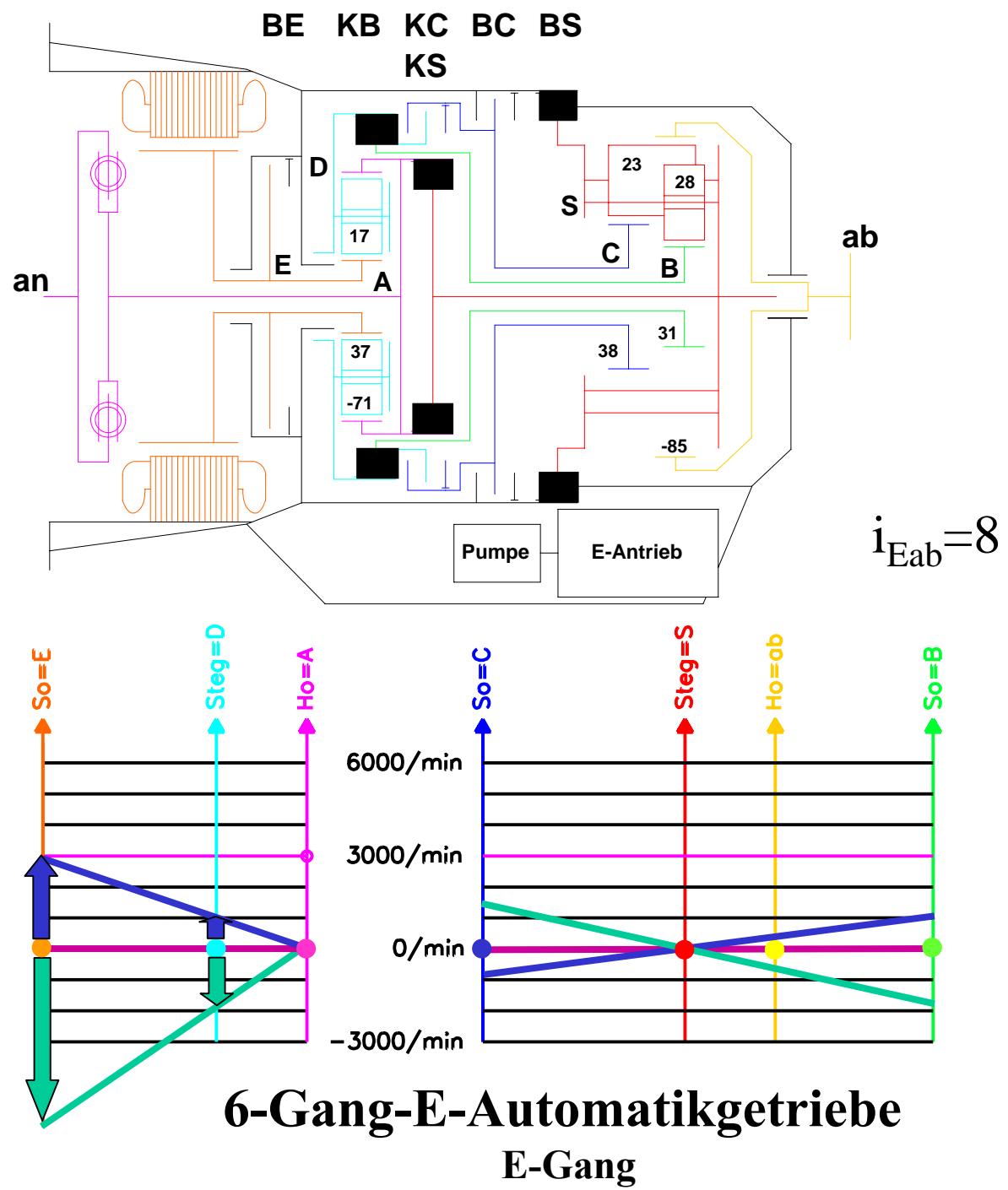
**Elektrisches Getriebe mit
zwei permanenterregten
Synchronmaschinen**
 $T_{max} = 150 \text{ Nm}$, $n_{max} = 4000/\text{min}$



Komplette Schaltlogik des E-Automaten



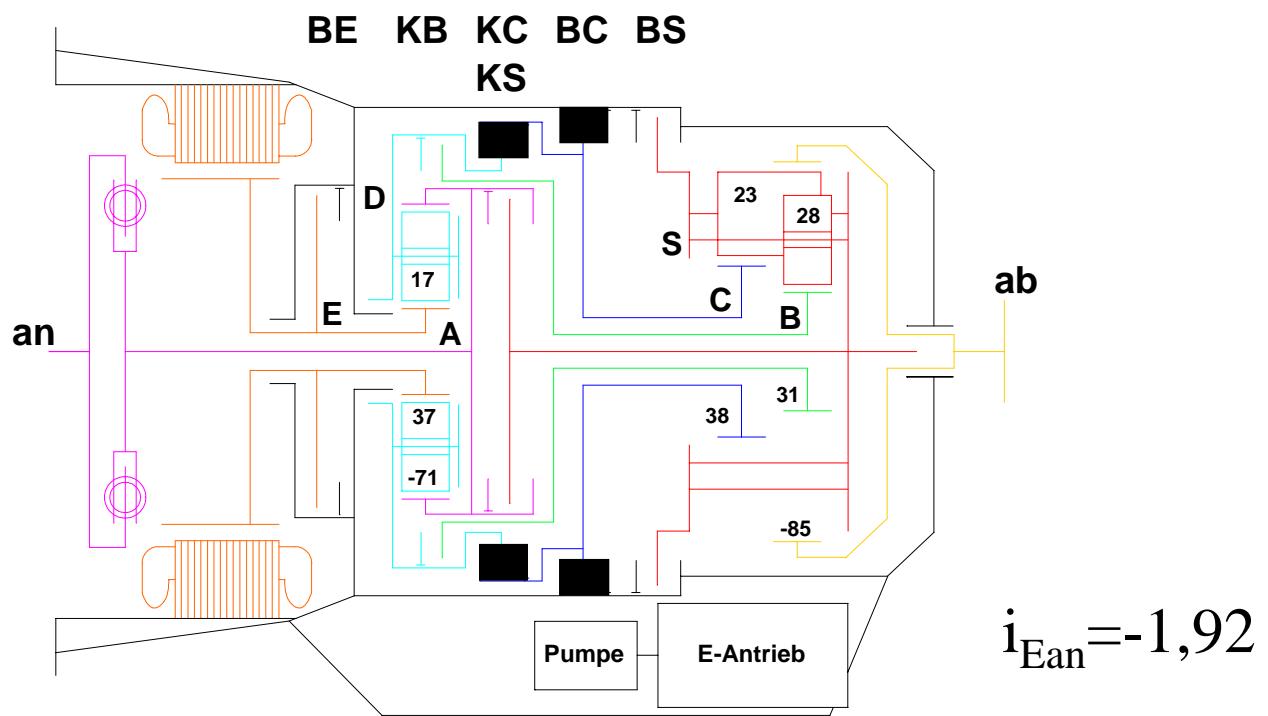
	KC	KS	KB	BS	BC	BE	nan/nab	-Tab/TE	TVM/TE
Parken									
E.-Gang 2							0,000	-6,53	0,00
E.-Gang 1							0,000	8,00	0,00
Neutral									
R.-Gang							iR=-3,40	-6,53	1,92
geared neutral r.							variabel	-6,53	1,92
VM-Start									
geared neutral v2							variabel	4,49	1,92
geared neutral v1							variabel	8,00	1,92
1. Gang							i1=4,171	8,00	1,92
2. Gang							i2=2,340	4,49	1,92
3. Gang							i3=1,521	2,92	1,92
4. Gang							i4=1,143	8,00	7,00
D. Gang							iD=1,000	variabel	variabel
5. Gang							i5=0,867	-6,53	-7,53
6. Gang							i6=0,691	∞	∞



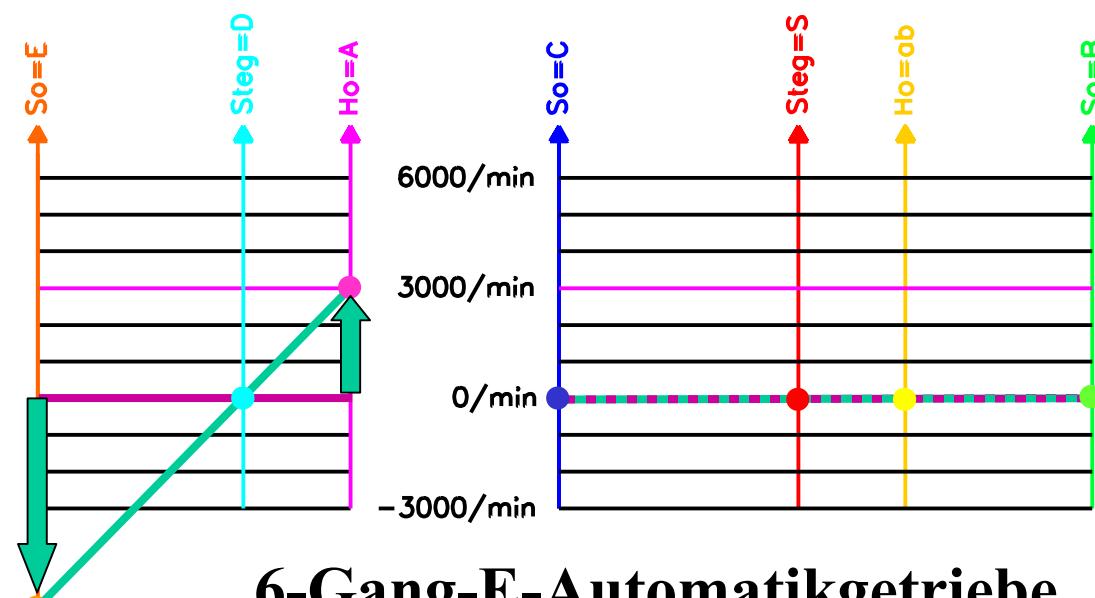


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$$i_{Ean} = -1,92$$

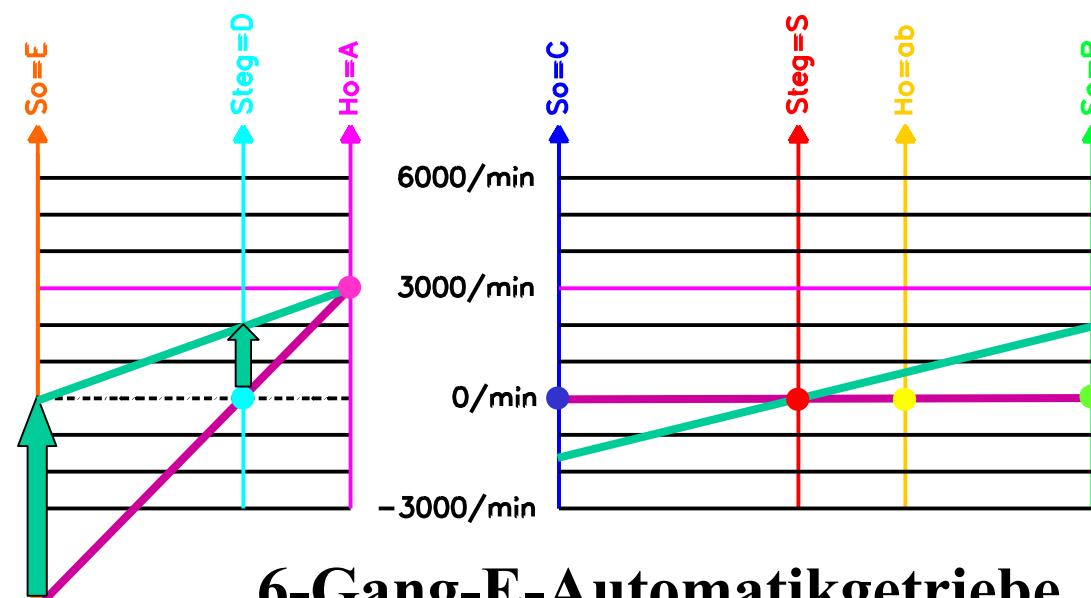
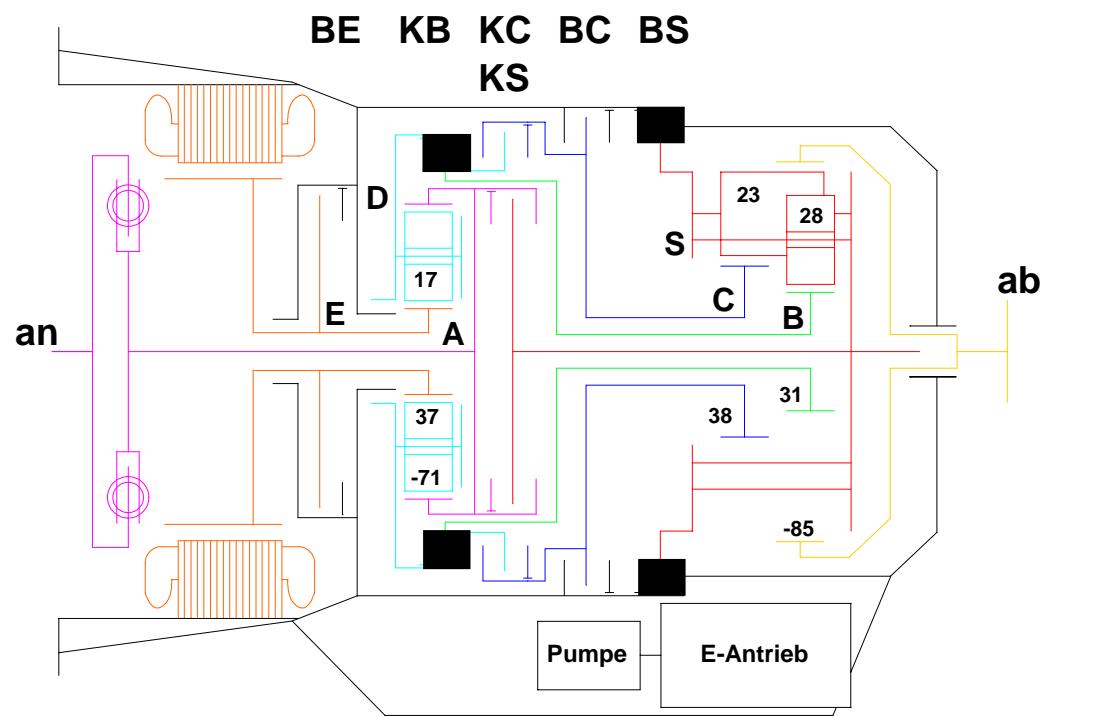


6-Gang-E-Automatikgetriebe
Motorstart bei stehendem Fahrzeug

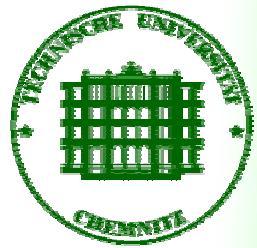


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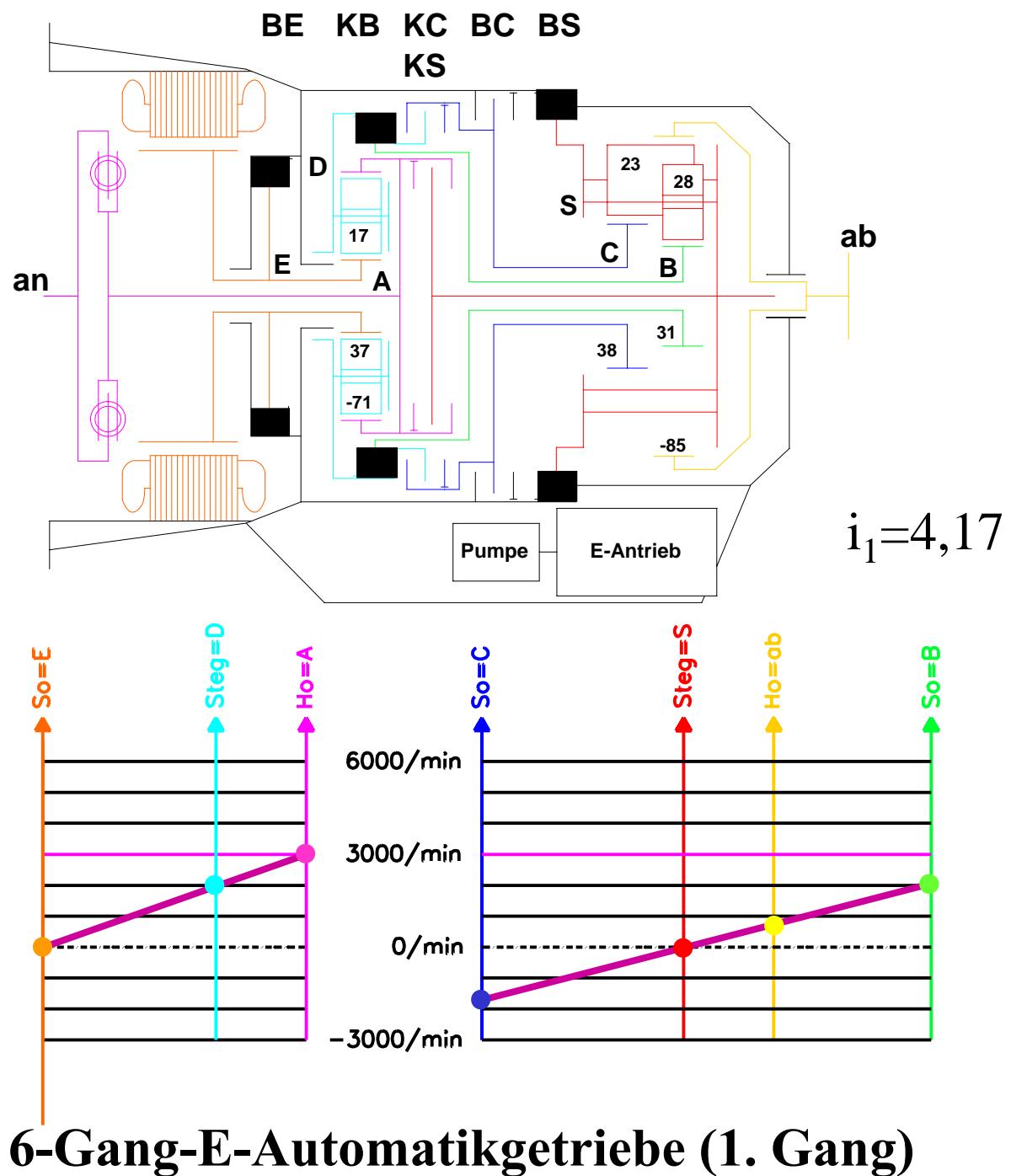


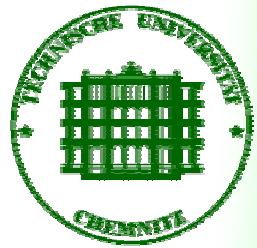
6-Gang-E-Automatikgetriebe
Anfahren aus geared neutral in den 1. Gang



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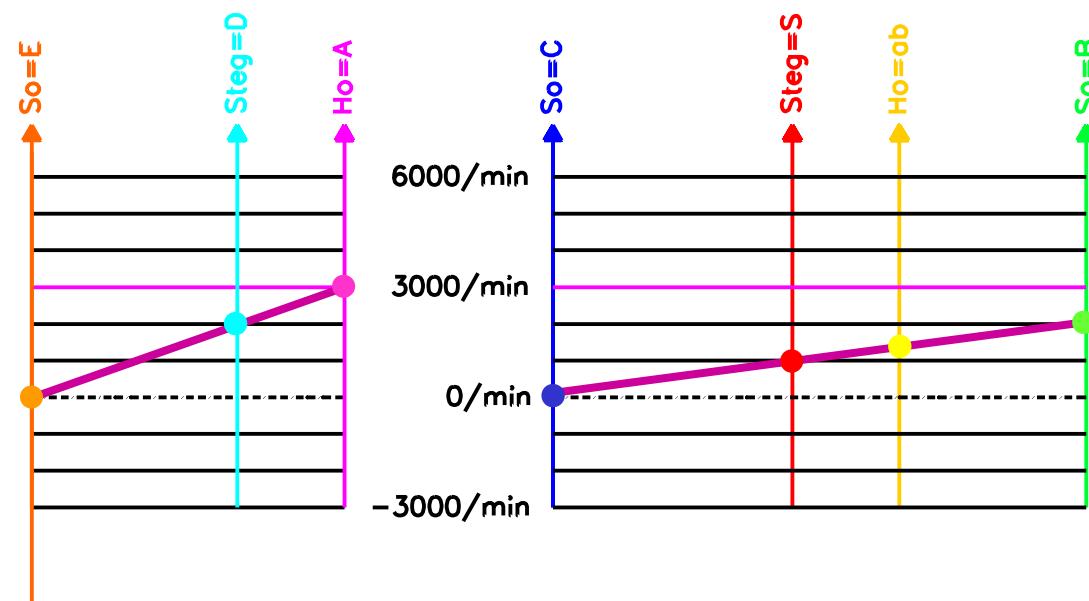
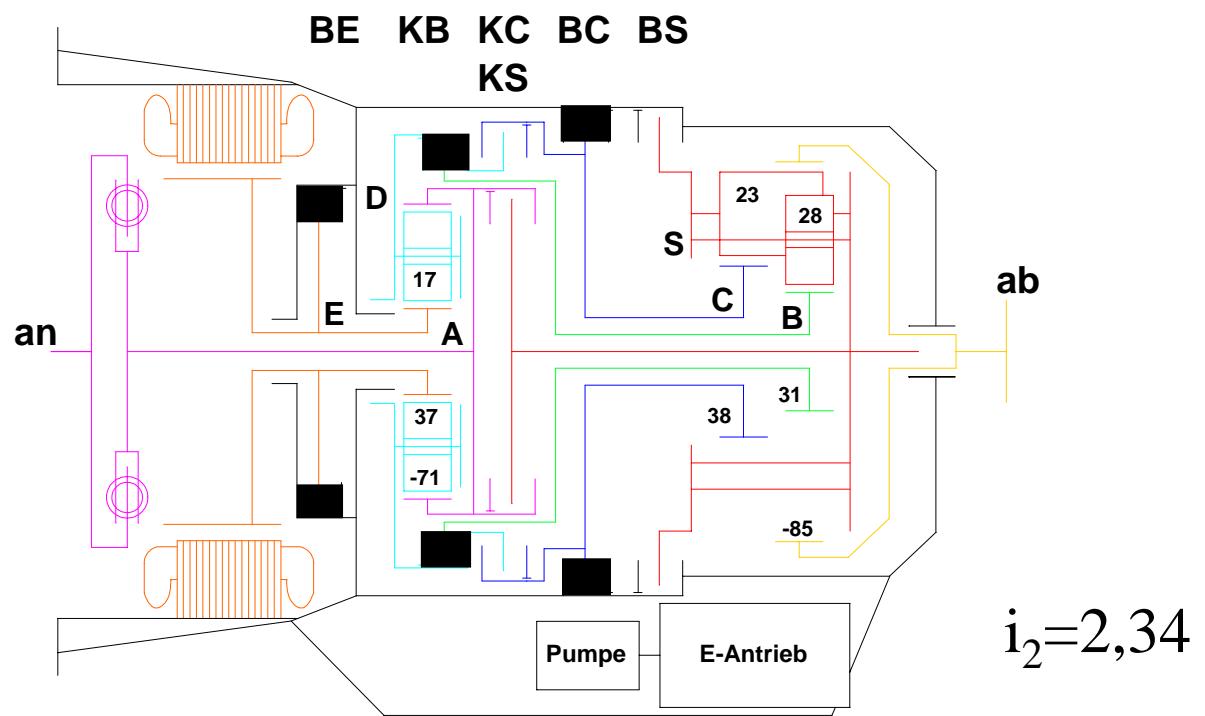
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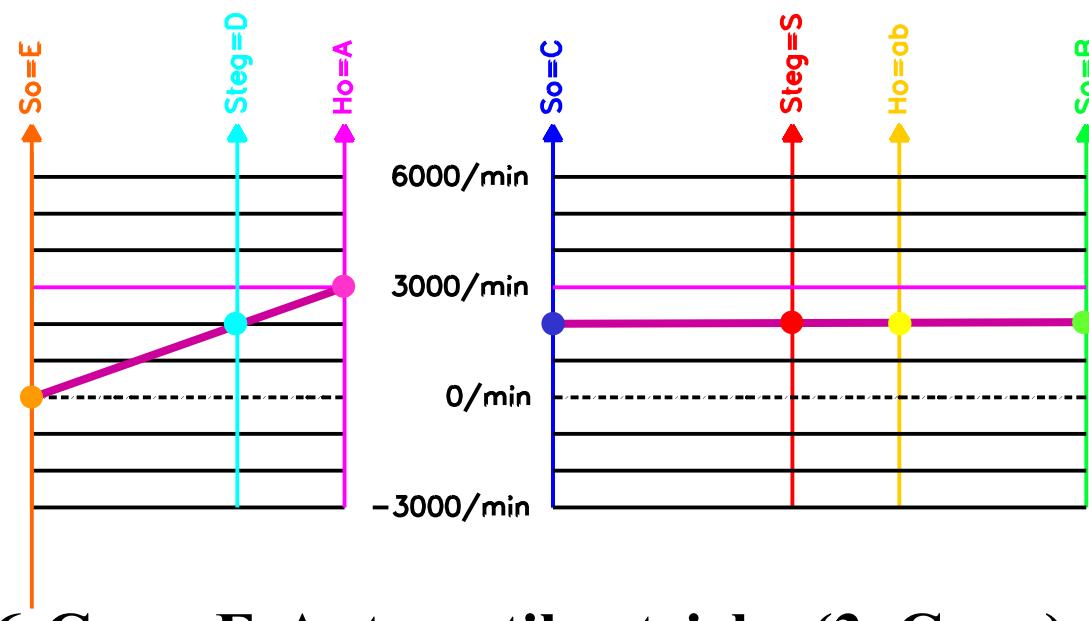
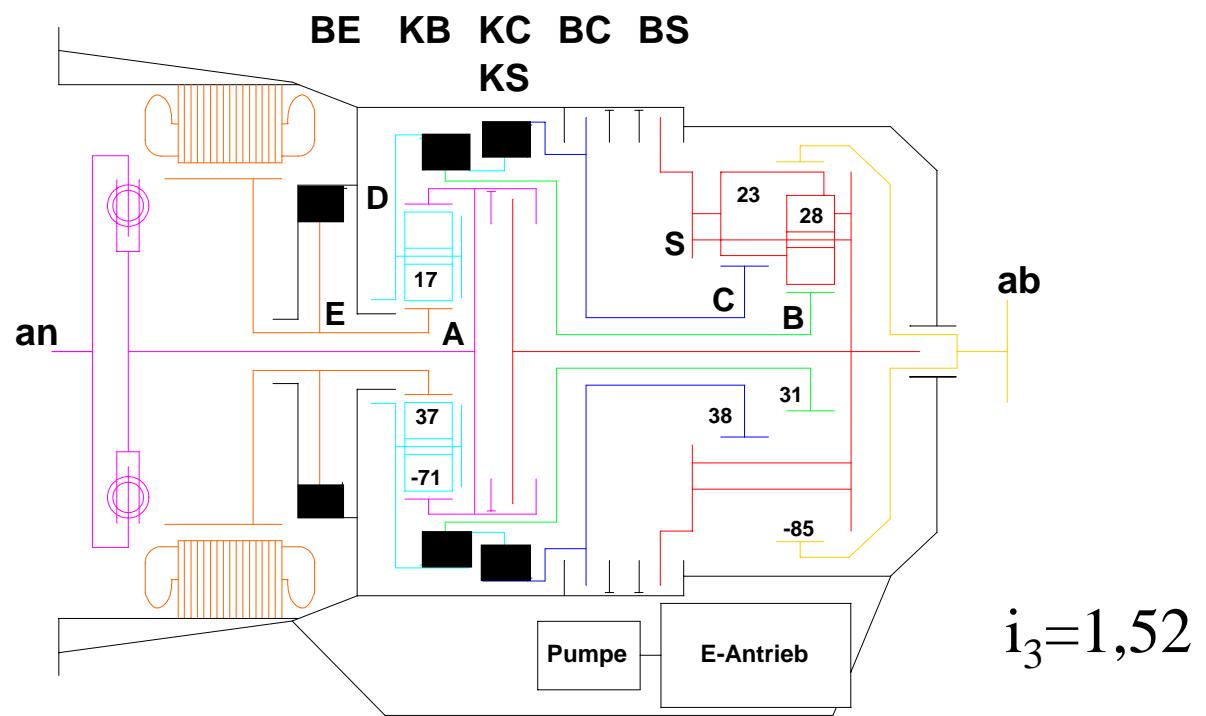


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6-Gang-E-Automatikgetriebe (2. Gang)

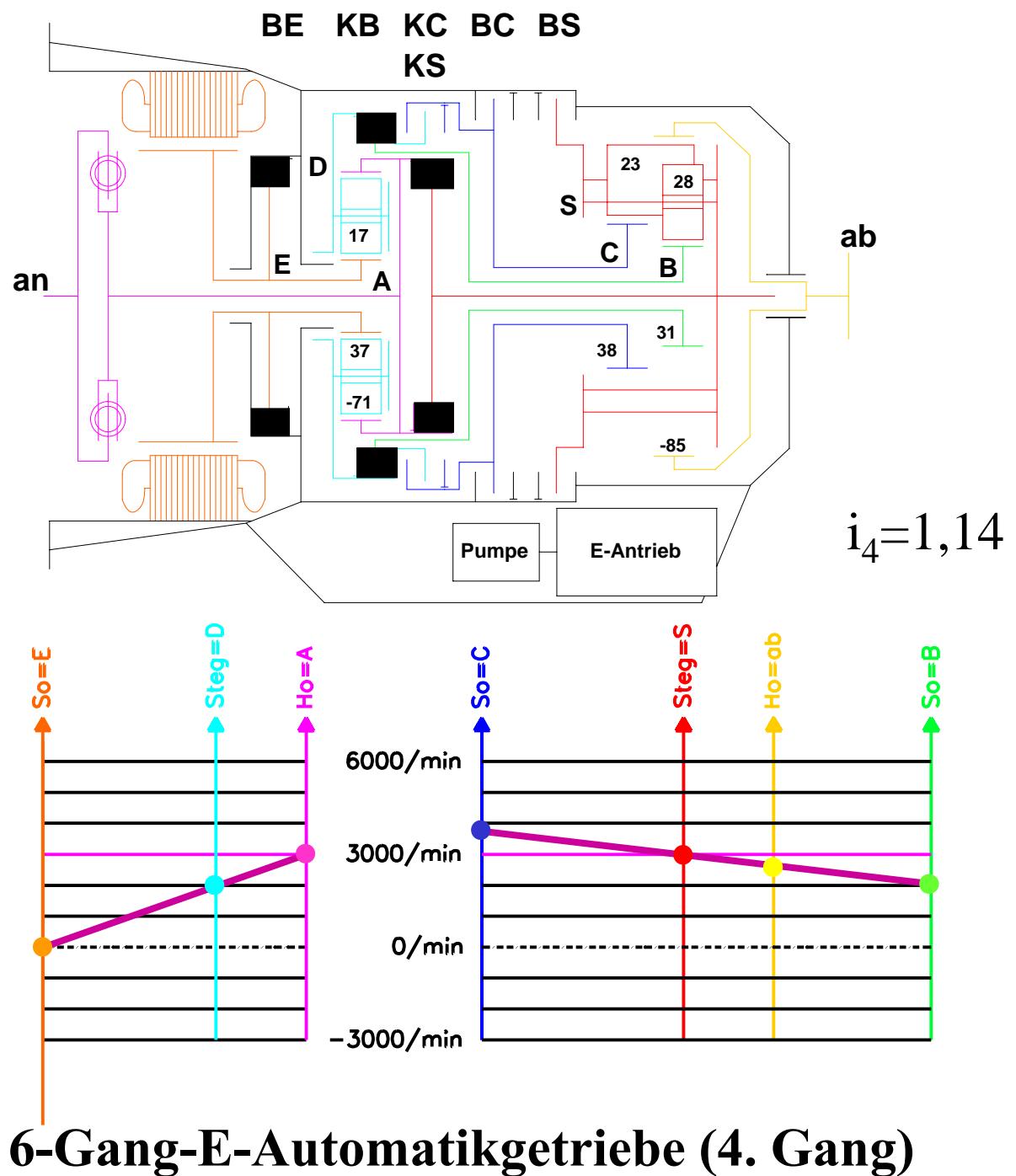


6-Gang-E-Automatikgetriebe (3. Gang)



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20



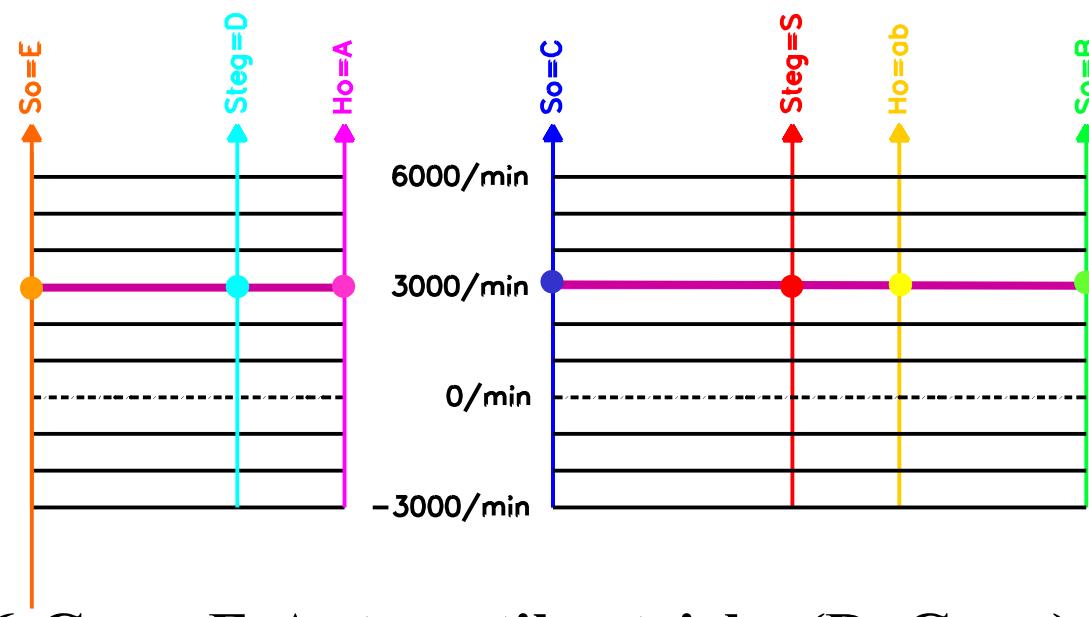
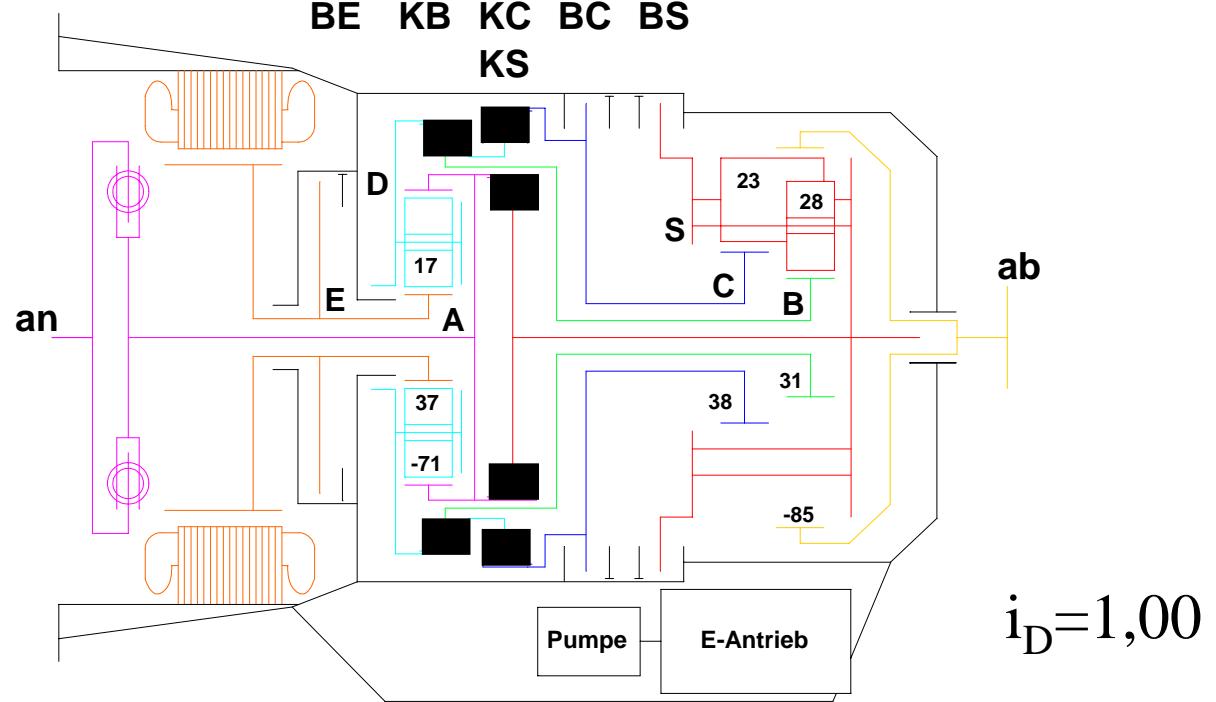


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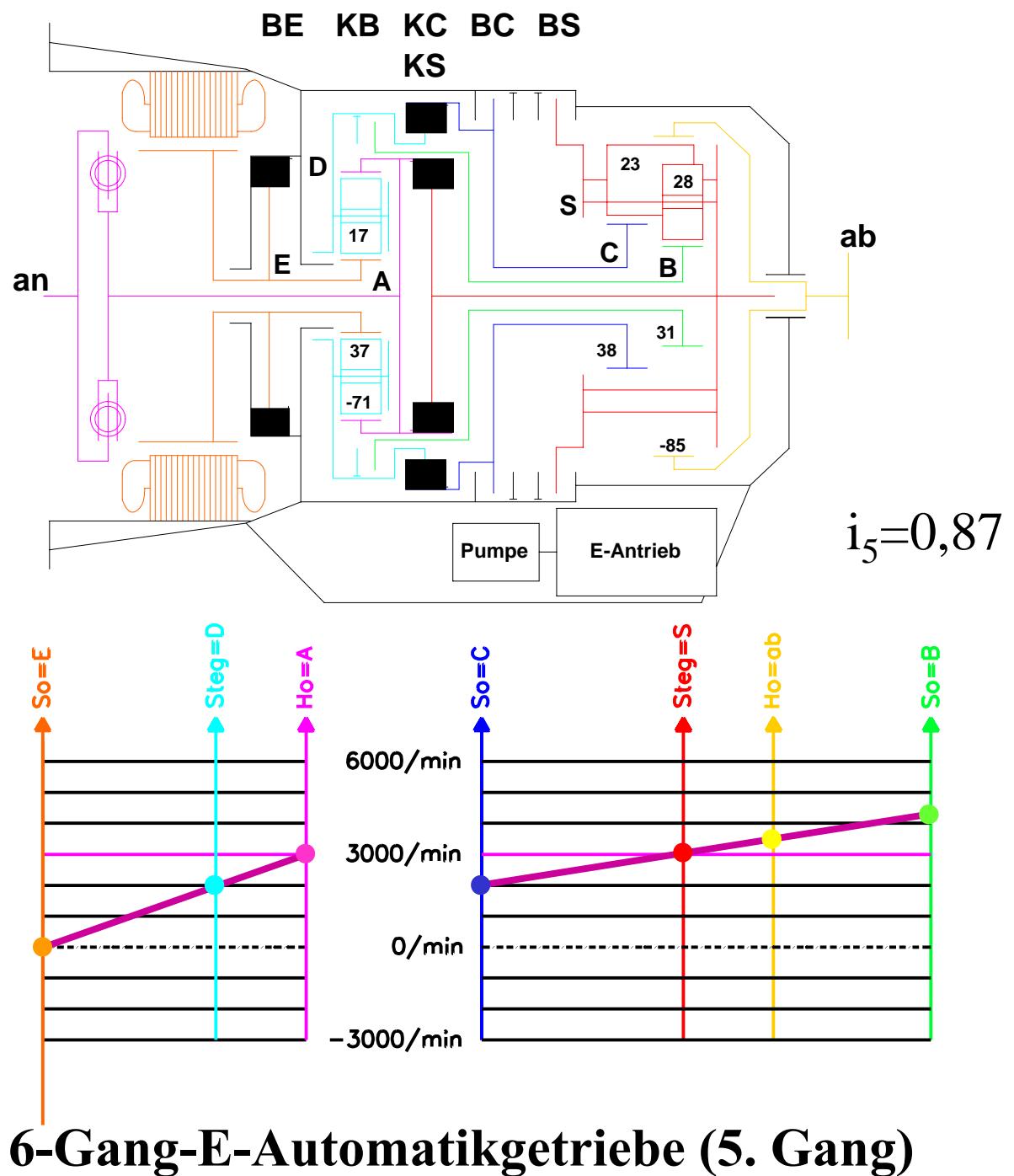
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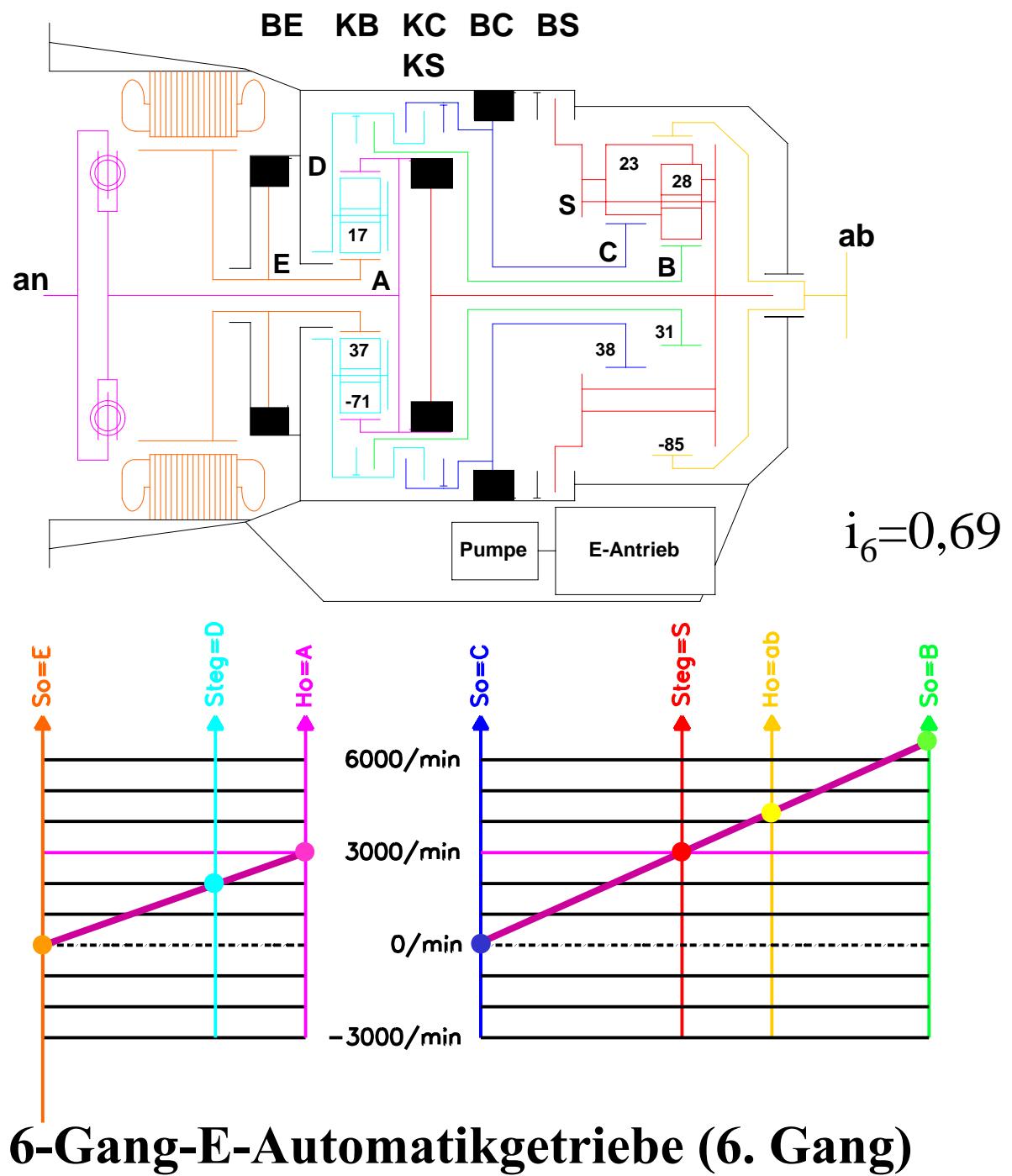
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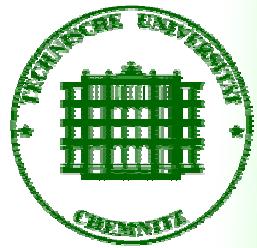
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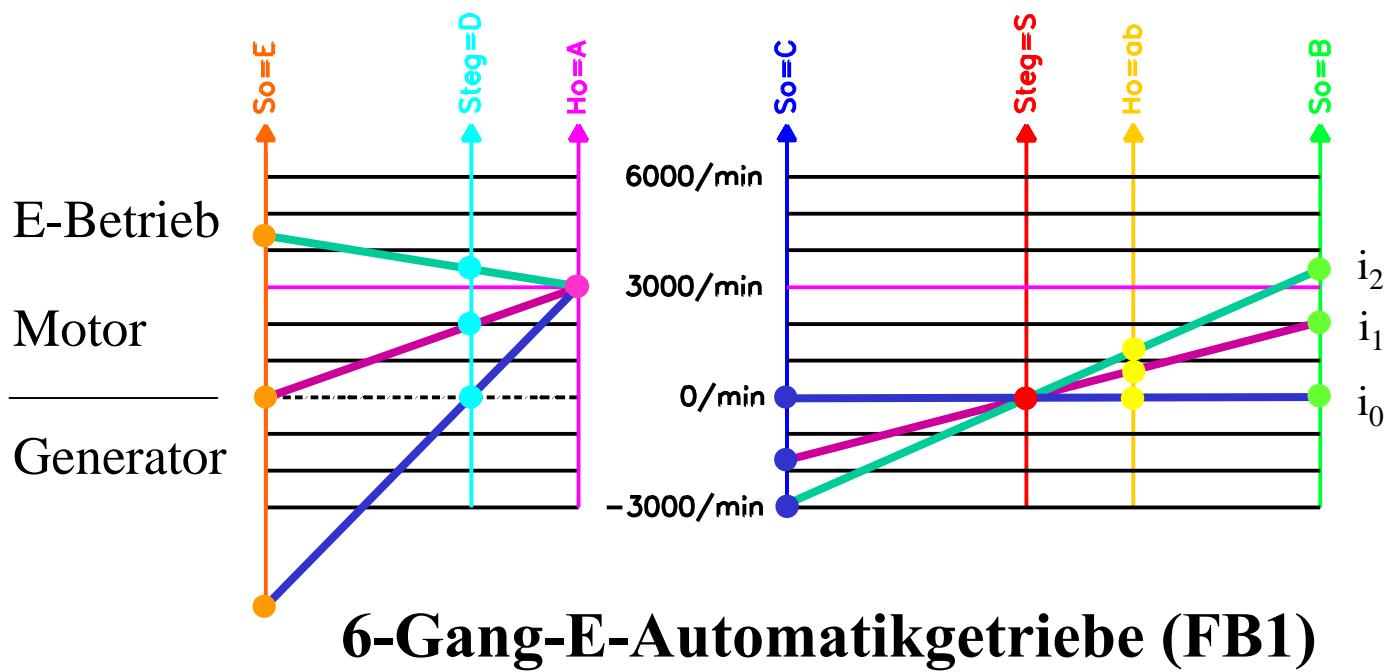
6-Gang-E-Automatikgetriebe (D. Gang)

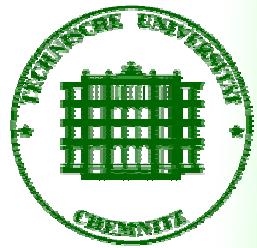




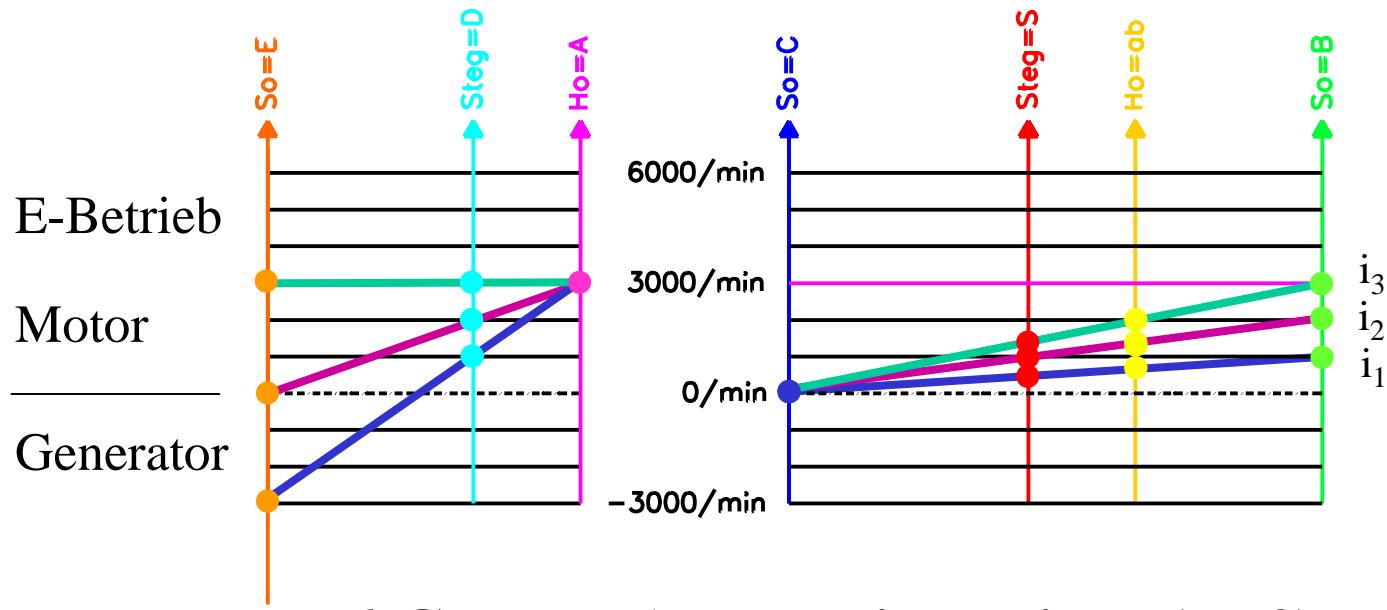


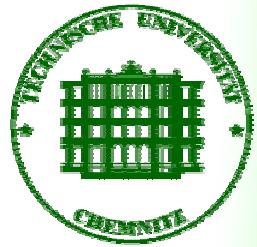
E-Automat



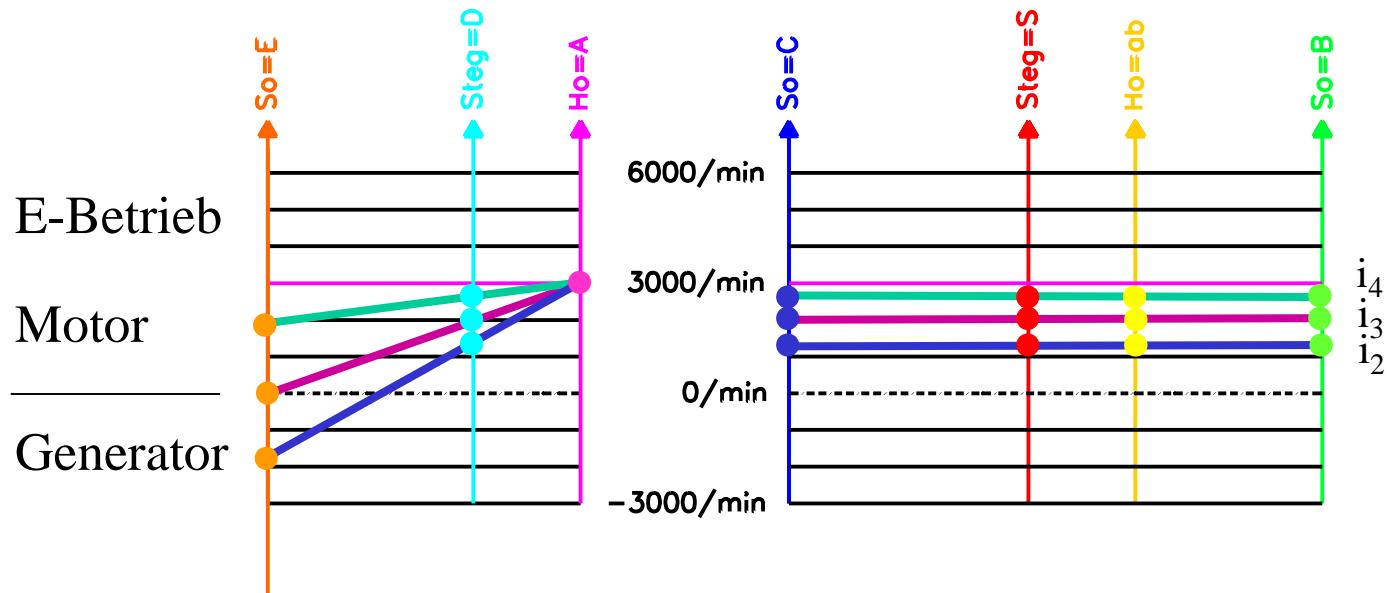


E-Automat





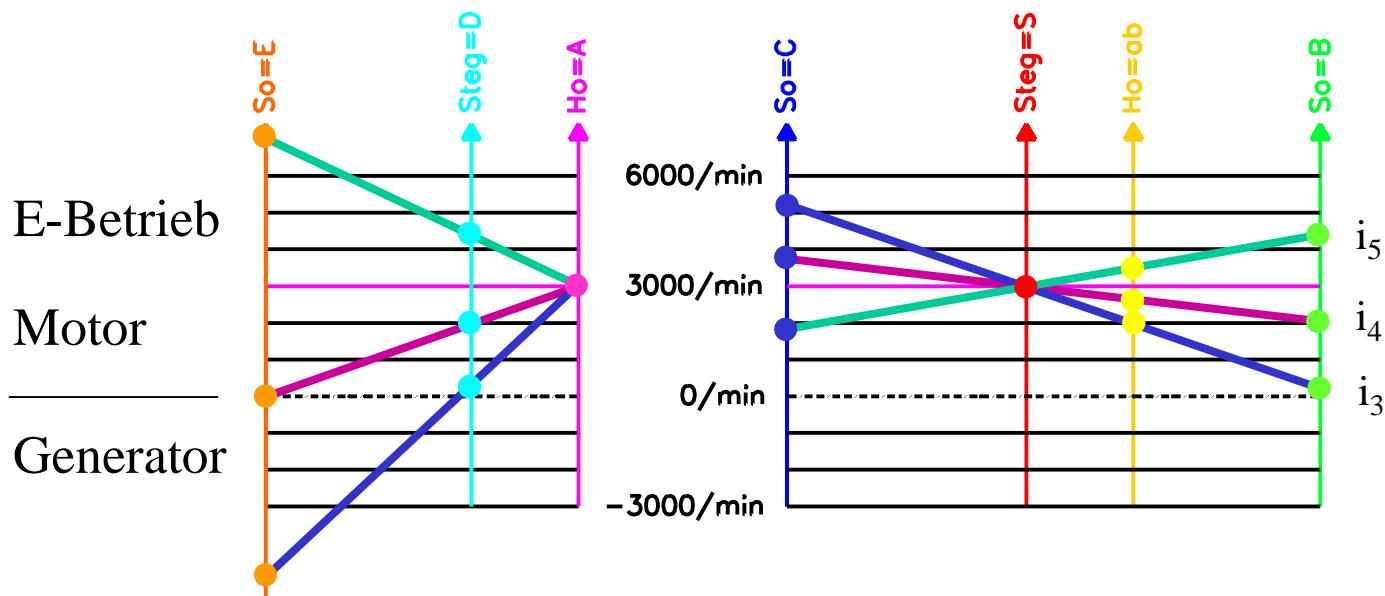
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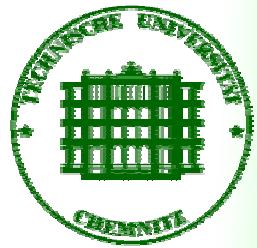
6-Gang-E-Automatikgetriebe (FB3)



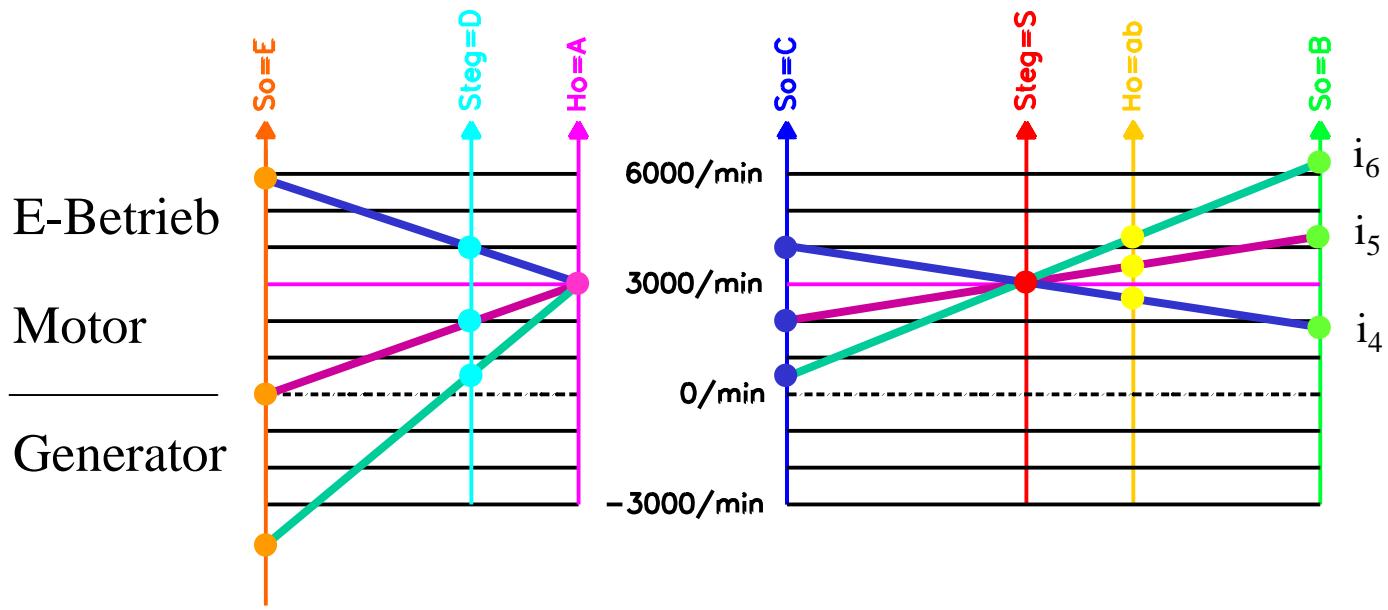
E-Automat



6-Gang-E-Automatikgetriebe (FB4)



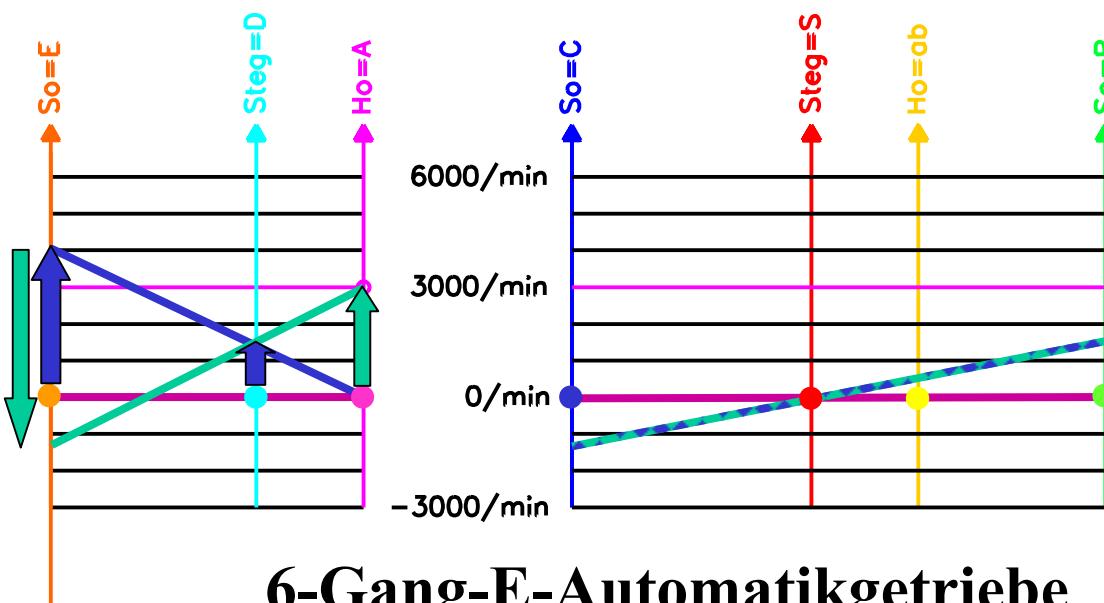
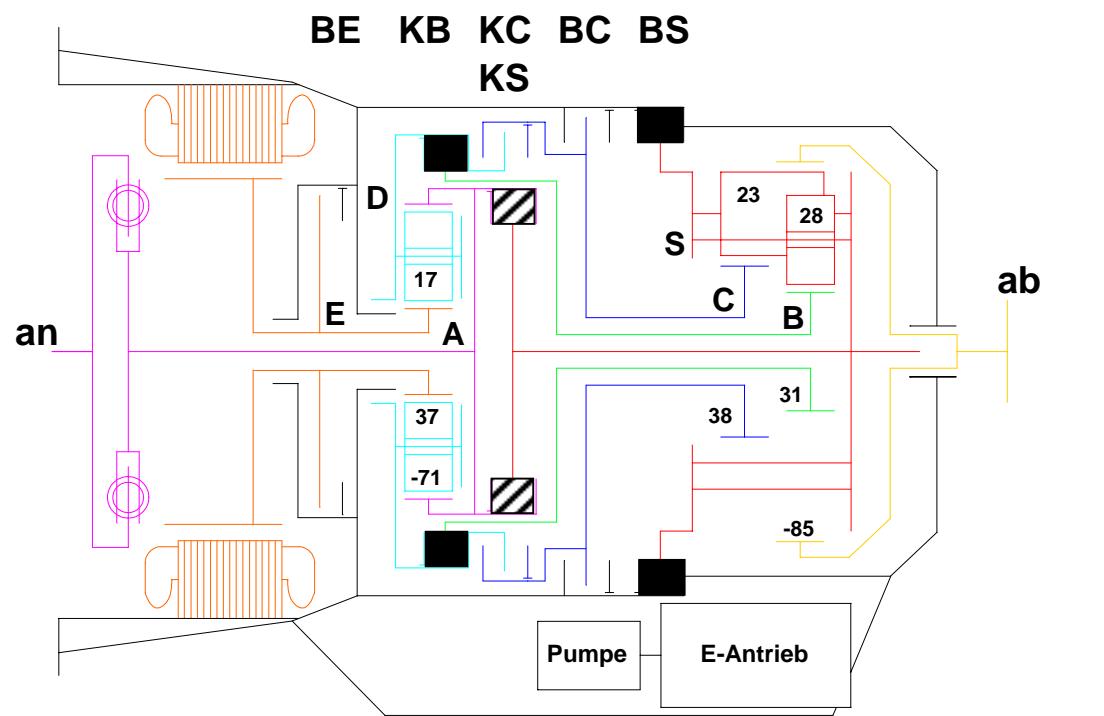
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6-Gang-E-Automatikgetriebe (FB5)



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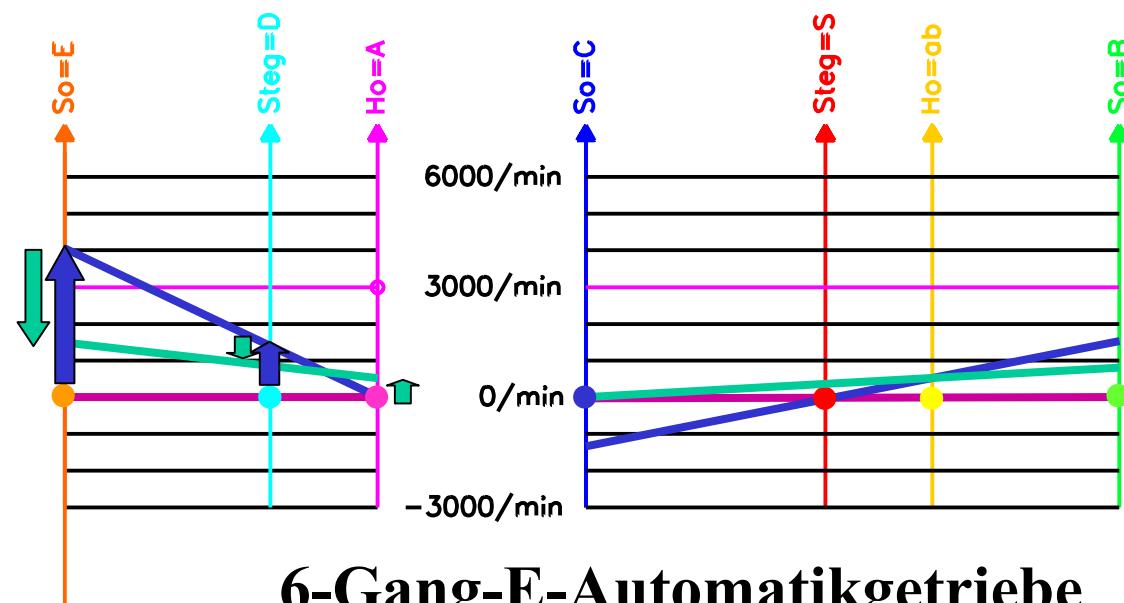
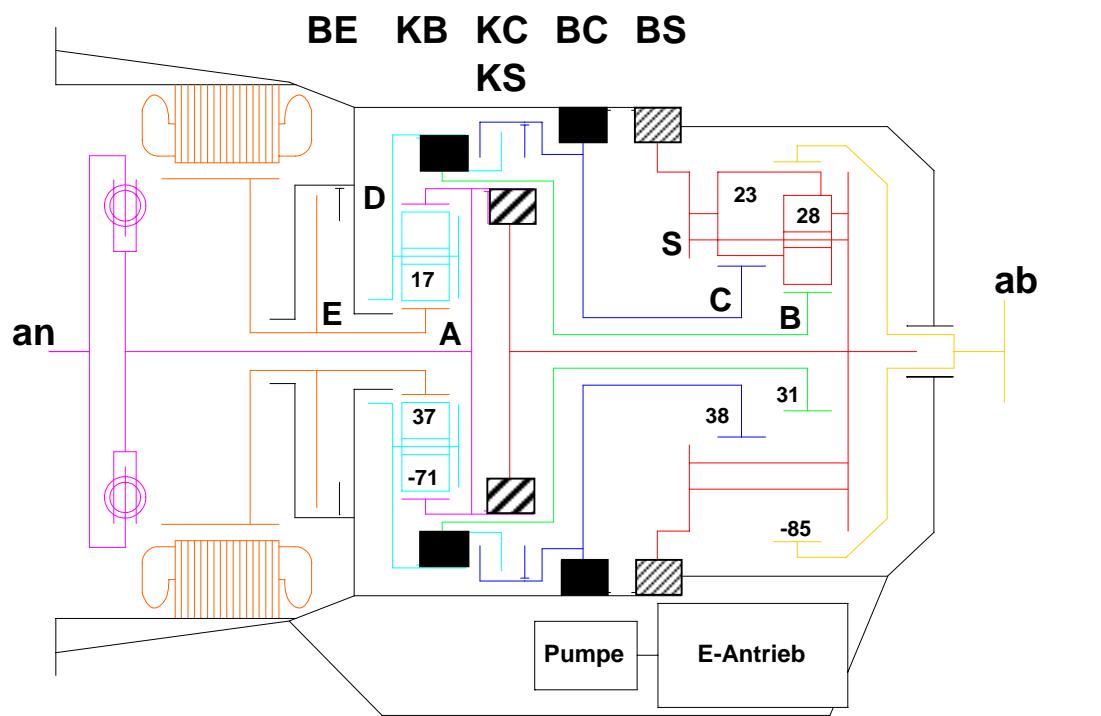


6-Gang-E-Automatikgetriebe
Motorstart aus E-Gang nach FB1



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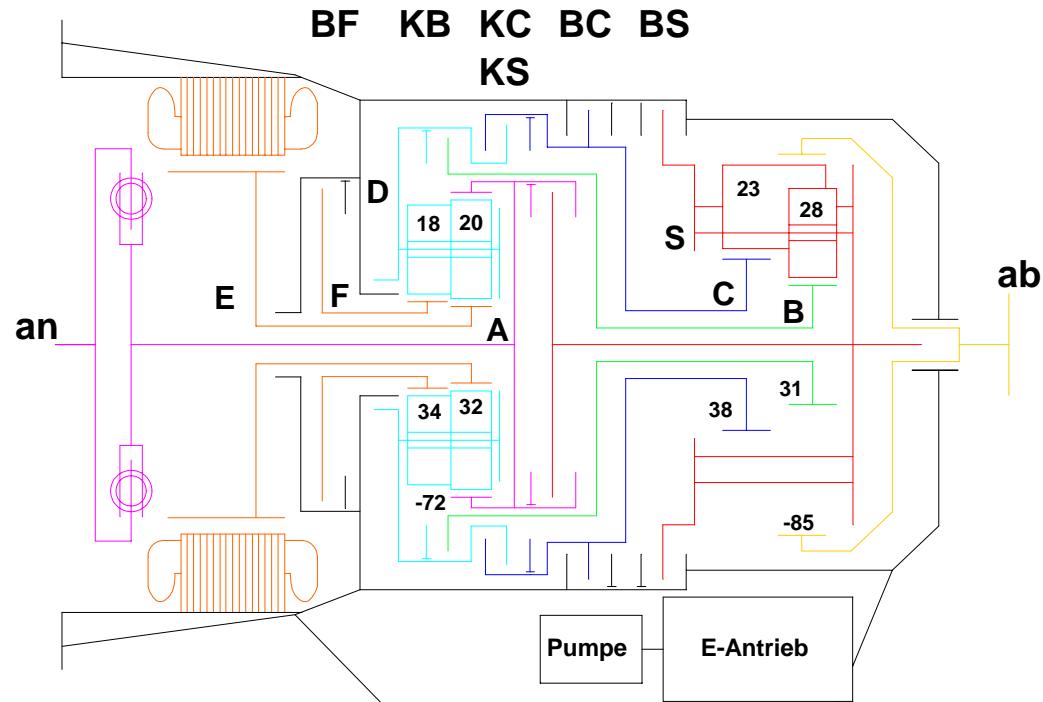
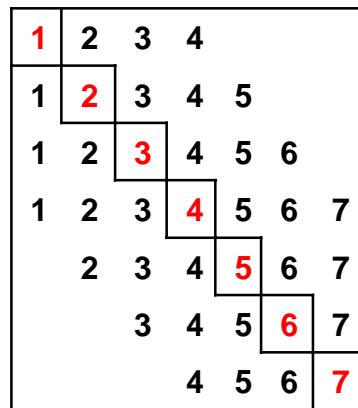
6-Gang-E-Automatikgetriebe
Motorstart aus E-Gang nach FB2



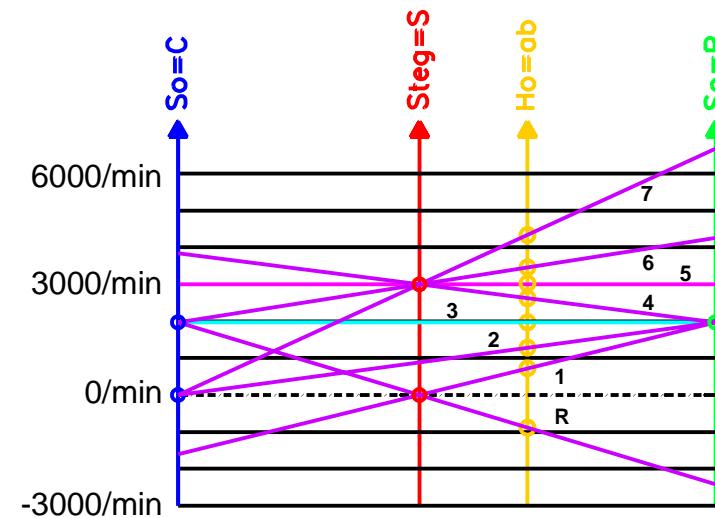
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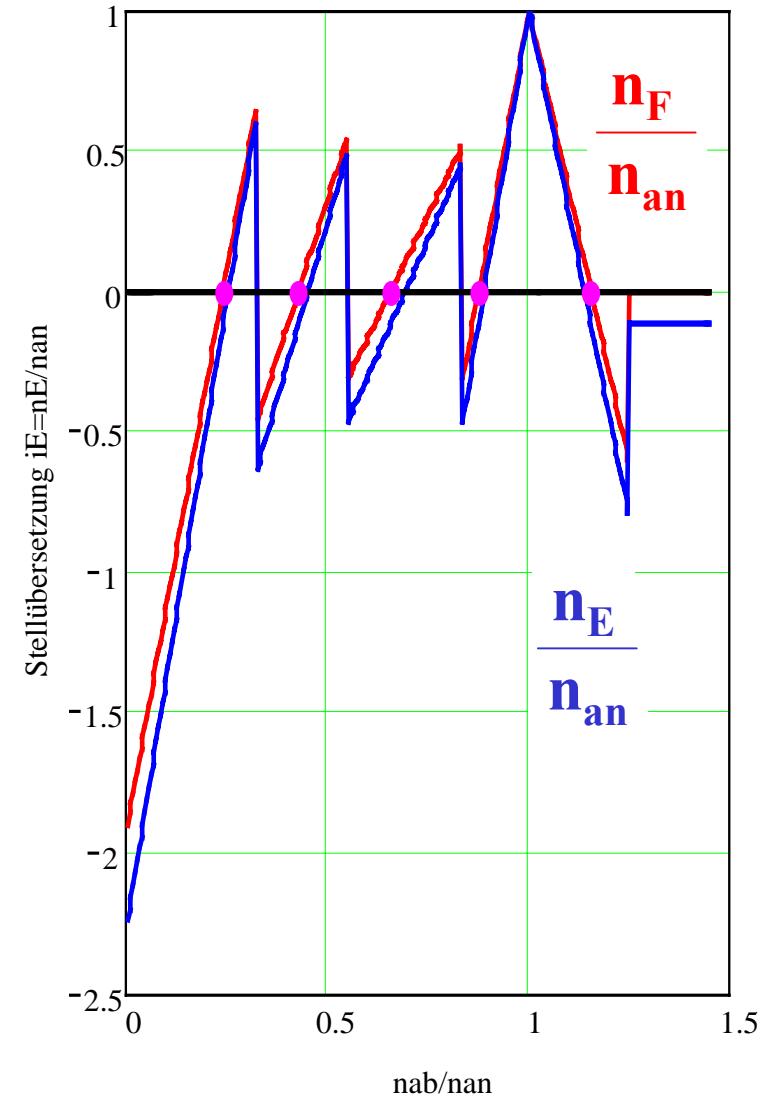
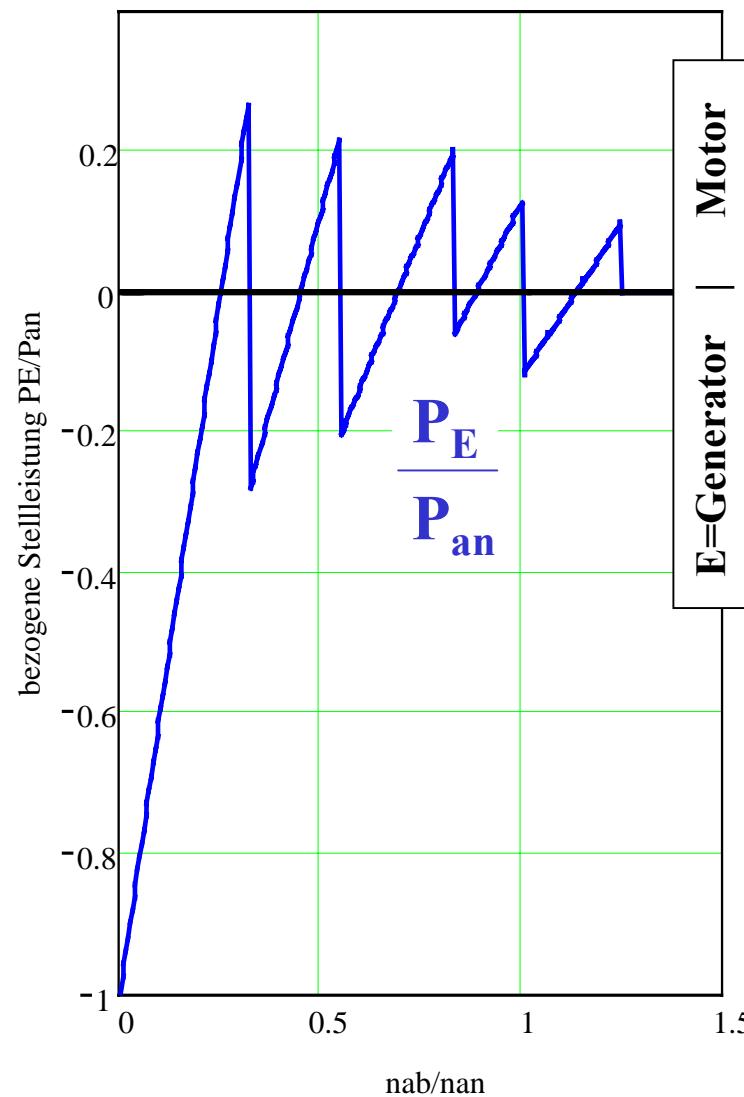
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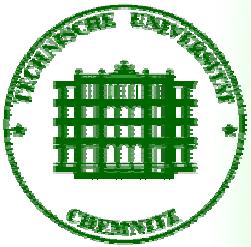
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Gang	KC	KS	KB	BS	BC	BF	i _{ges}
R							-3,40
N							
1							4,181
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6							0,867
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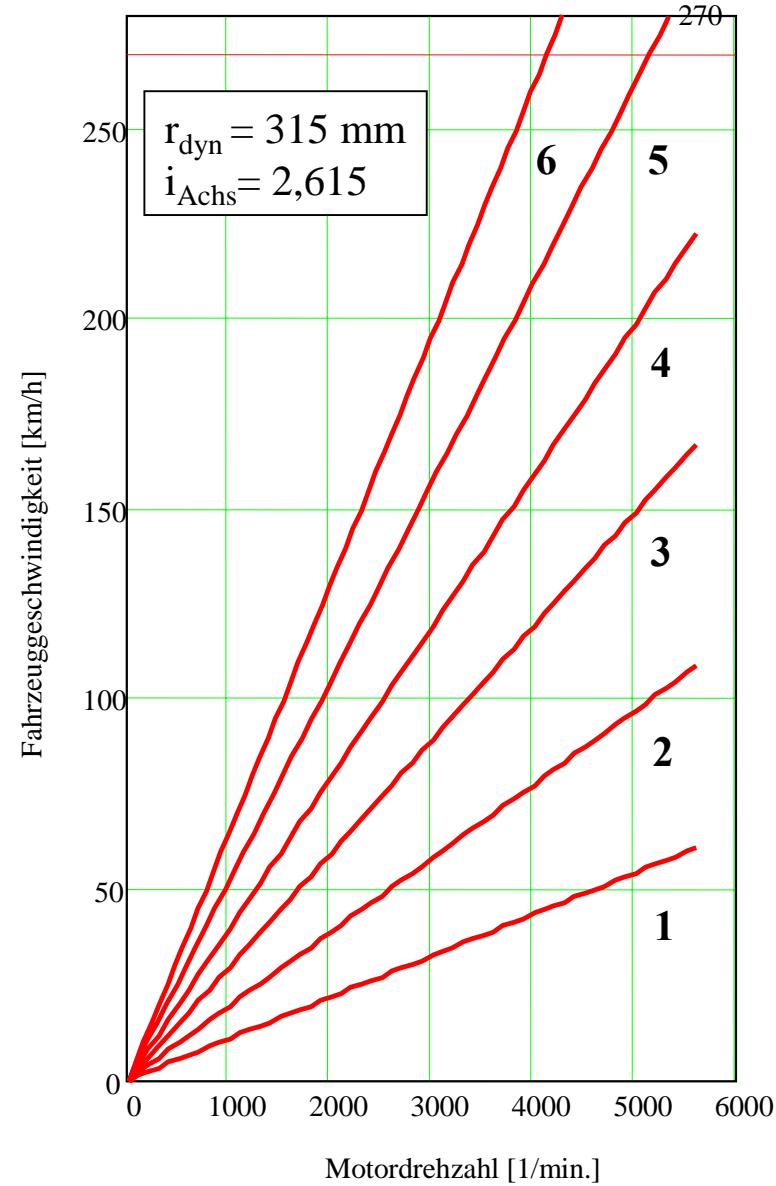
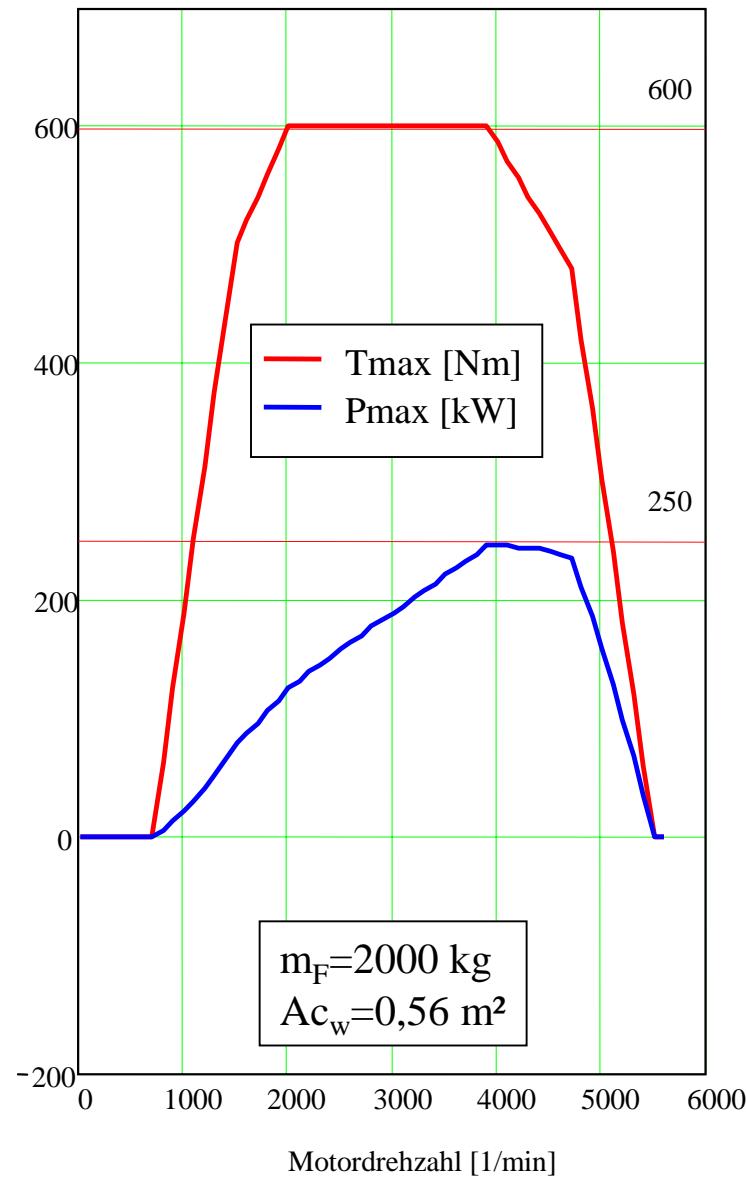


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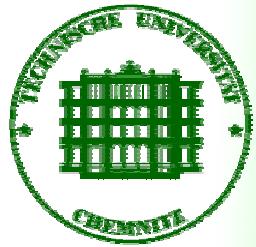
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Motor- und Fahrzeugdaten für Anwendungsbeispiel

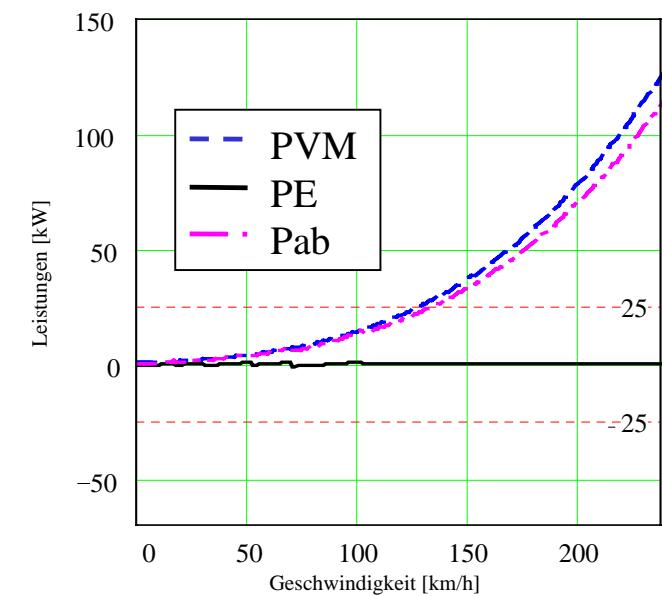
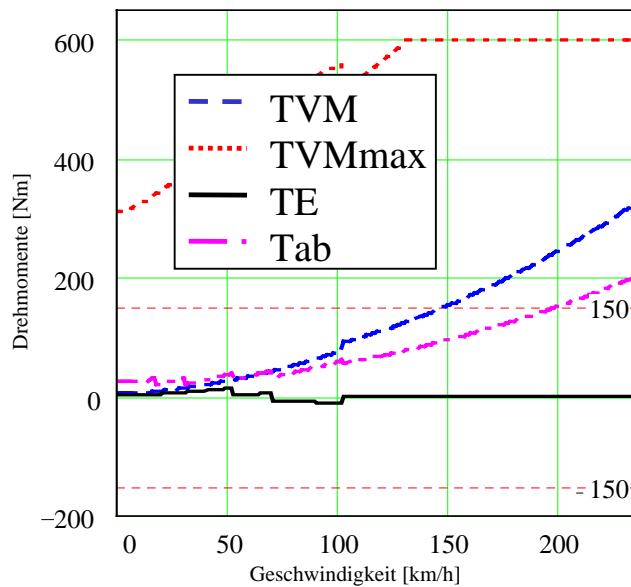
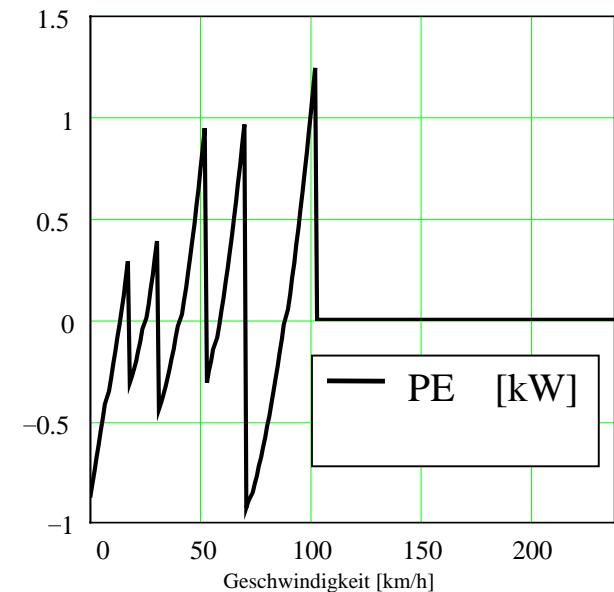
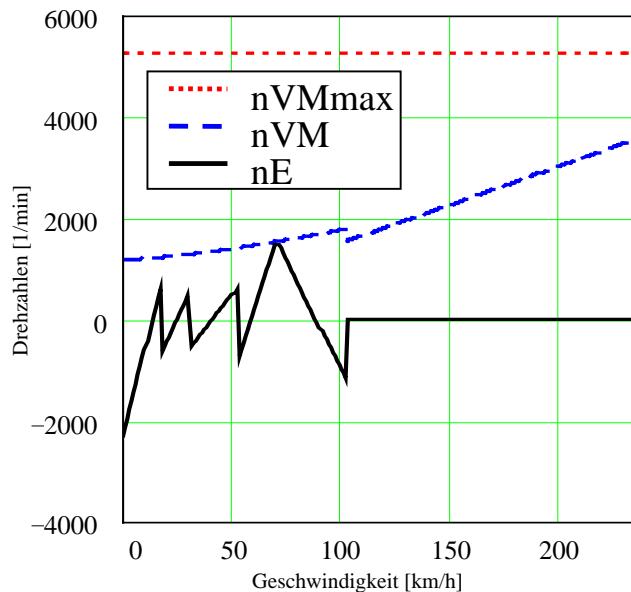


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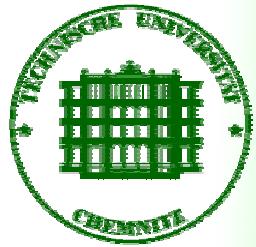
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Peter Tenberge

E-Automat

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Fahrt mit konstanter Geschwindigkeit voll stufenlos fahrbar

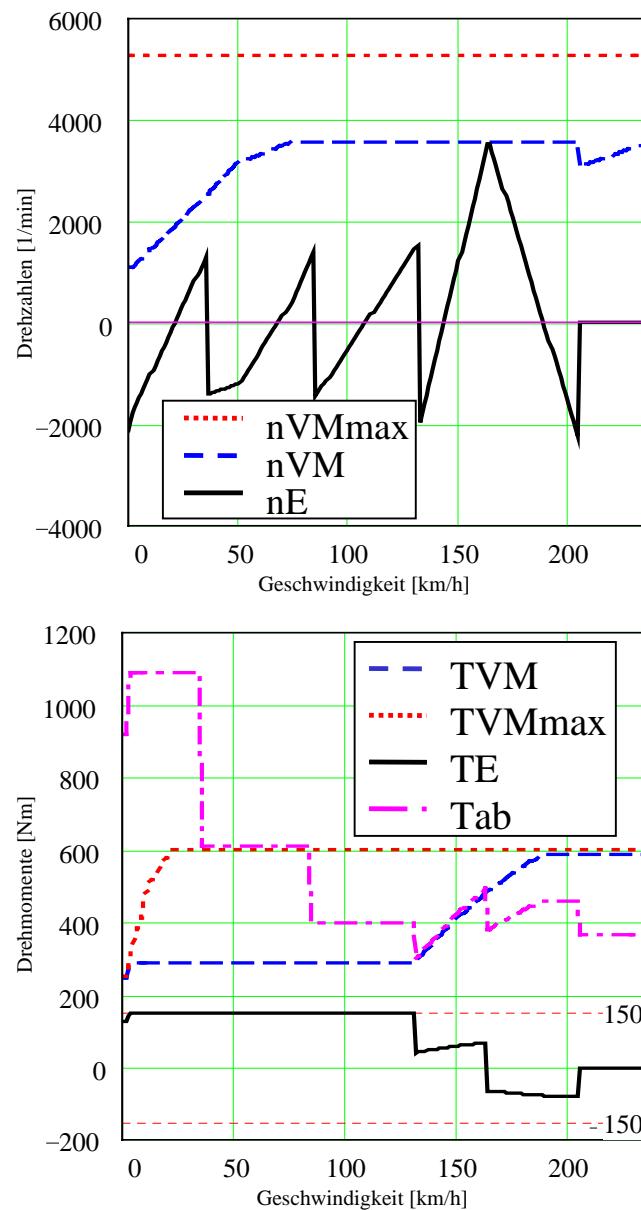


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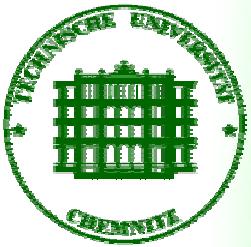
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Teillastbeschl. $t_{0-100 \text{ km/h}} = 11,6 \text{ s}$ mit $\frac{\text{TE}_{\max}}{\text{TVM}_{\max}} = \frac{1}{4}$ voll stufenlos fahrbar

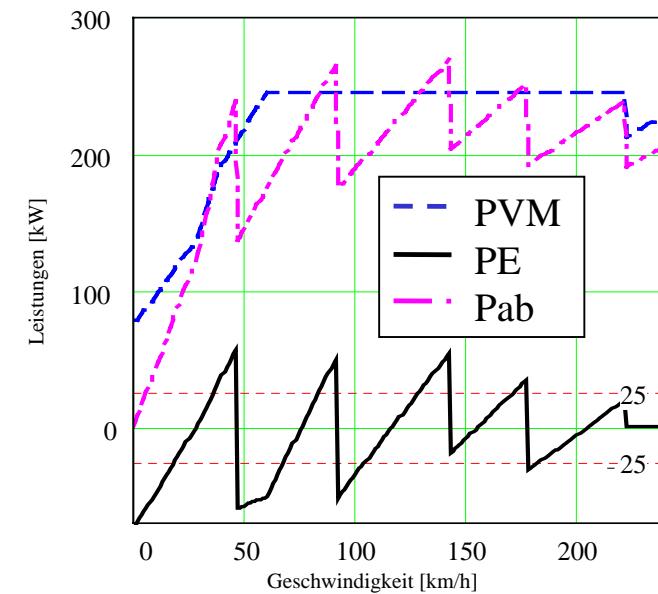
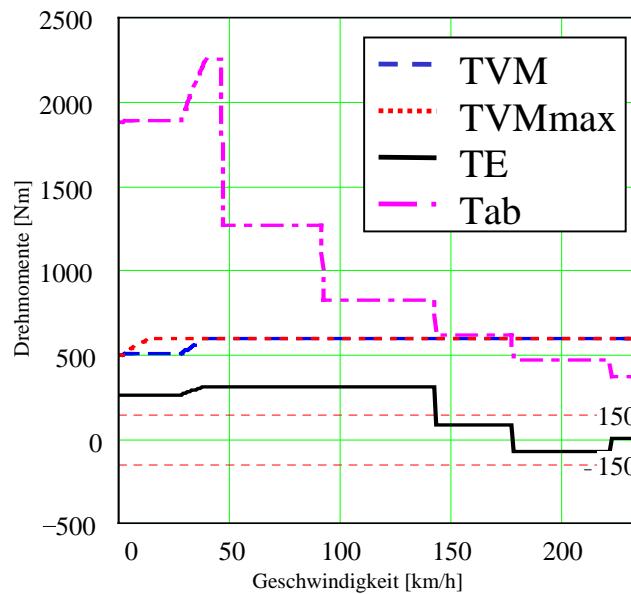
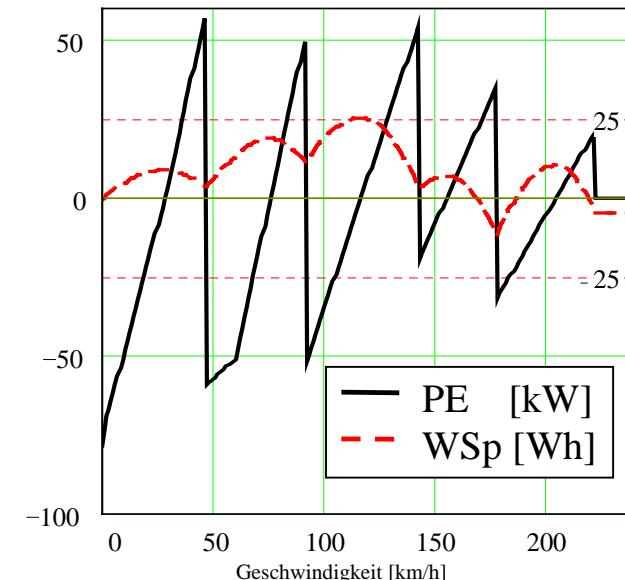
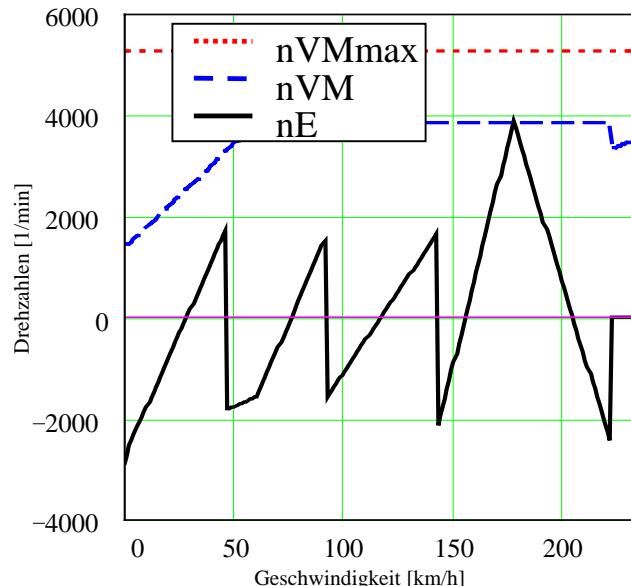


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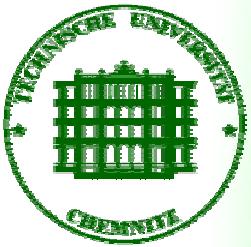
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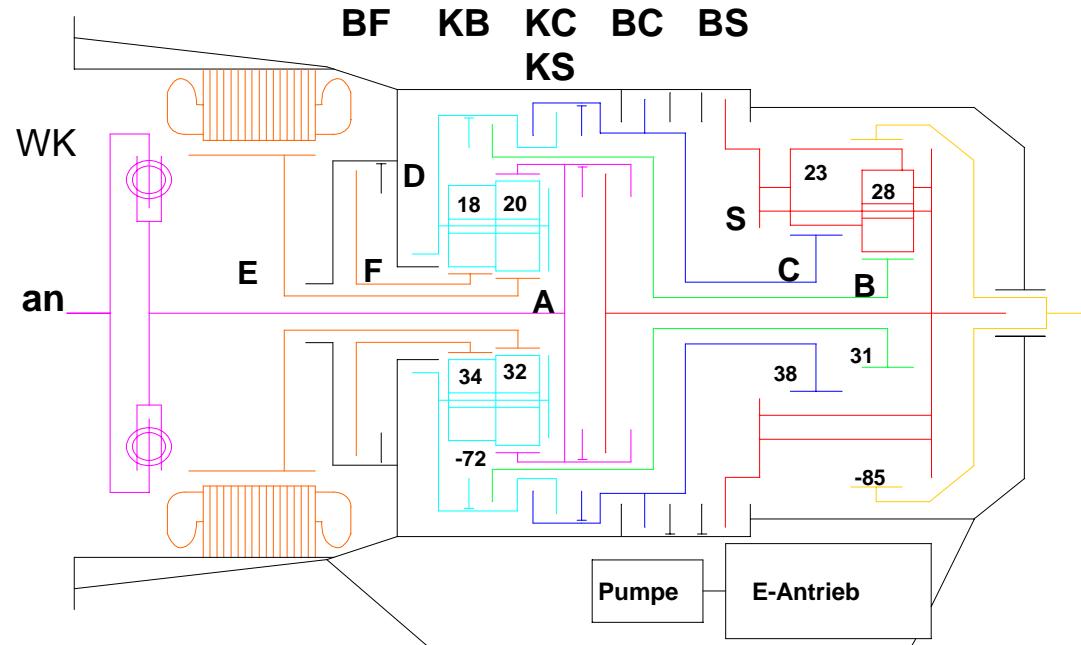
Vollastbeschl. $t_{0-100 \text{ km/h}} = 5,5 \text{ s}$ mit $\frac{TE_{\max}}{TVM_{\max}} = \frac{1}{4}$ erst ab $i=1,24$ stufenlos fahrbar



Eigenschaften des E-Automaten

- identisches Schaltgetriebe wie 6-Gang-Automat mit Lepelletier-Planetenradsatz
 - 6 + 1 Gänge wie Wandler-Automat
 - zusätzlicher 7. Gang bei $i=1$
 - gleicher Wirkungsgrad wie Wandler-Automat
 - gleicher Bauraum im Tunnel wie Wandler-Automat
 - gleiche Drehmomentkapazität wie Wandler-Automat
- 42V-E-Maschine + Bremse BE anstelle Wandler + WK
Zusatzaufwand: Leistungssteuerung + Speicher
 - => Starter/Generator-Betrieb
 - => Rekuperation im gesamten Übersetzungsbereich
 - => Anfahren aus geared neutral oder mit Bremse BE
 - => stufenloser Fahrbetrieb ab $i=1,24$ bis Overdrive
 - => stufenloser Fahrbetrieb bis $T_{VM}=2 \text{ TE}_{max}$ bei $i>1,24$
dabei kleine Energieschwankungen im Speicher
 - => rein elektrischer Fahr- und Rangierbetrieb
 - => Motorstart aus E-Betrieb heraus möglich

Zusammenfassung



Ein Großteil der Bauteile des E-Automaten sind identisch zum 6-Gang-Wandler-Automaten
⇒ einfache und kostengünstige Adaption
⇒ auch bei kleinen Stückzahlen geringes Entwicklungs- und Marktrisiko.

E-Automat = gute Alternative zu CVT