RT - RK
COMPUTER BASED SYSTEMS

White paper

Permanent Magnet Motor Control IC

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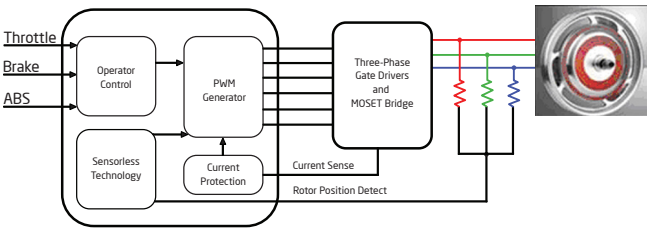
Customer

The customer is well known international IC manufacturer, covering industrial, audio and various data conversion markets. Their product portfolio comprises of numerous ICs for above mentioned fields. The company also offers high-end customer support from the product idea to the final market ready product

Project Overview

The goal of the project was development of the Sensor-less Permanent Magnet Motor control IC for the target markets of electric bikes, hand tools, and office equipment.
As the initial target was electric bike market, it defined sharp criteria regarding high current, high torque start with consistent detection of rotor position from the stand still, or from the "free" rotation. External contractor's patented algorithm for position detection was a back bone of the project including several follow-up patents generated throughout the project evolution.



Control interface scheme

A short list of required and achieved features:

- Motor is started in a closed control loop from both sand-still and free running condition.
- Symmetric trapezoidal excitation is used to drive the motor.
- Current is limited to a value chosen for target motor. The user can switch between several different limit values in an e-bike application.
- Active braking can be optionally engaged (for the e-bike application).
- Phase-to-phase short circuit detection.
- Control loop can be set to allow an extremely wide speed range from just few RPM under highest torque, up to more than 30000 RPM for hand tool applications.
- Tach signal in sensor-less motor driving technology implemented on demand.
- Used parameters are tailored for targeted motor in order to achieve needed performance. For example, in case of hand tools and office equipment applications, a very high initial acceleration is usually needed.
- Throttle level along with imposed current limit dictates the applied voltage in the e-bike applications.

An FPGA based prototyping platform on a custom tailored board gave comprehensive resources for development of the RTL defined IPs along with microprocessor integration, SW debugging, and testing. It also enabled rapid testing ground for performance improvement and comparison with existing competitive drive market solutions.

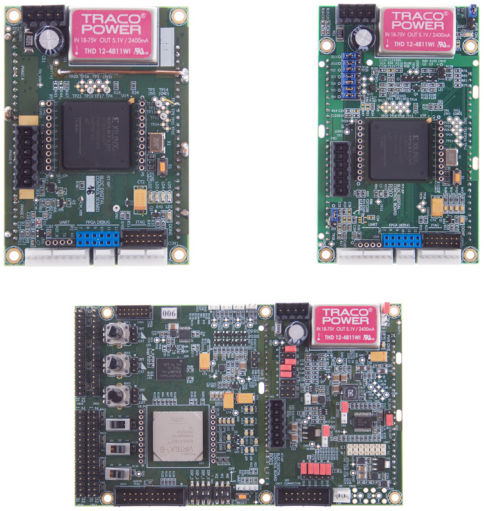


Figure 2. Prototyping FPGA board for motor control (Basic trapezoidal drive board - left, Advanced trapezoidal drive - right, Field oriented control board - bottom)

Main challenges during the development were:

- **From the system level and concept side**

Algorithm and concept verification, concerning that the main rotor position detection IP was based on a nonlinear behavior of the motor coil inductance, which was not covered in the existing simulation tools and packages forced the whole team to focus on experimental verification at the system level critical phases, where behavior of the motor was logged and results used in further steps as simulation feeders.
Separation of the tasks and implementation blocks between microprocessor and custom tailored RTL code. High torque and high current reliable start with prevention of reverse rotation, required severe experimental setup development and work on the real motor under various load and supply conditions.
Variable electrical parameters of the motors, along with their nonlinear drift with current and position.

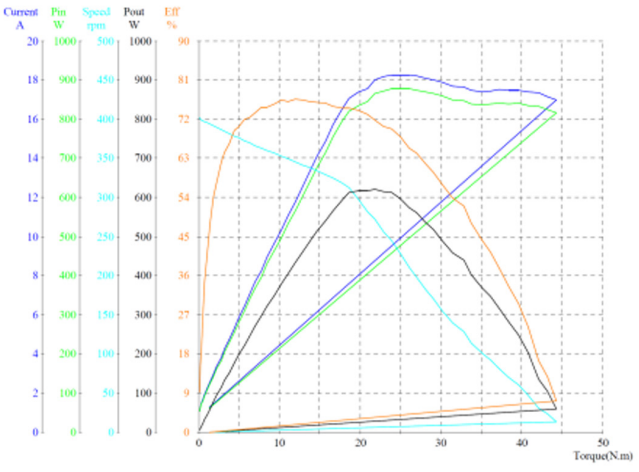


Figure 3 Sensor-less drive testing results

Figure 4 Scooter test unit with variety of motor types

- **From the implementation side**

Integration of the microprocessor and custom tailored RTL code into a single FPGA with on-board ADC and other necessary peripherals.
SW memory footprint maintenance, preserving existing features and accumulation of new ones.
Rotor position detection algorithm implementation and verification.

Benefits

Overall, RT-RK services included:

- System Architecture
- RTL code design and verification
- Prototyping experimental setup including field testing
- Firmware development and verification
- Field testing until top in class performance was reached
- Customer support, remote and on sites in the USA, Europe and China.

All development steps were either conducted or supported by RT-RK, in tight correspondence with the customer. The final solution fulfills the customer requirements in terms of price and performances. The complete development process and costs were transparent to the customer via regular meetings and appropriate reports.

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