Hybrid and Fuel Cell Engines

Overview

A hybrid vehicle is the combination of an internal combustion engine and an electric motor.

A mild hybrid, also know as a combined alternator starter (CAS) system, utilizes a high-efficiency engine and a 5kW to 25kW electric motor to power the vehicle. A mild hybrid is always operated in parallel mode. In this mode, an electric motor assists the engine by providing extra torque to the powertrain system in order to reach peak acceleration. The internal combustion engine can be a diesel or gasoline engine engineered to deliver enough power during normal operation.

The hybrid vehicle has the advantage of utilizing the electric motor, thereby reserving battery energy during high acceleration peaks.

The full hybrid functions in one of two modes: series and parallel modes.

Freescale's *SMARTMOS*™ analog portfolio provides power actuation (MC33927) and multiple switch detect interface family ICs, system basis chips (MC33389). The power actuation devices will support BLDC motors and static load controls. The Flexible I/O family provides a simple system power conservation solution providing a WAKE output with which the MCU power supply can be enabled when MCU activation is required. It allows optimized switch OPEN/CLOSE status verification of multiple switches, with changes immediately reported to the MCU.

Freescale's SMARTMOS™

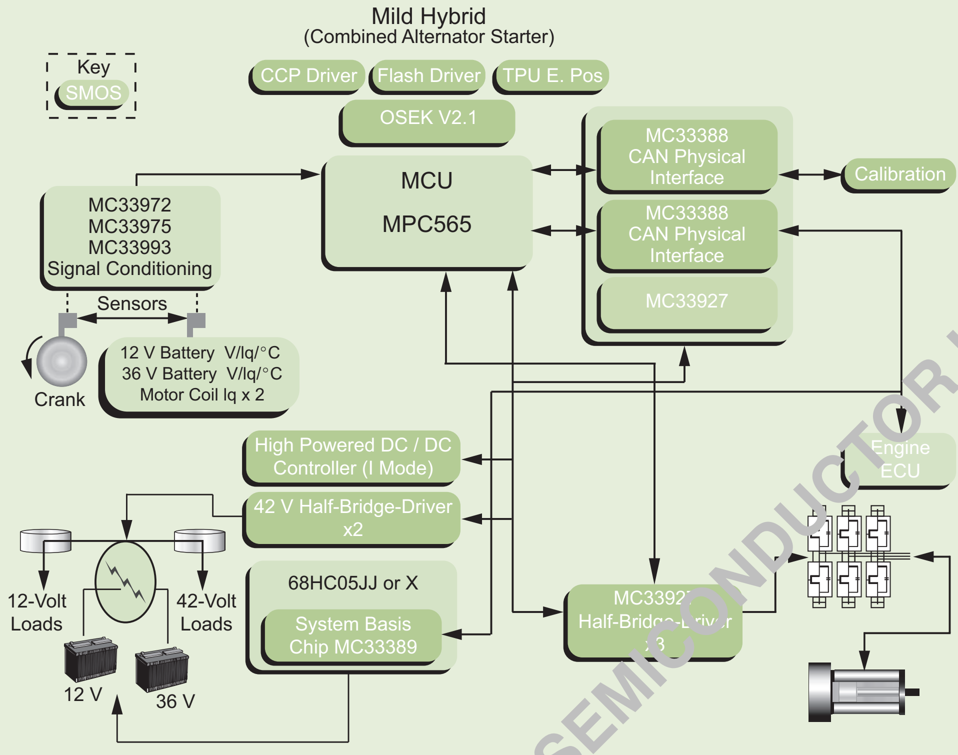
System Basis Chips are monolithic integrated circuits, combining many functions repeatedly found in standard Electronic Control Units (ECUs): power management, communications interface, system protection and diagnostic, low-power modes and wake-up.

Freescale Semiconductor offers a broad range of devices with LIN, low speed fault tolerant CAN, high speed CAN with wake-up capabilities, and bus failure diagnostics. These products are the ideal companion-chips for 8- and 16-bit MCUs.

Key Benefits

- Combines an internal combustion engine and an electric motor
- Provides extra powertrain system torque for peak acceleration
- Reserves battery energy during high acceleration peaks

HYBRID AND FUEL CELL ENGINES



Freescale Ordering Information[Note]

Part Number	Product Highlights	Additional Information
56F8xx Family	Flash-Based Hybrid Microcontrollers	www.freescale.com
68HC05 Family	8-Bit Microcontrollers	
MC33388	Fault Tolerant CAN Interface	www.freescale.com/analog
MC33389	System Basis Chip with Low Speed CAN	
MC33927	Three-Phase FET Pre-driver	
MC33972	22 Input Multiple Switch Detection Interface with Suppressed Wake-Up	
MC33975	22 Input Multiple Switch Detection Interface with Higher Wetting Current	
MC33993	22 Input Multiple Switch Detection Interface	
MPC565	32-bit Microcontroller	www.freescale.com

Note: Search on the listed part number.

Hybrid and Fuel Cell types

Series Hybrid
Both types of hybrids, series and parallel, are currently being deployed for use around the world. A series hybrid uses a high efficiency engine, or even a small turbine, to generate electrical power for the electric motor. The engine is designed to charge a large battery pack; in turn, it powers an electric motor to provide power to the drive wheels. The engine or turbine turns on, generating electricity when the battery pack drops below a minimum charge level. The driving range of a series hybrid vehicle can achieve distances up to 400 miles without stopping. A very sophisticated electronics module controls the electric motor, ensuring quick and smooth acceleration reaching passing speeds.

Parallel Hybrid
The second type of hybrid powertrain system is a parallel hybrid with an internal combustion engine. The combustion engine works in conjunction with a small electric motor, 5kW to 25kW, to provide extra torque to the powertrain system in the car. The parallel hybrid can also utilize the engine to charge the battery pack during less intense power driving cycles, such as cruising at

freeway speeds. A compelling feature of the parallel hybrid is the ability to turn the engine off and run the electric motor from the battery pack for shorter in-town driving. In this case, the parallel hybrid acts as a fully electric vehicle, becoming virtually emissions free. The driving range of a parallel hybrid can reach up to 400 miles or more before battery recharge is necessary.

Fuel Cells

A fuel cell designed vehicle converts hydrogen rich fuels into electrical energy stored in the vehicle's battery pack. A fuel cell vehicle can be made to operate from a variety of hydrogen fuel sources including pure hydrogen, methanol, and gasoline. A fuel cell vehicle will use the stored electrical energy to drive a 50kW, or larger electric motor. Some vehicles will use more than one electric motor to directly drive 2- or 4-wheels. A properly running fuel cell will produce electrical energy and pure water. Currently, fuel cells have two challenges under investigation. First, how to transport and store hydrogen fuel in the vehicle. Secondly, the cost of producing a powerful fuel cell is too high for general fleet deployment. Currently, neither appears to be a long-term impediment to deploying the technology.

Design Challenges

In addition to the development of hybrid and fuel cell powertrain systems, 42 V in conjunction with existing 12 V systems can be used to deliver the increasing energy to the large electrical loads in future vehicles. A 42 V power source can be found driving the large AC induction and switched reluctance electrical motors in hybrid vehicles. A high performance microcontroller will be used in conjunction with a power module to convert a chopping, or alternating voltage across the motor windings. The microcontroller must continually change the voltage across several winding positions and maintain optimal power efficiency using complex angle and time based calculations.

The technological solutions of the future are expected to drive the need for semiconductor electronics in the automotive industry to new heights. Hybrid and fuel cell vehicles have special electrical requirements for higher power semiconductors and additional computational performance to operate the motor within specified performance ranges, providing maximum efficiency. The need to switch very high currents with little heat dissipation should motivate semiconductor companies to quickly respond with more powerful, faster and even smarter semiconductors, capable of handling the increasing currents, while at the same time protecting the device and load. Additionally, it is anticipated these same power devices will be expected to be capable of detecting a fault condition, and notifying the main microcontroller of the potential problem.

Freescale Semiconductor Solution

Microcontroller Solution

Freescale Semiconductor's MPC565 microcontroller is designed to quickly adjust the phase relation to monitor speed and torque of the motor, due to the integration of the peripherals on-chip and floating point of the device. The 3-phase power can be generated with three pulse width modulations (PWMs) for a constant speed and load scenarios. In highly dynamic applications like a car, the computational overhead of maintaining the PWMs becomes significant. Freescale Semiconductor has addressed this computational loading issue by developing a timer processor unit (TPU) designed to handle most of the overhead. The TPU can be used to capture the current motor position and make modifications to the output channels to produce the correct PWM signals.

The MPC565 features 1MB of flash memory, 36KB SRAM with timers, as well as analog-to digital converter and communications channels, to handle a 3-phase DC converter and electric motor. The dual 16-channel, 10-bit QADC units are capable of measuring two of the power angles from the 3-phases so the third power angle can be easily calculated by the microcontroller. Both QADCs are necessary to measure two of the power angles concurrently reducing any possible error in computing the third power angle.

The MPC565 processor implements the *PowerPC*™ instruction set architecture with a full double precision floating point unit. The floating point unit is critical for efficient high precision calculations of angles, power vectors, and timing to the motor. The 66-timed channels are engineered to easily generate the control pulses and accept input from the motion sensor with very little intervention from the main core. *SMARTMOS*™ devices, merging power transistor technology with logic function, are designed to work with Insulating Gate Bipolar Transistors (IGBTs) and power metal oxide semiconductor field effect transistors (MOSFETs) to help control very high power outputs on electric motors, solenoids, and valve systems.

Hybrid Controller Solution

Furthermore, Freescale Semiconductor offers an extensive family of highly embedded, Flash-based hybrid controllers, designed specifically to meet the demanding needs of advanced motor control systems. The 56F800 family combines the computational power of a DSP core running at 40 MIPS (60 MIPS devices in development) with elaborate motor control specific peripherals. However, unlike other DSP architectures, the 56800 core incorporates much of the look and feel of a traditional microcontroller, like a software stack and a rich control oriented instruction set. The computational power of a DSP combined with the ease of use of a microcontroller, allows efficient control of even the most sophisticated motor control systems.

The motor control peripherals on the 56F800 family are designed specifically to excel in field oriented applications, while remaining flexible enough to control any motor topology. The PWM module can generate up to six independent channels of edge or center aligned PWM signals with 25ns resolution (15 bits), including deadtime insertion between complimentary PWM pairs. A patented deadtime distortion correction scheme significantly improves motor waveform quality, resulting in smoother and more efficient motor operation, especially at lower speeds. To accommodate early detection of potential system problems, the PWM module utilizes an elaborate fault protection network with multiple fault inputs, immediately disabling the PWM outputs at the first sign of trouble. The fault inputs can also be programmed to control the PWMs in a cycle-by-cycle fashion, resulting in up to four independent channels of current mode control. This can be especially important when controlling switched reluctance (SR) motors where the current waveform of each phase of the motor can be independently profiled for quieter operation.

To facilitate inter-module communications within the vehicle, a CAN module is incorporated on the 56F803, the 56F805, and the 56F807. The 56F805 and 56F807 also include an additional PWM module (for a total of 12 PWM channels), and two separate encoder modules, for control of more than one motor. The four separate ADCs on the 56F807 result in optimum control of dual motor systems, especially where field orientation is required for both motors. Each pair of ADCs can be synchronized to different PWM modules, resulting in completely independent control of both motors.

Development Tools[Note]

Tool Type	Product Name	Vendor	Description	Additional Information
Hardware/Software	MPC565	Contact vendor	Accelerated Technologies, Inc.	www.acceleratedtechnology.com
Hardware/Software	MPC565	Contact vendor	ASH WARE Inc.	www.ashware.com
Hardware/Software	MPC565	Contact vendor	Ashling Microsystems Ltd.	www.ashling.com
Hardware/Software	MPC565	Contact vendor	Green Hills Software	www.ghs.com
Hardware/Software	MPC565	Contact vendor	iSystems	www.isystems.com
Hardware/Software	MPC565	Contact vendor	Lauterbach	www.lauterbach.com
Hardware/Software	MPC565	Contact vendor	Metrowerks	www.metrowerks.com
Hardware/Software	MPC565	Contact vendor	PHYTEC	www.phytec.com
Hardware/Software	MPC565	Contact vendor	Vector	www.vector.com
Hardware/Software	MPC565	Contact vendor	Wind River Systems	www.windriver.com
Development Kit	MPC565	Contact vendor	Axiom	www.axman.com
Evaluation Kit	KIT33388DEVB	Metrowerks	Fault Tolerant CAN Interface	www.metrowerks.com
Evaluation Kit	KIT33389DWEVB	Metrowerks	System Basis Chip	
Evaluation Kit	KIT33993DWBEVB	Metrowerks	22 Input Multiple Switch Detection Interface	

Note: Search on the listed product name.

Related Documentation[Note]

Document Number	Description	Additional Information
APDPAK	Analog ICs Integrated Solutions Pitch Pack	www.freescale.com
SG187	Automotive Product Selector Guide	
SG1002	Analog Product Selector Guide	

Note: Search on the listed document number.

Learn More: Contact the Technical Information Center at +1-800-521-6274 or +1-480-768-2130.
For more information about Freescale products, please visit **www.freescale.com**.

SG2027
REV 2
6/2005

June2005

freescale semiconductor