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MPC563xM-based Cost Effective ECU Chipset

Operation of the Suitcase Demo

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Contents

1 Introduction

This document describes the operation of the cost-effective four cylinder Stage V Drive-by-Wire engine control demo. It is part of a number of documents that cover the MPC563xM-based Engine Control Unit (ECU) Reference Design and the suitcase-based control system demo built around it.[1]

The demo is a collection of engine sensors and actuators, along with some other components that simulate sensors or actuators in a more appropriate, portable, or visual way. These are run by a fully functional ECU based upon an appropriate Freescale analog chipset, driven by an MPC5634M microcontroller.

This document provides the demo operator with discrete demonstrations to run and knowledge about what these demonstrations show or simulate, including what this represents on an engine control system.

The suitcase demonstrator provides an opportunity to interact with the engine control system.

Much of the collateral used to create the ECU is available for the creation of new designs. These items are listed at the end of the document.

1. The MPC563xM family of devices consists of the MPC5632M (768K flash memory, 48K SRAM), the MPC5633M (1M flash memory, 64K SRAM), and the MPC5634M 1.5M flash memory, 94K SRAM).

2 Engine control module reference design hardware

The MPC563xM ECU demo system consists of the MPC5634M ECU reference design hardware as well as an example control system to show the typical electronics for a four cylinder engine. There are two boards, an 'engine' board containing the ECU, throttle body, pedal and ignition coils, and a 'sensor' board containing the injectors as well as various sensors and actuators.

2.1 Devices used in the MPC563xM ECU reference design

The centerpiece of the MPC563xM engine control reference design demonstration is the ECU containing a chipset fully capable of driving a Stage IV or Stage V port fuel injection gasoline engine. This document is focused on the engine simulations and does not discuss the content of the ECU itself other than this brief introduction. For an overview of the hardware, see Application Note AN4156, "MPC563xM Engine Control Unit Reference Design, 4-cylinder Hardware Design."

The ECU board is visible and the following devices can be seen:

- MPC5634M 32-bit Power Architecture Microcontroller: contains the software with the intelligence to run the demo. All the family members have sufficient capability and the MPC5634 is used.
- MC33800 16-way Low Side Drivers/Octal Switch: drives the low side outputs such as HEGO heaters, fan, tachometer, temperature gauge, and others.
- MC33902 CAN physical interface: calibration CAN physical layer; could be removed for production.
- MC33905 System Basis Chip: provides the internal and external 5V supply, the K-line PHY, and a second CAN physical layer. It also contains a watchdog.
- MC33810 Ignition/Injection Driver: drives and runs diagnostics on the four injectors and the four IGBTs that run the ignition coils.
- MC33926 5A H-Bridge: a single 5A H-bridge alternative to the dual 5A MC33932 driver. It is packaged in PQFN but is also available in SOIC. It is currently not used in this demo.
- MPXH9005 Barometric Pressure sensor: used for atmospheric pressure correction and is mounted on the PCB.
- MC33932 Dual 5A H-Bridge: half of this device runs the electronic throttle body.
- MC9S08SG8E2MTJ 8-bit Microcontroller: wired to run a more sophisticated software watchdog looking at some basic engine parameters rather than just a software challenge-response. At present the feature is not coded.
- MC33879 Configurable Octal Switch: drives eight outputs individually configurable as either high or low side. It is currently not used in this demo.

Engine control systems can vary in sensors and actuators used and so the ECU contains a little duplication of function in order to demonstrate alternative drivers. For example, both single and dual 5A H-bridge drivers are present, in different packages, along with the MC33879 configurable octal switch that can be configured as a dual H-bridge 1A stepper motor driver. The demo implements one specific set of sensors and actuators. Accordingly, not every chip in the ECU is used in the demo.

3 Demonstrations available

3.1 Power on

With mains power applied (100–240V), the switch mode power supply hidden behind the engine board produces 13.5V. The green power LED illuminates. There is no mains switch, but the socket is fused and accessible from the top side.

3.2 Key on operation

Key on produces the first visible activity. The five gauges illuminate and run a self-test. The voltmeter should show around 13.5V and the ammeter should register under 1A, which is the running current of the ECU plus lighting.

Upon application of power, the fuel pump on the sensor board runs for 2s. This is driven by an output of the MC33800 low side driver, which is first configured over a SPI communications link. This priming fuel pulse pressurizes the fuel rail at the engine to ensure that the fuel is delivered from the very first injection event as intended. A gasoline ECU often has no feedback of fuel rail pressure as this is controlled by a mechanical regulator. The delivery of fuel is set by the duration of injection, so if the pressure is incorrect then the quantity of fuel delivered will be wrong. Without this priming pulse, the rail pressure during cranking phase would be determined by the leak-down rate and the duration of engine off time.

It is common to run the fuel pump via a relay, and to return a diagnostics line back to the ECU to show that power was applied. However, in this demo the pump is driven directly using an output of the MC33800; hence, diagnostics can use SPI. Timing is controlled by the MPC5634M microcontroller based upon its crystal reference.

3.3 Electronic throttle demo

With power applied to the ECU, the pedal can be pressed to move the throttle. The pedal sensor is supplied with a separate 5V rail from the MC33905 System Basis Chip (SBC) which is itself enabled over SPI. By using an independent 5V sensor supply, a short to battery or ground (which can happen, for example, if wires are crushed during engine maintenance) does not disable the ECU. The pedal position is read using the Analog-to-Digital Converter (ADC) on the microcontroller. The MCU uses this input to determine how much current to apply to the throttle body motor, which in turn sets the position of the plate. The drive signal is generated using pulse width modulation (PWM) from a MIOS channel, and current is boosted by half of the MC33932 dual H-bridge device.

Although in theory a single low side driver might suffice as the throttle plate works against a spring, the H-bridge permits bi-directional motoring, making it easier to overcome backlash and friction in the mechanics and making closed-loop accurate positional control possible.

The throttle does not respond directly to the pedal in the way that it would if connected by a steel cable. Rapid movements at the pedal will be seen to be filtered out from the subsequent movements of the throttle plate. This is an emissions feature: sharp throttle movements cause fast changes in manifold pressure. When this happens the equilibrium quantity of fuel wetting the inside of the manifold changes, resulting in a rich or lean spike, which is bad for emissions as it can overload the catalyst and cause noxious gases to escape from the exhaust. Thus Drive-By-Wire makes it easier to reach Stage V emissions by disconnecting driver demand from throttle position.

3.4 Engine cranking

Rotating and holding the ignition key in the crank position puts the demo into cranking mode. A signal from the key goes to the engine simulator board and in response it produces synchronized cam and crank sensor signals. The board is also based upon the MPC5634 because one of the software drivers available from Freescale to run on the eTPU generates these signals exactly for the purpose of testing.

The engine cranking signal is not provided to the ECU. It receives only the simulated crank signal and cam signals, which can be observed using an oscilloscope at two of the BNC panel connectors on the sensors board. Two anti-phase 0-5V digital signals drive the differential crank sensor interface circuit in the ECU. The circuit itself is designed for the true variable reluctance sensor output, responds from 30rpm and 150mVp-p up to 15,000rpm and 350Vp-p. The digitized 5V square wave crank and cam signals are applied to the eTPU, which executes the task of missing tooth detection and 360 degree synchronization, then 720 degree synchronization after the cam signal is detected. Time window filtering is also applied by the eTPU on every single tooth over the whole rpm range.

To diagrammatically represent the crank signal, there is a non-working example of a 36-1 crank trigger wheel along with a variable reluctance cam sensor on the board. Creating an actual toothed spinning trigger wheel at up to 6000rpm for crank, mechanically linked to a second cam trigger wheel geared for half speed, was considered dangerous; hence, the use of a simulator board. The simulator board also generates a synchronous analog engine knock signal.

The cranking demo responds in three ways:

1. If the ‘engine’ is cranked for under two seconds it will not start.
2. The engine will continue to be cranked for as long as the key is held in the cranking position.
3. If the engine has been cranked for more than 2s, then when the key is released the engine will ‘start.’

This functionality comes from the engine simulator: the ECU simply responds to the engine signals. Mode 2 is useful for showing the sequencing of the injections and ignition events. On a four cylinder engine the two middle pistons move together (cylinders 2 and 3) and the two outer pistons move together (cylinders 1 and 4) for the best engine balance from four cylinders. This then makes for two possible firing orders: we have used 1-3-4-2 (alternative is 1-2-4-3). This sort of configuration is performed in C software in the enhanced Timer Processing Unit (eTPU) Application Programing Interface (API). See AN3678, "eTPU Automotive Function Set" and its associated application notes on the different engine functions.

As soon as engine turning is detected, the fuel pump is re-started. Operating the pump only when the engine is turning is a safety measure to avoid pumping fuel over the area in the event of an accident that ruptures a fuel pipe.

Because the cranking rpm is relatively slow at 120rpm (two turns a second) the initial synchronization can take a moment or two. The ECU is set up to run sequential fuelling at crank and because of this it needs to see the cam signal before it will fire injectors. Sequential Electronic Fuel Injection (SEFI) in crank keeps any unburned fuel from being pushed straight into the exhaust. It is a requirement for meeting Stage V emissions.

3.5 Idle operation

Releasing the key from cranking will cause it to spring back to the run position and the engine will ramp from 120rpm to idle speed, currently 800rpm. During idle the tachometer reading can be seen. This is driven by one pulse per cylinder event from the eTPU based on an angle match signal derived from the 60-2 crank signal. The eTPU automatically tracks crank position so once the tachometer function is set up no additional software intervention is required to have the tachometer track engine speed. The gauge itself is driven by a low-current protected 12V signal from the MC33800. Although the MC33800 could be driven over SPI, for diagnostics purposes it is often preferable to have a direct drive output of the tachometer signal. The built-in PWM function of the MC33800 is only available on the gate drives, and a continuously variable PWM with engine alignment must be driven directly.

During idle, the four fuel channels of the eTPU drive the sequence of injectors via the MC33810. Likewise, four ignition channels drive the ignition coils. The MC33810 is ideal for the configuration. Separating the ignition loads from other functions using a dedicated semiconductor device permits a PCB layout that keeps these 400V and 10A signals contained and away from sensitive analog signals like crank position and communications links.

The fuel injection duration as well as the ignition timing is done automatically by the eTPU. A time or angle match is set up inside the eTPU microcode that respond to the engine crank angle and crystal based system clock. The interface to the user is a small piece of C code that comes with the Freescale Set 2 eTPU software library. The application software just has to call the API to set the parameters (fuel injection end angle and pulse width, ignition dwell and fire angle) and the eTPU will drive the appropriate pin as commanded.

3.6 Drive-by-Wire demo

It is the throttle, not the pedal, that controls the engine speed by restricting the flow of air into the engine. Pressing on the pedal causes the throttle to open, as seen earlier. This opening of the throttle causes the engine speed to increase; the throttle lets in more air, the ECU matches this with more fuel, and the engine thus produces more power and accelerates. In this case, the engine simulator uses the throttle position sensor to set engine speed. Pedal units usually contain at least two position sensors, often cross connected so that a voltage increase on one track corresponds with a voltage decrease on the other track. This is a safety feature to detect faults and thus prevent runaway engine operation.

The engine speed can be controlled indirectly by pressing on the pedal. Maximum speed is currently set at 6000rpm to match the tachometer, at which point the system can draw up to 15A, depending upon settings such as coil dwell and which other actuators are active. When the pedal is released, the throttle closes, causing the engine to return to idle speed.

The throttle plate is connected to half of the MC33932 dual H-bridge driver so that the DC motor can be driven in both directions. However, the throttle plate is sharp and the motor is strong. Therefore, to avoid injury on this demo the motor is only driven by a variable pulse width in the opening direction, and is closed by the return spring only. This setup uses only two of the four transistors of the H-bridge. A result of this safety measure is that precise control of the plate is not possible due to mechanical friction.

Using a single-sided PWM permits manual operation of the throttle plate, although the return spring is quite stiff. Without operating the accelerator pedal, the engine speed can be controlled by pressing open the throttle.

3.7 Oxygen sensor heater demo

Up to 90% of the total toxic emissions from an engine during a drive cycle can occur in the first thirty seconds before the catalyst ‘lights off,’ that is, becomes hot enough to catalyze noxious gases into less harmful ones. This is true even though international emissions test drive cycles take 10–20 minutes. The reactions in the catalyst are exothermic, so once they start the catalyst keeps itself hot.

To meet Stage V emissions requirements, techniques such as close-coupled catalysts and over-retarded spark are employed to heat up the catalyst as quickly as possible. This would be of no use if the mixture could not be controlled at the same time, so the Exhaust Oxygen sensor (O_2 or lambda sensor) incorporates a heater to get it to working temperature as soon as possible. This heater has a positive temperature coefficient, so its resistance rises as it gets hot. The higher resistance reduces the power of the heater and introduces a degree of temperature self-regulation, but in some circumstances such as continuous high load running, the sensor can still overheat. To help protect it, the heater can be turned off or partially driven using PWM.

As the initial current for some types of O_2 sensors can be more than 8A, the demo uses the MC33800 to drive the heaters via external FETs. The challenge here is diagnosing faults, so this function is built in to the device. The MC33800 has an ohmic function that pulls a small current through the heater using an external reference resistor, measures the voltage drop across the heater, and converts this to a ground-referenced voltage to be read by the ADC. This resistance indicates to the ECU that the heater is still present and a reasonable value. It even permits some degree of temperature determination due to the PTC nature of the heating element.

The heaters are powered when the yellow LEDs are on. It takes about two minutes before the heating has also warmed the metal collar with its thermal readout. A PWM is used to restrict the temperature to around 75°C, the same as a cup of coffee. Powered continuously, these sensors would reach a couple of hundred degrees Celsius. The heaters are in fact driven by real PWM operating at a specific duty cycle. The PWM is gated in the seconds range to limit the heater temperature in a visible way. In a real application a faster PWM is typical, using the internal PWM feature of the MC33800 which is controlled by sending the value over SPI.

3.8 Air-to-fuel ratio demo

The primary purpose of a fuel injection system is to apply exactly the right amount of fuel to match the amount of oxygen ingested by the engine. On top of this ideal stoichiometric ratio of air to fuel, there is a wobble running fractionally rich to fractionally lean. This is needed so that the catalyst has access to unburned oxygen for use in oxidizing hydrocarbons and CO to water and CO_2. The oxygen is captured during the lean running periods, then when the mixture runs rich it is used to complete combustion of the partially burned combustion products. Unfortunately, this requirement conflicts with the ability of the catalyst to reduce nitrogen that has reacted with oxygen, the efficiency of which drops rapidly as the air-to-fuel ratio moves to lean. By regularly shifting back to slightly rich, the catalyst can also strip the oxygen atoms from the oxides of nitrogen (NO_x).

A non-linear lambda exhaust oxygen sensor works like a 0.9V chemical battery. As with all batteries, to work they need a difference of ions at the two plates. In the case of O_2 sensors the required chemical is oxygen. The 'battery' works, that is, produces an output, when there is a difference of oxygen concentration across it. This is achieved by placing one electrode in the exhaust and the other in reference oxygen, which can be atmospheric air.

With oxygen on the outside and none in the exhaust, a signal is produced. With oxygen also in the exhaust there is no output. The true response is logarithmic based on partial gas concentrations, but the effect is a sharp transition when the engine changes from rich to lean running.

In the demo, the sensors are not in an exhaust so their output is simulated using a potentiometer. It can also be read on the adjacent Air to Fuel Ratio (AFR) gauge. In this case, the potentiometer forces the condition; that is, setting the mixture to rich causes a longer injection pulse.

To make this fuel calibration effect visible and audible the injection duration has been exaggerated and rather than a continuous function, a binary distribution has been programmed into the ECU. Turning the mixture dial clockwise causes the gauge to read Rich and the duration of the injection pulse to increase significantly. The effect is a bit more visible at higher rpm. The tone of the injectors can be heard to change when going from rich to lean and vice versa. The ADC is used to read the simulated O_2 signal, and the indication of rich or lean causes the MCU to schedule a long or short injection pulse. This is a RAM parameter passed to the eTPU, which then drives the injector for the commanded duration. The eTPU injection event can be configured either to start or to end on a specific crank angle.

3.9 Engine temperature demo

It is quite common today for the radiator fan to be driven by the ECU rather than via a thermally operated switch that sits in the coolant water. The ECU is able to control the fan in a more intelligent way, for example running two speeds or proportional PWM control such that the fan can operate quietly for a higher quality impression of the car. The ECU can also run better diagnostics and apply power in a way that does not disturb engine idle stability due to electrical load.

Although an Engine Coolant Temperature (ECT) sensor is mounted on the demo, because it is not in coolant a potentiometer is used to simulate engine temperature. Turning it clockwise increases the simulated temperature to the ECU. The ECU reads this via the microcontroller's ADC and responds by driving the temperature gauge to a higher figure. The gauge itself is driven by the MC33800 using a 12V PWM of about 5Hz. This allows the ECU to simulate the variable resistance that the gauge expects to see.

When the temperature reaches 80°C, the fan is switched on to low speed. This is achieved using the constant current output of the MC33800. When the temperature hits 100°C, the fan is switched to high speed. The constant current output would normally drive a linear solenoid or gauge, but it is suitable for the low-current fan. Because the fan uses a BLDC motor with inductive feedback it is not possible to drive it too slowly. Although the high and low speeds are not visually that different, the difference in airflow can be felt.

3.10 Ignition and injection diagnostics demo

The MC33810 includes comprehensive diagnostics on both ignition and injection outputs. As well as the usual open and short circuit detection, the MC33810 is able to monitor the voltage of the spark event that is reflected onto the low tension side of the coil. By this means it can also monitor high tension faults such as a disconnected lead or failed plug. It is even smart enough, should it detect such a fault, to protect the coil by pulling the energy back through the IGBT. This can prevent failure of the coil wire enamel insulation.

To detect open circuits, a small test current (which can be seen due to the efficiency of the LEDs) is pulled through the actuator. This is achieved by disconnecting the ignition coil, or injector. The relevant LED will then glow, caused by the 100uA that the SMOS device uses for diagnostics. For the coil this current is pulled through the feedback resistor so it can still be detected even though the coil itself is driven by the IGBT.

Many of the SMOS devices used in this ECU report faults to the microcontroller using the SPI communications link. To meet most emissions standards, persistent faults that cause emissions to exceed normal levels must be logged by the ECU and indicated to the driver. The software polls the diagnostic information inside a dedicated task and decides whether to switch on the MIL lamp.

3.11 Manifold pressure and canister purge demo

When a car is refueled, 50 liters of hydrocarbon vapors are displaced in order to put into the tank 50 liters of gasoline. To prevent these hydrocarbons from escaping into the atmosphere, the vapors are first pushed through a canister containing carbon (charcoal). The charcoal absorbs the hydrocarbons because the carbon has an extremely large active surface area.

This carbon canister has limited capacity. To ensure that it does not become saturated, thus letting hydrocarbons straight through to the atmosphere, the canister must be purged. This is achieved by drawing in fresh air through the canister into the inlet manifold. Any hydrocarbons present will then be fully burned by the engine.

This purging operation is usually controlled by a solenoid operated gas valve. However, the pintle on these valves cannot easily be seen and moves only a few millimetres, so an open solenoid is fitted to the demo.

When the ECU operates the valve it does not know the concentration of hydrocarbons in the canister. If it is high, then the engine receives additional fuel and the amount delivered by the injectors must be reduced. If it is low, then additional fuel will be required. These rich or lean excursions can cause torque changes that are felt by the driver. To minimize this, the ECU chooses when to open the canister such that any torque change is imperceptible, based upon engine conditions such as manifold vacuum.

When the syringe is pulled, it applies a partial vacuum to both the vacuum gauge and a Freescale MPX2100 pressure sensor fitted behind the board. The sensor is read by the MCU using the ADC, and it operates the solenoid when the pressure has reduced from atmospheric (100kPa) down to about 70kPa.

The static error caused by the mismatch of engine running and no manifold vacuum results in the MIL being lit. When vacuum is pulled on the sensor it can also be observed that the MIL no longer shines continuously. Currently, only some elements of the error reporting software are coded.

3.12 Calibration demo

This demonstration will be available if there is a laptop available with the INCA calibration application from ETAS installed. Note that INCA software is node locked to a particular MAC address.

Calibration is the process by which ECU parameters are tuned to match an individual engine. The ECU uses the Controller Area Network (CAN) protocol to communicate with the PC. The PC requires an adapter to add the CAN capability, here the tool most likely is the ETAS ES581 USB to CAN interface. The PC is informed about the memory mapping inside the ECU using a variables file called A2L, and it can then request values of these variables (measurement) or changes to them (calibration). Calibration is only possible if the variables are stored in, or copied to, RAM locations. Currently a measurement demonstration is configured in which some key variables such as rpm and throttle position can be displayed on a dashboard set up on the PC.

A production ECU always carries some overhead in order to provide a calibration function. This might be, for example, pins and a communication port, or for the MPC5634M, a hidden bus on the silicon die that is accessible when using a higher pin count calibration package. One low-cost implementation is to use a larger part in the same family that is pin compatible; that solution is shown here. The MPC5634M 1.5 MB memory variant has more flash memory and RAM than required by the application, and thus includes spare RAM that is used to shadow variables for calibration purposes.

The ECU application includes software to administer this calibration function. The protocol used is a standard called XCP, a development of the CAN Calibration Protocol CCP. The software, provided by ETAS, is available with the INCA tools package. See your Freescale or ETAS representative for further details.

3.13 Knock processing

This demonstration will be available if there is a laptop available with a compatible CAN interface and with the Freescale FreeMaster tool installed. FreeMaster can be downloaded from Freescale.com.

Knock is a heat-induced phenomenon in which unburned combustion gas is compressed beyond its ignition point by the pressure wave that precedes the flame front of a spark-ignited mixture. This end gas spontaneously and rapidly combusts, exciting resonances across the combustion chamber that propagate through the engine block. These resonances are detected by an accelerometer attached to the block.

Engines are noisy, and the noise produced by the knock event is buried within high levels of background noise. A typical processing scheme filters out expected knock frequencies for the crank angle over which they are expected to occur, and then integrates the energy to return a magnitude that can be tested against a threshold previously declared as 'knock.'

The problem is complicated by a range of factors such as the presence of engine noise at the same frequencies expected of knock, the short time window that reduces the selectivity of frequency banding, the fact that knock is a continuous effect so there is always a level beyond detection, and the significant variability of combustion from event to event.

The MPC5634M offers multiple solutions for processing knock. A powerful DSP engine is on-chip, and filtering schemes such as IIR, FIR, and FFT are available as library functions and can be arranged to take only a few percent of CPU time. Further, a hardware 4 pole IIR filter is on-chip and ADC samples can be streamed directly to this filter.

In this demonstration the hardware decimator/filter solution is used. A knock signal has been recorded from an engine on a dynamometer, and this signal is played back from the engine simulator board that generates the crank and cam signals. Over a defined crank angle window, the MCP5634M on the ECU makes ADC conversions of this analog knock signal. These are sent automatically into the decimator and put through a 4 pole IIR filter centred at 7kHz. Both the input data and the filtered results are sent over the CAN link to the Freemaster tool for display on the PC. The Freemaster tool uses the second available CAN on the ECU so it can run side by side with the INCA calibration tool.

4 Collateral available from this demonstration platform

Many of the work products pertaining to the ECU central to this demonstration are available for use in new designs.

These include:

- Schematics. Full circuits for all devices are available.
- Bill of materials. The list of components used in the ECU.
- PCB layout Gerber files. The board is four layers.
- Operating system. An open source operating system, CocoOS, was used. This can be found at http://www.cocoos.net/
- eTPU drivers for crank, fuel, and spark. Each of the eTPU functions has an associated Application Note. See the References section below.

- SPI configuration drivers for the SMOS devices used.
- ETAS XCP calibration software stack. Note that this is available by agreement to customers that have purchased the INCA calibration tool.

Note that the Freescale work products remain under Freescale copyright but are generally available under a free license. CocoOS is released under a GPL or BSD license. Please contact your Freescale representative for further information.

5 Summary

The cost effective Engine Control Unit demonstrator shows how an MPC5634 microcontroller, along with a small number of analog SMOS devices, can interface with the sensors and control the actuators sufficient for a Stage V or Stage VI four-cylinder port fuel injection gasoline engine.

Appendix A References

The following references are available on www.freescale.com to support the MPC4563xM Reference Engine Control Unit. The Document column name can be used as the keyword search.

Table A-1. References

Document	Title
e200z3coreRM	*e200z3 Power Architecture Core Reference Manual*
MPC563xMRM	*MPC563xM Microcontroller Reference Manual*
MPC5634M	*MPC5634M Microcontroller Data Sheet*
AN3768	*eTPU Automotive Function Set*
MC33800	16-way Low Side Driver
MC33905	System Basis Chip
MC33810	Ignition/Injection Driver
MC33926	5A H-Bridge
MC33932	Dual 5A H-Bridge
MC9S08SG	8-bit Microcontroller
MC33879	Configurable Octal Switch
MPXx6115	Pressure Sensor Range

Appendix B Glossary

Below are terms that are commonly used in this document and in the automotive industry.

Table B-1. Glossary

Abbreviation	Definition
API	Application programming interface
ADC	Analog-to-digital converter
BLDC	Brushless direct current (motor)

Table continues on the next page...

Table B-1. Glossary (continued)

Abbreviation	Definition
CAN	Controller area network
CCP	CAN calibration protocol
DSP	Digital signal processing
ECT	Engine coolant temperature (sensor)
ECU	Engine control unit
eTPU	Enhanced time processor unit
FET	Field effect transistor
FFT	Fast Fourier transform
FIR	Finite impulse response (filter type)
GPIO	General-purpose input/output
HEGO	Heated exhaust gas oxygen (sensor)
IACV	Idle air control valve
IGBT	Insulated gate bipolar transistor
IIR	Infinite impulse response (filter type)
LED	Light-emitting diode
MIOS	Multiple input output system
MCU	Microcontroller
MIL	Malfunction indicator lamp
NOx	Group term for various oxides of nitrogen
PHY	Physical layer (for communications interface)
PQFN	Power quad flat no-lead package (see AN3278)
PTC	Positive temperature coefficient
PWM	Pulse width modulation
RPM	Revolutions per minute
SBC	System basis chip
SEFI	Sequential electronic fuel injection
SMOS	Smart metal oxide semiconductor
SOIC	Small outline integrated circuit
Stage IV	European passenger car emissions level
XCP	Variable transport layer calibration protocol

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