

## **Control of Electro-Mechanical Brake with Electronic Control Unit**

**Venkata Ramesh Mamilla<sup>1</sup> and M.V. Mallikarjun<sup>2</sup>**

*<sup>1,2</sup> Associate Professor, Department of Mechanical Engineering, Qis College of Engineering & Technology, Ongole – 523272, Andhra Pradesh, India  
E.mail: maa\_ram@yahoo.co.in, mvmsharma@yahoo.co.in*

### **Abstract**

This paper deals with a study of electro-mechanical braking (EMB) system and the design basics of its control based Electronic Control Module (ECM). Electro-mechanical braking systems also referred to as brake by-wire, replace conventional hydraulic braking systems with a completely dry electrical component system. This occurs by replacing conventional actuators with electric motor-driven units. The braking force is generated directly at each wheel by high performance electric motors, they are controlled by an ECU and actuated by signals from an electronic pedal module. The EMB includes all brake and stability functions such as ABS, EBD, TCS, ESC, BA and ACC.

### **Introduction**

The need for better fuel economy, simplified system assembly, more environmentally friendly systems, ease of vehicle maneuverability, and improved safety systems has resulted in new types of braking systems. The centerpiece of the current braking systems is a hydraulic assembly under the hood of the vehicle that brings together the electronic control unit, wheel pressure modulators, pressure reservoir, and electric pump. The interaction of mechanics and electronics is key to the success of the braking system. The microcomputer, software, sensors, valves, and electric pump work together to form the basis of the system.

### **Electro-Hydraulic Brakes**

Compared to the operation of conventional braking systems, by depressing the brake pedal with the Electro-Hydraulic Braking System (EHB), the appropriate command is transmitted electronically to the electronic controller of the hydraulic unit. This determines the optimum braking pressure and actuates the brake calipers hydraulically (see Figure 1).

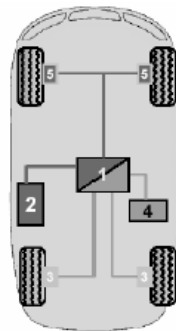


- (1) EHB electronic actuator unit with pedal
- (2) EHB hydraulic unit
- (3) Sensors
- Hydraulic connections
- Electric signal
- Hydraulic Fail Safe

**Figure 1:** Electro-Hydraulic Braking System.

### Hybrid Braking

The Hybrid Braking System is the solution approach for vehicles without a fully dimensioned on-board network for dry Electro-Mechanical Brakes (EMB) on all four wheels. There can be integrated electrical parking brake functionality at the rear wheels, eliminating the need for long hydraulic lines and handbraking cables leading toward the rear axle. Since EMB wheel brake modules with integrated electrical parking brake function are already installed at the rear wheels, there is no longer any need for long hydraulic lines and hand-braking cables leading toward the rear axle. The front axle is operated hydraulically, as with conventional braking systems. This results in a two-circuit system with two hydraulic wheel brakes on the front axle, and two electro-mechanical wheel brake modules at the rear axle.

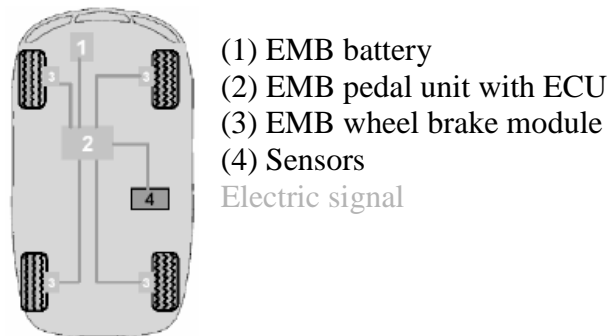


- 1) Electronic Brake System (EBS) hydraulic unit with Electronic Control Unit (ECU)
- (2) Pedal/Booster
- (3) EMB wheel brake module
- (4) Sensors
- (5) Conventional wheel brake
- Hydraulic connections
- Electric signal

**Figure 2:** Hybrid Braking System.

### Electro-Mechanical Brake

The Electro-Mechanical Braking Systems represents a complete change in requirements from the previous hydraulic and electro-hydraulic braking systems. The EMB processing components must be networked using high-reliability bus protocols that ensure comprehensive fault tolerance as a major aspect of system design. The use of electric brake actuators means additional requirements, including motor control operation within a 42-volt power system and high temperatures, and a high density of electronic components.



**Figure 3:** Electro-Mechanical Braking System.

The EMB involves in pure brake-by-wire technology, which dispenses with brake fluids and hydraulic lines entirely. The braking force is generated directly at each wheel by high-performance electric motors, controlled by an ECU, and executed by signals from an electronic pedal module. The EMB includes all brake and stability functions, such as the Anti-lock Braking System (ABS), Electronic Brake Distribution (EBD), Traction Control System (TCS), Electronic Stability Program (ESP), Brake Assist (BA), and Adaptive Cruise Control (ACC). It is virtually noiseless, even in ABS mode.

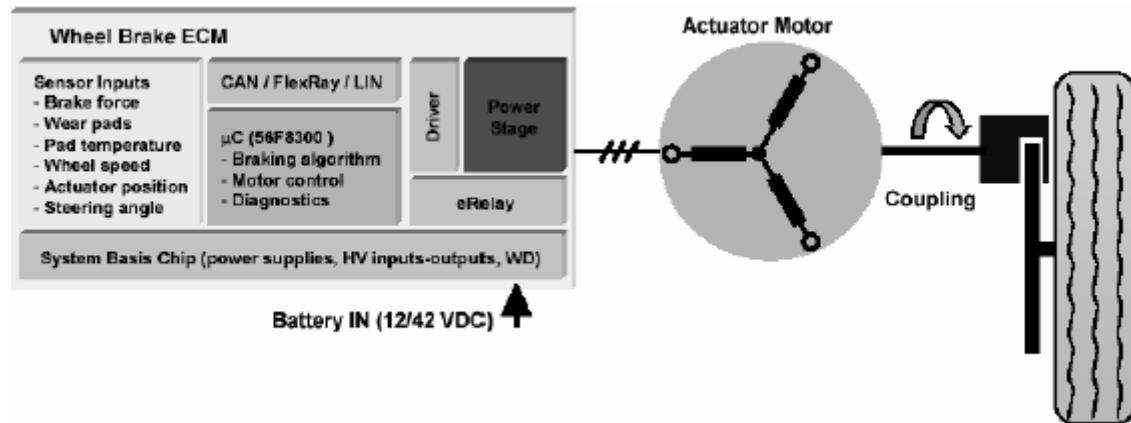
Advantages of the EMB:

- Shorter stopping distances and optimized stability
- More comfort and safety due to adjustable pedals
- No pedal vibration in ABS mode
- Virtually silent
- Environmentally friendly with no brake fluid
- Improved crash worthiness
- Saves space and uses fewer parts
- Simple assembly
- Capable of realizing all the required braking and stability functions, such as ABS, EBD, TCS, ESP, BA, ACC, etc.
- Can easily be networked with future traffic management systems
- Additional functions, such as an electric parking brake, can easily be integrated

### **Electronic Control Module**

Control of the electric motor actuator is performed by the Electronic Control Module (ECM). Increased microcontroller processing power, combined with a digital signal processing capability and a flexible set of peripherals (motor-control related), all provided on single chip, make a 56F8300 device very well suited for use as the EMB processing core. Such a core allows incorporation of intelligent and advanced braking features that can dramatically enhance driver comfort and safety. Figure 4 illustrates

the functional block diagram of the ECM for an electro-mechanical braking system. The main function of the ECM is to receive the sensor signals from the brake system and vehicle, process these signals, and provide appropriate voltage vectors so the motor actuator can obtain the desired torque response.



**Figure 4:** Functional Block Diagram of ECM.

The ECM controller is partitioned into several blocks, including:

- a. Sensor input processing
- b. Microcontroller
- c. Power electronics and input relay

### Sensor Input Processing

Sensor inputs to the ECM unit might come from brake force measurement, brake pads, wheel speed, or the electric motor position. These inputting signals are conditioned and appropriately filtered to be accommodated by the Analog-to-Digital converter at the microcontroller level.

In modern automobiles, the communication and wireless functions make electromagnetic emissions very critical. The circuit design must take into consideration the effect of electromagnetic noise in the vehicle. The circuit should be protected against electrostatic discharge. The protection of these sensitive ECM units from temperature, shocks, and random vibrations under adverse road condition must be considered.

### Microcontroller

A 56F8300 device is a member of the 16-bit 56800E core-based controller family. Its processing power, combined with the functionality of a microcontroller and a flexible set of peripherals, creates an extremely cost-effective solution on a single chip. Because of its low cost, configuration flexibility, and compact program code, a 56F8300 device is well suited for intensive automotive applications. The 56800E core is based on a Harvard-style architecture consisting of three execution units operating in parallel, allowing as many as six operations per instruction cycle. The MCU-style

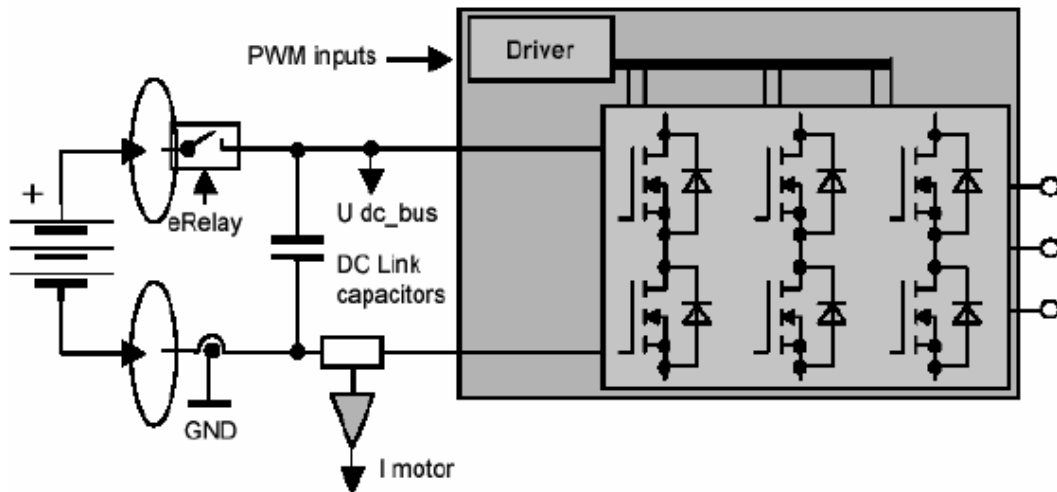
programming model and optimized instruction set allow straightforward generation of efficient, compact 16-bit control code. The instruction set is also highly efficient for C/C++ compilers, enabling rapid development of optimized control applications.

### Power Electronics and Input Relay

A power inverter is used to apply the desired voltage across the motor phases. The DC-to-AC inverter topology most widely used today for exciting sinusoidal and trapezoidal PMAC machines is the 3-phase full bridge inverter. Due to lower automotive voltages, power MOSFETs are commonly used as power electronic switches. Advances in power electronic control have made it possible to control electric motors able to provide significant torque with minimum loss in the power unit. The automotive power MOSFETs can provide hundreds of amperes of current, thus making it possible to use them even for electric braking in larger vehicles Figure -5 shows a 3-phase inverter used for a PMSM machine.

A power MOSFET driver device is used to amplify digital PWM signals from the microcontroller. The current and voltage sensors are used to sense the phase currents and voltage, thus providing feedback for the motor control part of the electro-mechanical brake software. Either a Hall-effect sensor or a shunt resistor is used to sense the electric motor actuator current. The DC-link capacitors are used to filter DCBus voltage.

Either mechanical or electronic relays may be used as disconnecting devices to switch off the electronic system from the vehicle battery bus.



**Figure 5.3:** Phase DC-to-AC Inverter.

The electronic relay (eRelay) is a self-protected silicon switch with very low on-state resistance, e.g.,  $2m\Omega$ . It is configured as a high-side switch used to replace electro-mechanical relays, fuses, and discrete devices in power management applications. This silicon device is designed for harsh environments, and it includes

self-recovery features. The device is suitable for loads with high in-rush current, as well as motors and all types of resistive and inductive loads. The different implemented features of this device, such as diagnostics, control, etc. are programmable and accessible via Serial Peripheral Interface (SPI).

For maximum device protection, the device has several programmable overcurrent low and high detection levels. If the load current level ever reaches the selected overcurrent low detect level, and the overcurrent condition exceeds the programmed overcurrent time period, the device will latch the output off.

## Conclusion

In electro-hydraulic braking (EHB), EMB is designed to improve connectivity with other vehicle systems, thus enabling simpler integration of higher-level functions, such as traction control and vehicle stability control. This move to electronic control eliminates many of the manufacturing, maintenance, and environmental concerns associated with hydraulic systems. An increase in flexibility for the placement of components is also provided by EMB systems, compared to those of EHB, with the total elimination of the hydraulic system.

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