Smaller and smarter motor control drives HEV/EV market forward

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Integration and device-level intelligence in motor drive control deliver space reduction and cost-effective solutions for electric and hybrid vehicles.

As the hybrid electric vehicles/electric vehicles (HEV/EV) market begins to increase, the need for efficient and smarter motor-position control becomes more critical. Today more than ever, original equipment manufacturers (OEMs) are focused on how to enhance the capability of electric motors (for example, torque control), while maintaining a high-level of system visibility via diagnostics to always know the health of the system. To reach these goals, highly-integrated solutions in the motor-position control, especially dealing with motor efficiency and torque control, are essential.

Introduction

As the demand grows worldwide for a more energy-efficient means of transportation, HEV/EVs will be at the forefront of the conversation. To better understand the potential and the growth of the electric and hybrid vehicle market, it is imperative to know which types of vehicles we are referring to within this paper. In their report, "Hybrid Electric Vehicle Systems Demand Forecast 2007 to 2021," Strategy Analytics [1] classify each vehicle under the HEV/EV umbrella into one of four separate categories:

1. Mild hybrid
2. Full hybrid
3. Plug-in hybrid
4. Pure electric

Each of these divisions takes into consideration the wattage of the electric motor in the vehicle and what exactly the motor is in charge of inside of the system. For example, in their report, Strategy Analytics classifies a mild hybrid as a vehicle with "one electric motor of <20 kW" that is "used to provide brake recuperation and torque assist" along with "an internal combustion engine." Once you get an understanding of the trade-off between mild a hybrid versus pure EV, it will be easier to understand the total available market for motor position sensors in this sector. **Table 1** lists the system categories as they are defined in the Strategy Analytics' report and will be used throughout the rest of this paper

Now that we have an understanding on the types of vehicles being discussed, let us delve into some market analysis to get a better understanding of the potential addressable market for those automakers who are investing in the HEV/EV portions of their fleet.

As shown in **Table 1**, it is possible to have anywhere from one to four motors per each vehicle. (Four motors take into consideration that every wheel has a motor of its own). Each motor used will require the appropriate system to drive and control these motors safely and efficiently. These systems will need to have visibility and granularity of control to enable the required appropriate levels of torque and motor control. Keeping in mind the knowledge that

System	System definition	System includes
Mild hybrid	Any system whereby one electric motor of <20 kW is used to provide brake recuperation and some torque assist to the vehicle, in conjunction with an internal combustion engine.	Hybrid system electronic control units (ECUs) (including motor and battery controllers), wiring/cables, sensors, DC/DC converter(s), battery pack(s), other storage devices.
Full hybrid	Any system whereby one or more electric motors >20 kW is used to provide brake recuperation and propulsive power to the vehicle, in conjunction with an internal combustion engine.	Hybrid system ECUs (including motor and battery controllers), wiring/cables, sensors, DC/DC converter(s), battery pack(s), other storage devices.
Plug-in hybrid	Any system whereby one or more electric motors is used to provide brake recuperation and propulsive power to the vehicle, in conjunction with an internal combustion engine. A larger, plug-in rechargeable battery pack enables greater use of electric-only drive.	Hybrid system ECUs (including motor and battery controllers), wiring/cables, sensors, DC/DC converter(s), battery pack(s), other storage devices.
Pure electric	Any system whereby electric motors alone, powered from batteries, are used to propel the vehicle	EV System ECUs (including motor and battery controllers), wiring, sensors, DC/DC converter(s) electric motor(s), batteries/other storage devices.

***Table 1**. Different categories of electric vehicles used by Strategy Analytics.* *Table courtesy of Strategy Analytics [1].*

motors and their system needs, **Table 2** (also from the Strategy Analytics report) gives an estimated snapshot of the units of each type of vehicle that will be in the market from 2015-2021.

Table 2 shows the steady growth in the HEV/EV market and the interest in the automotive market for electric solutions. As this demand increases, OEMs will continue to search for ways to improve the performance of these vehicles while simultaneously increasing the ease of the system to diagnose itself with built-in diagnostics, protection and monitoring.

To understand the future of this new and booming market, it is critical to understand a couple of the main driving factors upon which car manufacturers in this space are focused. First is the importance of enabling these vehicles to have precise and accurate motor control for their electric motor driver (inverter). And second, why integration in these systems at the device level is key to delivering a smaller, smarter, and more cost effective solution to the HEV/EV market.

Precise and accurate motor control

For any vehicle, electric or not, the motor is at the center of the power-train required to drive the vehicle forward. Electric vehicles specifically require position information about these motors, including angle and velocity data, to ensure that the motor control system works efficiently and precisely. The data collected by the inverter is then actively used to control and monitor the current flowing in each of the motor phases. The process of controlling and regulating the motor current is what is used to

(K-units)	2015	2016	2017	2018	2019	2020	2021	CAGR (2015-2021)
Mild hybrid	1,344	2,091	2,767	3,396	3,974	4,574	5,136	13.70%
Full hybrid	2,277	2,597	2,734	2,887	2,922	2,951	3,020	2.20%
Plug-in hybrid	352	755	1,086	1,518	2,007	2,374	2,871	21.00%
Pure electric	322	419	540	648	756	858	959	12.60%
Total	**4,295**	**5,861**	**7,127**	**8,450**	**9,658**	**10,758**	**11,987**	**10.80%**

***Table 2**. Units of each type of vehicles used by Strategy Analytics.* *Table courtesy of Strategy Analytics [1].*

create the torque for the motor. Torque control for electric vehicles is critical to both customers and auto manufacturers alike. Some of the major areas torque is vital are:

1. High torque is needed at low speeds for starting the motor and climbing inclines
2. Torque control enables high power at the higher speeds used for cruising speeds
3. Fast torque response for acceleration events requires precise motor control
4. Precise motor and torque control enables high efficiency for regenerative braking

Controlling and understanding the torque in an electric motor allows the vehicles to deliver smoother power to the wheel of the car for the user. Understanding the exact position of the motor is pivotal to ensuring appropriate torque control. By knowing the exact location of the motor shaft and having an intelligent system that can make decisions based on the motor data, an electric vehicle's control system is able to precisely and accurately calculate the torque available to the driver. The more accurate the control, the better experience the user will have when dealing with any of the circumstances listed.

A high-level snap shot of the motor control system used in electric and hybrid vehicles is shown in **Figure 1**. To envision how this system works, imagine that you as the driver have decided to change speeds while driving. As you accelerate (or decelerate) the engine/motor control unit (inverter), running off of the power of the car battery drives the motor forward. A position sensor (usually resolver), then reads the angle information from the motor and translates this into a form that the microcontroller of the inverter system can act on. Once this data is transmitted to the microcontroller, the motor control system then can increase or decrease the amount of motor torque. These increases or decreases in speeds are both handled the same, and the appropriate amount of torque is delivered to the system based on of the user's original input.

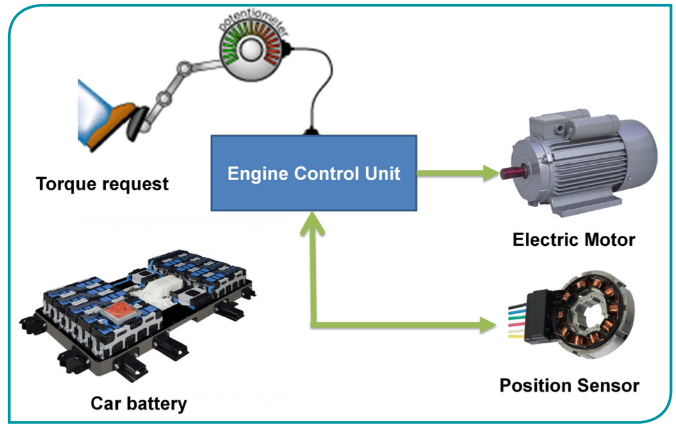

Figure 1. *Engine control unit and where the position sensor fits.*

Integration

With an understanding of the importance of motor control in an HEV/EV drive system, we can now investigate the various approaches in the market today that are meant to enhance these systems that control vehicle torque.

At the heart of the motor control system is an inverter board that houses the power for the microcontroller, motor drives, and the sensor interfaces required to read and act on the information gathered from the electric motor. To be able to do this, the electronics for this system are found under the vehicle's hood in close proximity to the motor itself. The location of this board brings to the surface a couple of challenges faced by hybrid and electric vehicle manufacturers.

Since the space under the hood of any car is already very limited, ensuring that a solution has a small form factor and footprint is essential. To enable smaller solutions, electronic component suppliers are focusing on how to integrate more functionality and even more devices into one package. Automotive devices are now being introduced to the market that integrates all of the components (such as signal chain, communications or power) needed to enable a portion of the system onto one chip. Combinations of these chips are then used to reduce the number of components needed on the board to control the motor.

By incorporating more functionality and devices into one package, hybrid and electric vehicle manufacturers can cut down the overall board size needed for the inverter system, as well as some costs for extra components no longer needed. Smaller and more cost-effective solutions at the component level enable OEMs with cutting-edge solutions without having to pass these cost on to the consumer.

As the market trends toward integration, another factor being addressed is the overall intelligence and connectivity of the system. What exactly does this mean? As modules inside of the vehicle become more complex, there is always a need to have system diagnostics and health checks to ensure they are functioning appropriately. In the case of the HEV/EV motor control system, these types of checks would enable the health of the motor, drive circuitry, and even position sensors to be a known variable upon which the system can act. Having this level of visibility inside of the motor system allows smarter and quicker evaluation of the drive should an error or issues occur. Smarter motor controls that can report and take actions on the status of their own system are fundamental to the success of the HEV/EV market.

Summary

Enabling automotive system suppliers and car makers with smarter, smaller and more cost-effective solutions is critical in the HEV/EV market. As this market begins to rapidly expand, solutions with a high-level of integration in their motor control are at the heart of the growth of the electric vehicle. Ultimately, delivering a high-performance system at a completive cost to the consumer is really what drives forward the future of this market.

These HEV/EV solutions include the PGA411-Q1 resolver sensor interface and the C2000™ microcontroller. You can learn more about TI HEV/EV solutions on our website.

References

1. *Mak, K. (2014). Hybrid Electric Vehicle Systems Demand Forecast 2007 to 2021 Data File. Strategy Analytics.*
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