JAGUAR

LAND ROVER

WBG Devices in Automotive
Areas to Target

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About Me

- Luke Evans
- Principal Engineer with specialist knowledge of Power Electronics
- Hybrid and Electric vehicles
- >10 years, past 7 of which in automotive sector

Please note that points raised today are my own technical opinion. They do not reflect the corporate veiw of JLR. Due to confidentiality I cannot disclose which future direction JLR may take, however I can provide an industry insight from an active particiapant

Automotive Power Electronics

- Power Electronics is all over the car!
- Braking system
- Electric super charger
- Electric Power Steering
- 12V load management
- Actuators
- Hybrid Electric Vehicles
  - > Charger
  - > DCDC
  - > Electric Air-Con
  - > Traction Inverter
  - > And so on…….

Focus of Presentation

Focus of Todays Presentation:

- Chargers
  - AC- DC for EV/PHEV/HEV charging
- DCDC
  - 48V-12V and 300V-12V
- Inverters
  - Traction inverters for EV/PHEV/HEV

Why Electrify Vehicles?

CO2 Emissions Targets

2015 Laws

- The law requires that the new cars registered in the EU do not emit more than an average of **130 grams** of CO_2 per kilometre (g CO_2/km) by 2015.
- This means a fuel consumption of around 5.6 litres per 100 km (l/100 km) of petrol or 4.9 l/100 km of diesel.

Why Electrify Vehicles?

CO2 Emissions Targets

2021 Laws

- By 2021, phased in from 2020, the fleet average to be achieved by all new cars is **95 grams** of CO_2 per kilometre.
- This means a fuel consumption of around 4.1 l/100 km of petrol or 3.6 l/100 km of diesel.
- The 2015 and 2021 targets represent reductions of 18% and 40% respectively compared with the 2007 fleet average of 158.7g/km.

Why Electrify Vehicles?

Non-compliance is expensive…..

If the average CO_2 emissions of a manufacturer's fleet exceed its limit value in any year from 2012, the manufacturer has to pay an **excess emissions premium** for each car registered.

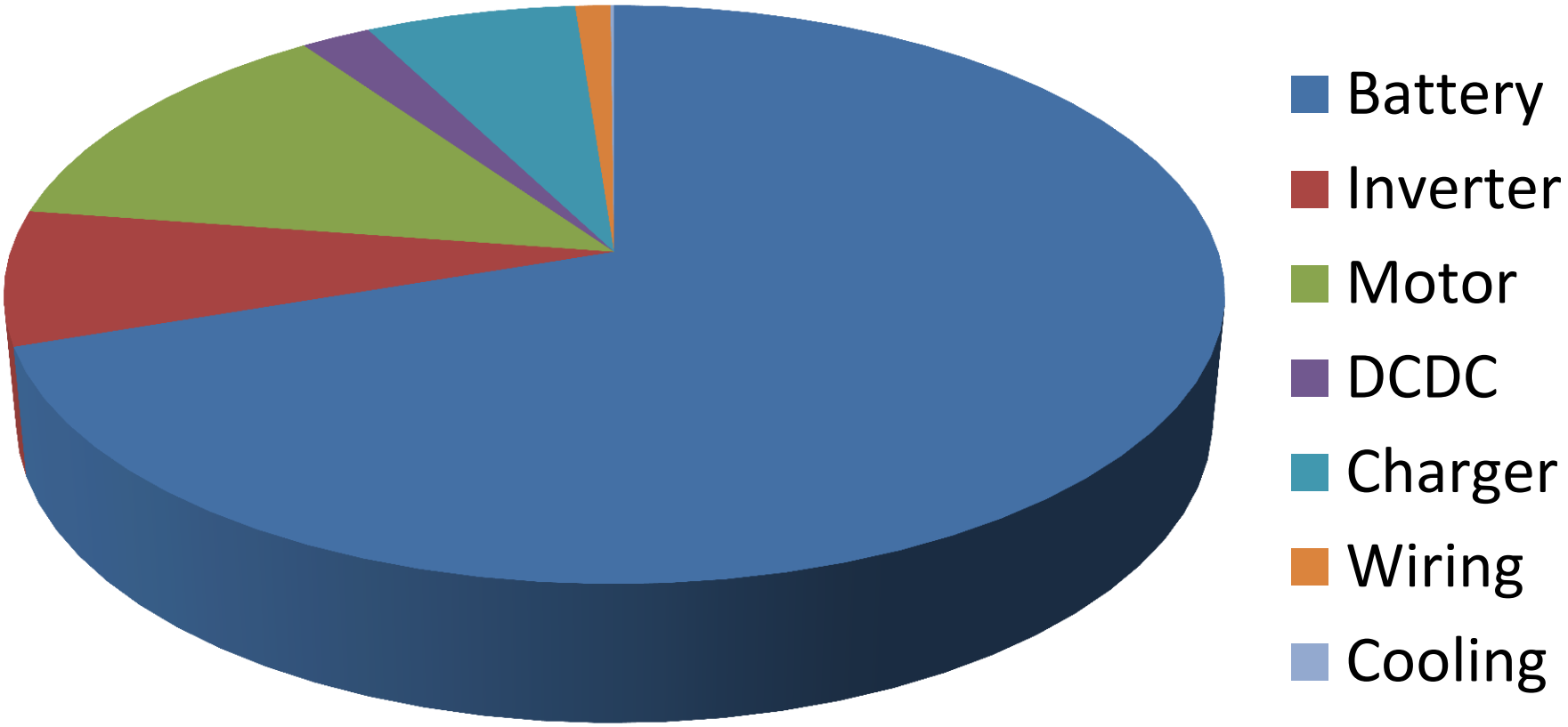
- This premium amounts to
- €5 for the first g/km of exceedance
- €15 for the second g/km
- €25 for the third g/km
- €95 for each subsequent g/km.
- From 2019, the cost will be €95 from the first gram of exceedance onwards.

Hybrid System Cost

Main Components of Hybrid System:

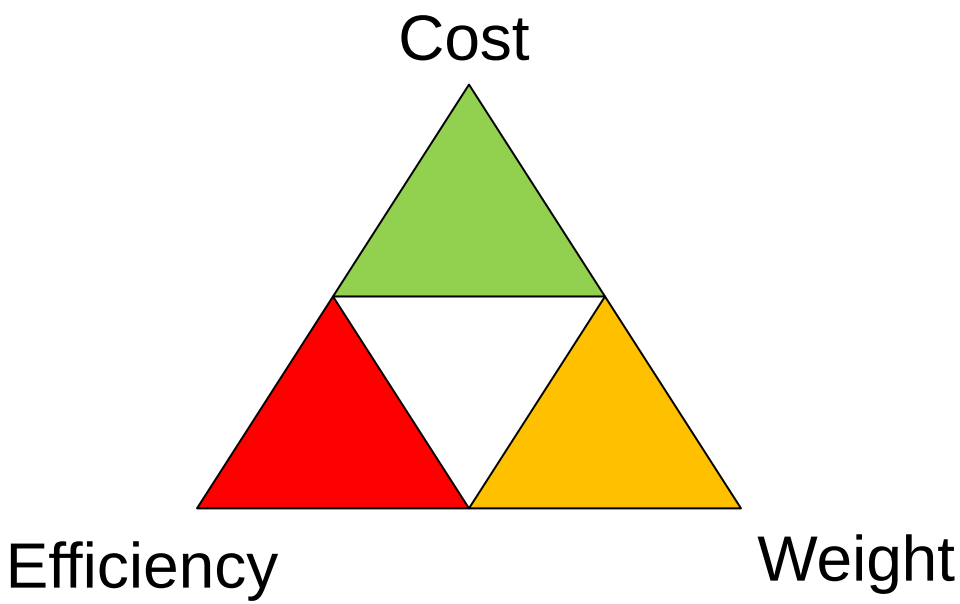
- E-Machine
- HV Battery
- HV Battery and Electronics
- Inverter
- Charger
- DCDC Converter
- EDS
- Cooling System

HV System Cost

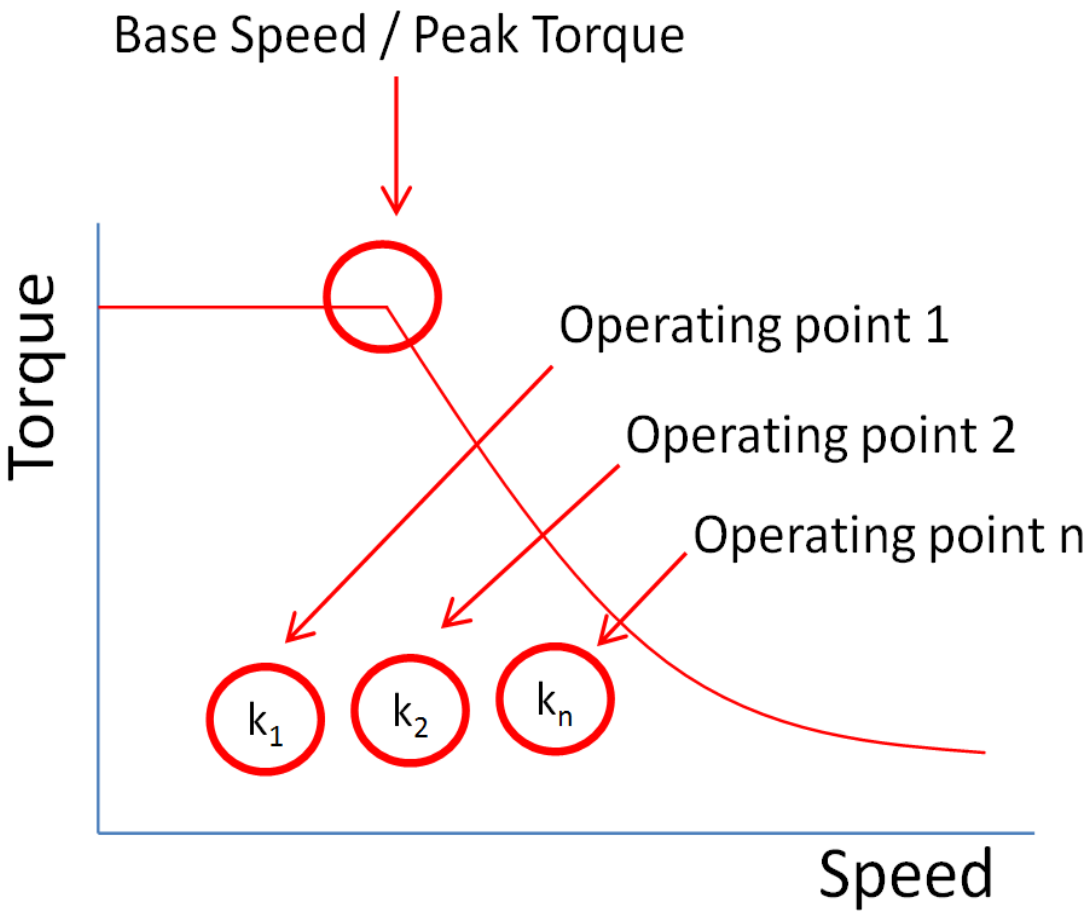


How can WBG Help?

- HV Battery is highest cost part
- Smaller battery = less range
- Smaller battery with less weight = same range



Inverter Operating Regions



- System sizing calls for inverter to be able to operate at base speed, peak torque
- However, rarely spent at operating point

Inverter Operating Regions

Torque [Nm]	RPM 25	74	123	172	221	270	319	368	417	466	515	564	613	662	711	760	809	858	907	956	1005
1785	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1683	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1581	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1479	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1377	0.0%	0.0%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1275	0.0%	0.0%	0.1%	0.6%	1.0%	0.7%	1.1%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1173	0.0%	0.0%	0.3%	0.4%	0.2%	0.3%	0.7%	0.4%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1071	0.0%	0.0%	0.4%	0.3%	0.8%	0.4%	0.3%	0.0%	[illegible]	0.0%	0.0%	0.0%	0.0%	[illegible]	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
969	[illegible]	0.1%	[illegible]	0.7%	0.6%	0.8%	0.8%	0.5%	[illegible]	[illegible]	0.0%	0.3%	0.3%	[illegible]	[illegible]	0.0%	0.0%	0.0%	[illegible]	0.0%	0.0%
867	[illegible]	[illegible]	[illegible]	0.3%	0.8%	1.0%	0.5%	0.9%	[illegible]	0.4%	0.6%	0.2%	0.3%	[illegible]	0.0%	0.0%	0.0%	0.0%	[illegible]	0.0%	0.0%
765	[illegible]	0.1%	0.2%	0.7%	1.1%	0.9%	0.7%	0.5%	[illegible]	0.2%	0.4%	0.0%	0.0%	[illegible]	0.0%	0.0%	0.0%	0.0%	[illegible]	0.0%	0.0%
663	0.0%	0.2%	0.3%	0.8%	0.4%	0.6%	1.0%	0.5%	[illegible]	0.8%	0.8%	0.0%	0.0%	[illegible]	0.0%	0.2%	1.0%	[illegible]	[illegible]	[illegible]	0.0%
561	0.0%	0.1%	0.3%	0.5%	0.6%	1.0%	0.9%	0.8%	[illegible]	0.7%	0.0%	0.6%	0.5%	[illegible]	0.0%	0.6%	1.1%	1.8%	0.7%	0.0%	0.0%
459	0.0%	0.0%	0.3%	0.4%	0.4%	0.3%	0.6%	0.8%	0.5%	1.5%	0.8%	0.8%	0.5%	0.7%	0.8%	0.0%	0.7%	0.7%	2.4%	3.9%	0.0%
357	0.0%	0.1%	0.3%	0.4%	0.2%	0.4%	0.4%	0.7%	1.1%	1.0%	0.3%	0.4%	0.0%	0.8%	1.3%	0.4%	0.7%	0.5%	0.6%	5.1%	0.2%
255	0.0%	0.1%	0.3%	0.2%	0.3%	0.2%	0.5%	0.9%	1.3%	1.2%	0.5%	1.4%	1.1%	0.0%	3.0%	0.2%	0.9%	0.8%	0.4%	1.0%	0.0%
153	0.0%	0.0%	0.2%	0.1%	0.2%	0.1%	0.3%	0.5%	1.0%	0.5%	0.3%	1.3%	0.8%	0.1%	0.7%	0.2%	0.3%	0.3%	0.3%	0.1%	0.0%
51	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.1%	0.0%	0.2%	0.3%	0.3%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%

$\sum = 74\%$

$\sum = 9\%$

$\sum = 8.2\%$

$\sum = 15.8\%$

74% of driving time spent at 3 key operating points:

- Urban (Round town driver)
- Rural (A and B roads)
- Motorway (High speed driving)

How WBG can help

- We need ability to deliver very high torque and power for short periods of time
- We need to have a wide efficency region as spend most of the time in that region
- When spending time in the lower power regions, cooling system is not working hard and is also more efficent
- WBG with high operating temperatures for short periods would allow downsizing of the cooling system for peak power/torque events
- WBG would allow higher voltage operation which would improve motor efficiency.

There is a price….

COST!

- Increase in cost of inverter must be reflected by a lower system cost.
- Cost is the key driver for automotive sector

However….

- Reduction in component size (e.g through reduced cooling) has other advantages…

Competitor Vehicle Boot Space

Non Hybrid Variant

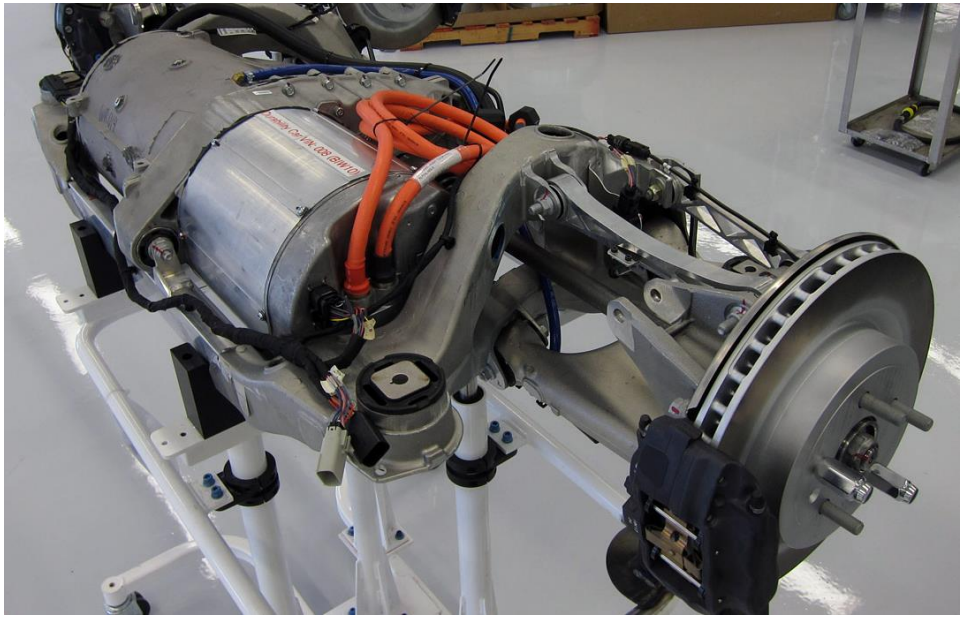
Large floor space

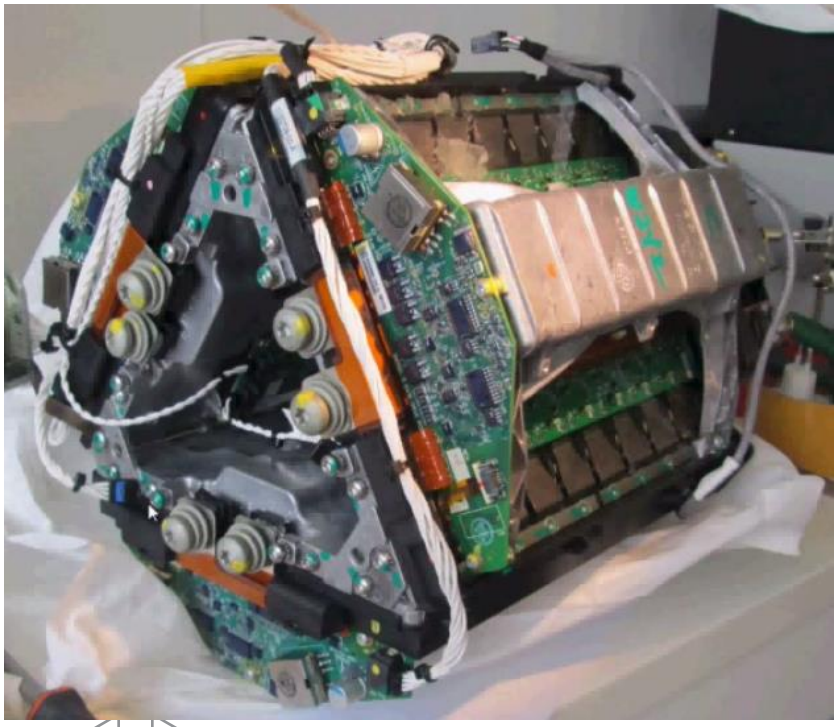
Hybrid Variant

Reduced floor space

Inverter – Motor Integration

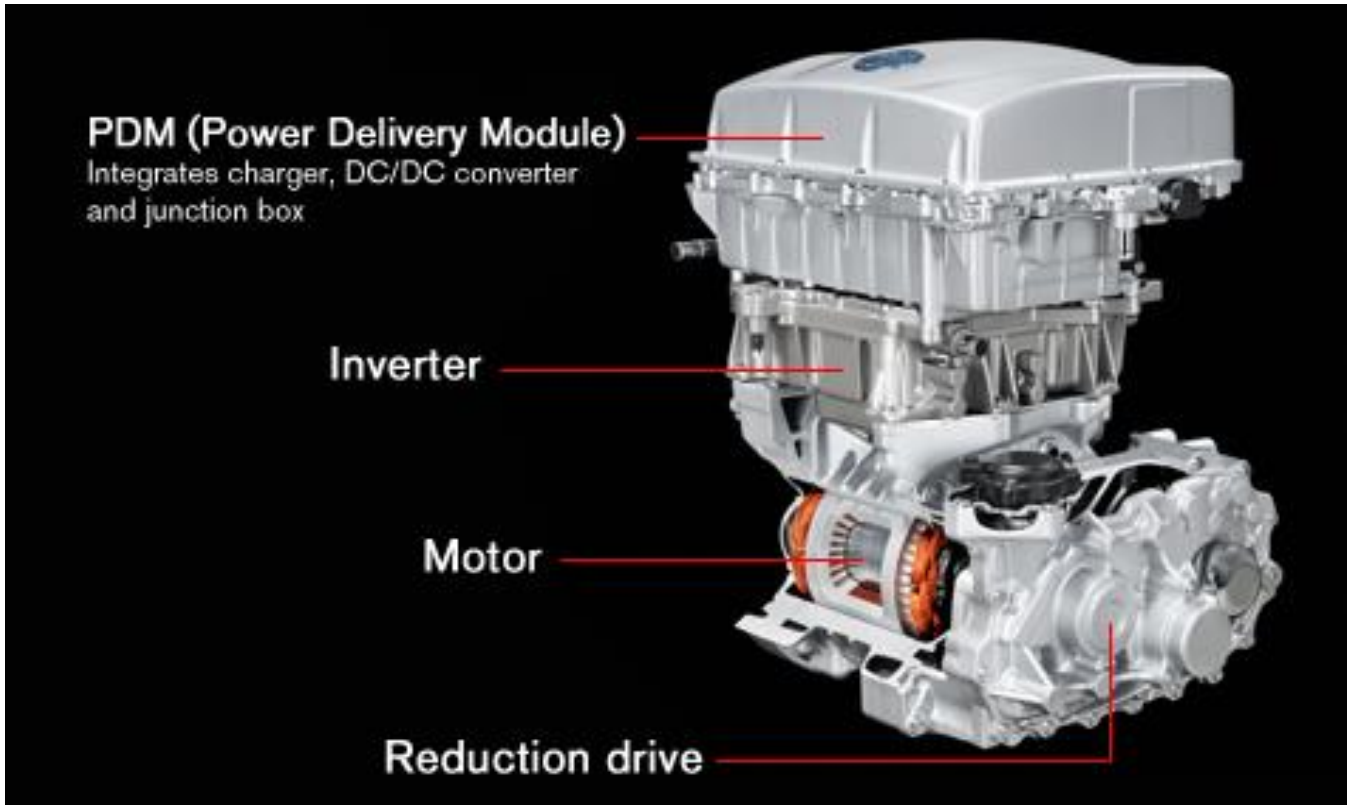
Tesla Model S





Inverter – Motor Integration

- Nissan Leaf:



Advantages

- Speed of assembly into vehicle
- No HV cabling and expensive connectors
- EMC is easier to manage
- Reduce mass

How WBG can help?

- Higher temperature operation
  - > Thermal differences between inverter and motor less problematic
  - > Single cooling circuit with main ICE to reduce cost
- Higher switching frequency (~25kHz) reduces DC link capacitor volume
- Higher switching frequency allows faster motor speed and smaller motor

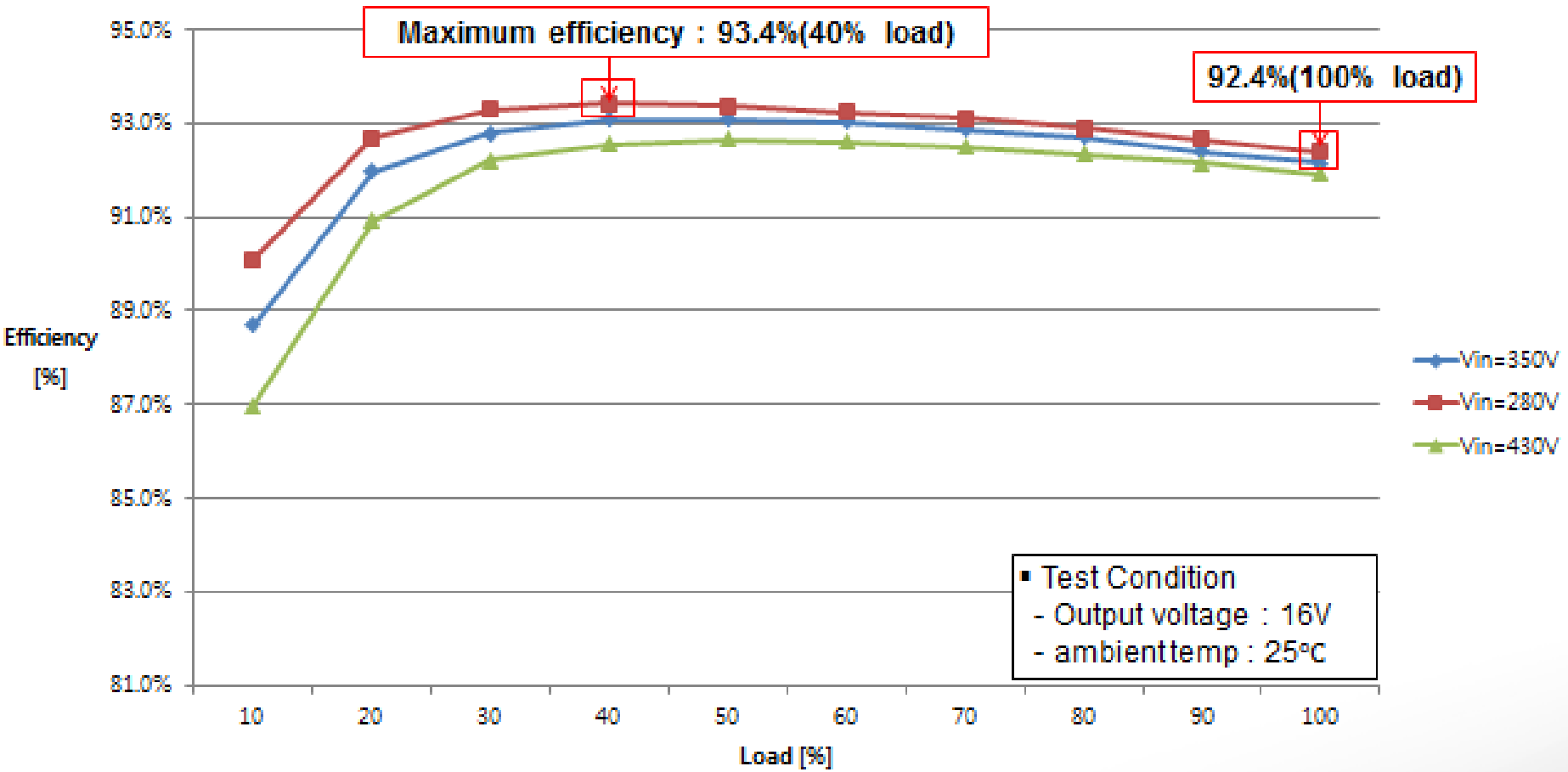
DCDC Converters

Typical Specs:

- 200-400V Input range
- 12V Output
- 2-3kW
- Isolated conversion
- Mass 3-4kg
- Water cooled
- ~94% Efficient

- 32V-52V Input range
- 12V Output
- 2-3kW
- Non Isolated conversion
- Mass 2kg
- Air cooled
- ~94% Efficient

Efficecny Curve



Automotive Wants…

- Smaller DCDC (Less weight)
- No water cooling
- Higher peak efficiency
- Flatter efficiency curve

How WBG can help?

- Higher switching frequencies
- Smaller magnetics
- Higher effiencies
  - > Either removes water cooling (air cooled)
  - > Or same volume and no cooling

Don’t forget the golden rule of cost!

On Board Chargers Current Status

- Key Stats
  - 7kW AC Charging
  - 100kW DC Charging
  - Tri-Standard (IEC, SAE, GBT)
  - AC→DC Efficiency: ~93%
  - Weight = 11kg

Future Wants

- Charger is dead weight during driving
  - Mass reduction
  - Higher power = faster charge time
  - High temperature operation not required
- Faster charge times

Final Requests

- Cost is key in automotive
- If WBG is be used then cost benefit must be clear
  - Component cost
  - System cost
  - Attribute improvements
- Reliablity must not be reduced
  - 15 year lifetime
  - 8000h of driving

Hybrid Vehicle Capability

If you thought that HEV where small city cars, think again…..

http://www.landrover.co.uk/above-and-beyond/the-silk-route.html