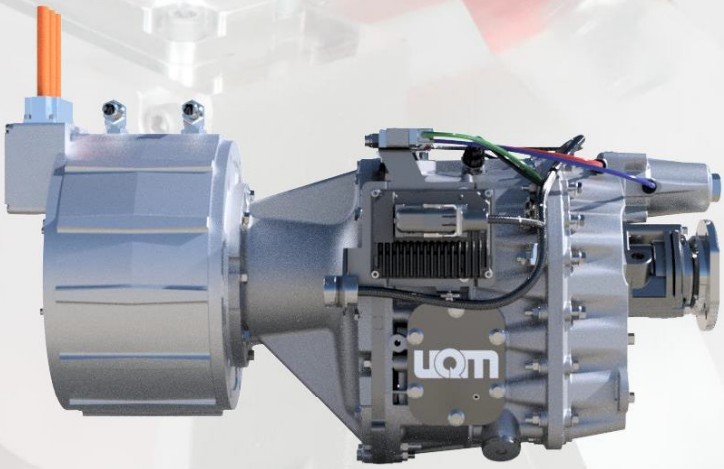
System Specification



UQM PowerPhase®DT Drivetrain

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1. POWERPHASE®DT DRIVETRAIN TECHNICAL OVERVIEW

The UQM **PowerPhase® Drivetrain 250HD** complete with 2-speed transmission has been proven in the field with over 2 million miles of operation. Furthermore, it has been proven to be the highest efficiency electric drivetrain on the market today, allowing 10-15% higher efficiency at the vehicle level when tested against other transit bus EVs in Altoona testing trials (see Altoona press release 2015). The proposed drive system is much smaller than competing direct drive solutions, allowing better packaging and more payload capacity due to weight saving. The smaller size and mass is due to the advanced UQM motor and control technology coupled with the torque multiplying function of the transmission. Another benefit of 2-speed transmissions is the ability to keep the e-motor in **the highest efficiency operation region over more of the vehicle's drive cycle**…resulting in higher vehicle efficiency and battery cost savings.

The UQM PowerPhase®DT Drivetrain system results in the following benefits as compared to alternative drivetrain solutions available:

- Total drivetrain volume is **32% less** than alternative direct drive motors.
- Total drivetrain weight is **53% less** than alternative direct drive motors.
- Drivetrain efficiency (DC input to power/torque output) 90% plus at output speed of 1415rpm. More efficient than alternative direct drive motors, resulting in improved range or need for less batteries.
- Proven drivetrain system in transit bus applications – Over 2 million on-the-road miles and best-in-class, **record setting performance** and **reliability** as demonstrated with UQM customer in the Altoona testing trials in 2015.
- UQM proprietary software that provides increased power and efficiency.

1.1 CALIBRATION SUPPORT

The following section lays out our UQM calibration/support methodology for working with customers.

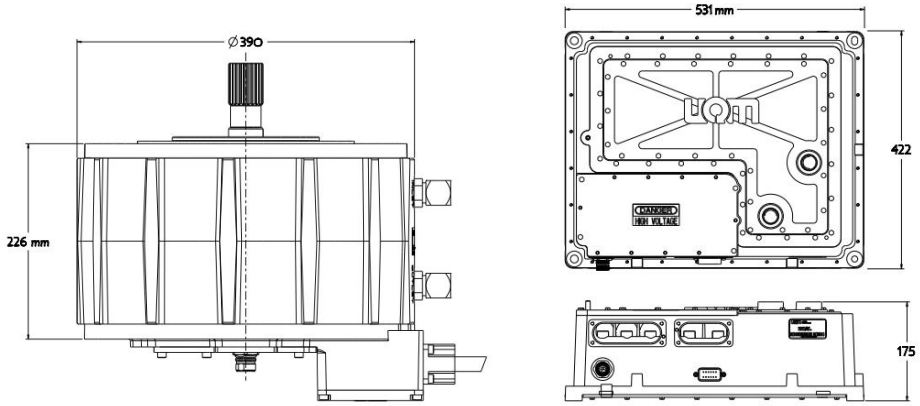
UQM Technical Support

- Software calibration for Transmission Controller (TCU) and Motor Controller (MCU) to maximize drivability and efficiency.
- Vehicle Control Unit (VCU) calibration with UQM partner or customer VCU vendor.
- Vehicle testing and commissioning.
- Drivetrain mechanical and electrical installation review.
- Vehicle software calibration refinement and final calibration and tuning before launch.

1.3 TECHNICAL SOLUTION – UQM DRIVETRAIN SYSTEM

The components of the system consist of the following:

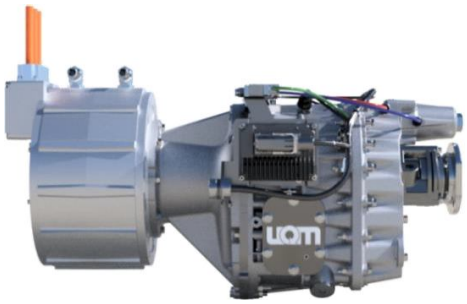
- **UQM PowerPhase® 250HD E-Motor Motor and Inverter**



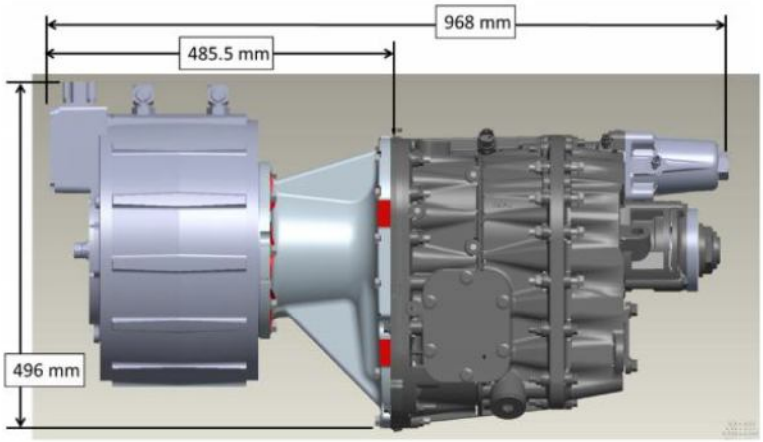
Dimensions:

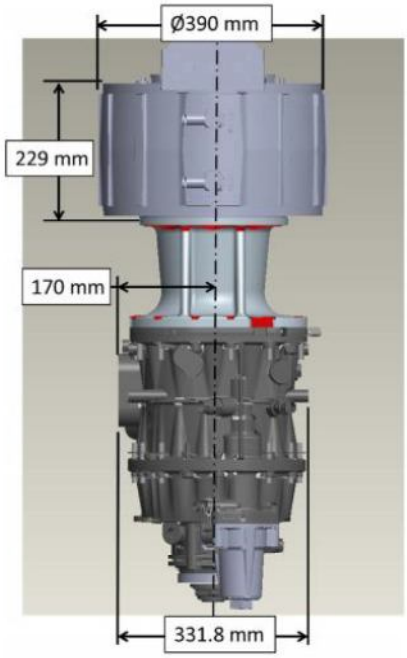
531mm by 422mm by 175mm
Weight: 40 kg

- **UQM PowerPhase® 250HD E-Motor and 2-Speed Transmission Assembly**



E-motor Weight: 85 kg
Transmission Weight: 92 kg





2. PERFORMANCE SPECIFICATION

Performance Highlights of the **UQM PowerPhase®DT 250HD**:

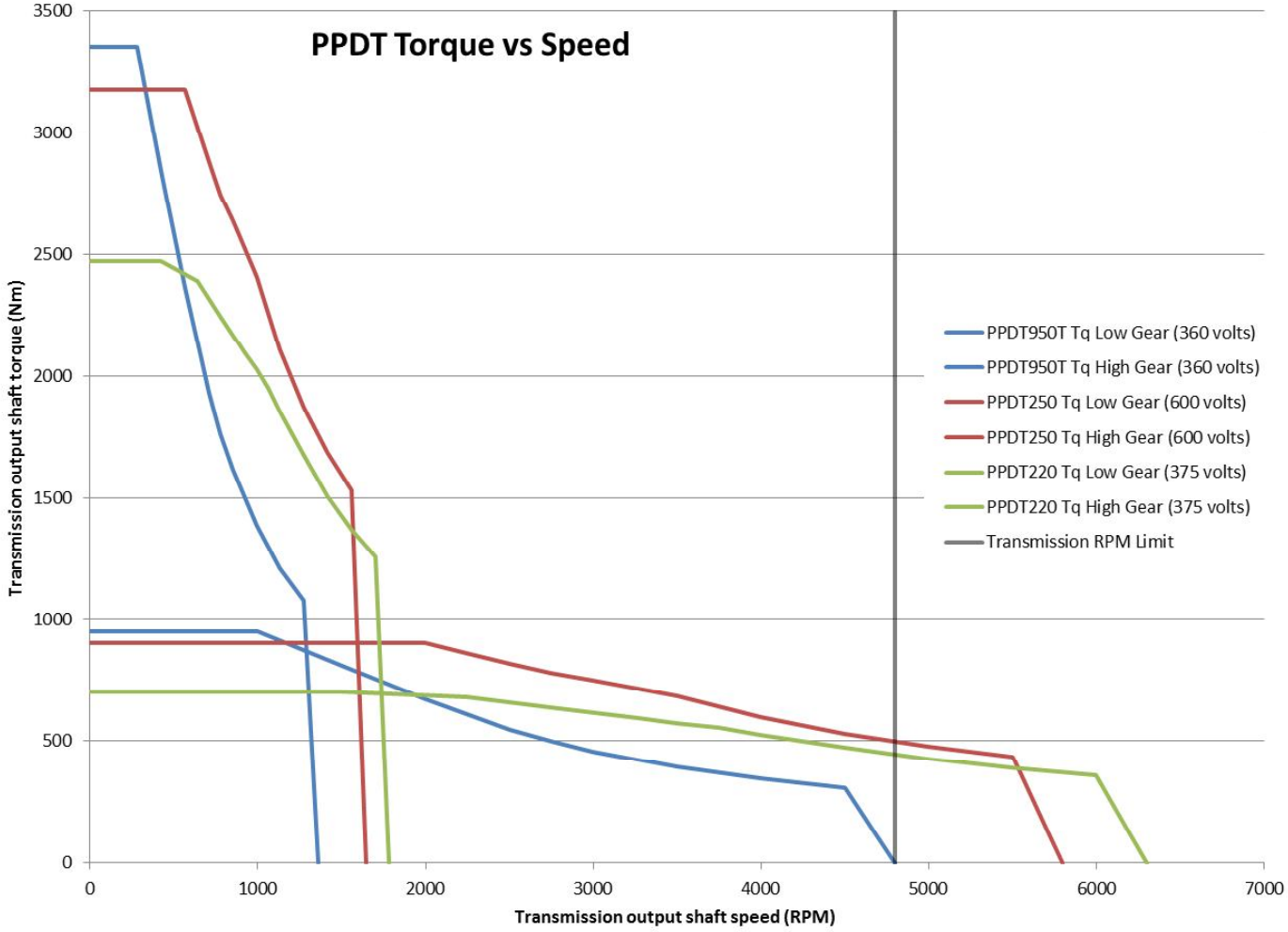
- Extremely high peak power: 250 kW in a small package.
- Impressive peak torque output: 3050 Nm
- Excellent continuous Torque, Power and Efficiency
- Higher Voltage Range 450 – 750 VDC

TABLE 1: PERFORMANCE POWERPHASE®DT 250HD – MOTORING

Specifications	Value	Unit
1st Gear Ratio	3.53:1	
2nd Gear Ratio	1:1	
Maximum Speed (Transmission output 2nd gear)	4800	rpm
Max Speed 1st Gear (Transmission output 1st gear)	1558	rpm
Max Speed for Peak Torque (Transmission output)	566	rpm
Peak Torque (Transmission output 1st Gear)	3050	Nm
Peak Motor Power	250	kW
Speed Range for Peak Motor Power	3500-4800	rpm
Peak Motor Power Minimum Duration	60	s
Continuous Motor Power Rating	150	kW
Continuous Torque (0 – 3000 rpm)	1180	Nm
Voltage for Peak and Continuous Power Ratings	600	V
Peak System Efficiency	94%	

UQM POWERPHASE®DT SYSTEMS

TORQUE VS. SPEED AT TRANSMISSION OUTPUT



3. PERFORMANCE SPECIFICATION FOR SYSTEM WITH UQM HD220, HD950T

Performance Highlights of the **UQM PowerPhase®DT 220HD/950T**:

220HD – High Power at Low Voltage!

Requirement	Value
1st Gear Ratio	3.53:1
2nd Gear Ratio	1:1
Maximum Speed (Transmission output 2nd gear)	4800 rpm
Max Speed 1st Gear (Transmission output 1st gear)	1700 rpm
Max Speed for Peak Torque (Transmission output)	425 rpm
Peak Torque (Transmission output 1st Gear)	2370 Nm
Peak Motor Power	220 kW
Speed Range for Peak Motor Power	3275-4800 rpm
Peak Motor Power Minimum Duration	60 s
Continuous Motor Power Rating	120 kW
Continuous Torque (0 – 566 rpm)	1120 Nm
Voltage for Peak and Continuous Power Ratings	375V
Peak System Efficiency	93%

950T – High Torque at Low Voltage!

Requirement	Value
1st Gear Ratio	3.53:1
2nd Gear Ratio	1:1
Maximum Speed (Transmission output 2nd gear)	4500 rpm
Max Speed 1st Gear (Transmission output 1st gear)	1275 rpm
Max Speed for Peak Torque (Transmission output)	283 rpm
Peak Torque (Transmission output 1st Gear)	3220 Nm
Peak Motor Power	140 kW
Speed Range for Peak Motor Power	2500-4500 rpm
Peak Motor Power Minimum Duration	60 s
Continuous Motor Power Rating	100 kW
Continuous Torque (0 – 566 rpm)	1350 Nm
Voltage for Peak and Continuous Power Ratings	360V
Peak System Efficiency	93%

220HD (+) – High Continuous Power!

Requirement	Value
1st Gear Ratio	3.53:1
2nd Gear Ratio	1:1
Maximum Speed (Transmission output 2nd gear)	4800 rpm
Max Speed 1st Gear (Transmission output 1st gear)	1700 rpm
Max Speed for Peak Torque (Transmission output)	425 rpm
Peak Torque (Transmission output 1st Gear)	2370 Nm
Peak Motor Power	220 kW
Speed Range for Peak Motor Power	3275-4800 rpm
Peak Motor Power Minimum Duration	60 s
Continuous Motor Power Rating	140 kW @ 60C 150 kW @ 40C (Coolant temp)
Continuous Torque (0 – 566 rpm)	1420 Nm
Voltage for Peak and Continuous Power Ratings	375V
Peak System Efficiency	93%