


  
 Technische Hochschule  
 Ingolstadt  
 Fakultät für Maschinenbau

*New Trends in  
 Automotive Mobility*  
*Electric Drive Train*

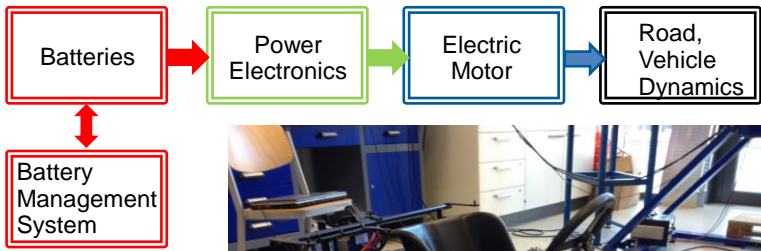
Prof. Dr. Harald Göllinger    11/2016

*Zukunft in  
 Bewegung*



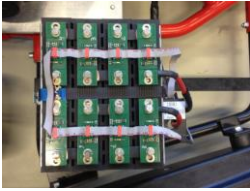



*Electric Drive Train  
 Overview*



```

    graph LR
      B[Batteries] --> PE[Power Electronics]
      PE --> EM[Electric Motor]
      EM --> RD[Road, Vehicle Dynamics]
      BMS[Battery Management System] <--> B
  
```

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## Electric Drive Train Comparison of battery types



type of batteries	energy	power	life time		cost	
	density	density				
	Wh/kg	W/kg	cycles	years	€/kWh	
lead	30-35	200-300	300-400	2-3	100-150	
nickel-cadmium	45-50	80-175	>2000	3-10	<600	memory effect, toxic
nickel metal hydride	60-70	200-300	>2000	10	300-350	interesting
sodium nickel chloride	90-100	160	1000	5-10	<300	operating temperature 270-350°C
lithium-ion	90-150	500-700	>1000	>5	300-600	
lithium polymer	110-130	ca. 300	<600	k.A.	300	up to 100°C
zinc air	100-220	ca. 100	k.A.	k.A.	60	not rechargeable
supercaps	5	1000-5000	500000	10		

source: Braess, Seiffert

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## Electric Drive Train Comparison of Lithium Ion batteries



### Cylindrical type

- 1 Positive pole
- 2 PTC (Positive Temperature Coefficient Device)
- 3 Gasket
- 4 Collector
- 5 Insulator
- 6 Cathode
- 7 Anode
- 8 Negative pole (cell can)
- 9 Separator
- 10 CID (Current Interrupt Device)
- 11 Exhaust gas hole



### pouch cell „coffee bag“



### Prismatic type

- 1 Internal terminal
- 2 Sealing tap
- 3 Isolation frame body
- 4 Lead
- 5 Cathode
- 6 Separator
- 7 Anode
- 8 Case
- 9 (Lower) Gasket
- 10 (Upper) Gasket
- 11 Terminal
- 12 Anode cap
- 13 Anti-explosion valve



Source:

[https://eu.industrial.panasonic.com/sites/default/pidseu/files/li-ion\\_cylindrical\\_3d\\_illustration\\_shadow\\_rgb.jpg](https://eu.industrial.panasonic.com/sites/default/pidseu/files/li-ion_cylindrical_3d_illustration_shadow_rgb.jpg)  
[http://www.batteryuniversity.com/\\_img/content/pouch22.jpg](http://www.batteryuniversity.com/_img/content/pouch22.jpg)

## Electric Drive Train

### Battery Technology is the key technology

Tesla builds battery factory in Nevada (together with Panasonic)



50 GWh in annual battery production by 2020  
Enough for 500,000 Tesla cars  
Powered by renewable energy  
Net zero energy factory

<http://f2.wp.com/www.mein-elektroauto.com/wp-content/uploads/2014/11/Elektroauto-Hersteller-Tesla-Motors-bekommt-das-Grundst%C3%BCck-f%C3%BCr-die-Gigafactory-geschenkt.png?resize=700%2C404>

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## Electric Drive Train

### Battery Technology is the key technology

Ongoing discussion within Volkswagen group about the strategy



#### VW-CHEF MÜLLER ZUR BATTERIEFERTIGUNG

**So einen Blödsinn machen wir sicherlich nicht**



VW-Chef Matthias Müller stellt sich strikt gegen eine eigene Batterieproduktion des Autobauers, meldet das Handelsblatt.

#### VW-Betriebsratschef: Wir müssen Batterien bauen

Der Trend hin zu Elektromobilität gefährdet viele Arbeitsplätze von Volkswagen. Betriebsratschef Osterloh spricht deshalb eine Drohung aus.

18.10.2016, von CARSTEN GERMIS, HAMBURG

f Teilen t Twittern x Teilen E-mailen



Bernd Osterloh fordert eine eigene Batteriefabrik für Volkswagen.

source:

<http://www.faz.net/aktuell/wirtschaft/unternehmen/osterloh-besteht-auf-bau-einer-batteriefabrik-14486729.html>

<http://www.auto-motor-und-sport.de/news/vw-chef-mueller-zur-batteriefertigung-so-einen-blodsinn-machen-wir-sicherlich-nicht-1033338.html>

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*Electric Drive Train  
Battery Technology is the key technology  
In 2015, Daimler stops producing own lithium-ion cells, but ...*





## FOR SALE

### COMPLETE LITHIUM-ION CELL PRODUCTION LINES




Assets located near Dresden, Germany | Preview by appointment

<p><b>CONTACT:</b> Sebastian Geissler litec@maynards.com +49 8151 99 89753</p> <p style="text-align: center;">Sole Conducted By: <b>Maynards</b> AUCTIONS   LIQUIDATIONS   APPRAISALS <a href="http://www.maynards.com">www.maynards.com</a></p>	<p><b>CELL-ASSEMBLY AT LI-TEC:</b></p> <ul style="list-style-type: none"> <li>• 3 fully automatic assembly machines (EFA)</li> <li>• First installed in 2011, additional two in 2012</li> <li>• Manufactured by GROHMANN</li> </ul>	<p><b>TECHNICAL FEATURES:</b></p> <ul style="list-style-type: none"> <li>• Very compact design: only 30m per line</li> <li>• Competitive cycle time</li> <li>• Inline drying concept</li> <li>• Laser cutting ability</li> <li>• Formation without degassing</li> </ul>
<p><b>ALSO AVAILABLE:</b></p> <ul style="list-style-type: none"> <li>• Semi-automated assembly stations (40/52 Ah cells)</li> <li>• Vacuum drying</li> <li>• Steel rule cutting</li> <li>• Robotized pick &amp; place stacking</li> </ul>		

Source:  
<http://www.manager-magazin.de/fotostrecke/daimlers-batteriefabrik-li-tec-in-sachsen-wird-verhoeckert-fotostrecke-130712-5.html>  
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*Electric Drive Train  
Battery Technology is the key technology  
Daimler stops producing own lithium-ion cells, but invests  
in Deutsche Accumotive*



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Source: <http://www.business-on.de/dateien/bilder/accumotive.jpg>

## *Electric Drive Train*

### *Types of electric motors*



Types of electric motors für electric vehicles:

direct current motor

- series-characteristic motor
- shunt-wound motor

three-phase ac motor

- asynchronous motor
- synchronous motor
  - permanently excited synchronous motor
  - separately excited synchronous motor

special motors

- brushless dc motor
- transversal flux motor
- switched reluctance motor

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## *Electric Drive Train*

### *How to select an electric motor*




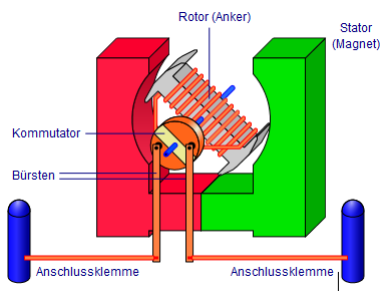
Criteria in the selection of the motors

compact construction,  
light weight (high power density),  
High efficiency,  
easy controllability in a wide speed and torque range,  
overload,  
low noise,  
low cost, and  
low maintenance requirements.

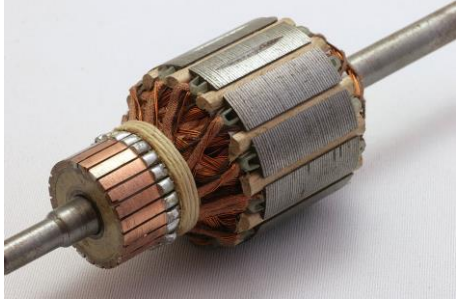
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*Electric Drive Train*  
*Permanent-magnet DC Motor*





basic structure




armature

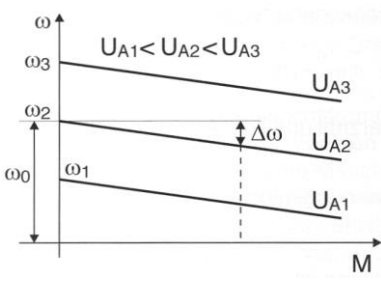
source: [upload.wikimedia.org/wikipedia/commons/a/a8/Gleichstrommaschine.svg](http://upload.wikimedia.org/wikipedia/commons/a/a8/Gleichstrommaschine.svg)  
[de.wikipedia.org/wiki/Gleichstrommaschine#mediaviewer/File:Kommutator\\_universalmotor\\_stab.jpg](http://de.wikipedia.org/wiki/Gleichstrommaschine#mediaviewer/File:Kommutator_universalmotor_stab.jpg)

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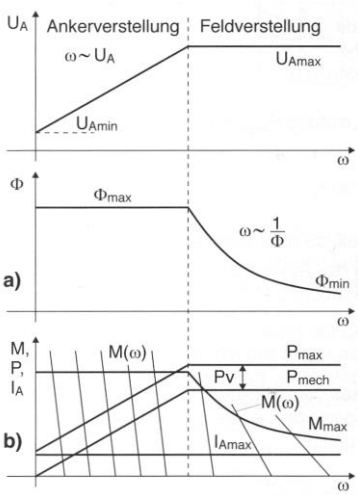
*Electric Drive Train*  
*Permanent-magnet DC Motor*



turn rate  $\omega = f(U_A, M)$



turn rate as function of field weakening

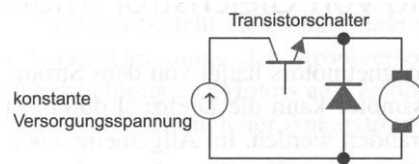
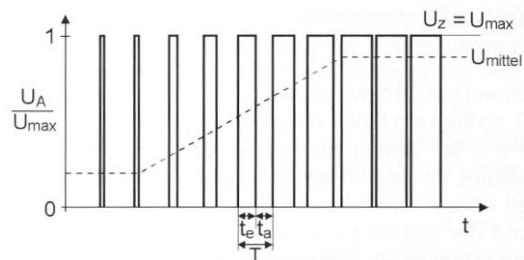


source: Roddeck, Einführung in die Mechatronik

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## Electric Drive Train

### DC Motor: Pulse Width Modulation of the Armature Voltage

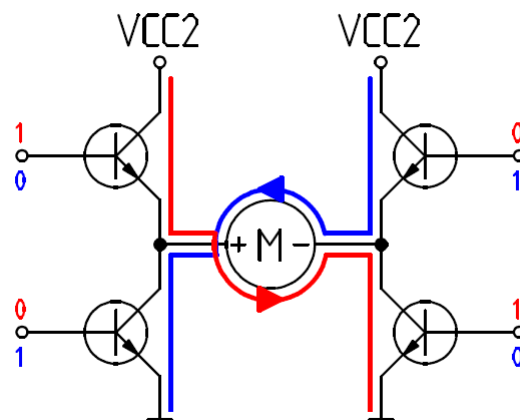


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source: Roddeck, Einführung in die Mechatronik

## Electric Drive Train

### DC Motor: using an H-bridge


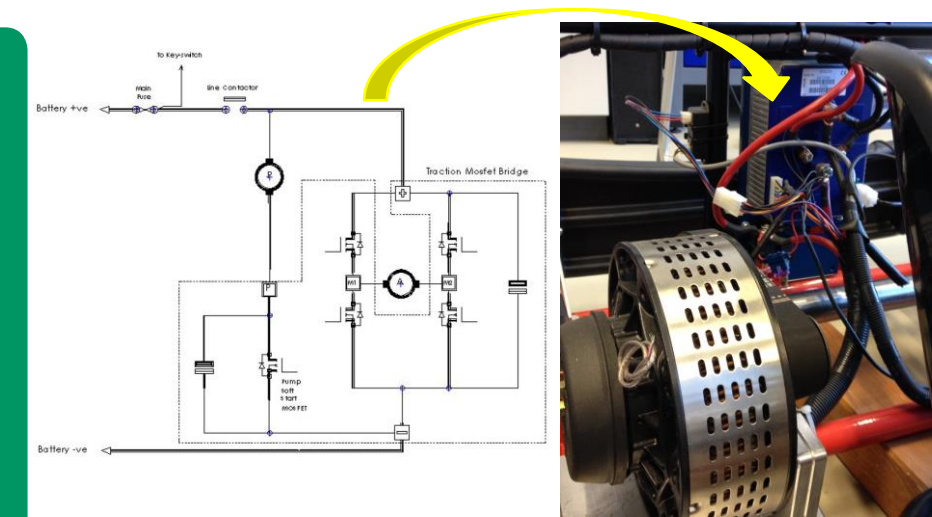


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source: www.polulu.com BASIC-Tiger Application Note No. 059

### Electric Drive Train

#### DC Motor: using an H-bridge as part of the Ekart drive train





source: Millipak 4QPM Controller Manual V1.01

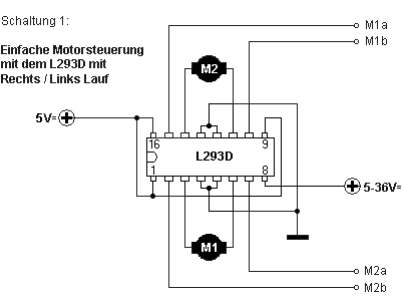
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### Electric Drive Train


#### DC motor: driver IC with H-bridge



Schaltung 1:  
Einfache Motorsteuerung mit dem L293D mit Rechts / Links Lauf

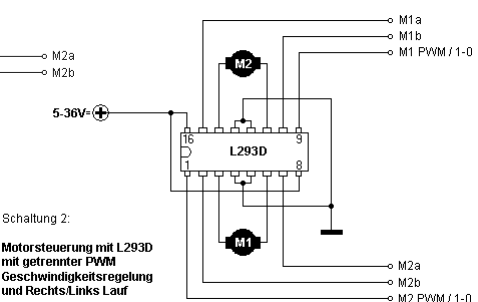


Ansteuerung des L293D mit TTL-Signalen	a	b
M1 oder M2	1	0
links	1	0
rechts	0	1
normaler Stop	0	0
sofortiger Stop	1	1



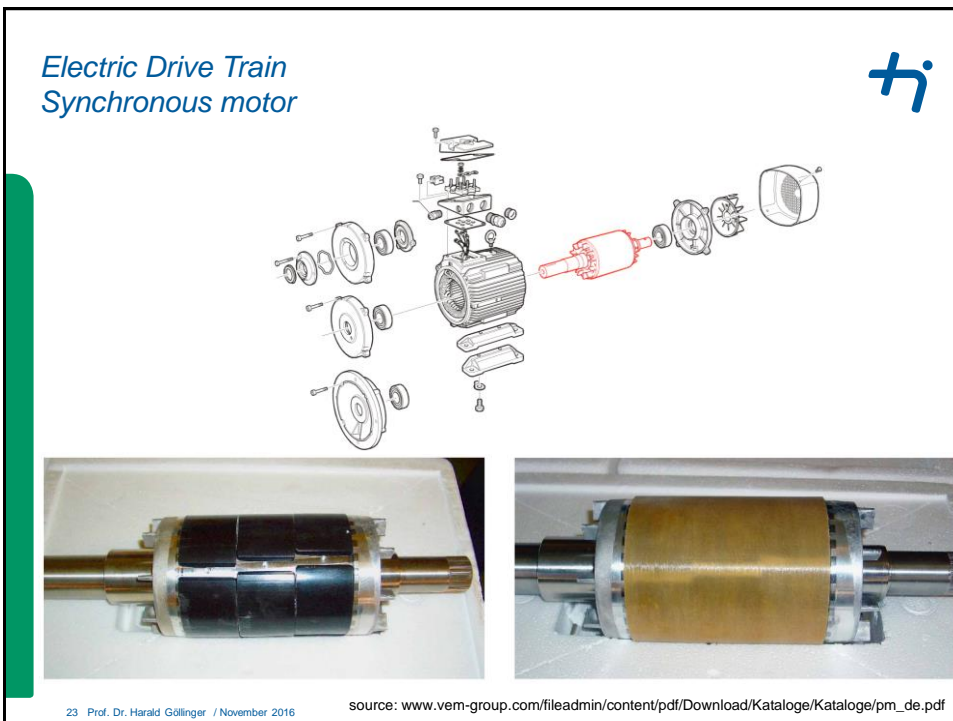
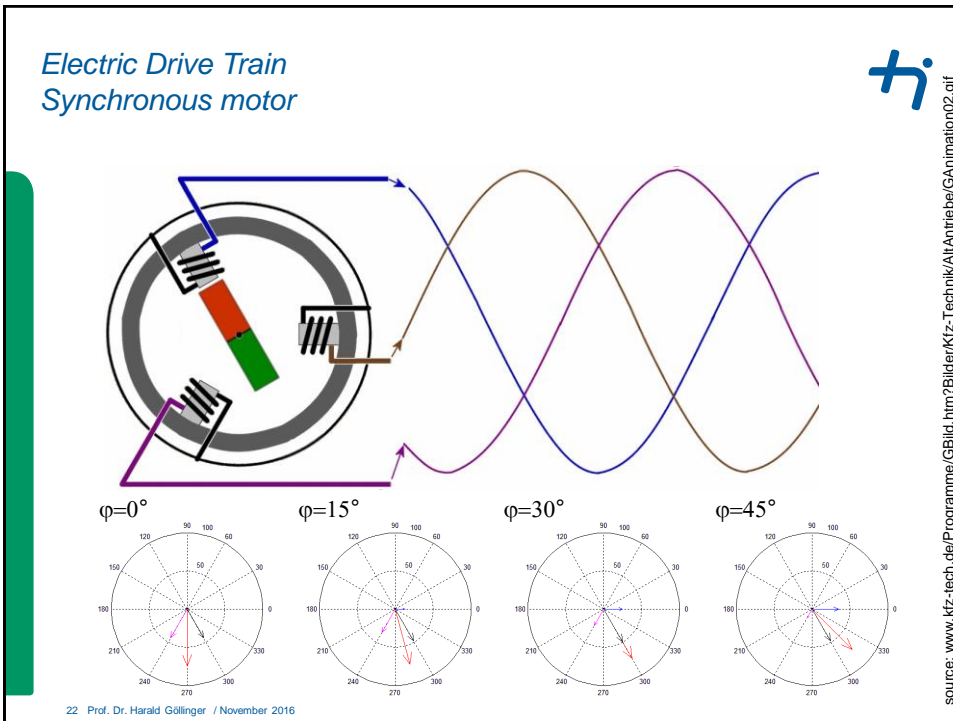
source: www.skilltronics.de

Schaltung 2:  
Motorsteuerung mit L293D mit getrennter PWM Geschwindigkeitsregelung und Rechts/Links Lauf


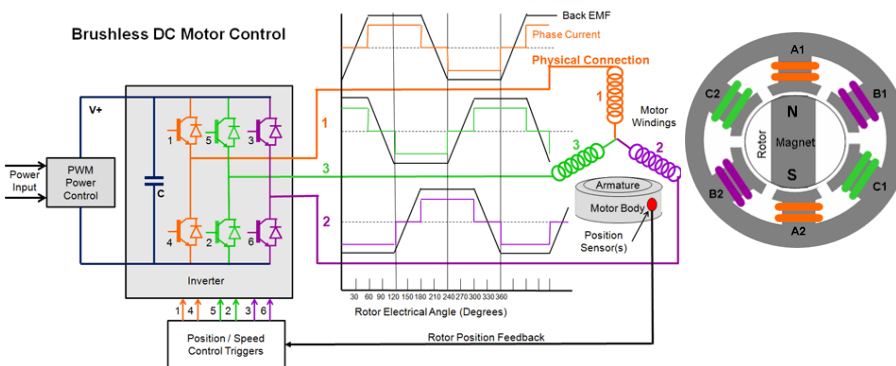


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### Electric Drive Train Synchronous motor: Brushless DC- Motor

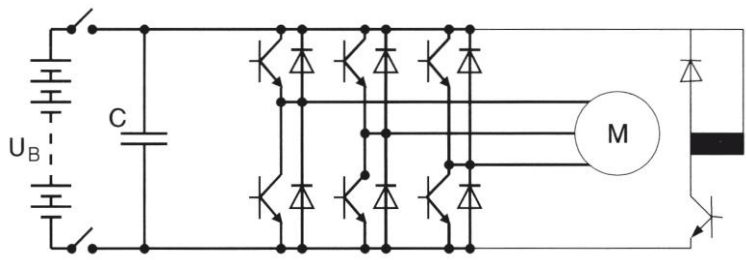



source: <http://www.mpoweruk.com/motorsbrushless.htm>  
[der-schweighofer.at](http://der-schweighofer.at) Elektromotor Motor Blade SR, Blade 200 SR X etc.

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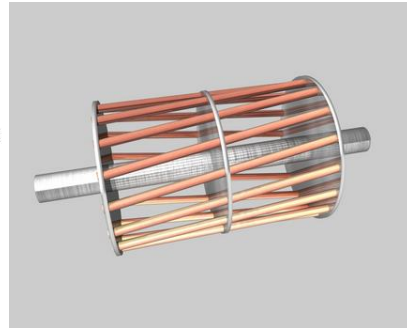
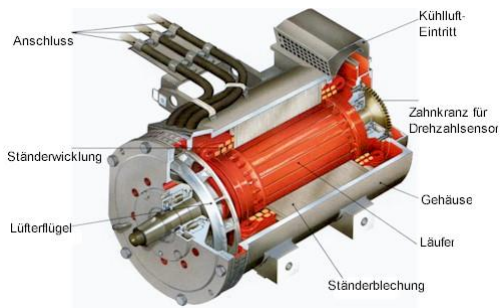
### Electric Drive Train Power electronics driving a synchronous motor

Three-phase ac motors are commonly used today in electric vehicles. Power electronics converts the dc voltage of the traction battery into ac voltages with variable amplitude and frequency.



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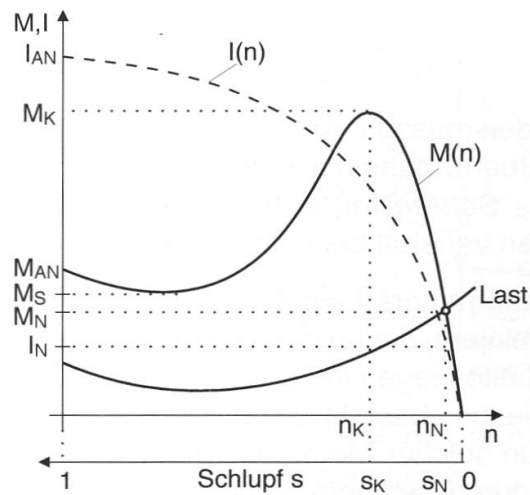
## Electric Drive Train Asynchronous motor



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source: [www.xplore-dna.net/mod/page/view.php?id=249](http://www.xplore-dna.net/mod/page/view.php?id=249)  
<http://www.hgaechter.ch/elmaschinen/asynmotor.htm>

## Electric Drive Train Asynchronous motor: turn rate vs. torque



source: Roddeck, Einführung in die Mechatronik

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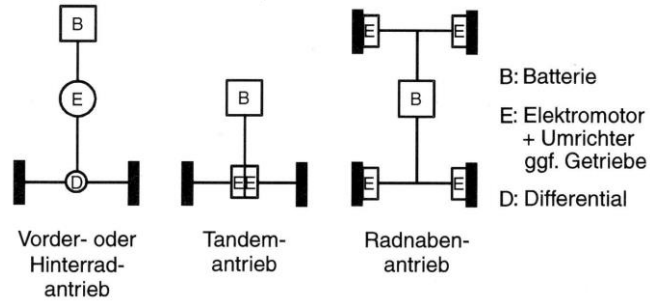
## Electric Drive Train The Drive Train



Traction battery with battery management and the required charger  
Electric motor with electronic control (inverter) and cooling  
optionally necessary gear and a differential  
Power transmission to the driving wheels

Ancillaries: steering and braking assistance, heating and air conditioning system  
Charging Dock or on-board charger

Variants of the powertrain:



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## Electric Drive Train Example: BMW i3



Source: [www.bloomberg.com/bw/articles/2013-11-21/bmw-bets-on-carbon-fiber-bodies-for-cars](http://www.bloomberg.com/bw/articles/2013-11-21/bmw-bets-on-carbon-fiber-bodies-for-cars)



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*Electric Drive Train*  
*Example: BMW i3*



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*Electric Drive Train*  
*Example: BMW i3*



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*Electric Drive Train*  
*Example: BMW i3*



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*Electric Drive Train*  
*Example: BMW i3*



Lithium-Ion battery  
Capacity of 22 Kwh  
125 kW/170 hp electrical motor  
Rear wheel drive  
Acceleration: 0-60mph in 7,2 s  
Top speed: 150 km/h  
Range: 130 - 160 kilometer

Range Extender:  
Gasoline engine drives a generator, range up to 340 km

35.000 – 40.000 €



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*Electric Drive Train*  
*Example: Tesla Model S*



source: [https://upload.wikimedia.org/wikipedia/commons/c3/2013\\_Tesla\\_Model\\_S\\_%282811322176214%29\\_cropped.jpg](https://upload.wikimedia.org/wikipedia/commons/c3/2013_Tesla_Model_S_%282811322176214%29_cropped.jpg)

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*Electric Drive Train*  
*Example: Tesla Model S*



source: Von jurvetson (Steve Jurvetson) - <http://www.flickr.com/photos/jurvetson/7408464122/in/photostream/>,  
 CC BY 2.0, <https://commons.wikimedia.org/w/index.php?curid=20007822>

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## Electric Drive Train

### Example: Tesla Model S 2016



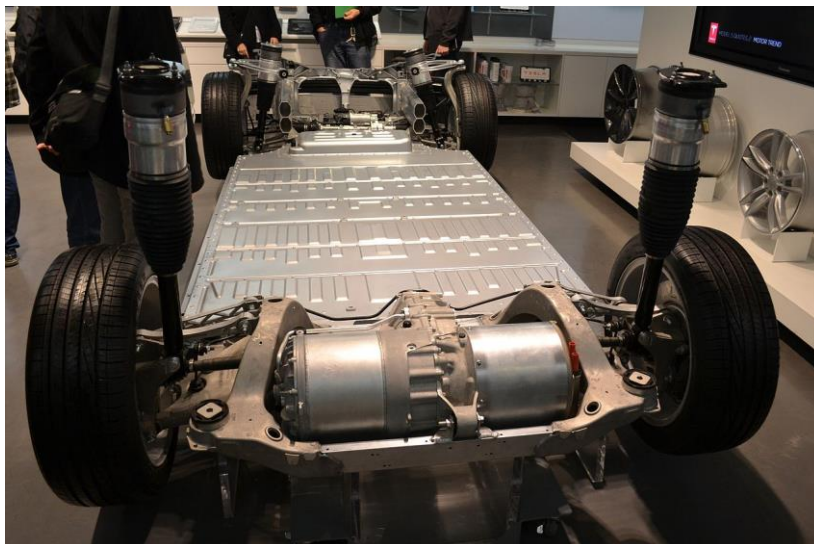
	<b>P90D</b>	<b>90D</b>	<b>75D</b>	<b>60D</b>
	<b>Performance</b> All-Wheel Drive	All-Wheel Drive	All-Wheel Drive Show rear wheel drive specs	All-Wheel Drive Show rear wheel drive specs
<b>Range</b>	316 miles (NEDC)	346 miles (NEDC)	304 miles (NEDC)	253 miles (NEDC)
<b>Acceleration</b>	2.8 seconds 0-60 mph (Ludicrous) 3.1 seconds 0-60 mph	4.2 seconds 0-60 mph	5.2 seconds 0-60 mph	5.2 seconds 0-60 mph
<b>Torque</b>	713 lb-ft	485 lb-ft	387 lb-ft	387 lb-ft
<b>Top Speed</b>	155 mph	155 mph	140 mph	130 mph
<b>Motor Power</b>	503 hp rear, 259 hp front 532 hp (Ludicrous) * 463 hp *	259 hp front and rear 417 hp *	259 hp front and rear 328 hp *	259 hp front and rear 328 hp *

source: [https://www.tesla.com/en\\_GB/models?redirect=no](https://www.tesla.com/en_GB/models?redirect=no)

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## Electric Drive Train

### Example: Tesla Model S drive train



source: [https://commons.wikimedia.org/wiki/File:Tesla\\_Motors\\_Model\\_S\\_base.JPG](https://commons.wikimedia.org/wiki/File:Tesla_Motors_Model_S_base.JPG)

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*Electric Drive Train*  
*Example: Tesla Model X*



source: <http://www.automobilemag.com/news/2016-tesla-model-x-p90d-review/>

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*Electric Drive Train*  
*Example: Tesla Model X*



source: <http://www.automobilemag.com/news/2016-tesla-model-x-p90d-review/>

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## Electric Drive Train

### Example: Tesla Model X



source: <http://www.automobilemag.com/news/2016-tesla-model-x-p90d-review/>

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## Electric Drive Train

### Example: Tesla Model X



	<b>P90D</b>	<b>90D</b>	<b>75D</b>	<b>60D</b>
	<b>Performance</b> All-Wheel Drive	All-Wheel Drive	All-Wheel Drive	All-Wheel Drive
<b>Range</b>	290 miles (NEDC)	303 miles (NEDC)	259 miles (NEDC)	220 miles (NEDC est.)
<b>Acceleration</b>	3.2 seconds 0-60 mph (Ludicrous) 3.8 seconds 0-60 mph	4.8 seconds 0-60 mph	6.0 seconds 0-60 mph	6.0 seconds 0-60 mph
<b>Torque</b>	713 lb-ft (Ludicrous) 612 lb-ft	485 lb-ft	387 lb-ft	387 lb-ft
<b>Top Speed</b>	155 mph	155 mph	130 mph	130 mph
<b>Motor Power</b>	503 hp rear, 259 hp front  532 hp (Ludicrous) * 463 hp *	259 hp front and rear  417 hp *	259 hp front and rear  328 hp *	259 hp front and rear  328 hp *

source: [https://www.tesla.com/en\\_GB/modelx](https://www.tesla.com/en_GB/modelx)

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## Electric Drive Train Example: Nissan LEAF



<http://www.nissan.co.uk/content/dam/services/gb/brochure/Leaf%20Brochure.pdf>

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## Electric Drive Train Example: Nissan LEAF



### 1. RAPID CHARGER

**30 MINS.** Go from 0-80% in approximately half an hour: rapid charging is the fastest battery boost available, making life easier and longer trips possible. The national network of rapid chargers is expanding all the time, for example at Nissan dealers and motorway service stations.



### 2. HOME CHARGING UNIT

**4-8 HOURS.** Charge your Nissan LEAF overnight using a Home Charging Unit and reach full charge in approximately 8 hours, or even 4 hours with the optional 6.6kW on-board charger. Be sure to have your Home Charging Unit installed by an approved electrician.



### 3. CABLE + DOMESTIC PLUG

**12 HOURS.** Use your Nissan EVSE cable to charge your LEAF where you like – at public charging stations, at work or at home (so long as the domestic socket is on a professionally installed dedicated circuit). Providing 10A power, it will charge from empty to full in approximately 12 hours.

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<http://www.nissan.co.uk/content/dam/services/gb/brochure/Leaf%20Brochure.pdf>

**Electric Drive Train**  
*Example: Nissan LEAF: software*



<http://www.nissan.co.uk/content/dam/services/gb/brochure/Leaf%20Brochure.pdf>

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**Electric Drive Train**  
*Example: Nissan LEAF: how do you sell this car?*



Doorplan	Grade	Engine	Transmission	Basic	VAT	Total Retail Price	On The Road Price	On The Road Price after Government Incentive*
5 door	VISIA	80kW AC Electric Motor	Single Reduction Gear (Auto)	21,612.50	4,322.50	25,935	25,990	20,990
	ACENTA	80kW AC Electric Motor	Single Reduction Gear (Auto)	23,695.83	4,739.17	28,435	28,490	23,490
	TEKNA	80kW AC Electric Motor	Single Reduction Gear (Auto)	25,362.50	5,072.50	30,435	30,490	25,490

Basic and Total Retail includes delivery to the dealership and number plates. On the road price includes £55 government first registration fee.  
 \* Government applied Ultra Low Carbon Car Consumer Incentive (referred to as 'Government Incentive') of £5000 can be applied to LEAF sales between January 2011 and May 2015.

<http://www.nissan.co.uk/content/dam/services/gb/brochure/Leaf%20Brochure.pdf>

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## Electric Drive Train

Example: Nissan LEAF: how do you sell this car?



### NEW LEAF FLEX - (Battery Leasing)

Doorplan	Grade	Engine	Transmission	Basic	VAT	Total Retail Price	On The Road Price	On The Road Price after Government Incentive**
5 door	VISIA FLEX	80kW AC Electric Motor	Single Reduction Gear (Auto)	17,445.83	3,489.17	20,935	20,990	15,990
	ACENTA FLEX	80kW AC Electric Motor	Single Reduction Gear (Auto)	19,520.17	3,905.83	23,435	23,490	18,490
	TEKNA FLEX	80kW AC Electric Motor	Single Reduction Gear (Auto)	21,195.83	4,239.17	25,435	25,490	20,490

Basic and Total Retail includes delivery to the dealership and number plates. On the road price includes £55 government first registration fee.

\*\* Government applied Ultra Low Carbon Car Consumer Incentive (referred to as 'Government Incentive') of £5000 can be applied to LEAF sales between January 2011 and May 2015.

\* Price excludes obligatory monthly battery rental

Contract Term*	Monthly Battery Rental including VAT	Annual Mileage*			
		7,500 miles	9,000 miles	10,500 miles	12,000 miles
36 months and over	£70	£77	£85	£93	£109
24 months	£80	£87	£95	£103	£119
12 months	£90	£97	£105	£113	£129

\* Additional combinations of contract term and annual mileage are available.

Monthly Battery Rental includes Roadside Assistance for all breakdowns. Battery Lease contract provided by RCI Financial Services Ltd t/a Nissan Finance and is subject to status. Excess mileage is charged at £7.50 incl VAT/100 miles or part thereof. Terms and conditions apply.

<http://www.nissan.co.uk/content/dam/services/gb/brochure/Leaf%20Brochure.pdf>

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## Electric Drive Train

Example: VW e-up!



0-100 km/h:	12,4 s (gasoline 13,2 s)
Torque:	210 Nm (gasoline: 171 Nm)
Electrical motor:	60 kW/82 hp (gasoline: 55 kW/75 hp)
Battery:	Lithium-Ion battery with 18,7 kWh
Range:	160 km
Weight:	1130 kg (gasoline: 1030 kg)
Cost:	less than 3€ / 100 km (gasoline: 6,68 € / 100 km)

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<http://www.auto-motor-und-sport.de/bilder/preis-vw-e-up-elektro-kleinwagen-ab-26900-euro-7412056.html>

*Electric Drive Train*  
*Example: Mitsubishi iMiEV*



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*Electric Drive Train*  
*Example: Renault Zoe*



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## Electric Drive Train Example: Renault Zoe



<http://www.autobild.de/bilder/renault-zoe-im-test-4290949.html#bild0>|[ref=http://www.autobild.de/artikel/renault-zoe-test-4290633.html](http://www.autobild.de/artikel/renault-zoe-test-4290633.html)

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## Electric Drive Train Example: Renault Zoe



Motor:	3-phase synch. motor
Battery:	Lithium-Ion
Battery capacity:	22 kWh/65 Ah
Continuous power:	43 kw (58 hp)
Max. power:	65 kw (88 hp)
Max. torque:	220 Nm
Max velocity:	135 km/h

Front wheel drive

Range: 184 km

Price: 21.700 € (+ 79 €/month rent for the battery)



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*Electric Drive Train*  
*Example: Renault Twizy*



<http://www.renault.de/renault-modellpalette/ze-elektrofahrzeuge/twizy/twizy/galerie/>

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*Electric Drive Train*  
*Example: Renault Twizy*



<http://www.renault.de/renault-modellpalette/ze-elektrofahrzeuge/twizy/twizy/galerie/>

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## Electric Drive Train

### Example: FIA Formula E



**2014–15** 11 races held in 10 different cities



All teams were supplied with the Spark-Renault SRT 01E (chassis by Dallara, electric motor by McLaren, battery system by Williams, tyres by Michelin)

**2015–16** 10 races in 9 different cities.

For this season eight manufacturers were allowed to develop new powertrains.

**2016–17** new season starts in October 2016

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[https://commons.wikimedia.org/wiki/File:Spark-Renault\\_SRT\\_01\\_E\\_@Frankfurt\\_2013\\_Lucas\\_dj\\_Grassi.JPG](https://commons.wikimedia.org/wiki/File:Spark-Renault_SRT_01_E_@Frankfurt_2013_Lucas_dj_Grassi.JPG)

## Electric Drive Train

### Example: Audi starts in Formula E



**2016-17 season:** Audi expands its partnership with Formula E Team ABT Schaeffler Audi Sport



**2017-18 season:** Audi also announced plans to launch its own factory-backed motorsport program

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[https://fortune.com.files.wordpress.com/2016/09/at168969\\_medium.jpg?w=840&h=485&crop=1](https://fortune.com.files.wordpress.com/2016/09/at168969_medium.jpg?w=840&h=485&crop=1)

## Electric Drive Train

### Example: FIA Formula E Roborace



motor racing series for driverless cars  
Part of the Formula E championship support package from the 2016-17 season.



From [carmagazine.co.uk](http://carmagazine.co.uk):  
"The organisers say the series will showcase the safety of autonomous cars and their potential ability to perform extreme manoeuvres when required, helping to build public confidence in driverless technology in the process."

Source: [www.carmagazine.co.uk/car-news/motoring-issues/2016/roborace-car-revealed-meet-the-fias-autonomous-racing-58roborace](http://www.carmagazine.co.uk/car-news/motoring-issues/2016/roborace-car-revealed-meet-the-fias-autonomous-racing-58roborace)  
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<http://le-formel.de/news/technikanalyse-so-funktioniert-ein-roborace-2346.html>

## Electric Drive Train

### ... is a very old idea!



1859 Raymond Louis Gaston Planté invents the rechargeable lead accumulator

1866 Werner von Siemens invents the DC motor with electromagnet

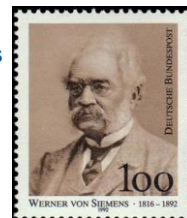
1881 Gustave Trouvé presents an electrical car on a trade show in Paris, that is fully operational and suitable for everyday use

1860 Christian Reithmann and  
1862 Alphonse Beau de Rochas  
file patents for a four cycle engine

1876 the Otto motor is introduced to the market

1886 Karl Friedrich Benz files a patent for a vehicle with a combustion engine

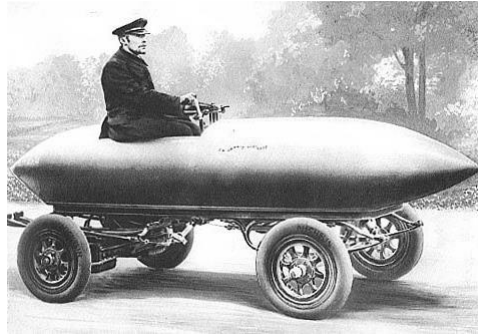
1892 Rudolf Diesel files a patent for a „Neue rationelle Wärmekraftmaschine“



## Electric Drive Train ... is a very old idea!



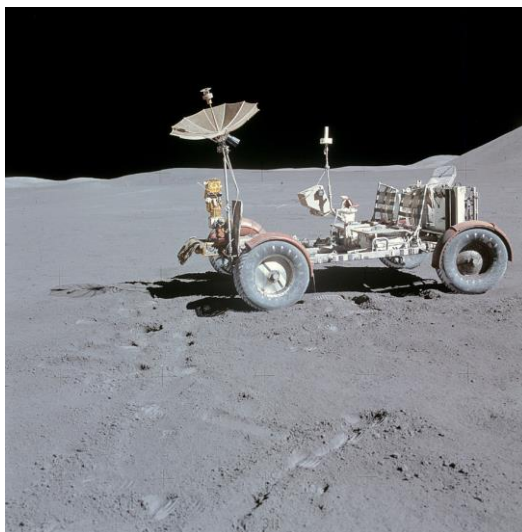
In 1899, Camille Jenatton set a speed record with „La Jamais Contente“ of more than 100 km/h, exactly 105,882 km/h.  
(2 motors with 25 kW each)



source: [www.wikipedia.de](http://www.wikipedia.de)

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## Electric Drive Train History: Lunar Roving Vehicle



4 wheel hub motors, 200 W each,  
2 motors for steering, 100 W each,  
2 silver zinc potassium hydroxide  
batteries 36V with 121 Ah

source: [www.wikimedia.org](http://www.wikimedia.org)

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*Electric Drive Train  
History: Electric Cars of the '90s*



source: wikipedia.de

source: wikipedia.de



source: cityei.de



source: wikipedia.de

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*Electric Drive Train  
Electric Drive Trains in everyday life*



sources: www.forklift.de, www.directindustry.de, www.otto.de, www.kettler.de, www.quantya.us

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## Electric Drive Train

### Electric Drive Trains in everyday life



sources: www.wikipedia.de

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## Electric Drive Train

### History: Tesla Roadster



215 kW (292 hp), 370 Nm - 400 Nm  
 0-60 mph in 3,7 s  
 Vmax 125 mph (201 km/h)

source: www.teslamotors.com

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### Electric Drive Train

Big companies try out the „new“ idea of electric drive trains



source: [www.focus.de](http://www.focus.de)



source: [www.welt.de](http://www.welt.de)



sources: [www.rp-online.de](http://www.rp-online.de)