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Application Note

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MPC563xM Engine Control Unit Reference Design

4-Cylinder Hardware Design

by: Randy Dees, Lei Gao, Mike Garrard, Karl-Ferdinand Leiss, and Hua Qian
MSG Automotive Applications
Austin, Texas
USA

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1 Introduction

The MPC563xM[1] family of microcontrollers are intended for low-end automotive Powertrain applications, primarily 4-cylinder engines. They can also be used for other applications as well. This application note describes a basic 4-cylinder Engine Control Unit (ECU) Reference Design. The reference design includes a case and all of the electronics required to run a Stage IV or V port fuel injected gasoline engine.

The MPC563xM devices are based on the e200z335 32-bit Power Architecture core and includes up to 1.5M Bytes of internal flash and up to 94K of internal SRAM. The ECU implements all of the external drivers to implement a 4-cylinder gasoline engine using Freescale SmartMOS devices.

The MPC563xM Reference Design uses the following devices:

- MPC563xM - 32-bit RISC Power Microcontroller - optimized for Powertrain Automotive applications (referred to in this application note as the main MCU)
- MC33810 - Ignition Injector Device (IID)

1. The MPC563xM Family consists of the MPC5634M, the MPC5633M, and the MPC5632M that offer differing sizes on internal SRAM, Flash, and other features.

- — 4 low side drivers for injectors
- — 4 IGBT predrivers for ignition
- — Dwell time monitor, overlapping dwell compensation, spark duration, coil sense
- — SPI interface to MCU for diagnostic information

- MC33905 - System Basis Chip SBC
  - — Two 5 volt power supplies
  - — LIN interface
  - — CAN interface
  - — Watchdog
- MC33902 - High Speed CAN Interface with diagnostic port SPI interface to MCU for diagnostic information
- MC33661 - LIN Transceiver
- MC33800 - Multi-Function Engine Control/Driver
  - — Octal Serial Switch, Hex Gate Driver and HEGO driver and 2 Constant Current drivers
  - — 6 x 1A LS Outputs - internal PowerFETs
  - — 2 x 4A LS Outputs - internal PowerFETs
  - — 2 x CCD - Constant Current LS drivers with dithering
  - — 6 x Gate Pre-Drivers (HEGO) - measures resistance via internal analog MUX
- MC33926 - Single 5A H-Bridge - 225 mOhm, PQFN or SOIC package
- MC33932 - Dual 5A H-Bridge Driver, HSOP package
- MC33879 High Side/Low Side Drivers
  - — 8 floating MOSFETs
- MPXH9002 - Barometric Pressure Sensor
- MC9S08SG8 - Low Cost, High Performance 8-bit Microcontroller (Secondary/Safety MCU) 20-pin package SPI Internal Clock

2 System Features Overview

The MPC563xM Engine Reference Design is a fully functional Engine Control Unit (ECU) hardware design that is capable of running a four-cylinder gasoline engine while meeting stringent requirements for emissions. The design is packaged in a robust enclosure that allows evaluation on an engine in a dynamometer and in vehicles.

This ECU implements a range of sensors and actuators typical of a drive-by-wire port fuel injection engine control system meeting the EU Stage-V emissions level. It is intended to be representative rather than an exact feature set. One example of possible sensors and actuators is shown in the block diagram Figure [CROSS REFERENCE FIGURE 1].

Some of the sensors would be expected on all such systems, such as the engine and air temperature sensors. Some would not, such as the fuel level input. Some of the actuators would be expected on all such systems, such as the four fuel injectors. Some would not, such as the fuel efficiency gauge. There are three sources of variation possible on this ECU design:

1. Whilst some inputs are dedicated to particular functions, for example the knock sensor pins on the MCU, others are general, such as most other ADC inputs, and thus might be used for different functions.
2. Whilst some outputs are dedicated to particular functions, for example the ignition coil pins from the IGBTs and MC33810, others are general, such as the MC33800 low side drivers, and thus might be used for different functions.
3. In a small number of cases alternative devices might be connected to the output pins: specifically, jumpers can be used to configure whether the MC33932 or the MC33879 is connected to the external actuator. This allows the option of driving either low, high or totem pole 1A loads, or a 5A H-bridge.

Features of the module include:

- 32-bit Power Architecture core Microcontroller with 1.5 MBytes of flash and 94 KBytes of SRAM.
- 8-bit Microcontroller connected to be able to perform intelligent safety checking
- Two CAN interfaces, ISO 11898-2 and 11898-5 compliant, one wired for diagnostic capabilities
- One LIN (LIN 2.0 and 1.3 compliant, and SAE J2602 compatible) or K-Line interface

- Four ignition coil drivers
- Four 'high impedance' injector drivers
- Air Pressure sensor
- One 5A H-bridge DC motor throttle control[2]
- A dual 5A H-bridge stepper motor control for D.C. motors such as variable cam actuation or EGR
- Two MOSFET pre-divers for oxygen sensor heater control
- One 1A constant current driver with dithering for solenoid control
- Seven low-side drivers for control of fuel pump, relays, coolant temperature gauge, tacho etc.
- Eight 1A high/low side drivers for stepper motor control[2]
- Internal debug connectors for both JTAG and nexus (requires uncased board)
- Analog inputs for resistive sensors such as thermistors, and voltage sensors such as MAP
- Digital inputs for rotary sensors such as crank, cam and vehicle speed

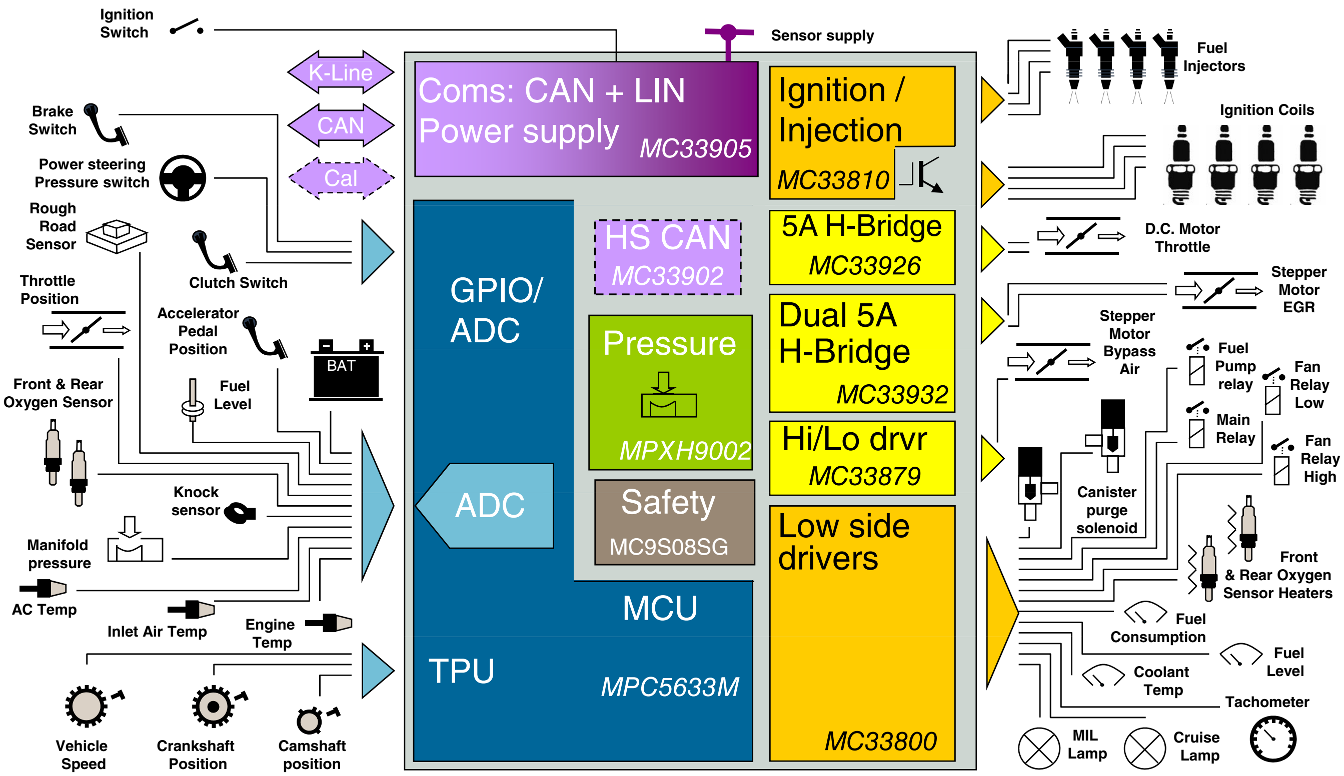

Figure 1. MPC563xM example engine reference design block diagram

2.1 Enclosure overview

The enclosure used in the design is a commercially available robust unit manufactured by Cinch in the USA and purchasable through distributors such as Newark. The intent is to enable the hardware to be evaluated in harsh environments such as an engine bay or dynamometer. The case is not rated for full automotive temperature range, nor has the board been evaluated for this. Although a heat-sink bracket is used, the enclosure is designed for heat-sinking of leaded TO220 package devices and so the thermal paths from the SMD SMOS (surface mount transistors) is not ideal. The enclosure is waterproof. It is also clip together. If it is desirable to open it up without the dedicated and somewhat costly tool available from Cinch, removal of the 10 barbs on the long edges is recommended. This permits the case to be opened using a screwdriver to gently lever the two large barbs on the short edges. With the case seal removed this process can be repeated many times. Removing the small

2. Two options are implemented for air control: full Electronic Throttle Control using an H-bridge driven DC motor control or four 1A totem outputs for a bypass air stepper motor.

barbs will at the same time adversely affect the sealing of the enclosure. The two loom side connectors are keyed and cannot be installed incorrectly. Terminals for the loom side connector are available in two sizes to fit different wire gauges. The smaller size was used for the powertrain demonstration built around this ECU. Hole blanks are available for sealing the loom-side header in positions where wires are not fitted.

2.2 Software overview

The demonstration software available does not, nor is it intended to meet Stage V emissions. It is intended to be non-production code that might be examined to provide an example idea as to how these devices can be controlled. Freescale has no control over the exact engine or system configuration to which the ECU might be attached, nor do we run validation programs on engines or cars. However, parts of the code might successfully be used within an application to achieve the desired functions. It is the responsibility of all users to validate their own code.

Due to the complexity of the task, a description of the code architecture and functionality will be released in a separate application note.

2.3 Layout overview

The PCB layout is available in Gerber and Altium formats. The Gerber files are an industry standard for multiple layer boards that requires the user to re-construct the PCB from multiple files. The order of the layers is important and must be adhered to. Free Gerber viewers are available such as Gerbtool ***[link]***. The Altium format contains all layers pre-assembled. It is more powerful and also more complex to drive, but provides better features such as Net identification and search. A free viewer is available as a large download ***[link]***.

With the connector on the left, the PCB is divided approximately into four sections as shown in ***Figure x.x***[artwork p10]. At the top by the heat-sink are the high voltage and high current drivers. The ignition coils are particularly noisy, and emit broadband noise up to the 10's MHz region as the energy stored in the coils is transferred to the spark plugs. Switching of multiple amps is required and produces hundreds of volts. These drivers are closely couple with the front connector via high current tracks, and kept clear of sensitive inputs. The high current motor driver tracks are likewise kept toward the top region of the board, with the somewhat lower current injectors and PWM outputs from the MC33800 and MC33879 further down.

In the bottom right corner is the digital section. This includes the MPC5634M microcontroller, with closely coupled tracks for the crystal oscillator and carefully applied capacitor decoupling. The high speed digital NEXUS interface is in this corner as well as the lower speed JTAG interface. Also associated with the digital side is the MC9S08 safety micro, and digital CAN interfaces.

The bottom left corner contains the analog inputs. Some, such as the crank sensor interface, must be particularly sensitive as the input signal might be only 150mVp-p. Analog inputs such as throttle and MAP are critical to engine control and should be kept as quiet as possible.

In-between the analog and high current drivers is the power supply. This forms some degree of barrier to some of the noise.

General advice on laying out PCBs can be found on the Freescale website, such as presentation FTF11_ENT_F0964 from workshops held at the Freescale Technology Forum events.

3 MPC563xM overview

The MPC563xM family of devices are highly integrated, 32-bit Power Architecture microcontrollers that are intended primarily for low-end 4-cylinder gasoline engines; however they can be used for many other types of applications. The device contains many features designed for powertrain control. The MPC563xM Reference ECU makes use of these and shows the hardware connected in a representative way. Two of the features that are highlighted in this design are the enhanced Timing Processing Unit (eTPU) and the knock processing sub-system incorporated into the device.

Note that this MCU is avalable on a stand-alone evaluation board with built in de-bugger at a very competitive price: part number TRK-MPC5634M.

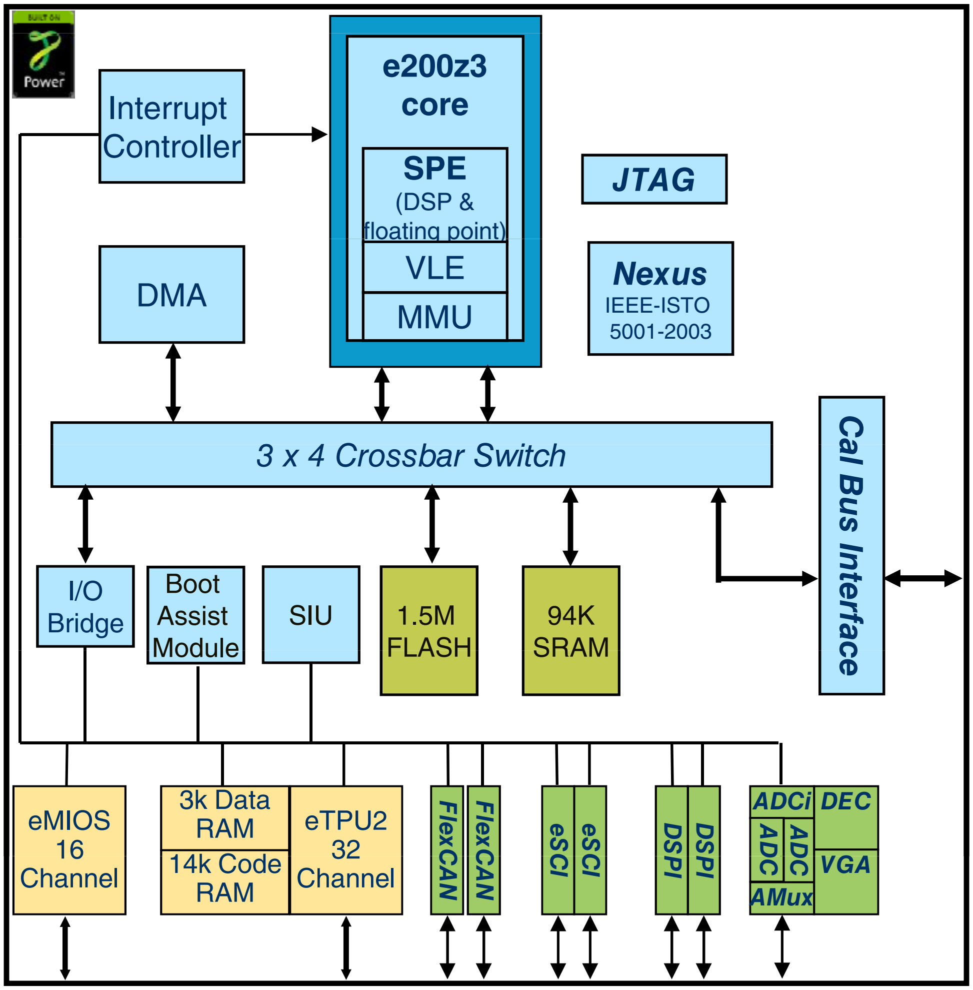

Figure 2. MPC5634M block diagram

Features of the MPC563xM microcontrollers are:

- Powerful Power Architecture CPU core that supports traditional PowerPC instruction set or the Variable Length Encoded (VLE) instruction set for reduced code footprint
- Integrated knock detection hardware and DSP engine
- Hardware floating point support for model based code
- Compatible CPU/device/pinout roadmap for application migration (more IO and more memory or less memory and IO)
- Hardware or software calibration solutions

The devices are available in several different memory configurations and feature options.

Table 1. MPC563xM family memory options

Feature	MPC5632M	MPC5633M	MPC5634M
Flash Memory Size	768 KBytes	1 MBytes	1.5 MBytes
SRAM Memory Size	48 KBytes	64 KBytes	94 KBytes

The table below shows the different package and speed options for the device. The MPC563xM ECU Reference Design uses the largest memory configuration device (MPC5634M) and the 144 PQFP package.

Table 2. MPC563xM package and speed options

Package	MPC5632M	MPC5633M	MPC5634M
144 PQFP	40, 60 MHz	40, 60, 80 MHz	60, 80 MHz
176 PQFP	—	60, 80 MHz	60, 80 MHz
208 MAPBGA	—	60, 80 MHz	60, 80 MHz

The MPC563xM devices include a multitude of on-chip peripherals for timing control and communications. The table below shows the peripheral modules available in the devices.

Table 3. On-chip peripherals

<table>
<tr><th colspan="2" rowspan="2">Feature</th><th rowspan="2">Protocol</th><th colspan="3">Number available</th></tr>
<tr><th>MPC5632M</th><th>MPC5633M</th><th>MPC5634M</th></tr>
<tr><td rowspan="2">Timers (measurement and generation)</td><td colspan="2">enhanced Modular Input/Output System (eMIOS)</td><td>8 channels</td><td colspan="2">16 channels</td></tr>
<tr><td colspan="2">enhanced Timing Processing Unit (eTPU)</td><td colspan="3">16 channels</td></tr>
<tr><td rowspan="3">Timers (interrupts)</td><td colspan="2">Peripheral Interrupt Timers (PIT)</td><td colspan="3">4 channels</td></tr>
<tr><td colspan="2">Real Time Interrupt (RTI)</td><td colspan="3">1 channel</td></tr>
<tr><td>System Timer Module (STM)</td><td></td><td colspan="3">4 channels</td></tr>
<tr><td rowspan="5">Communications Interfaces</td><td rowspan="3">enhanced Serial Communications Interface (eSCI)</td><td>RS-232D</td><td colspan="3" rowspan="3">2 interfaces</td></tr>
<tr><td>LIN[1]</td></tr>
<tr><td>K-Line</td></tr>
<tr><td colspan="2">Deserial/Serial Peripheral Interface (DSPI)</td><td colspan="3">2 interfaces[2]</td></tr>
<tr><td>Flexible Controller Area Network (FlexCAN)</td><td>CAN</td><td colspan="3">2 interfaces</td></tr>
<tr><td rowspan="4">Analog</td><td colspan="2">enhanced Queued Analog to Digital converter (eQADC)</td><td colspan="2">32 channels</td><td>34 channels</td></tr>
<tr><td colspan="2">Differential Channels[3]</td><td colspan="3">4 differential channels</td></tr>
<tr><td colspan="2">Variable Gain Amplifiers (x2, x4)[4]</td><td colspan="3">4</td></tr>
<tr><td colspan="2">Decimation Filters</td><td colspan="3">1</td></tr>
</table>

1. Local Interconnect Network
2. Microsecond bus compatible
3. Differential channels use two of the single-ended channels.
4. Only usable on the differential channels.

3.1 Internal SRAM

Depending on the device in the family, the SRAM available is different on each of the members of the MPC563xM family devices.

Table 4. SRAM Configurations

		Description	MPC5632M	MPC5633M	MPC56334M
		Standby SRAM Size	24 KBytes	24 KBytes	32 KBytes
Start Address	End Address	Total SRAM Size	48 KBytes	64 KBytes	94 KBytes
0x4000_0000	0x4000_5FFF	24 KBytes	Standby SRAM	Standby SRAM	Standby SRAM
0x4000_6000	0x4000_7FFF	8 KBytes	SRAM	SRAM	Standby SRAM
0x4000_8000	0x4000_BFFF	16 KBytes	SRAM	SRAM	SRAM
0x4000_C000	0x4000_FFFF	16 KBytes	Not Available	SRAM	SRAM
0x4001_0000	0x4001_77FF	30 KBytes	Not Available	Not Available	SRAM

Part of the SRAM is powered by a separate SRAM Standby Supply voltage (VSTBY). VSTBY can either be a 1.0V supply (0.95 to 1.2V) or a supply between 2.0 and 5.5 volts. If stand-by operation is not required, VSTBY can be connected to ground.

Attention

VSTBY must never be left floating.

On the MPC563xM ECU Reference Design, VSTBY is grounded.

3.2 Flash Memory

The MPC563xM Devices contain internal nonvolatile flash memory for holding code for execution. The following table shows the blocks of the flash that are available on the different members of the family.

Table 5. Flash array map

Start Address	Use	Block	Size	MPC5632M (768 KBytes)	MPC5633M (1 MByte)	MPC5634M (1.5 MBytes)	Bank[1]
0x0000_0000	Low Address Space 256 KBytes	0[2]	16 KBytes	Available	Available	Available	Bank 0, Array 0
0x0000_4000		1a[2]	16 KBytes	Available	Available	Available	
0x0000_8000		1b[3]	32 KBytes	Available	Available	Available	
0x0001_0000		2a[2]	32 KBytes	Available	Available	Available	
0x0001_8000		2b[3]	16 KBytes	Available	Available	Available	
0x0001_C000		3[2]	16 KBytes	Available	Available	Available	
0x0002_0000		4[2]	64 KBytes	Available	Available	Available	
0x0003_0000		5[2]	64 KBytes	Available	Available	Available	
0x0004_0000	Mid-Address Space 256 KBytes	6	128 KBytes	Not available	Available	Available	
0x0006_0000		7	128 KBytes	Not available	Available	Available	

Table continues on the next page...

Table 5. Flash array map (continued)

Start Address	Use	Block	Size	MPC5632M (768 KBytes)	MPC5633M (1 MByte)	MPC5634M (1.5 MBytes)	Bank[1]
0x0008_0000	High Address Space 1.0 MBytes	8	128 KBytes	Available	Available	Available	Bank 1, Array 1
0x000A_0000		9	128 KBytes	Available	Available	Available	
0x000C_0000		10	128 KBytes	Available	Available	Available	
0x000E_0000		11	128 KBytes	Available	Available	Available	
0x0010_0000		12	128 KBytes	Not available	Not available	Available	Bank 1, Array 2
0x0012_0000		13	128 KBytes	Not available	Not available	Available	
0x0014_0000		14	128 KBytes	Not available	Not available	Available	
0x0016_0000		15	128 KBytes	Not available	Not available	Available	
0x00FF_C000	Shadow Block 16 KBytes	S0	16 KBytes	Available	Available	Available	Bank 0, Array 0

1. Read while write (RWW) can only be performed between Bank 0 and either of the arrays in Bank 1. RWW cannot be done between Array 1 and Array 2 of Bank 1.
2. Can boot from this block.
3. Cannot boot from this block.

Two of the blocks on the MPC563xM Low Address Space are not bootable. See the device reference manual for details on the boot process and the valid boot configuration identifier.

3.3 Reset Configuration

Information to be added.

3.4 External ADC connections

Description to be added.

3.4.1 Power Management Controller (PMC) Monitor Channels

Many of the PMC reference and output voltages can be monitored by the on chip Analog to Digital Converter (eQADC). These on-chip voltages can therefore be monitored by the application software. As well as monitoring power supplies on all pin banks, and ADC references, there is an internal temperature sensor and bandgap reference for application use. Some of these signals can only be converted by one of the on-chip ADCs. The available PMC signal channels are shown in the following table.

Table 6. Power Supply ADC Monitor Channels

ADC Channel	ADC	MPC563xM Description
40	ADC0/ADC1	VRH
41	ADC0/ADC1	VRL
42	ADC0/ADC1	50% x (VRH - VRL)
43	ADC0/ADC1	75% x (VRH - VRL)
44	ADC0/ADC1	25% x (VRH - VRL)
45	ADC0, ADC1	Band Gap
128	ADC0, ADC1	Temperature Sensor
144	ADC0	Buffered Band Gap voltage
145	ADC0	Reference voltage for the 1.2V Low Voltage Detect
146	ADC0	Reference voltage for the 1.2V regulator controller
147	ADC0	Reference for the 3.3V Low Voltage Detect[1]
162	ADC0	50% of VDDEH1B
163	ADC0	50% of VDDEH1B
164	ADC0	50% of VDDEH4B
165	ADC0	50% of VDDEH6A
166	ADC0	50% of VDDEH6B
167	ADC0	50% of VDDEH7
180	ADC0	Reference voltage for 5.0V Low Voltage Detect [1]
181	ADC0	Reference for the LVI3p3_h6 sampling reference
182	ADC0	Reference for the 3.3V Supply Regulator
183		Not Used
196	ADC1	VRC33 - 3.3V supply of the device
197	ADC1	VRC33 - 3.3V supply of the device
198	ADC1	VDD12 - 1.2V supply of the device
199	ADC1	50% of VDDEH1A

1. The voltage on this channel should be compared to the buffered Band Gap voltage to determine the actual low voltage trip point.

3.5 Internal Power Supplies

The VDD Regulator Input (VDDREG) is the 5 volt input to the internal 3.3 volt regulator and 1.2 volt regulator controller. If the internal regulators are not being used, VDDREG can be tied to VSS to disable their operation. However, this disables internal low voltage detect circuits. To keep the internal low-voltage detect circuits powered, VDDREG can be connected to 5 volts, even when the internal regulator circuits are not used.

3.5.1 3.3 Volt Power Supply

The 3.3 volt internal regulator is completely contained within the device and only requires the input supply (VDDREG) and a bypass capacitor on the 3.3 volt output (VRC33). The 3.3 volt supply is used for internal operation of the device, including powering parts of the flash module within the device.

The 3.3 volt regulator is intended to power internal circuitry only and was not designed to power external pins of the device. However, there are times that this supply could be used power a small number of pins. {Note - this needs to be evaluated further.}

NOTE

In the 144 QFP package, the JTAG/Nexus pins output a 3.3 volt level, however, these signals are not powered by the 3.3 internal regulator. These pins are powered by the 5 volt power supply and the output voltage is limited in the output drivers of the signals. On the MPC563xM ECU VRC33 is used for the reference on the debug connector for the JTAG/Nexus interface.

3.5.2 1.2 Volt Power Supply Input and Regulator Controller

The majority of the internal device circuitry is powered by the 1.2 volt VDD input. This includes all of the CPU core and the majority of the internal logic of the device. An internal regulator controller is implemented to provide a low cost power supply option. By utilizing an external transistor, the power loss from reducing the 5 volt supply to 1.2 volts does not have to be dissipated within the MCU package and can be handled externally.

The 1.2V regulator controller provides a current signal (VRCCTL) that feeds the base of an external NPN transistor. This controls the current flow from the 5 volt supply (approximately 3-7V range permissible) connected to the transistor collector and the transistor emitter provides the 1.2 volt supply. Inside the package, a sense signal is connected to the VDD internal supply input. This signal is compared to an internal Band Gap reference that sets the regulator reference voltage. Depending on the voltage on VDD, the current on the VRCCTL signal is raised or lowered to maintain the 1.2 volt level.

3.5.2.1 Power Management Controller 1.2V External Circuitry

The figure below shows the required external circuitry for the internal regulators of the device. Some of this circuitry may not be required, but space should be saved for all of these components for the target system. Evaluation of the final board layout and the external power supply may allow some of these components to be removed.

Regulator stability is controlled by many factors, including the phase response of the regulator loop. The transistor response and parasitic components due to PCB layout impact the phase response yet are external to the MCU. It can also be affected by noise coupling from the supply feeding the regulator (5 volt supply). The loop also depends on the gain of the transistor, the impedance of the 5V power supply, and the transient response time of that supply. Slower transient response times will require additional bulk capacitance at the MCU to compensate for the response time of the power supply.

A bypass capacitor should be added right at the collector of the external NPN pass transistor, which should be connected to VDDREG.

A snubber circuit should be connected on the VRCCTL signal from MCU to the base of the external pass transistor. This resistor-capacitor arrangement adjusts the phase of the loop to compensate for excessive parasitic inductance and eliminate any oscillation. The snubber circuit also reduces any noise coupling from the source supply for the pass transistor. This provide the most robust solution for any typical situation

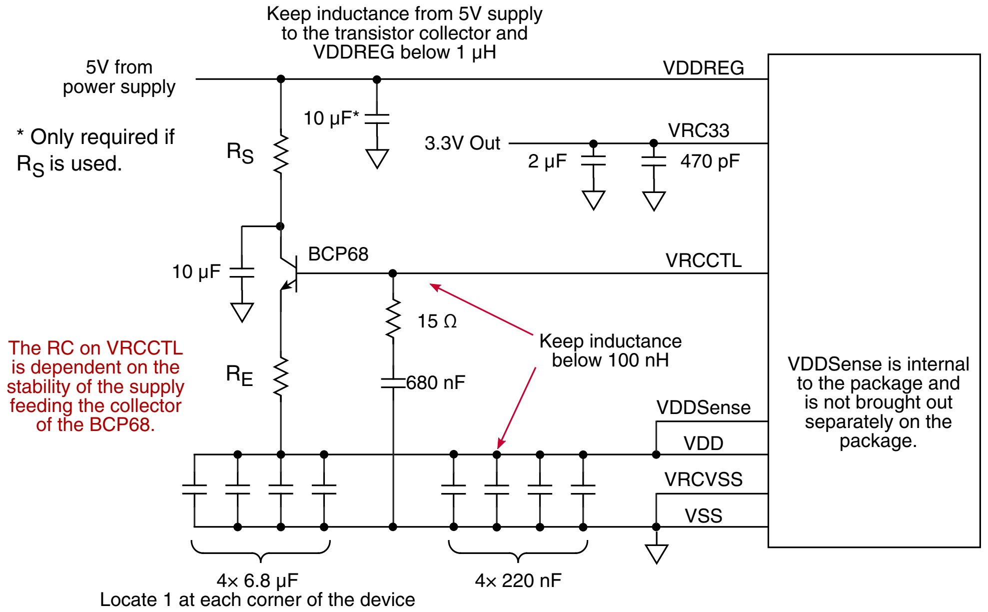

Figure 3. PMC External Circuitry

The following table shows the recommended components for the 1.2V regulator circuit. The worst case typical system components should be used until a complete evaluation of the target system power supply has been performed. R_E is not required for the MPC563xM devices. It can either be shorted or a 0 Ω resistor can be used.

Table 7. Recommended external components for the 1.2V regulator controller

Components		MPC563xM Worst Case Typical System
VDD Bypassing		4 x 6.8 uF[1,2]
		4x220 nF ceramic
Snubber	Resistor	15 Ω
	Capacitor	680 pF
Source bypass capacitor (pass transistor collector) [3]		10 uF[2]
VDDREG bypass capacitor[3]		10 uF
Source resistor (R_S in the above figure)		3.3 Ω
Emitter resistor (R_E in the above figure)		0 Ω

1. Maximum ESR of 200mΩ each
2. The VDD and source bypass capacitors should be the same type of capacitor to keep the series impedance matched.
3. The source bypass capacitor and the VDDREG Bypass capacitor can be the same if there is no Resistance between VDDREG and the collector of the pass transistor.

A series resistor (R_S) can be used on the pass transistor collector to reduce the power dissipation required by the pass transistor. Depending on the transistor selected, the power dissipation to required to drop the VDDREG voltage (nominal 5 volts) down to the VDD voltage (1.2V) may be more than the transistor package allows for the temperature encountered and heatsinking provided. If R_S is used, both the transistor collector and VDDREG should be bypassed. If R_S is not used, a single bypass capacitor can be used for both. In this case, the capacitor should be close to the transistor collector, but should still be placed close to VDDREG.

An alternate method to reduce the power dissipation requirements of the pass transistor is to use a nominal 3.3V source (if a suitable external 3.3V supply is available in the target system) for the transistor collector. In this case, VDDREG should still be connected to the nominal 5 volt supply. Both supplies should be well bypassed.

3.6 Recommended Power Supply Bypass Capacitors

The table below shows the recommended number and values of bypass capacitors for each of the digital power supply pins.

Table 8. Recommended Digital Power Supply Bypass Capacitors

Supply	Quantity	Value	Notes
VDDREG	1	10 uF[1]	The capacitor should be located very near the collector of the pass transistor and tied to the ground plane as near to the MCU as possible.
VDD	4	6.8 uF[2]	Locate at the 4 corners of the device.
	4	220 nF	
VRC33	1	2.2uF	
VDDEH	4	10 nF	
VDDPLL	1	100 nF	
	1	10 nF	
VSTBY	1	10 nF	

1. Depending on the impedance of the power supply, a value of up to 100 uF may be required. This depends on the transient response time and impedance of the supply.
2. See the PMC External Circuitry section of this application note.

The table below shows the recommended bypass capacitors for the Analog power supplies of the device.

Table 9. Recommended Digital Power Supply Bypass Capacitors

Supply	Quantity	Value	Notes
VDDA	1	10 uF	Connect directly from VDDA to VSSA.
VRH	1	10 nF	
VRL	0	-	Connector to ground plane of the board.
VSSA	0	-	

3.7 MCU Peripherals

The MPC563xM includes many on-chip peripherals. These peripherals are mapped to the pins of the device and in some cases, multiple functions are available on the same pin of the device. The use of the peripheral pins is shown in this section for the on-chip peripherals.

Table 10. On-chip peripheral summary

Peripheral Module	Symbol	Functionality	Number of Modules	Number of channels (total)
Deserial/Serial Peripheral Interface	DSPI	Synchronous serial communication (SPI)	2	2
Enhanced Queued Analog to Digital Converter	eQADC	Analog to Digital interface	1	Up to 34
Enhanced Modular Input/Output System	eMIOS	Timing channels	1	Up to 16
Enhanced Serial Communications Interface	eSCI	Asynchronous Serial interface	2	2
Enhanced Timing Processing Unit	eTPU	Programmable timing processor	1	32
Flexible Controller Area Network	FlexCAN	CAN serial communications	2	2

In addition to the on-chip peripherals with pin interfaces, some peripherals are available internally that do not use pins of the device, such as the Decimation filter (one) and a number of timers.

Table 11. Internal peripherals

Module	Symbol	Functionality	Number of Modules	Number of total channels
Decimation Filter	DECF	Digital filtering of ADC outputs	1	1
Variable Gain Amplifier	VGA	Amplification of analog signals prior to the ADC (differential channels only)	1	4
Peripheral Interrupt Timers	PIT/RTI	Timers for generating interrupts at different intervals	1	5
System Timers Module	STM	Task monitor timers	1	4

3.7.1 eTPU pin connections

The enhanced Timing Processor Unit (eTPU) is an independent controller designed specifically to handle timing events. The eTPU can process timing pulses generated by the crankshaft position sensor of an engine and use them to create an angle clock against which it and eMIOS channels can perform angle domain tasks. Examples are driving tachometer, injector solenoids and the ignition coils (for the spark plugs). This hardware co-processor is so well suited to running an engine that it is possible to stop the main CPU core and still continue to gently drive a car just on the eTPU. The eTPU continues to track crank and cam position and fire injectors and coils accurately and repeatedly until it is given new instructions. Much support for the eTPU can be found on the Freescale web site under the eTPU (http://www.freescale.com/etpu), including a configuration tool, application notes and code for the engine position, fuel and spark functions used in the ECU. The eTPU can also be used for many other types of timing operations.

The following table shows the allocation of the eTPU pins/channels for the MPC563xM Engine Reference Design.

Table 12. eTPU pin usage

Channel	Schematic Symbol	Direction	Default State (during and after reset)	MCU Pin Number	Function selected	Connection and description
eTPUA0	CRANK_I	Input		52	eTPU	Input from the Crank interface circuit.
eTPUA1	—	—		51	Not Used	—
eTPUA2	—	—		50	Not Used	—
eTPUA3	TPU_MON	Output		49	eTPU	Output to the S08 8-bit MCU that is used to monitor the status of the eTPU for safety requirements.
eTPUA4	—	—		47	Not Used	—
eTPUA5	932B_SF	Input		45	GPIO (input)	Fault status input from the MC33932 driver B
eTPUA6	932A_SF	Input		44	GPIO (input)	Fault status input from the MC33932 driver A
eTPUA7	926_SF	Input		43	GPIO (input)	Fault status input from the MC33926
eTPUA8	CAM2_I	Input		42	eTPU	CAM sensor input 2
eTPUA9	CAM1_I	Input		41	eTPU	CAM sensor input 1
eTPUA10	810_MAXI	Input		40	eTPU	Maximum current feedback input from the MC33810 (MAXI)
eTPUA11	810_NOMI	Input		39	eTPU	Nominal current feedback input from the MC33810 (NOMI)
eTPUA12	IGN4_O	Output		38	eTPU	Control to MC33810 GIN3 (ignition 4)
eTPUA13	IGN3_O	Output		37	eTPU	Control to MC33810 GIN2 (ignition 3)
eTPUA14	IGN2_O	Output		35	eTPU	Control to MC33810 GIN1 (ignition 2)
eTPUA15	IGN1_O	Output		33	eTPU	Control to MC33810 GIN0 (ignition 1)
eTPUA16	INJ4_O	Output		32	eTPU	Control to MC33810 DIN3 (injector 4)
eTPUA17	INJ3_O	Output		31	eTPU	Control to MC33810 DIN2 (injector 3)
eTPUA18	INJ2_O	Output		30	eTPU	Control to MC33810 DIN1 (injector 2)
eTPUA19	INJ1_O	Output		29	eTPU	Control to MC33810 DIN0 (injector 1)
eTPUA20	—	—			Not Used	—
eTPUA21	926_DIS	Output		27	GPIO (output)	Control for MC33926 DIS(able)
eTPUA22	—	—			Not Used	—
eTPUA23	932_DIS	Output		23	GPIO (output)	Control for MC33932 DIS(able)
eTPUA24	905_INT	Input		21	GPIO or IRQ[12]	Interrupt from the MC33905

Table continues on the next page...

Table 12. eTPU pin usage (continued)

Channel	Schematic Symbol	Direction	Default State (during and after reset)	MCU Pin Number	Function selected	Connection and description
eTPUA25	879_EN	Output		20	GPIO (output)	Connected to MC33879 EN(able)
eTPUA26	CAN_B_NERR	Input		19	GPIO (input)	Connected to MC33902 NERR
eTPUA27	—	—			Not Used	—
eTPUA28	CAN_B_NSTB	Output		17	GPIO (output)	Connected to MC33902 NTSB
eTPUA29	TPI			16		Not used
eTPUA30	KNOCK_WINDOW	Output?		15	eTPU	Knock Window output for reference
eTPUA31	CAN_B_EN	Output		14	GPIO (output)	To MC33902 EN(able)

3.7.2 eMIOS connections

The eMIOS module of the MPC563xM allows for either measurement or creation of timing functions.

The eMIOS channels are divided into different classes of functionality, defined as small, medium or big.

		Small	Medium	Big
General purpose input/ output	GPIO	√	√	√
Single action input compare	SAIC	√	√	√
Single action output compare	SAOC	√	√	√
Output pulse width modulated, buffered	OPWMB		√	√
Input period measurement	IPM			√
Input pulse width measurement	IPWM			√
Double Action output compare	DAOC			√
Output pulse width modulation and frequency modulation, buffered	OPWFMB			√
Modulus Counter, Buffered	MCB			√

Although the eMIOS module is capable of 24 channels, only 16 are implemented on the MPC563xM devices. In addition, some of the channels are not connected to physical pins of the device package.

Channel	Small	Medium	Big	Available on pad?
0			√	Yes
1	√			Yes[1], No[2]
2		√		Yes
3	√			No[3]
4		√		Yes
5	√			Yes[4]
6	√			Yes[4]
7	Not implemented			
8			√	Yes
9			√	Yes
10			√	Yes
11		√		Yes
12			√	Yes
13		√		Yes
14			√	Yes
15			√	Yes
16	Not implemented			
17	Not implemented			
18	Not implemented			
19	Not implemented			
20	Not implemented			
21	Not implemented			
22	Not implemented			
23[5]			√	Yes

1. MPC5634M only
2. MPC5632M and MPC5633M
3. Channel 3 is not available on a physical pin, but can be used to generate timed interrupts or by utilizing the deserialization feature of the DSPI.
4. Channels 5 and 6 are shared with JTAG functions which are required to program the flash with a debugger or flash programmer. These channels can be used for timed interrupt generation, or by utilizing the deserialization features of the DSPI, or by using the serial boot option to program the flash in the factory (this is not advised due to the time overhead).
5. Channel 23 is implemented since it can be used as a clock to all of the other eMIOS channels.

The following table shows the allocation of the eMIOS channels and the MCU pin numbers used on the MPC563xM Engine Reference Design.

Table 15. eMIOS connections

Channel	Schematic Symbol	Direction	Default State (during and after RESET)	MCU Pin Number	Pin Function Used	Channel Type	Description
eMIOS0	TACH_O	Output		54	eMIOS or eTPU	Big	Engine speed Tachometer output. This can be driven either by the eMIOS function or the eTPUA25
eMIOS1	—			—		Small	Pin only available on the MPC5634M, not available on the MPC5632M or MPC5633M
eMIOS2	932B_IN1	Output		55	eMIOS	Medium	Used for H-Bridge control to the MC33932 B_IN1
eMIOS3						Small	Internal channel only, not connected to a pin.
eMIOS4	932B_IN2	Output		56	eMIOS	Medium	Used for H-Bridge control to the MC33932 B_IN2
eMIOS5						Small	Internal channel only, not connected to a pin.
eMIOS6						Small	Internal channel only, not connected to a pin.
eMIOS8	810_SPKDUR	Input		57	eMIOS	Big	Used to measure the spark duration from the MC33810 SPKDUR.
eMIOS9	PURGE_VALVE_O	Output		58	eMIOS	Big	Control for Purge Valve solenoid
eMIOS10	VSPEED_I	Input		60	eMIOS	Big	Input for measuring the Speed input
eMIOS11	932A_IN1	Output		62	eMIOS	Medium	Used for H-Bridge control to the MC33932 A_IN1
eMIOS12	926__IN1	Output		63	eMIOS	Big	Used for H-Bridge control to the MC33926 IN1 for Electronic Throttle Control
eMIOS13						Medium	
eMIOS14	—	Not Used		64		Big	
eMIOS15						Big	
eMIOS23	926_IN2	Output			eMIOS	Big	Used for H-Bridge control to the MC33932 B_IN2 for Electronic Throttle Control

3.7.3 DSPI Connections

This section covers the connections of the De-serial Serial Peripheral Interface. There are two options for the connection of the microcontroller SPI communications port to multiple slave devices: series and parallel. In series, the SPI data lines are daisy chained such that the output of one device feeds the input of the next device. The chip select and clock lines are connected in parallel. Long messages are compiled and sent to all devices simultaneously. The message for the last device passes through all the other devices to get there. The message for the second last device passes through all but the last device, and so on. The devices respond to their unique messages when the chip select line is de-asserted. This configuration always uses only four pins on the microcontroller, and is facilitated on the MPC563xM MCUs because the SPI message queue can be any length and is delivered to the SPI port automatically using DMA.

The second option, parallel connection, is used in the Reference Design. In this configuration the data and clock lines are connected in parallel to all devices, and each device has an individual chip select pin on the MCU. In parallel connection the software is more simple because each device is accessible individually as if it were the only device connected. The disadvantage is that more MCU pins are used. As the MCU still has spare pins, using individual chip selects caused no issues.

The SPI link is used initially to configure the analog devices, and then to retrieve messages from them. The latter are usually status reports that would inform of errors. The safety watchdog within the MC33905 also works over the SPI link.

Table 16. DSPI pin usage

Channel	Schematic Symbol	Direction	MCU Pin Number	Connection and description
DSPI_B_SOUT	879_MOSI	Output	96	Serial data to all SPI devices
	800_MOSI			
	810_MOSI			
	905_MOSI			
	SAFE_MOSI			
DSPI_B_SIN	879_MISO	Input	95	Serial data from all SPI devices
	800_MISO			
	810_MISO			
	905_MISO			
	SAFE_MISO			
DSPI_B_SCK	879_SCLK	Output	89	Serial clock to all SPI devices
	800_SCLK			
	810_SCLK			
	905_SCLK			
	SAFE_SCLK			
DSPI_B_PCS[4]	879_CS	Output	88	Chip select for MC33879
DSPI_B_PCS[1]	800_CS	Output	92	Chip select for MC33800
DSPI_B_PCS[2]	810_CS	Output	90	Chip select for MC33810
DSPI_B_PCS[1]	905_CS	Output	97	Chip select for MC33905
DSPI_B_PCS[1]	SAFE_CS	Output	87	Chip select for MC9S08SG safety MCU

3.7.4 MPC563xM Analog Channel usage

The following table shows the usage of each of the MPC563xM analog inputs in the MPC563xM ECU Reference Design.

Table 17. MCU analog channel usage

Channel	Schematic Symbol	MCU Pin Number	Description
AN0 (DAN0+)	—	143	Not Used
AN1 (DAN01)	—	142	Not Used
AN2 (DAN1+)	—	141	Not Used
AN3 (DAN1-)	UP_O2_I	140	Input to measure the Upstream Exhaust Oxygen (O2) Sensor
AN4 (DAN2+)	INTAKE_PRESS_I	139	Input to measure the Intake Air Pressure
AN5 (DAN2-)	—	138	Not Used
AN6 (DAN3+)	KNOCK_I_POS	137	Differential (positive) input from the knock sensor
AN7 (DAN3-)	KNOCK_I_NEG	136	Differential (negative) input from the knock sensor
AN9	—	5	Not Used
AN11	—	4	Not Used
AN12[1]	—		Not Used
AN13[1]	—		Not Used
AN14[1]	—		Not Used
AN15[1]	—		Not Used
AN16	800_LRFB	3	Connected to the MC33800 Load resistance feedback pin to measure the HEGO heater resistance
AN17	VBAT_MON	2	Connected to the module supply voltage to measure battery voltage
AN18	905_MUX	1	Input from the MC33905 System basis Chip that can be used to read the Vbat (battery Voltage), 5V current output, and the MC33905 temperature
AN21	—	144	Not Used
AN22	932A_FB	132	Connected to measure the MC33932 H-bridge load current feedback (H-bridge A)
AN23	932B_FB	131	Connected to measure the MC33932 H-bridge load current feedback (H-bridge B)
AN24	926_FB	130	Connected to measure the MC33926 ETB H-bridge load current feedback
AN25	DOWN_O2_I	129	Input to measure the Downstream Exhaust Oxygen Sensor (Catalyst monitor sensor)
AN27	INTAKE_TEMP_I	128	Input to measure the Intake Air Temperature
AN28	PEDAL_A_I	127	Input to measure the Pedal Position Track A
AN30	FUEL_LEVEL_I	126	Input to measure the fuel level.
AN31	PEDAL_B_I	125	Input to measure the Pedal Position Track B
AN32	COOLANT_TEMP_I	124	Input to measure the coolant temperature
AN33	THR_POS_B_I	123	Input to measure the Throttle position Track B
AN34	THR_POS_A_I	122	Input to measure the Throttle position Track A

Table continues on the next page...

Table 17. MCU analog channel usage (continued)

Channel	Schematic Symbol	MCU Pin Number	Description
AN35	BAP_I	121	Barometric Pressure Input for measuring the air pressure sensor fitted inside the ECU.
AN38	—	9	Not Used
AN39	—	8	Not Used
AN36, AN37	—	—[2]	
AN8, AN10, An19, AN20, AN26, AN29	—	—[3]	

1. This pin supports digital functions and therefore has higher leakage when used as an analog signal.
2. Only available on 176 and 208 packages
3. Not available on device

3.7.4.1 MCU Analog Input Filtering

The inputs to the MCU analog to digital converter (ADC) requires some type of input conditioning. This section provides different types of examples for the different types of inputs.

The simplest conditioning circuit is a pi resistor/capacitor network as shown in the following example figure. C47 provides protection from electrostatic discharge and is essential on nearly every ECU pin, fitted close to the connector to contain energy away from other circuitry. It should be high voltage, 200V capable. Several kV at a lower voltage discharge into this capacitor and charge becomes a survivable lower voltage, which discharges for a longer duration through the resistor and then protection diodes on the MCU.

The series resistor is sized such that a permanent fault of short to battery does not cause errors on the adjacent ADC inputs. To achieve this a short to Vbat must result in under 1mA of current. With Vbat maximum at 16V and the clamping diodes at near 5V, at least [16V-5V]/1mA = 11k is required. 20k is used here for operation up to 24V. The protection diode can survive 3mA continuously and so the resistor could be lower, but during a short to battery fault the adjacent ADC pins may read in error by a number of counts.

Following the resistor and on the MCU pin is capacitor C52. This serves two purposes: it creates a low pass filter in conjunction with R28, and it forms a reservoir to feed the ADC sample capacitor. The low pass filter removes high frequency interference and results in more accurate sensor readings. The reservoir means that when the ADC 0.8pF picofarad sample capacitance is connected, the sensor voltage stored on the reservoir capacitor is not discharged to the extent that it affects the sensor reading.

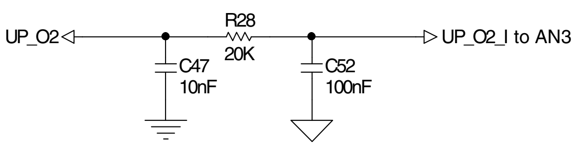

Figure 4. Simple RC π filter network

In some cases, a large resistor is connected between the sensor input and ground or a power supply rail. This component provides fault detection for on board diagnostics. In the event of a break in the wire to a sensor, the ADC input will be left floating. Because the ADC input is high impedance, floating inputs can pick up noise and provide false readings. Sensors such as throttle, pedal and MAP are often arranged not to use the ends of the 0-5V scale. In the event of a wire break, the addition of a high value resistor causes the input to pull in a predictable way to a known value that is outside the valid range for the sensor, and thus the break can be detected. The following figure shows such filter networks.

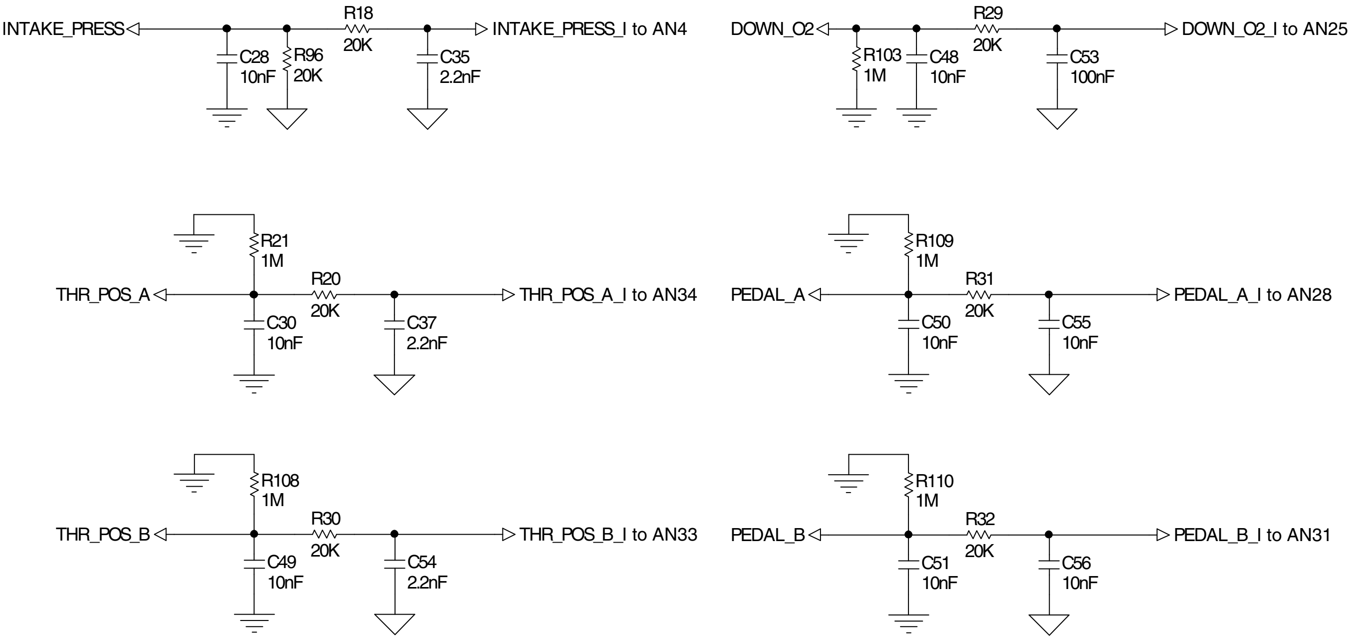

Figure 5. Resistor divider input filter

Some sensors consist of single passive resistors. To minimise wiring costs these are often connected to ground, and so require a pull up resistor to 5V to properly bias the input to a range that can be read by the ADC. These inputs are shown in the following figure.

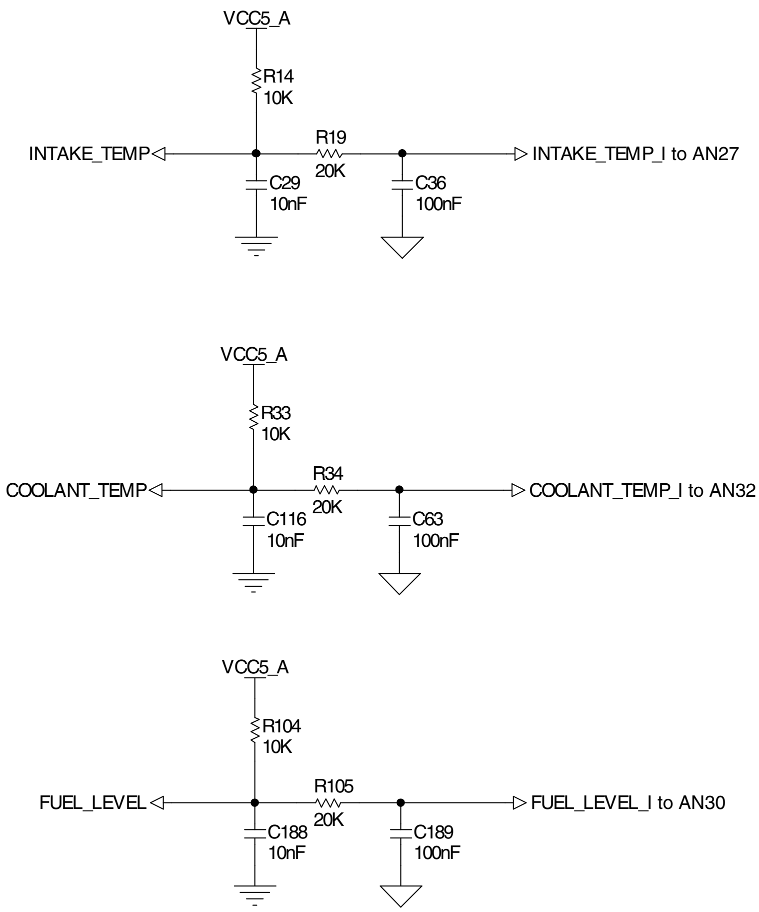

Figure 6. Pull up resistor filter network

The passive resistor and capacitor in-front of the ADC input create a continuous time low pass filter that removes higher frequency components from the incoming signal. As such, it acts as an anti-alias filter (AAF), but in general removing high frequency noise is the more significant action because the ESD capacitor also acts as an AAF and the ADC is capable of sampling very much faster than most engine signals. Sensors have different response times and so different frequency filters are used. For example, the thermal mass of the engine is large and so the engine coolant temperature changes slowly. However, the throttle position can change quickly. All the filters are low pass, allowing frequencies below cut-off and attenuating those above it. The cut-off point is the frequency at which the energy is half that of the unattenuated signal. The simple R-C low pass filter has a cut-off frequency calculated from F=1/2*Pi*R*C. Ten times above this the energy drops off at a consistent 20dB/decade, and ten times below this it the energy is unattenuated. Between the two is a gradual curve.

Approximately three filter frequencies are used in the ECU, ignoring the knock input. The fastest changing signals such as manifold pressure and throttle position use R-C values of 20k and 2n2, giving a filter frequency of 3.6kHz. A MAP sensor typically has a response time of about 1ms and the filter is placed above this. Somewhat slower sensors such as pedal position use R-C values of 20k and 10nF giving a filter of 800Hz. The slowest sensors, generally temperature, use the R-C values 20k and 100n for an 80Hz filter. Although this is much faster than any changes in the input signal, further filtering is performed in software, something that happens on all the analog inputs. The filter chosen represents a compromise between minimum analog frequency and the cost of the capacitor.

3.8 Knock processing overview

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 is to select by filtering the expected knock frequencies for the crank angle over which they are expected to occur, and then integrate the energy to return a magnitude that can be tested against a threshold previously declared as 'knock'. This mechanism is depicted in Figure x.y

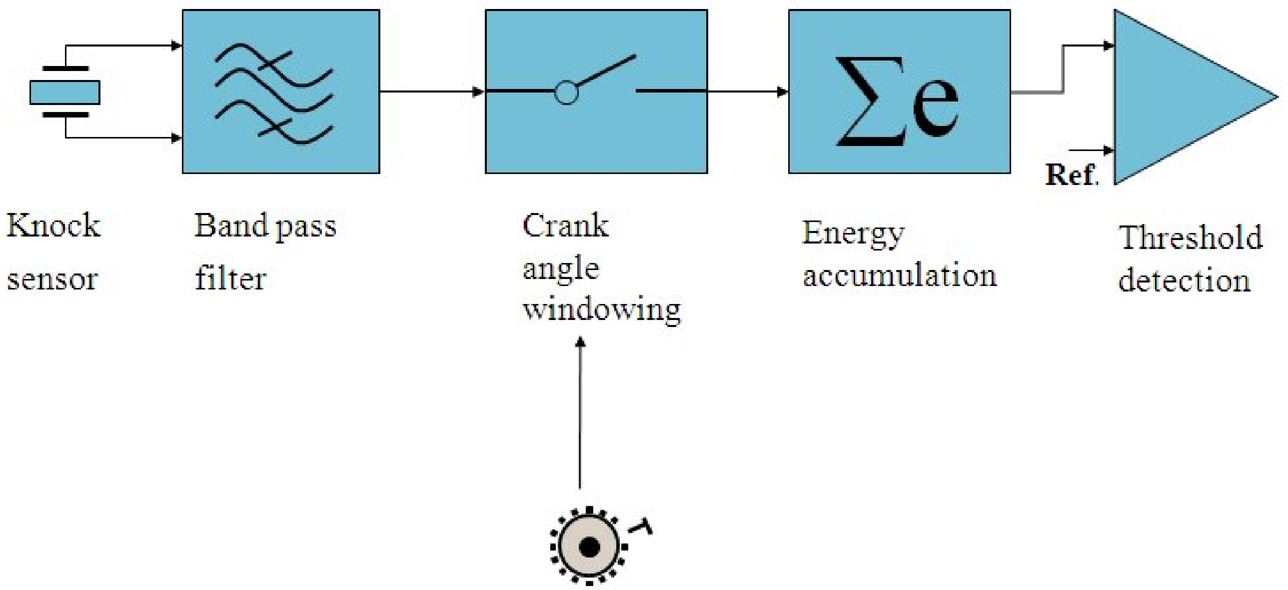

Figure 7. Basic knock detection

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, the thermal memory of the combustion chamber and the significant variability of combustion from event to event. This results in multiple approaches to detect knock, only one of which is shown in this document.

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 knock processing demonstration multiple blocks of the MCU are used. It is probably the simplest method because it is almost completely achieved through hardware configuration, and therefore requires no DSP software expertise. The block diagram is shown in ***Fig. x.y.***

An external piezoelectric knock sensor is connected to the ECU external pins, and, via some EMC protection and high frequency filtering discrete components, the signal is passed to the MCU. This filter also provides some Anti-Alias filtering, but a greater degree is actually provided by the sensor itself, which is a highly resonant component above the flat passband and its response drops off above resonance.

Bias resistors integrated into the MCU's differential analog inputs set the sensor at a suitable voltage for the differential input, and can also be used to implement an On-Board Diagnostic (OBD) test (Freescale patented for use on Freescale silicon).

Past the resistors, a variable gain function can be used to compensate for the different amplitude present from different cylinders and/or to compensate for the variation in amplitude over low to high rpm. The analog signal is then converted by the ADC, using a differential conversion and producing a signed digital representation.

The ADC is triggered at a regular 5 microsecond rate using a simple Periodic Interval Timer (PIT) timer, which frees up a higher performance eMIOS[3] channel for more complex use. To avoid the need to continuously present the same conversion command again and again, a streaming mode is enabled whereby the command resides locally in the ADC buffers. A gating scheme is implemented to permit the eTPU to control the crank angles over which samples are taken.

The digital output data is presented to the decimation filter, which is configured as a four pole Infinite Impulse Response (IIR) filter set to the preferred bandpass frequency. The decimation filter coefficients are fully programmable during run time to change the filter passband, and it can be zeroed before starting and also has a prefill mode to allow it to settle to the knock signal.

The narrowband filter removes higher frequency elements, which means that the signal can be downsampled without losing any low frequency information. This is done by the decimator hardware. The lower data rate further reduces the CPU load.

The DMA engine of the MCU moves data from the decimator into system RAM. The engine is configured to run ping-pong buffers whereby one half can be processed whilst the other half is being filled.

Once a buffer is full, the Signal Processing Engine (SPE) is used to accumulate the absolute result. This amounts to a single addition per sample, which is very little CPU load in comparision to running a software filter. In other devices in the MPC56xx family, such as the MPC5644A, the absolute-integrate function is built in to the decimation filter hardware.

3. enhanced Modular Input/Output subsystem.

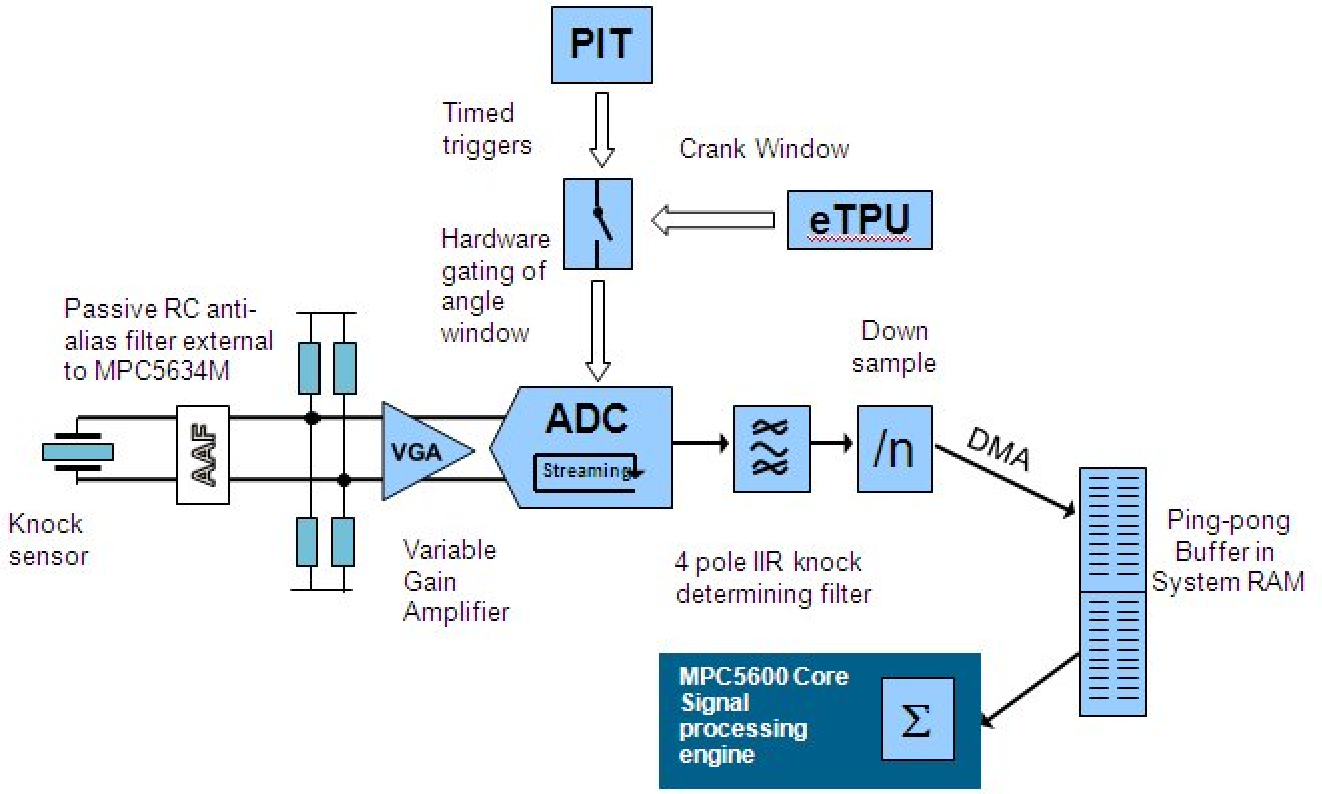

Figure 8. MPC5634M hardware knock detection

Some common variations to this scheme are the use of the SPE engine to run a different filter scheme such as FIR or FFT, adjustment to sample rates and angle windowing schemes, and the use of the decimation filter as a means to provide digital Anti-Alias filtering and downsampling. Software filtering might take about 5% of CPU load, and libraries for the SPE are available from Freescale. Details on the many variations of knock porcessing are beyond the scope of this Application Note.

3.8.1 Knock Analog Input

The knock sensor is typically wired as a differential analog signal in order to reduce noise. The sensor and input are high impedance and thus prone to noise pickup. In the MPC563xM ECU the knock sensor is connected with minimal circuitry external to the MCU, and relies on the built in, selectable pull-up and pull-down resistors to provide biasing for the sensor into the differential range of the ADC. The internal resistors can be FET switch alone (about 5K), 100K or 200K Ω. The choice is a trade-off between a lower impedance with less noise pickup but more signal attenuation, or the opposite.

The programmability available in these pull-up and -down resistors also allows for software to perform some diagnostics by enabling and disabling of the different resistor values and checking the analog input voltage.

The following schematic show an example knock sensor interface to the differential inputs on the MCU. The ESD capacitors are also a trade-off between protection and sensor load. Contact your sensor supplier for a recommended value, and then ensure that the MCU is appropriately protected to your level of ESD using the series resistors.

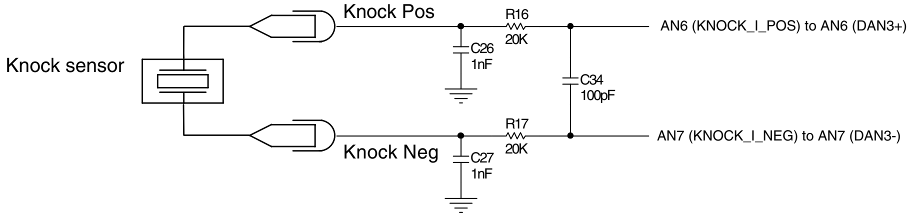

Figure 9. Knock sensor to MCU differential analog pins schematic

4 Freescale SmartMOS Analog Devices

Freescale manufactures many analog devices in the SmartMOS process that handle the requirements of an Engine Control Unit. This section describes the devices that are used in this reference design. Common across these devices is high robustness and diagnostics capability. Nearly all outputs are protected against short to battery, short to ground, open circuit and over temperature. Most report their status over a SPI communication link. Most are housed using the cost effective SOIC package, or high performance PQFN package.

Incorporated into the ECU is am air pressure sensor with analog output.

Table 18. SmartMOS Automotive Analog devices

Device	Name	Functional Description	System Function (in the ECU reference Design)
MC33800	16 way low side driver/ pre-driver	A combination of Low Side Drivers, constant current driver, and Octal Switchs (FET pre-driver)	Control for relays, fuel pump, coolant temperature, and HEGO heater driver with ohmic function.
MC33810	Ignition/Injection Driver	Four ignition drivers with spark voltage and duration diagnostics, and four Injector drivers	Drivers for the injector solenoids and pre-drivers for the IGBT ignition coil transistors
MC33879	Configurable Octal Serial Switch	Eight output configurable 1A High or Low Side switch and Drivers with output load detect current disable	Configured as four half bridge outputs to produce a 1A stepper motor driver as alternative for bypass air.
MC33902EF	High Speed CAN Interface	High Speed CAN Interface with embedded 5.0V Supply	Used for high speed CAN with a diagnostic port
MC33905	System Basis Chip	Integrated power supplies, with LIN and CAN transceivers and safety watchdog	5 ECU volt Power supply, 5V sensor supply, CAN and K-line physical interfaces
MC33926	5A H-Bridge	DC Motor H--Bridge	Throttle Control
MC33932	Dual 5A H-Bridge	Dual Motor H-Bridge	Dual DC motor for variable cam control and/or DC. motor Exhaust Gas Recirculation (EGR)
MPXH9002	Barometric Air Pressure Sensor	A ratiometric analog output piezoresistive transducer	Atmospheric (barometric) air pressure detection

4.1 MC33905S System Basis Chip Overview

The MC33905S is a System Basis Chip (SBC) that includes two 5 volt power supplies, one CAN transceiver, and one LIN transceiver, along with a robust safety watchdog engine. There are two package sizes and other options available with different numbers of LIN drivers (zero, one, or two), wake-up pins (one, two, three, or four), and LIN terminations (none, one or two). These options are shown in the table after the feature list. The MPC563xM Reference ECU uses the MCZ33905SB5EK (or MCZ33905S5EK depending on availability and when the ECU was manufactured).

Features of the MC33905 are:

- Low drop out split regulators for adaptable application power and configuration
- Power sharing with external PNP transistor to lower thermal loading
- Failsafe state machine watchdog accessible using SPI and using the SAFE pin
- Secured SPI for watchdog
- High protection on external outputs
- Diagnostics Feedback on feature health
- Multiple analog monitoring delivered to MUX output
- High precision VSupply voltage monitoring via SENSE pin
- Integrated CAN regulator with wake up capability
- Configurable dual I/O with wake up capability
- Under-voltage management for eg: cranking
- Lin 2.0, 1.3 compliant and SAE J2601 compatible
- ISO 11898-5 high speed CAN interface compatibility for baud rates of 40 kb/s to 1.0 Mb/s

Table 19. SBC device variations

Freescale Part number	V_{DD} Output Voltage	Lin Interface(s)	Wake-up / LIN Master Termination	Package	V_{AUX}	V_{SENSE}	MUX
MC33905D (Dual LIN)							
MCZ33905BD3EK/R2[1]	3.3V	2	2 Wake-Up + 2 LIN terms + 2 Wake-Up + 1 LIN terms or 4 Wake-Up + no LIN terms	SOIC 54-pin exposed pad	Yes	Yes	Yes
MCZ33905D5EK/R2	5.0V						
MCZ33905BD5EK/R2[1]							
MC33905 (Single LIN)							
MCZ33905BS3EK/R3[1]	3.3V	1	3 Wake-Up + 1 LIN terms or 4 Wake-Ups + no LIN terms	SOIC 32-pin exposed pad	Yes	Yes	Yes
MCZ33905S5EK/R2	5.0V						
MCZ33905SB5EK/R2[1]							
MC33904							
MCZ33904B3EK/R2[1]	3.3V	None	4 Wake-Up	SOIC 32-pin exposed pad	Yes	Yes	Yes
MCZ33904A5EK/R2	5.0V						
MCZ33904B5EK/R2[1]							
MC33903							
MCZ33903B5EK/R2[1]	3.3V[2]	None	1 Wake-Up	SOIC 32-pin exposed pad	No	No	No
MCZ33903B5EK/R2[1]	5.0V[2]						
MC33903D (Dual LIN)							
MCZ33903BD3EK/R2[1]	3.3V	2	1 Wake-Up + 2 LIN terms or 2 Wake-Up + 1 LIN terms or 3 Wake-Up + no LIN terms	SOIC 32-pin exposed pad	No	Yes	Yes
MCZ33903BD5EK/R2[1]	5.0V						

Table continues on the next page...

Table 19. SBC device variations (continued)

Freescale Part number	V_{DD} Output Voltage	Lin Interface(s)	Wake-up / LIN Master Termination	Package	V_{AUX}	V_{SENSE}	MUX
MC33903S (Single LIN)							
MCZ33903BS3EK/R2[1]	3.3V	1	2 Wake-Up + 1 LIN terms or 3 Wake-Up + no LIN terms	SOIC 32-pin exposed pad	No	Yes	Yes
MCZ33903BS5EK/R2[1]	5.0V						

1. "B" versions are recommended for new design. Design changes in the "B" version resolved V_{SUP} slow ramp issues, enhanced device current consumption and improved oscillator stability.
2. V_{DD} does not allow usage of an external PNP on the 33903. Output current limited to 100 mA.

The block diagram is shown in the following figure.

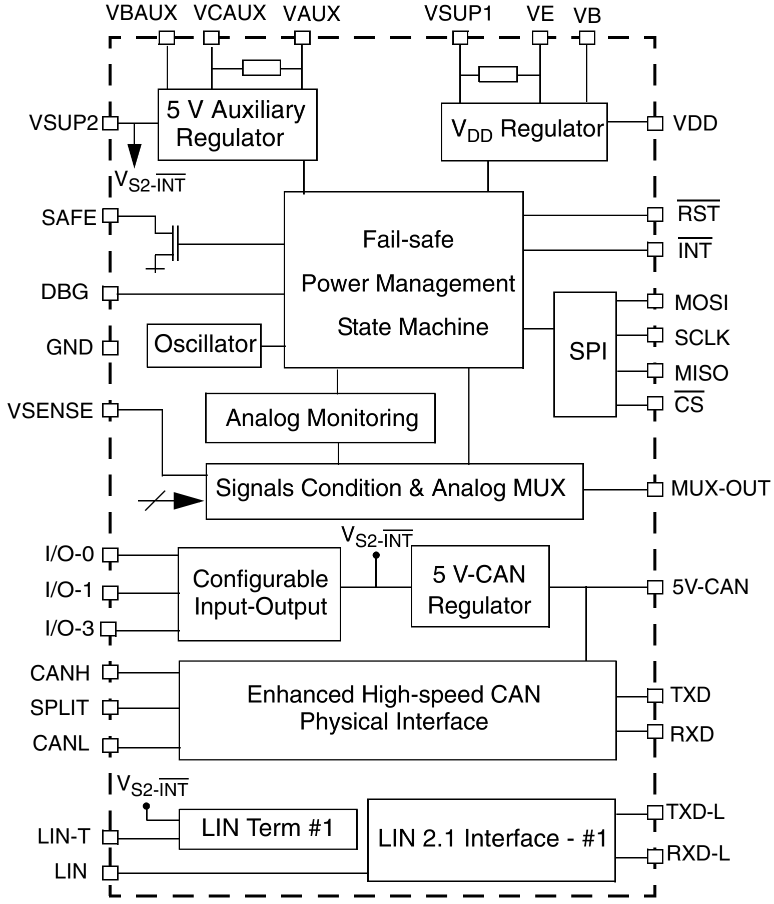

Figure 10. MC33905 block diagram

Below is the schematic used in the MPC5634M ECU. Note that the V-AUX secondary internal 5V supply is incorrectly used as an external sensor supply (VCC5_SENS) without short to battery protection. Please contact Freescale the appropriate protection discrete components.

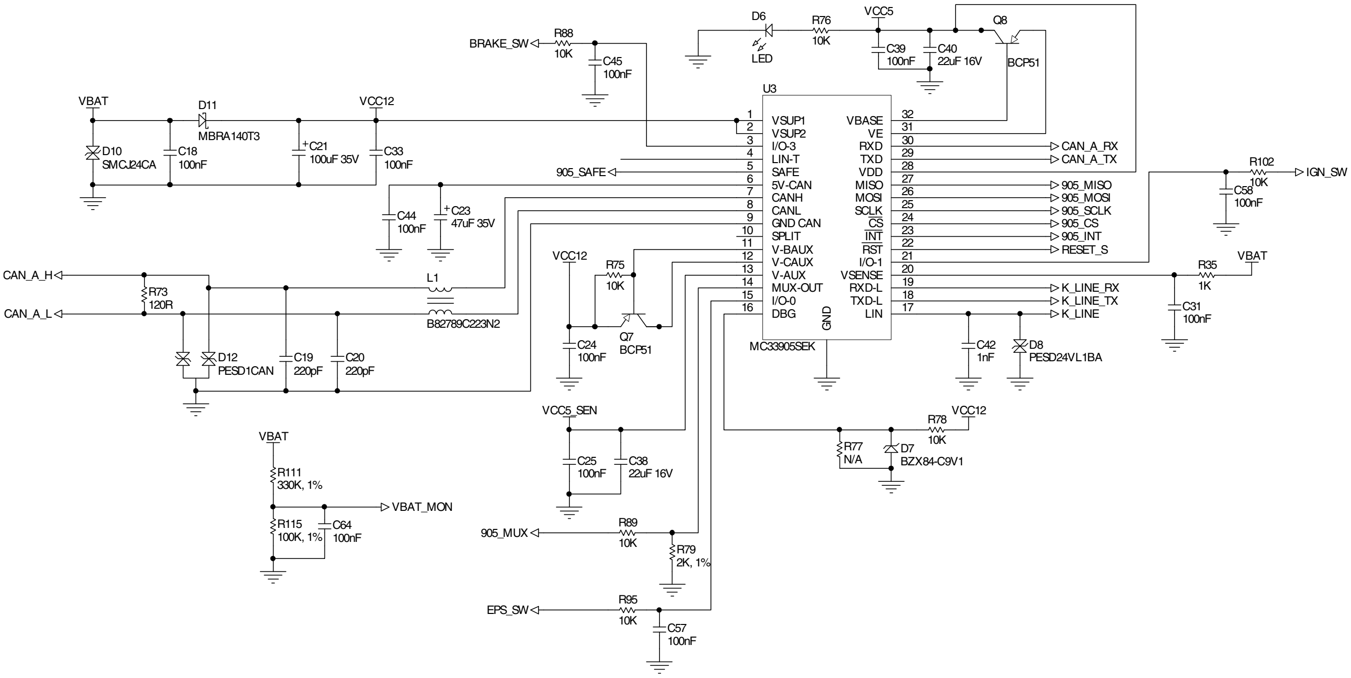

Figure 11. MC33905 SBC Schematic

In the above drawing, the BCP51 transistor Q8 is used to boost the current rating of the supply used to power the MCU. The BCP51 transistor Q7 is used to enable the V-AUX supply, which is then used to power external sensors.

When using the external pass transistor Q8, the MCU 5 volt power supply output can generate 250 mA of current and requires 2.7 Watts of thermal dissipation (1.8W in the external pass transistor and 0.9W in the MC33905). Without the external PNP pass transistor, the MC33905 can supply up to 150 mA. The auxiliary regulator can generate either 3.3 volts or 5 volts and all of the thermal dissipation is in the external pass transistor. The Printed Circuit Board (PCB) should allow for this dissipation in the layout of the planes for these two transistors.

Key specifications of the SBC are shown in the following table. For full details see the latest data sheet on Freescale.com

Table 20. MC33905 key specifications

Specification	Min.	Nom.	Max.	
Full spec. operation voltage range	5.5		28	V
Cranking spec. voltage	4.0		5.5	V
Supply current, VDD on, V-CAN on, V-AUX off			8	mA
Supply current, VDD OFF. Wake-up from CAN, I/O-x inputs, <25C		15	35	uA
5V VDD output tolerance	-2		+2	%
Temperature pre-warning		140		C
V-AUX output tolerance	-5		+5	%
VAUX over-current threshold	230	330	430	mA
VDD under-voltage threshold down	4.5	4.65	4.85	V
I/O-2 pin and I/O-3 pin output HS switch drop @ I = -20 mA,		0.5	1.4	V
I/O pin positive threshold as input	2.1	3.0	3.8	V
Analog MUX output range	0		VDD-0.5	V
SAFE output voltage at -500uA		0.2	1.0	V

Table continues on the next page...

Table 20. MC33905 key specifications (continued)

Specification	Min.	Nom.	Max.	
CAN differential input voltage threshold	500		900	mV
LIN current Limit for Driver Dominant State	40	90	200	mA

The pin out of the SBC is shown in the following table. Note that in this and for other devices the table layout represents the pinout of both sides of the device.

Table 21. MC33905 pin out and connections

Description	MC33905 Pin Name	Pin Number		Pin Number	MC33905 Pin Name	Description
Battery Voltage Supply 1 - Supply input for the internal device supplies, power on reset circuitry, and the V_{DD} regulator	VSUP1	1		32	VB	Voltage Base - Base output pin for connection to the external PNP pass transistor
Battery Voltage Supply 2 - Supply input for the 5V-CAN regulator, V_{AUX} regulator, I/O, and LIN pins	VSUP2	2		31	VE	Voltage Emitter - Connection to the external PNP path transistor. This is an intermediate current supply source for the VDD regulator.
Input/Output 3 - Configurable pin as an input or high side output, for connection to external circuitry (switched or small load). The input can be used as a programmable wake-up input in Low Power mode. When used as a high side, no over-temperature protection is implemented. A basic short to GND protection function, based on switch drain-source over-voltage detection, is available.	I/O-3	3		30	RXD	Receive Data - CAN bus receive data output.
LIN Termination - Output pin for the LIN1 master node termination resistor.	LIN-T	4		29	TXD	Transmit Data - CAN bus transmit data input. Internal pull-up to VDD
Safe Output (active low) - Output of the safe circuitry. The pin is asserted LOW in case of a safe condition is detected (e.g.: software watchdog is not triggered, V_{DD} low, issue on the RESET pin, etc.). Open drain structure. This pin is connected to the driver disable circuit (905_SAFE). See Disable driver circuit	SAFE	5		28	VDD	Voltage Digital Drain - 5.0 or 3.3 V output pin of the main regulator for the Microcontroller supply.
5V-CAN - Output voltage for the embedded CAN interface. A capacitor must be connected to this pin.	5V-CAN	6		27	MISO	Master In / Slave Out - SPI data sent to the MCU. When the $\overline{CS}$ is high, MISO is high-impedance
CAN High - CAN high output.	CANH	7		26	MOSI	Master Out/Slave In - SPI data received by the device

Table continues on the next page...

Table 21. MC33905 pin out and connections (continued)

Description	MC33905 Pin Name	Pin Number		Pin Number	MC33905 Pin Name	Description
CAN Low - CAN low output.	CANL	8		25	SCLK	Serial Data Clock - Serial Data Clock
GND-CAN - Power GND of the embedded CAN interface	GND CAN	9		24	$\overline{CS}$	Chip Select (active low) - Chip select pin for the SPI. When the $\overline{CS}$ is low, the device is selected. In Low Power mode with V_{DD} ON, a transition on $\overline{CS}$ is a wake-up condition
SPLIT Output - Output pin for connection to the middle point of the split CAN termination	SPLIT	10		23	$\overline{INT}$	Interrupt Output (Active LOW) - This output is asserted low when an enabled interrupt condition occurs. This pin is a open drain structure with an internal pull up resistor to V_{DD}.
VB Auxiliary - Output pin for external path PNP transistor base	V-BAUX	11		22	$\overline{RST}$	Reset Output (active low) - This is the device reset output whose main function is to reset the MCU. This pin has an internal pull-up to VDD. The reset input voltage is also monitored in order to detect external reset and safe conditions.
VCOLLECTOR Auxiliary - Output pin for external path PNP transistor collector	V-CAUX	12		21	I/O-1	Input/Output 1 - Direct battery voltage input sense. A serial resistor is required to limit the input current during high voltage transients.
VOUT Auxiliary - Output pin for the auxiliary voltage.	V-AUX	13		20	VSENSE	Sense input - Direct battery voltage input sense. A serial resistor is required to limit the input current during high voltage transients.
Multiplex Output - Multiplexed output to be connected to an MCU A/D input. Selection of the analog parameter available at MUX-OUT is done via the SPI. A switchable internal pull-down resistor is integrated for V_{DD} current sense measurements.	MUX-OUT	14		19	RXD-L	LIN Receive Data - LIN bus transmit data input. Includes an internal pull-up resistor to VDD.
Input/Output 0 - Configurable pin as an input or output, for connection to external circuitry (switched or small load). The voltage level can be read by the SPI and via the MUX output pin. The input can be used as a programmable wake-up input in Low Power mode. In low power, when used as an output, the high side or low side can be activated for a cyclic sense function.	I/O-0	15		18	TXD-L	LIN Transmit Data - LIN bus transmit data input. Includes an internal pull-up resistor to VDD.

Table continues on the next page...

Table 21. MC33905 pin out and connections (continued)

Description	MC33905 Pin Name	Pin Number	Pin Number	MC33905 Pin Name	Description
Debug - Input to activate the Debug mode. In Debug mode, no watchdog refresh is necessary. Outside of Debug mode, connection of a resistor between DBG and GND allows the selection of Safe mode functionality.	DBG	16	17	LIN	LIN Bus - LIN bus transmit data input. Includes an internal pull-up resistor to VDD.
Ground substrate pad on the underside of the package	GND	External Package Pad used for ground and heatsinking.			

The MC33905 SBC contains one LIN and one CAN driver. These as well as other signals are connected to the MPC5634M MCU. The connections are shown in the following table. Note that the various safety, interrupt and reset pins have programmable functions: see the MC33905 data sheet for details.

SBC pin number	SBC pin name	MCU pin number	MCU pin name	Board signal name	System use
3	I/O-3	Indirectly controlled through the SPI		BRAKE_SW	Detects application of the vehicle brake using the brake switch.
5	SAFE			905_SAFE	SBC output indicating fault conditions.
14	MUX-OUT	1	AN18	905_MUX	Output of internal analog mux, used to monitor internal voltages.
15	I/O-0	Indirectly read through the SPI		EPS_SW	Detects engine load from power steering using PAS pressure switch.
16	DBG			DBG	Holds SBC watchdog off for development when a voltage between 8V and 10V is applied.
17	TXD-L	72	TXDB	K_LINE_TX	K-line diagnostics interface
18	RXD-L	69	RXDB	K_LINE_RX	K-line diagnostics interface
21	I/O-1	Indirectly read through the SPI		IGN_SW	ECU wake up signal from the ignition switch.
22	$\overline{RST}$			RESET_S	SBC reset output used optionally to reset the MCU, driven for under-volts or watchdog timeout. Note that the configuration pins 1 & 2 of jumper J1 are transposed in error on the schematic.
23	$\overline{INT}$	21	eTPUA24	905_INT	SBC output indicating interrupt conditions such as crank voltage, when configured over SPI
24	$\overline{CS}$	97	PCSB3	905_CS	SPI chip select line
25	SCLK	89	SCKB	905_SCLK	SPI clock
26	MOSI	96	SOUTB	905_MOSI	SBC SPI output
27	MISO	95	SINB	905_MISO	SBC SPI input

Table continues on the next page...

SBC pin number	SBC pin name	MCU pin number	MCU pin name	Board signal name	System use
29	TXD	84	CNTXC	CAN_A_TX	CAN physical interface input from MCU
30	RXD	81	CNRXC	CAN_A_RX	CAN physical interface output to MCU

The SBC supports an analog multiplexer output that allows the MCU Analog to Digital converter to monitor internal channels of the SBC including the die temperature, ratio divider of the VSUP1 voltage, ratio divided VDD voltage, internal reference voltage, and VDD current monitor.

4.2 MC33810 Eight Channel Ignition and Injector Driver

The MC33810 is an Quad Ignition/Injection Driver/Pre-driver (IID). It provides the interface between the MCU and both the fuel injector solenoid valves and the ignition coil IGBT's. Up to four injectors (4 low-side drivers) and four ignition coils (4 pre-drivers) can be independently controlled by one MC33810 device. It allows the use of external “dumb” high current IGBT devices, but still providing fault detection and protection functions present in smart IGBT's, which are more costly. Features of the the IID are listed below.

- 8-channels with 4 low-side drivers and 4 pre-drivers
- Pre-drivers work in one of three different modes; Ignition, general purpose gate mode, or 10-cylinder mode
- Ignition current and spark detection with programmable thresholds
- MCU SPI and parallel interface
- Power supply/oscillator/band gap reference/POR
- Diagnostic and error detection logic
- Self protection for shorts to battery
- Self protection for over current and over temperature detection

Below is a block diagram of the MC33810.

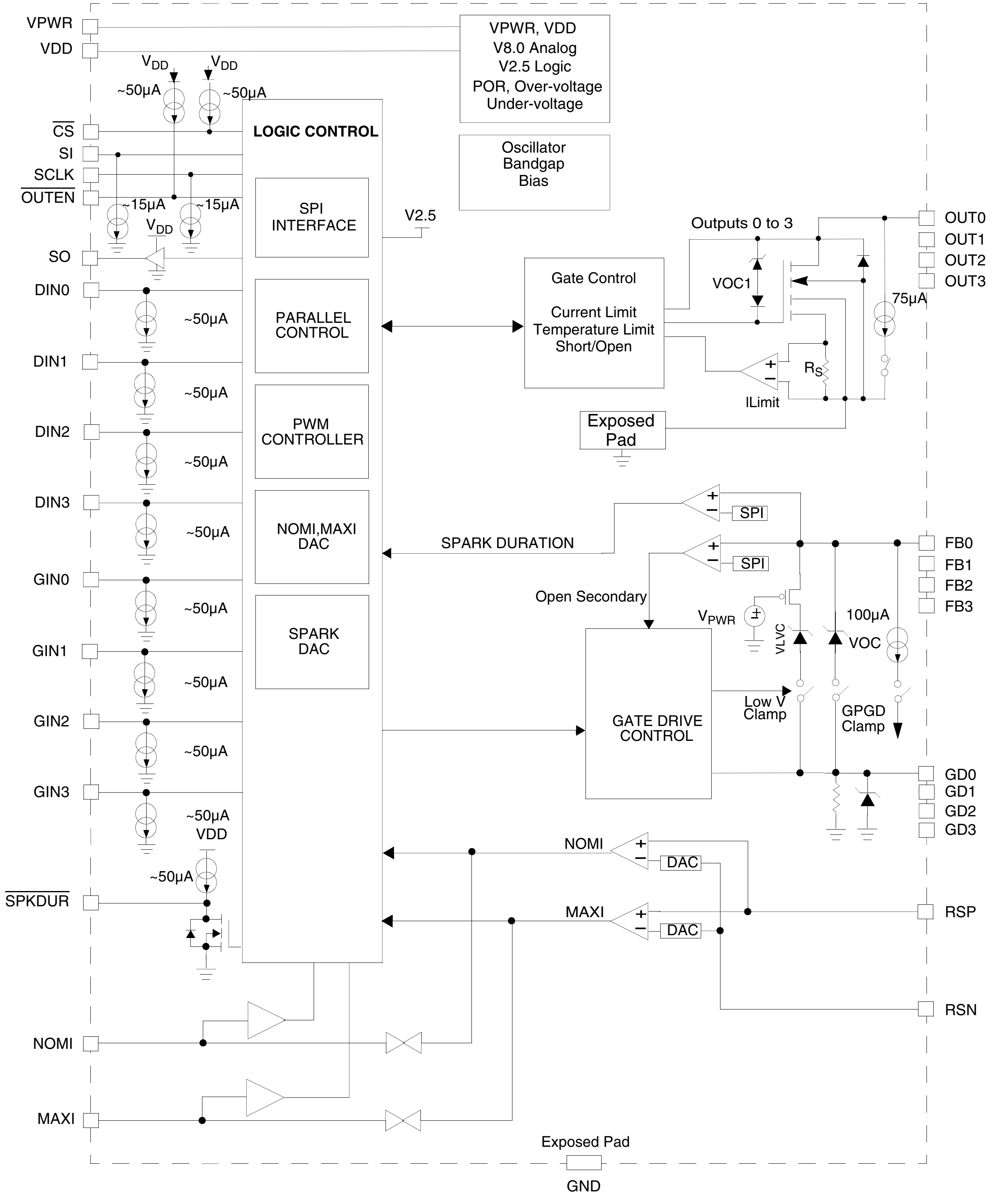

Figure 12. MC33810 block diagram

Additional features of the ignition pre-drivers are:

- Low voltage clamp
- Nominal coil current detection (NOMI), connected to the main MCU eTPU_A channel 11
- Maximum coil current detection (MAXI), connected to the main MCU eTPU_A channel 10
- Maximum dwell timer
- Overlapping dwell

- Spark duration measurement, connected to the main MCU eMIOS channel 8
- Open secondary detection
- Only requires one sense resistor per bank
- Can individually selected to be general purpose gate mode via the SPI interface for additional diagnostics

Additional features of the Injector drivers are listed below.

- Control via SPI or parallel (Parallel mode is used in the MPC563xM Engine Reference Design
- Clamp circuit
- Open load detect
- Over current detection
- Over temperature detection
- Self-protection by shutdown on over temperature, over voltage or both

Table 23. MC33810 Pin Out and Connections

Description	MPC33810 Pin Name	Pin Number	Pin Number	MPC33810 Pin Name	Description
Low side driver for Fuel Injector 1	OUT0	1	32	OUT2	Low side driver for Fuel Injector 3
Injector Driver Feedback Sense from IGBT collector	FB0	2	31	FB2	Injector Driver Feedback Sense from IGBT collector
Ignition Driver for IGBT on Cylinder 0	GD0	3	30	GD2	Ignition Driver for IGBT on Cylinder 2
SPI Chip Select connected to main MCU PCSC2	CS	4	29	MAXI	Maximum Current (MAXI) output to main MCU eTPUA10
SPI Clock connected to main MCU SCKB	SCK	5	28	NOMI	Nominal Current (NOMI) output to the main MCU eTPUA11
SPI data output (SOUT) from MCU SOUTB	SI	6	27	RSN	Ignition Resistance Sense connection to Ignition Ground
SPI data input to main MCU SINB	SO	7	26	RSP	Ignition Resistance Sense connection to Ignition sense resistor
MCU Interface supply voltage (5 volts)	VDD	8	25	VPWR	Protected battery power
The Output Enable disables all outputs when high. This signal is connected to a disable circuit. See Disable driver circuit	$\overline{\text{OUTEN}}$	9	24	GIN0	Ignition Driver Input from main MCU eTPUA15 (Cylinder 1)
Fuel solenoid input from the main MCU eTPUA19 (Cylinder 1)	DIN0	10	23	GIN1	Ignition Driver Input from main MCU eTPUA14 (Cylinder 2)
Fuel solenoid input from the main MCU eTPUA18 (Cylinder 2)	DIN1	11	22	GIN2	Ignition Driver Input from main MCU eTPUA13 (Cylinder 3)
Fuel solenoid input from the main MCU eTPUA17 (Cylinder 3)	DIN2	12	21	GIN3	Ignition Driver Input from main MCU eTPUA12 (Cylinder 4)
Fuel solenoid input from the main MCU eTPUA16 (Cylinder 4)	DIN3	13	20	$\overline{\text{SPKDUR}}$	Spark Duration output for the MCU to measure - connected to main MCU eMIOS8
Ignition Driver for IGBT on Cylinder 1	GD1	14	19	GD3	Ignition Driver for IGBT on Cylinder 3
Injector Driver Feedback Sense from IGBT collector	FB1	15	18	FB3	Injector Driver Feedback Sense from IGBT collector
Low side driver for Fuel Injector 2	OUT1	16	17	OUT3	Low side driver for Fuel Injector 4

Below is the schematic of the MC33810 used in the ECU reference design. The MC33810 is connected to the microcontroller through the SPI bus for configuration and diagnostics and directly to eTPU channels for driving the injectors and ignition coils.

The NOMI and MAXI signals are digital feedback of the ignition coil current. For a typical application the NOMI threshold would be set to a fraction (say 2/3) of the desired dwell current. The time between switching on the coil and the NOMI feedback can then be used to run a dwell time that adapts to changing conditions such as battery voltage and coil temperature. It also permits detection of subtle failures such as coil delamination. The MAXI would typically be set to a value larger than the saturation current of the coil, and indicate over-current due to, for example, an engine stall. The signal could cause an interrupt to switch the coil off.

The spark duration signal reports the time for which the spark burn event actually occurred, as indicated by the voltage reflected onto the primary of the coil. This not only gives an indication of the actual spark, but can be used to detect a break in the high tension circuit. If such an event is detected the MC33810 can shut down the coil softly, preventing damage due to excessive h.t. voltage.

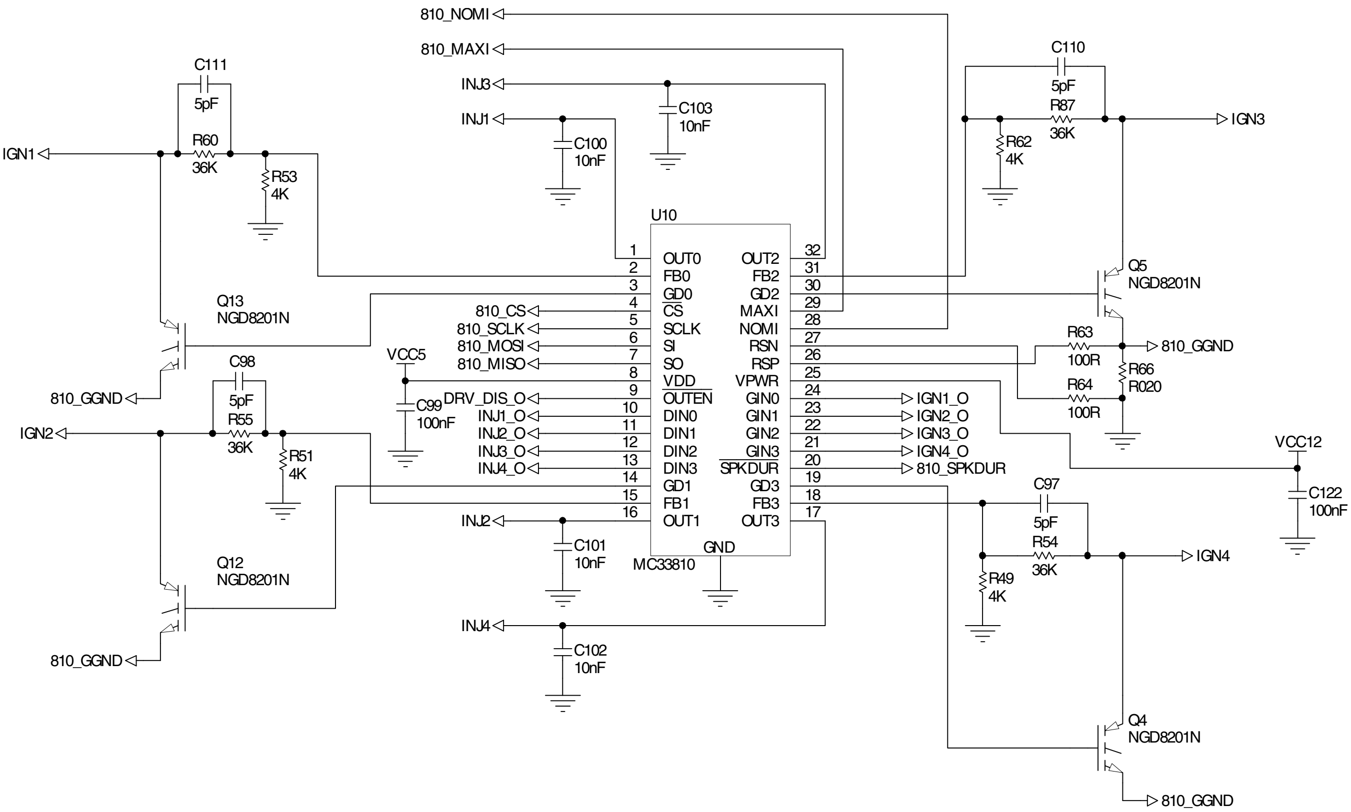

Figure 13. MC33810 IID Schematic

4.2.1 MC33810 Default Settings Commands

The control registers of the MC33810 are controlled over the SPI interface. After a Power-On Reset (POR), the default settings are shown below.

- All outputs off
- IGNITION gate driver mode enabled (IGBT Ignition Mode).
- PWM frequency and duty cycle control disabled
- Off State open load detection enabled (LSD)
- MAXI Digital-to-Analog comparator is set to 14A and the NOMI Digital-to-Analog comparator is set to 5.5A
- Spark detect level (VIL DAC) set to VPWR +5.5V

- Open secondary timer set to 100 μs
- Dwell timer set 32ms
- Soft shutdown disabled
- Low-voltage flyback clamp disabled
- Dwell overlap MAXI offset disabled

All of these features can be modified by the main MCU over the SPI interface.

4.3 MC33800 Low Side Drivers/Octal Switch

The MC33800 is a multi-function Engine Control IC. It has 6 PWM inputs for driving 6 MOSFET gate pre-drivers with built-in PWM generators, 2 constant current drivers (CCD) with internal dithering generator for precise solenoid valve control, and 8 low side switches (pairs controllable via direct inputs or connected by the SPI port. When used to drive oxygen sensor heaters the part is also capable of monitoring the health of the heater via a built-in ohmmeter function. The IC has over-voltage, under-voltage, and thermal protection. All drivers and switches, including the external MOSFETs, have over-current protection, off-state open load detection, on-state shorted load detection, and fault annunciation via the serial peripheral interface. Additional features of the MC33800 are:

- Outputs controllable via serial and/or parallel inputs
- PWM from 10Hz to 1.28kHz with control over SPI
- Wide operating voltage range, 5 < VPWR < 36V
- SPI interfaces to both 3.3V and 5V microprocessors
- Dither on CCDs programmable for both frequency and amplitude
- Low side drivers can be connected in parallel to increase current capability

A block diagram is shown below.

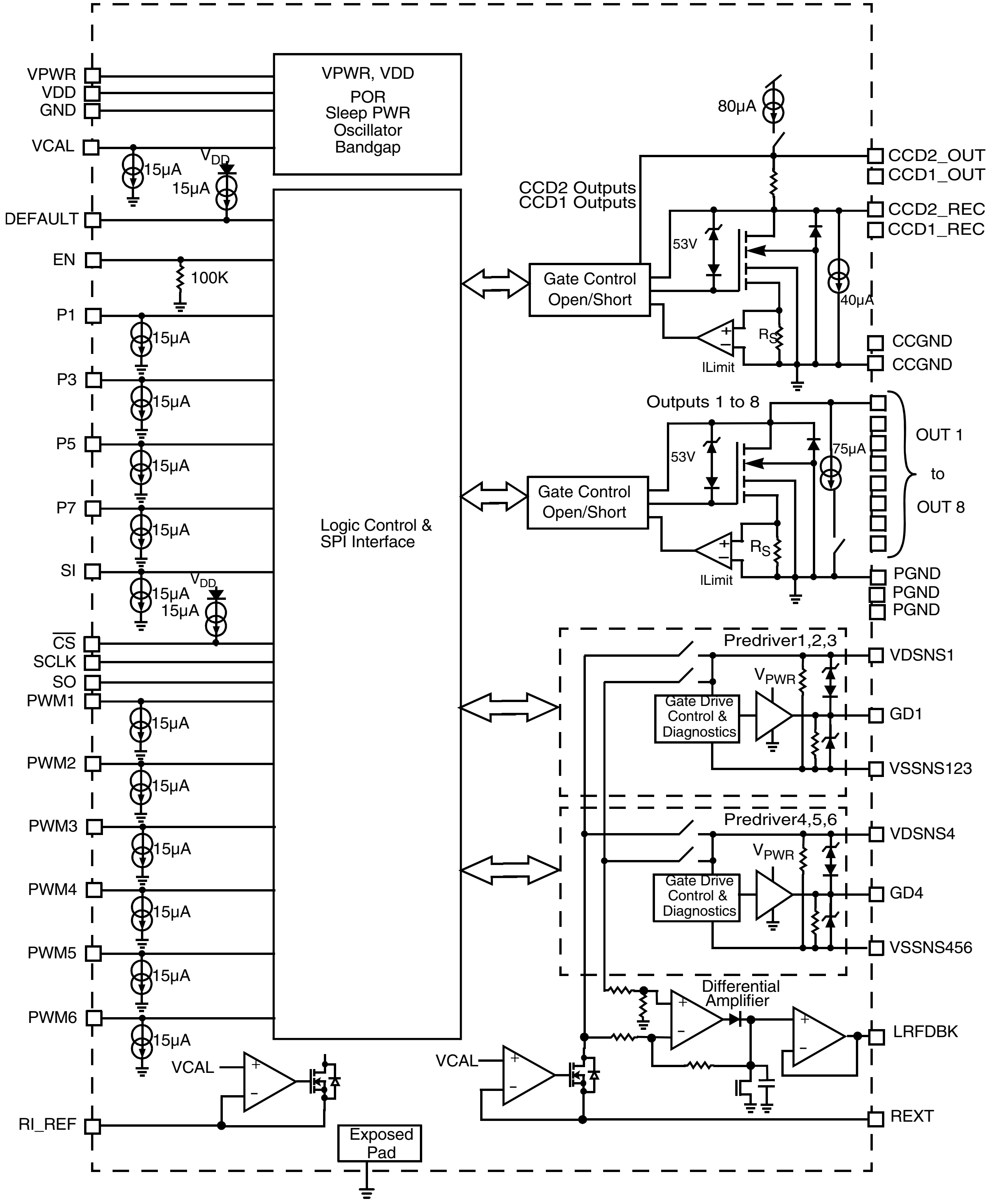

Figure 14. MC33800 Block diagram

The following table shows the pin out of the MC33800 and the use of each pin in the ECU.

Table 24. MC33800 Pin Out and Connections

Description	Pin Name	Pin Number		Pin Number	Pin Name	Description
Drain Voltage Monitor[1]	VDSN4	1		54	VDSN3	Drain Voltage Monitor[1]
Gate Drive for external MOS FET[1]	GD4	2		53	GD3	Gate Drive for external MOS FET[1]
Drain Voltage Monitor[1]	VDSN5	3		52	VDSN2	Drain Voltage Monitor for diagnostics on external MOSFET
Gate Drive for external MOS FET[1]	GD5	4		51	GD2	Gate Drive for external MOS FET
Drain Voltage Monitor[1]	VDSN6	5		50	VDSN3	Drain Voltage Monitor for external MOSFET
Gate Drive for external MOS FET[1]	GD6	6		49	GD1	Gate Drive for external MOS FET
Source Voltage Monitor Sense for MOS FETs 4, 5 and 6 - Ground	VSSNS456	7		48	VSSNS123	Source Voltage Monitor Sense for MOS FETs 1, 2, and 3 - Ground
Analog Output of the voltage across the load resistor during ohmmeter mode.	LFRDBK	8		47	REXT	Reference output to set current for ohmmeter function. Recommended 24 Ω resistor to ground.
SPI data input connected to main MCU SOUTB	SI	9		46	PGND1	Ground for OUT1
SPI clock connected to main MCU SCKB	SCLK	10		45	OUT1	High current low side driver, 700mR, 1A continuous, 4A limit
SPI chip select connected to main MCU PCSB1	CS	11		44	PGND2	Ground for OUT2
Parallel input for output 1. Can be set to control both Out1 and Out2.	P1	12		43	OUT2	High current low side driver, 700mR, 1A continuous, 4A limit.
Parallel input for output 3.Can be set to control both Out3 and Out4	P3	13		42	OUT3	Medium current low side driver, 1R, 350mA continuous, 1A limit.
Parallel input for output 5.Can be set to control both Out5 and Out6[1]	P5	14		41	OUT4	Medium current low side driver.
Parallel input for output 7.Can be set to control both Out7 and Out8	P7	15		40	OUT5	Medium current low side driver.
Parallel input pin for direct control of the GD1 Gate Drive Output , or as on/off control of the internal PWM controller.[1]	PWM1	16		39	PGND	Ground for OUT3-8
Parallel input pin for control of the GD2[1]	PWM2	17		38	OUT6	Medium current low side driver.
Parallel input pin for control of the GD3[1]	PWM3	18		37	OUT7	Medium current low side driver.
Parallel input pin for control of the GD4[1]	PWM4	19		36	OUT8	Medium current low side driver.
Parallel input pin for control of the GD5[1]	PWM5	20		35	DEFAULT	Output driver disable pin. Connect to ground for normal operation.
Parallel input pin for control of the GD6[1]	PWM6	21		34	SO	SPI data output connected to main MCU SINB
Ground for CCD2	CCD2_GND	22		33	VDD	5 volts

Table continues on the next page...

Table 24. MC33800 Pin Out and Connections (continued)

Description	Pin Name	Pin Number		Pin Number	Pin Name	Description
Output for the secondary constant current driver. [1]	CCD2_OUT	23		32	VCAL	2.5 volt precision reference input - decouple to ground with a 10nF capacitor.
Pin to connect the current recirculation Diode to VPWR.	CCD2_REC	24		31	GND	Ground
Enable pin connected to main MCU PCSB0 (GPIO) DRV_EN	EN	25		30	VPWR	Battery voltage supply for internal circuitry.
Reference Current mirror used to set the range for the Constant Current Drivers.	RI_REF	26		29	CCD1_GND	Ground for CCD1
Output for the primary constant current driver. [1]	CCD1_OUT	27		28	CCD1_REC	Pin to connect the current recirculation Diode to VPWR.

1. Not used in the MPC563xM Reference Design.

The schematics of the MC33800 in the MPC563xM ECU are shown in the following figure.

Due to the restricted number of pins on the ECU connector, not all the functions of the MC33800 are used. The installation is configured for a single exhaust system, with two exhaust oxygen sensors. One is upstream of the catalyst and is used to control the closed loop fuelling. The other is downstream of the catalyst and provides diagnostics information on the function of the catalyst. Both heaters are controlled using the MC33800 via an external twin FET package IRF7341. The inrush current of cold heaters can be high, up to 8A, hence the use of external FETs. The PTC nature of the heater means that the once at operating temperature the current typically falls to 1-2A. The gate series resistors can be used to trim EMI by slowing the switching rise and fall times, and the voltage divider resistors permit operation of FETs with limited Vds range.

The MC33800 drives directly a miscellaneous collection of actuators typical of a powertrain control system. Because these outputs are well protected, only a small ESD capacitor is required on the connector pin. Three actuators are driven via relays: the fuel pump, the main efi power relay, and the radiator fan. Three outputs are driven directly: the purge valve, the cluster temperature gauge and the tachometer. It is possible to drive all of these outputs over the SPI link but for diagnostics purposes it is useful to have a direct drive to the tachometer. There are sufficient pins on the MCU to use a direct drive.

The RI_REF resistor value of 39.2K Ω to ground sets the maximum output current (value 0x1FF) of CCD1 to 1075mA and of CCD2 to 232mA. These outputs are true constant current analog outputs and not battery voltage PWM. Only CCD1 is used on the ECU as a solenoid driver, proposed for idle air control when a throttle follower system is employed.

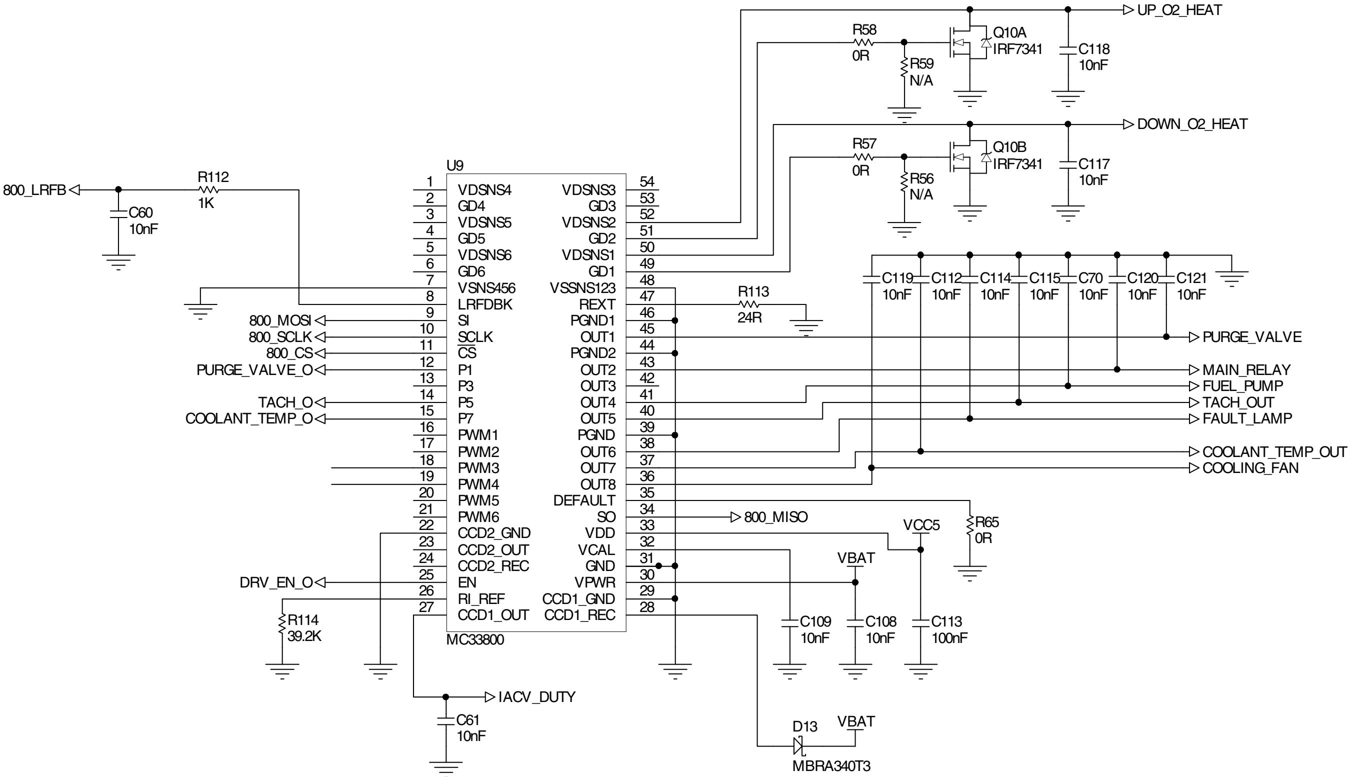

Figure 15. MC33800 Schematic

4.4 MC33932 Dual 5A H-Bridge

The MC33932 is a dual 5A H-bridge that can be used for several purposes in an engine control environment. Features of the MC33932 are:

- 8.0V to 28V continuous operation (transient operation from 5.0V to 40V) *
- 235mΩ maximum RDS(ON) @ 150°C (each H-Bridge MOSFET)
- 3.0V and 5.0V TTL / CMOS logic compatible inputs
- Over-current limiting (regulation) via internal constant-off-time PWM
- Output short-circuit protection (short to VPWR or GND)
- Temperature-dependant current-limit threshold reduction
- All inputs have an internal source/sink to define the default (floating input) states
- Sleep Mode with current draw < 50µA (each half with inputs floating or set to match default logic states)

The block diagram of the device is shown in the following figure.

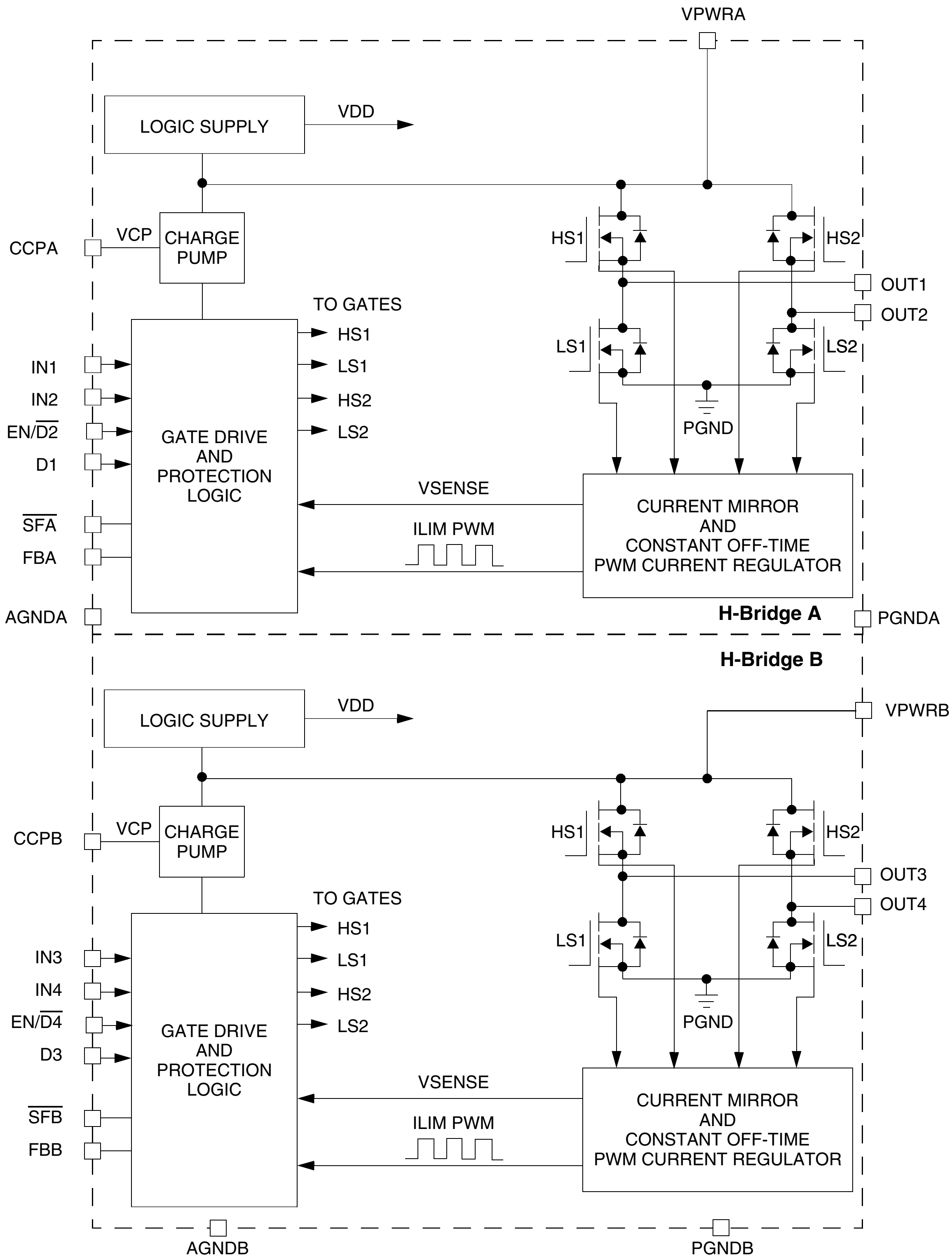

Figure 16. MC33932 Block Diagram

Schematics for the MC33932 in the MPC563xM Reference Design is shown in the following figure.

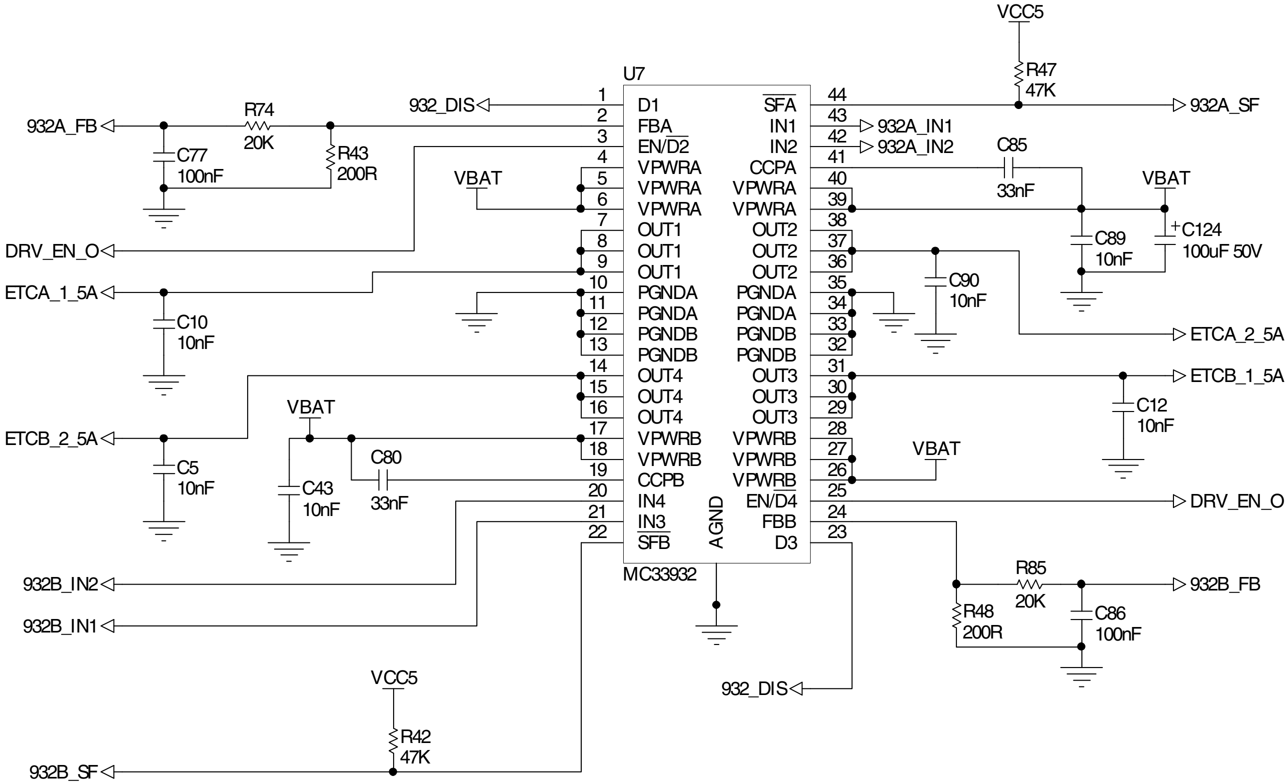

Figure 17. MC33932 Schematic

4.5 MC33926 5A H-Bridge Overview

The MC33926 is a Throttle Control H-Bridge device that is controlled by 2 PWM channels from the MCU. below shows the block diagram for the dvice.

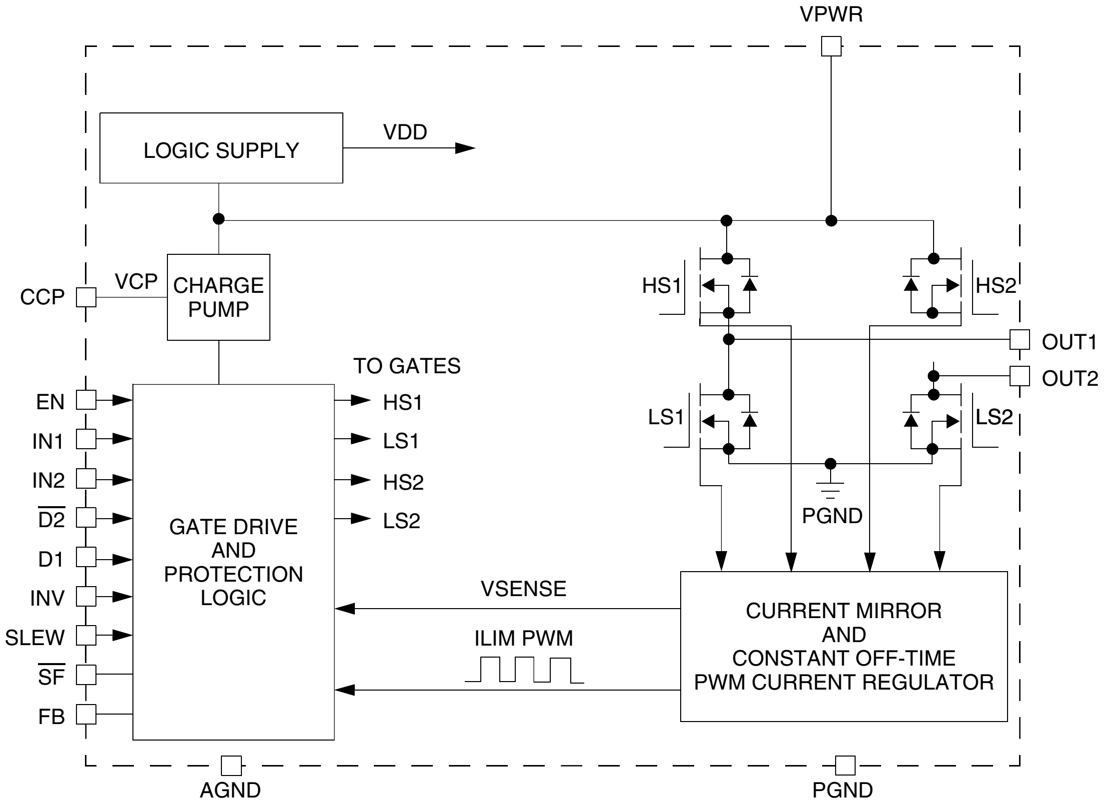

Figure 18.

Table 25. MC33926 Pin Out

Description	Pin Name	Pin Number	Pin Number	Pin Name	Description
	IN2	1	32	C_{CP}	
	IN1	2	31	VPWR	
	SLEW	3	30	OUT2	
	VPWR	4	29	OUT2	
	AGND	5	28	OUT2	
	VPWR	6	27	OUT2	
	INV	7	26	D1	
	FB	8	25	NC	
	NC	9	24	PGND	
	EN	10	23	PGND	
	VPWR	11	22	PGND	
	OUT1	12	21	$\overline{SF}$	
	OUT1	13	20	PGND	
	OUT1	14	19	PGND	
	OUT1	15	18	PGND	
	$\overline{D2}$	16	17	NC	

The following figure shows the schematic of the MC33926 in the MPC563xM ECU Reference Design.

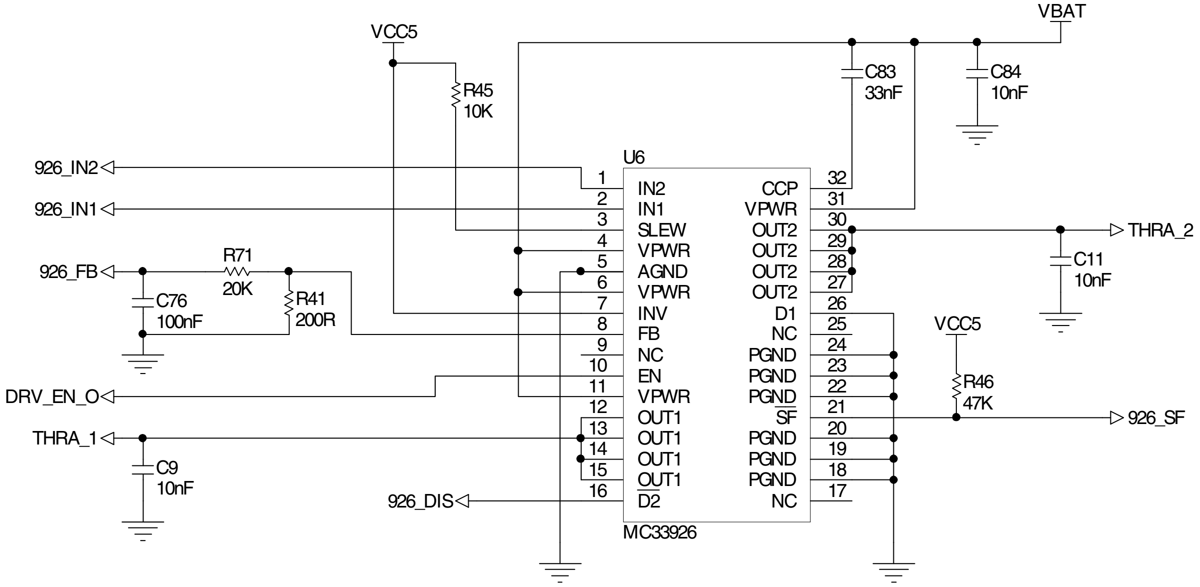

Figure 19. MC33926 system schematic

4.6 MC33879 high/low side driver overview

The MC33879 contains eight floating MOSFETS that can be configured as either high side or low side drivers.. These drivers can be combined to increase the current handling capabilities or paired as a bridge driver. A SPI interface is provide for diagnostic purposes.

The figure below shows the internal block diagram of the MC33897

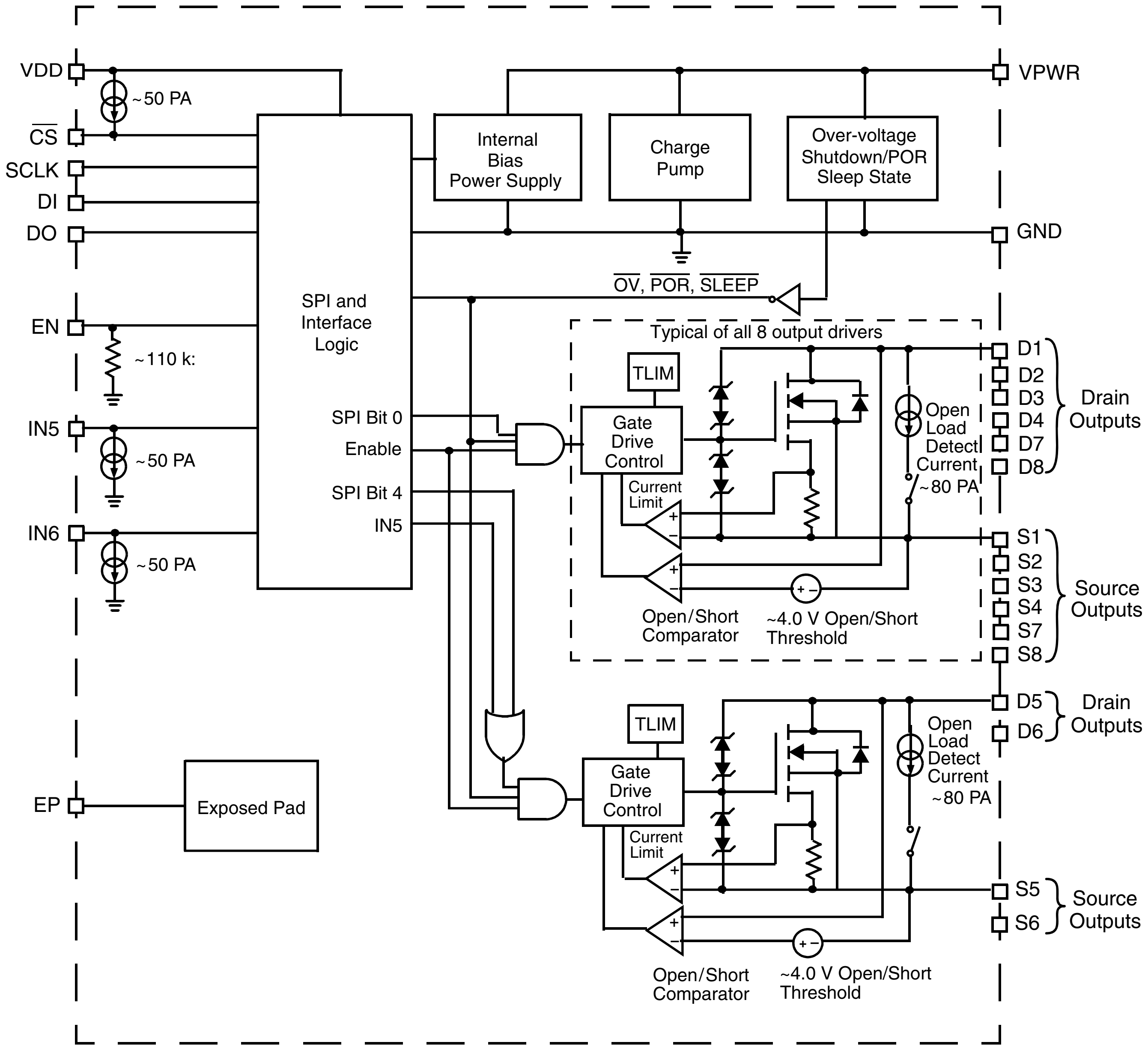

Figure 20. MC33879 block diagram

Below is the schematic of the MC33879 as used in the MPC563xM Engine Reference Design.

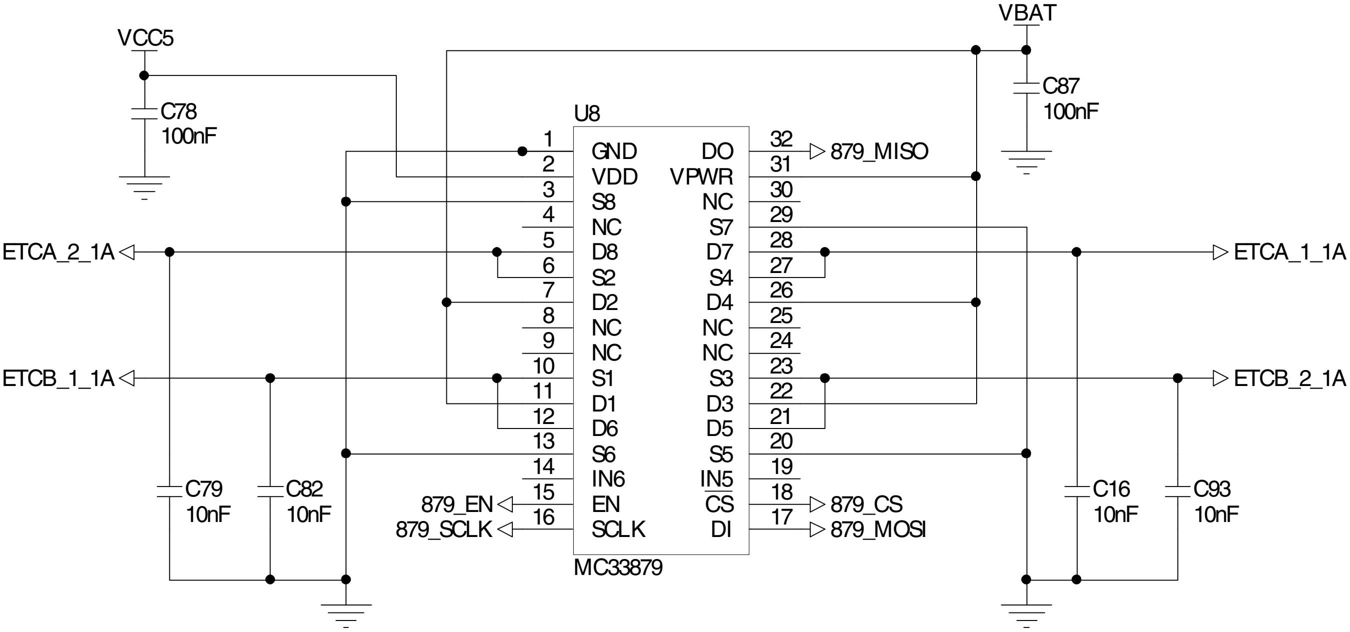

Figure 21. MC33879 Schematic

4.7 High-speed CAN with diagnostics: MC33902 interface

For target systems that require full diagnostics of the CAN interface, the Freescale MC33902 HS CAN transceiver is available as shown in Figure 22. Features of this device are:

- High-speed CAN interface for baud rates of 40 Kb/s to 1.0 Mb/s
- Compatible with ISO11898 standard
- Single supply from battery; no need for a 5.0 V supply for CAN interface
- I/O compatible from 2.75 V to 5.5 V via a dedicated input terminal (3.3 V or 5.0 V logic compatible)
- Low-power mode with remote CAN wakeup and local wake-p recognition and reporting
- CAN bus failure diagnostics and TXD/RXD pin monitoring, cold start detection, wake-up sources reported through the ERR pin
- Enhanced diagnostics for bus, TXD, RXD and supply pins available through pseudo-SPI via existing terminals EN, STBY, and ERR
- Split terminal for bus recessive level stabilization
- INH output to control external voltage regulator

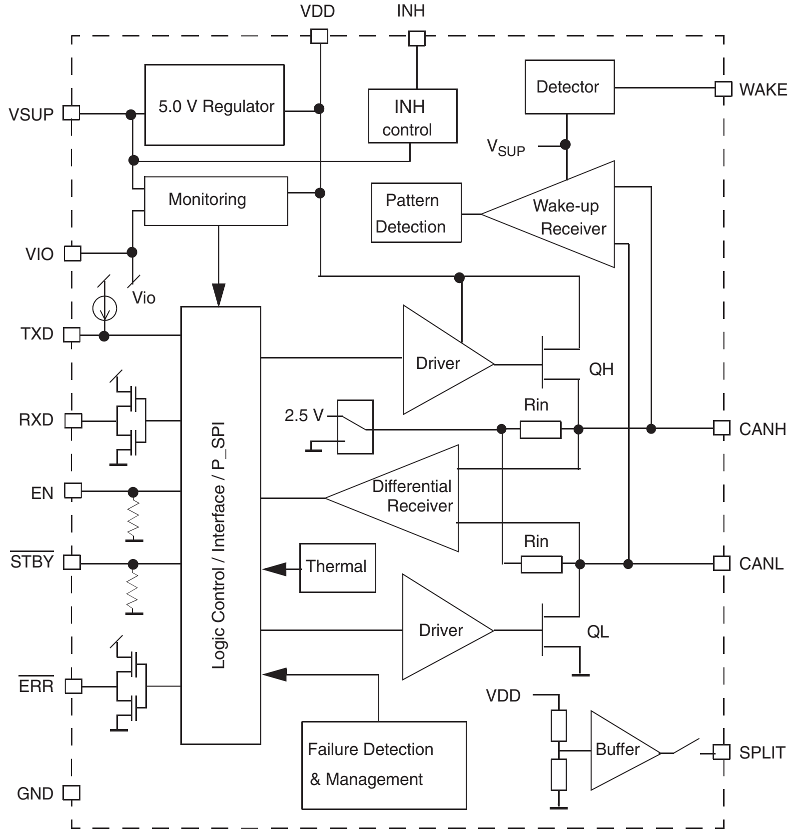

Figure 22. MC33902 block diagram

While a full SPI interface is not available for the diagnostic information, a quasi-SPI interface is available to communicate to the MCU. This interface is referred to as the P_SPI interface in the MC33902 data sheet.

The figure below shows an example schematic using the MC33902.

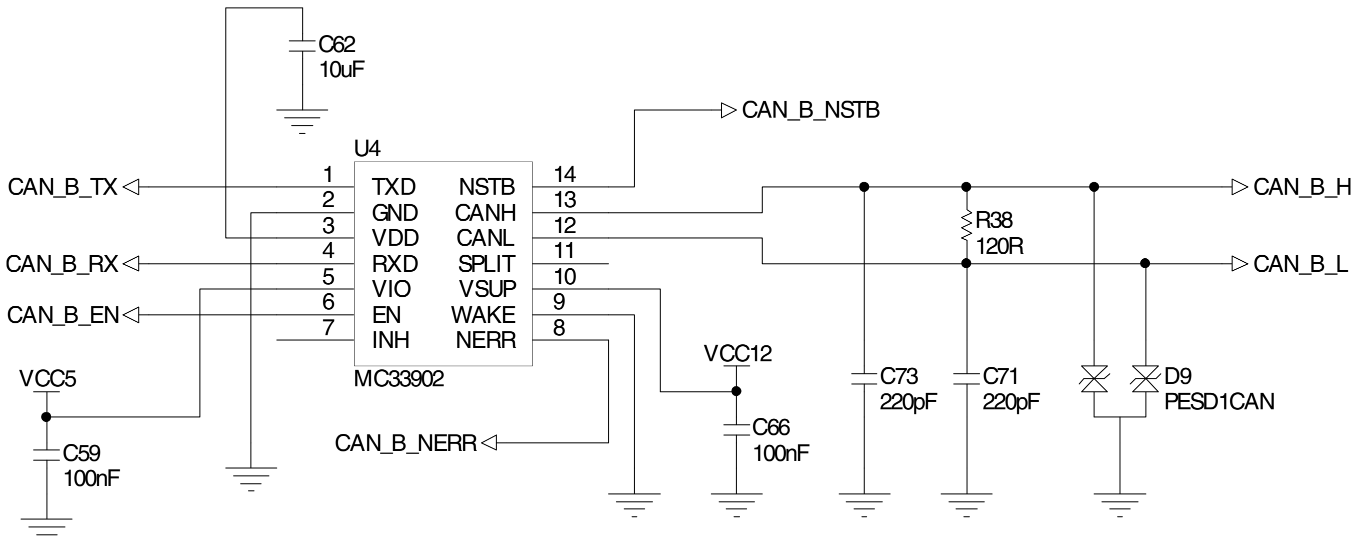

Figure 23. MC33902 High Speed CAN Schematic

NOTE

Decoupling shown as an example only.

Bus protection is shown as an example only.

Table 26 shows the pins of the MC33902 and the possible connections to a MCU and the target system.

Table 26. MC33902 pin definitions and example system connections

Pin number	Pin name	Pin direction	Full pin name	MCU or system connection	Description
1	TXD	Input	Transmit Data	MCU CAN TXDA	CAN transmit data input from the MCU.
2	GND	Output	Ground	Ground	Ground termination.
3	VDD	Output	VDD Internal Regulator Output	Bypass capacitors only	5 V power supply output. Requires external bypass capacitors.
4	RXD	Output	Receive Data	MCU CAN TXDA	CAN receive data output to the MCU.
5	VIO	Input	Voltage Supply for IO	3.3 V or 5 V	Supply voltage input for the digital input and output pins. This should be matched to the IO voltage supply of the MCU. Most typically, this is 5 V, but could also be 3.3 V.
6	EN	Input	Enable	Main MCU eTPUA31 (GPIO)	This is the enable input for the device in static mode control. This is the master output/slave input when used in SPI mode, and the MOSI (master out, slave in) during SPI operation.
7	INH	Output	Inhibit	Use depends on intended operation (see text below)	Inhibit output for control of an external power supply regulator.
8	$\overline{\text{ERR}}$	Output	Active Low Error	Main MCU eTPUA26 (GPIO)	Pin for static error and wakeup flag reporting MISO (master in, slave out) during SPI operation.
9	WAKE	Input	Wake	Tied to ground	Wake input.
10	VSUP	Input	Voltage Supply	Battery voltage	Battery supply pin, nominally 12 V.
11	SPLIT	Output	Split	Not Used	Output for connection of the CAN bus termination middle point .
12	CANL	Input/output	CAN Bus Low	CAN Bus Connector	CAN bus low pin.
13	CANH	Input/output	CAN Bus High	CAN Bus Connector	CAN bus high pin.
14	$\overline{\text{NTSB}}$	Input	Standby	Main MCU eTPUA28 (GPIO)	Standby input for device static mode control. CLK (Clock) during P_SPI operation.

The use of the Inhibit pin (INH) is dependent on the selected target system operation. INH can turn an external power supply on and therefore wake a connected MCU for operation to save power when MCU operation is not required. In MPC5500 and MPC5600 automotive power train applications (engine control), INH is typically not used. However, in automotive body and chassis applications, it may be used.

4.8 MPXH9115 barometric pressure sensor

The MPXH9115 barometric pressure sensor[4] is used in the MPC563xM ECU reference design to sense the air pressure for use when calculating the air to fuel ratio. It provides a ratio-metric analog output voltage that is connected to one of the inputs of the main MCU analog-to-digital converter channels (AN35). Internally, the MPXH9115 contains a piezoresistive transducer that is internally compensated over temperature with an internal Analog-to-Digital (10-bit) converter and a Digital-to-Analog (10-bit) converter.

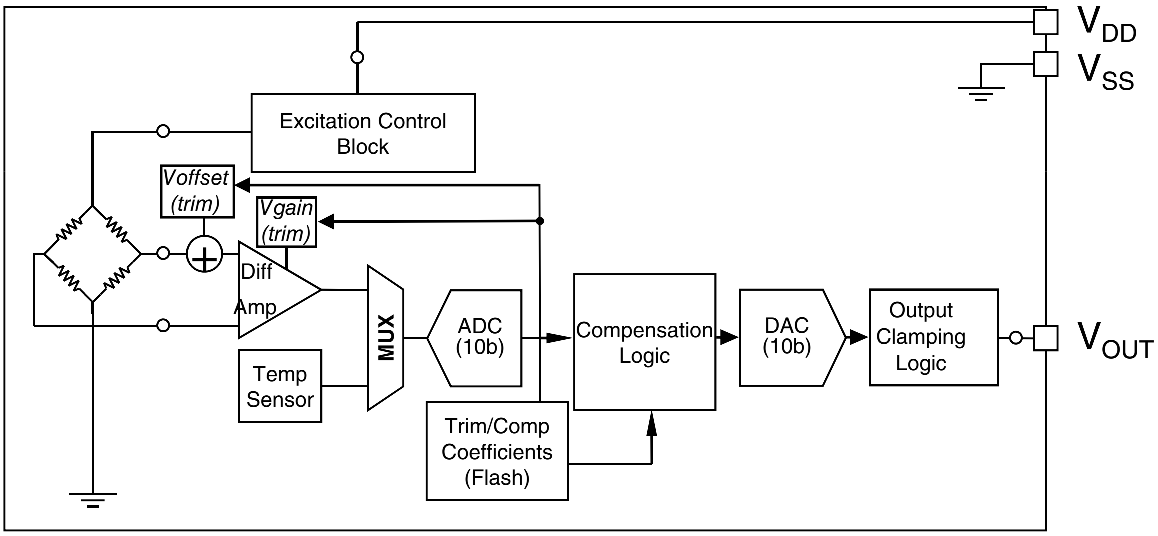

Figure 24. MPXH9115 block diagram

Schematics of the MPXH9115 as used in the MPC563xM ECU Reference Design are shown below.

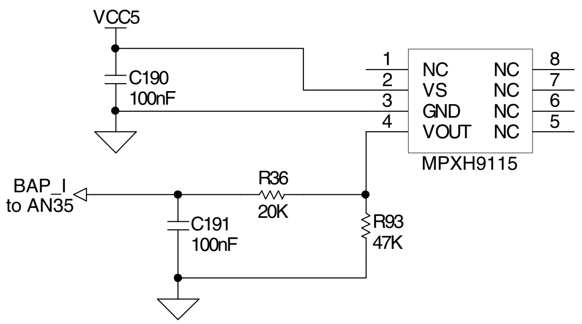

Figure 25. MPXH9115 system schematics

5 Other Circuitry

Description to be added.

5.1 Disable driver circuit

Description to be added of the circuit that allows all outputs to be disabled.

4. The MPXH9115 is a lower cost alternative to the MPXHZ6115 or MPX6115A.

5.2 CAM Select Circuitry

Two separate options are available for the CAM input circuitry that are jumper selectable.

5.3 MCU digital input translation

In some cases, digital inputs from outside of the ECU need additional protection and level translation. The circuit below shows one implementation used in the MPC563xM ECU Reference Design.

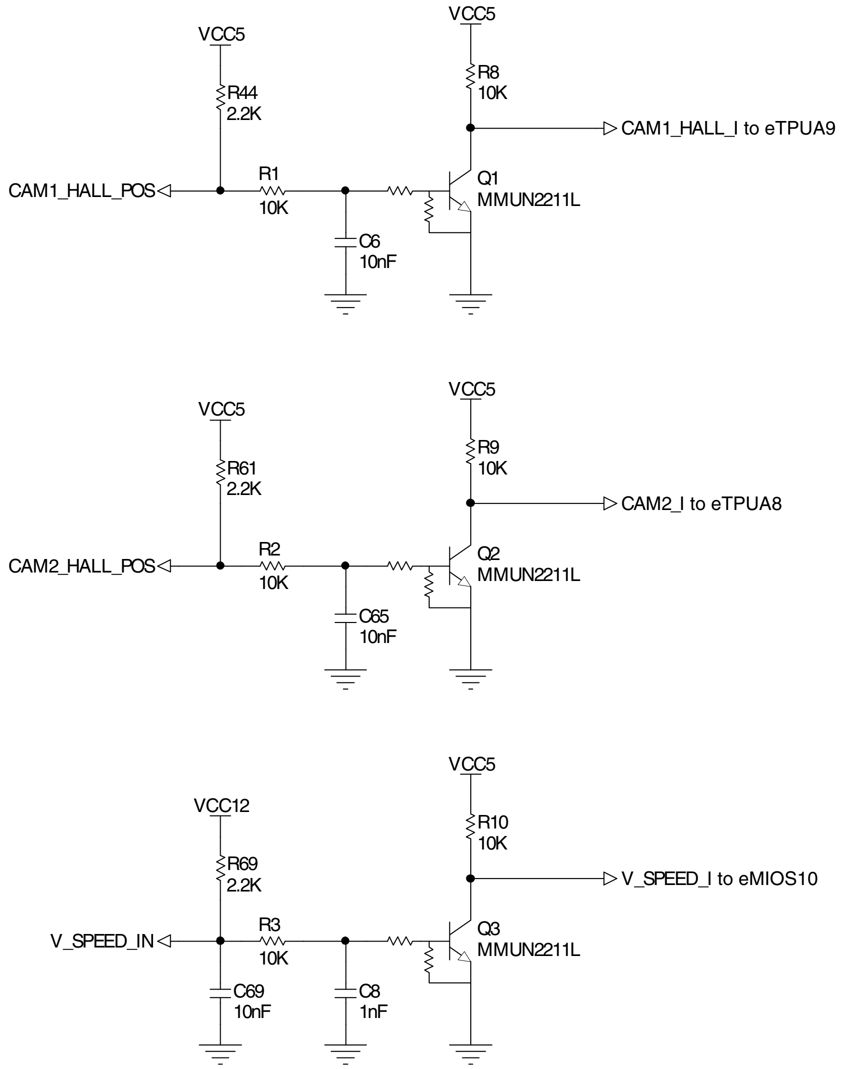

Figure 26. Transistor input filter

6 S08SG8 8-bit Safety MCU

The 8-bit S08SG8 MCU is used in this example system as a safety monitor device. It is connected via the SPI interface to the main 32-bit MCU and provides redundant capabilities for an independent health assessment of the entire system.

In particular, the system signals in the following table are routed to both the safety MCU and the main MCU.

Table 27. Redundant System Signals

Signal Name	Signal Type	S08SG8 Connection	Main MCU Connection	Signal Description
Coolant_Temp_I	Analog	PIA0/TPM1CH0/TCK/ ADP0/ACMP+	AN32	Temperature of the coolant for the engine
THR_POS_A_I	Analog	PTA1/PIA1/TPM2CH0/ ADP1/ACMP-	AN34	Throttle Control A
THR_POS_B_I	Analog	PTA2/PIA2/SDA/ADP2/ ACMPO	AN33	Throttle Control B
PEDAL_A_I	Analog	PTC0/TPM1CH0/ADP8	AN28	
PEDAL_B_I	Analog	PTC1/TPM1CH1/ADP9	AN31	
INTAKE_PRESS	Analog	PTC2/ADP10	AN4	Intake pressure

The following table shows the connections between the S08SG8 and the main MCU for SPI communication and for monitoring other activities of the main MCU. An additional safety feature of the S08SG8 is the capability of forcing the main MCU into reset it it detects improper system operation.

Table 28. SG08SG8 to Main MCU connections

Signal	Signal Type[1]	S08SG8 Connection	Main MCU Connection	Signal Description
TPU_MON	Digital Input	PT3/ADP11	eTPUA3	Connection to the main MCU eTPU to provide monitoring of the Main MCU functionality.
SAFE_CS	Digital Input	PTB5/TPM1CH1/$\overline{\text{SS}}$	PCSB5	SPI Chip Select
SAFE_MISO	Digital Output	PTB4/TPM2CH1/MISO	SINB	SPI Master In/Slave Out
SAFE_MOSI	Digital Input	PTB3/PIB3/MOSI/ADP7	SOUTB	SPI Master Out/Slave In
SAFE_SCLK	Digital Input	PTB2/PIB2/SPSCK/ ADP6	SCKB	SPI Clock
RESET_IN	Digital Output	PTA3/PIA3/SCL/ADP3	$\overline{\text{RESET}}$[2]	Main MCU Reset[3]

1. Signal direction is based on the S08SG8 direction.
2. Through a bipolar transistor to provide the open collector connection.
3. This connection is optional and can be disabled if needed.

The table below shows the Background Debug Mode connector pin out. The S08SG8 uses a 1 wire debug interface.

Table 29. S08SG8 BDM connector

Signal Name	Connector Pin	Connector Pin	Signal Name
BKGD	1	2	Ground
No connection	3	4	$\overline{\text{RESET}}$
No connection	5	6	VCC5 (5 volt supply)

Below is a schematic of the S08SG8 used in the engine reference design.

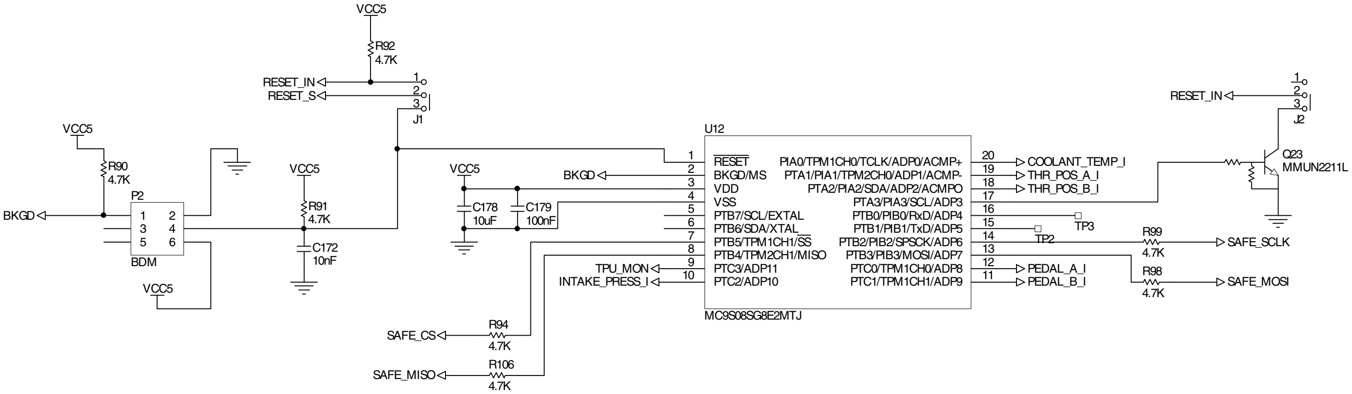

Figure 27. S08SG8 Schematic

7 Module internal jumpers and connectors

Inside the case of the MPC563xM ECU Reference Design, there are several internal connectors and jumper options. Some of the connectors are documented in other sections of this application note (JTAG connector, Nexus Connector, and the S08 BDM connector. There are other jumper connections available to select options in the module including a selection for forcing serial boot mode, connection of the K-Line transmit (TXDB pin) signal to the K-line receive (MCU RXDB pin) signal selection of the CAM inputs, selection of the

Jumper or Connector	Center (2)	Pin 1	Pin 3
P5	K-line TX	RXDB	Ground
P2	S08 BDM connector	6-pin BERG type	
P3	MPC563xM JTAG connector	14-pin BERG type	
P4	MPC563xM Nexus connector	38-pin Mictor	
J1	RESET_S	RESET_IN	S08 RESET pin
J2	RESET_IN	open	S08 PTA3
J3	CAM1_IN select	CAM1 Hall effect positive	CAM1 VRS positive
J4	CAM2_IN select	CAM2 Hall effect positive	CAM1 negative
J5	CAM1_I	CAM1_Hall_I	CAM1_VRS_I
J6	CAM1_VRS_NEG	Ground	
J7	ETCA_I	ETCA_1_5A	ETCA_1_1A
J8	ETCA_2	ETCA_2_5A	ETCA_2_1A
J9	ETCB_I	ETCB_1_5A	ETCB_1_1A
J10	ETCB_2	ETCB_2_5A	ETCB_2_1A
J11	BOOTCFG1 configuration	VCC5	Ground

8 Mechanical Housing, External Connectors, and PCB Specifications

The MPC5634M ECU has been designed to fit into a standard available case manufactured by Cinch. This housing is a modular integrated connector enclosures that is sealed for rugged environments.

Table 31. Mechanical Housing Components

Part Number	Manufacturer	Description	Quantity Required
581 01 60 032	Cinch	Enclosure (one heat-sink[1])	1
581 01 60 006 (blue) 581 01 60 005 (black)	Cinch	Header	1
581 01 30 028	Cinch	Mating Harness Connector	1
581 01 30 029	Cinch	Mating Harness Connector	1
425 00 00 873	Cinch	Female Terminal (18 AWG GXL, 16 AWG TXL)	56
425 00 00 872	Cinch	Female Terminal (20 AWG GXL, 18 AWG TXL	0
581 00 00 011	Cinch	Cavity Seal Plug	4

1. Alternately, the version with two heat-sinks can be used, but the second heat-sink is not used.

8.1 Connector Definition and Signal Description

The connector on the ECU is manufactured by Cinch and is part number 581 01 60 005 (board mount). It consists of two halves that each contain 30 pins for a total of 60 pins. The following figure shows the placement of the 2 halves of the connectors.

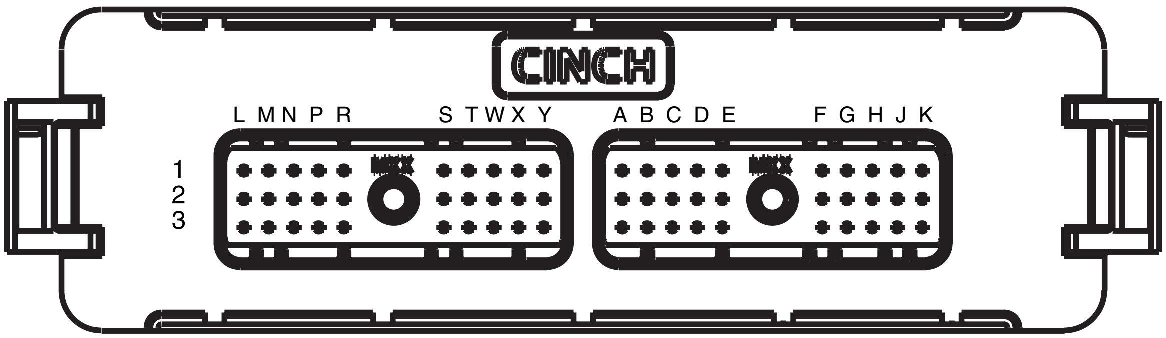

Figure 28. Cinch Connector Placement

The mating connectors (two) for the wiring harness are part number 581 01 30 029 and 581 01 30 028. This is sufficient for a simple 4-cylinder engine. Below shows the signal mapping for the two halves of the connector used for the ECU.

Table 32. ECU Connector first half (connects to 581 01 30 029)

Row	A	B	C	D	E		F	G	H	J	K
1	CAN_A_L	VCC5_SEN	IGN_SW	CAN_B_L	CAM1_IN		KNOCK_POS	THR_POS_A	PEDAL_A	INTAKE_PRESS	FUEL_LEVEL
2	CAN_A_H	GROUND	K_LINE	CAN_B_H	CAM2_IN		KNOCK_NEG	THR_POS_B	PEDAL_B	INTAKE_TEMP	COOLANT_TEMP
3	BRAKE_SW	EPS_SW	V_SPEED_IN	RESERVED	RESERVED		GROUND	DOWN_O2	UP_O2	RESERVED	RESERVED

Table 33. ECU Connector second half (connects to 581 01 30 028)

Row	L	M	N	P	R		S	T	W	X	Y
1	IGN4	IGN3	INJ2	INJ3	MAIN_RELAY		UP_O2_HEAT	VBAT	ETCA_1	ETCB_1	THRA_2
2	IGN1	GROUND	INJ4	INJ1	FUEL_PUMP		DOWN_O2_Heat	TACH_OUT	ETCB_2	ETCA_2	THRA_1
3	IGN2	GROUND	IACV_DUTY	PURGE_VALVE	COOLING_FAN		COOLANT_TEMP_OUT	FAULT_LAMP	GROUND	CPSP	CPSM

The following table lists each signal with the signal type, the signal purpose/description, and direction.

Table 34. ECU Connector Signal Descriptions

Signal Group	Signal	Location	Direction[1]	Signal Type	Polarity	Current	Description
Power Supply	VBAT	T1	Input	Power	—		Main power input, 12V battery voltage.
	GROUND	W3	I	Power	—		Ground reference for the module
	GROUND (ignition)	M2	I	GND	—		Ignition Ground
	VCC5_SEN	B1	Output		—		5 volt power output for external sensors 1
	GROUND (sensor)	B2	O	GND	—		Sensor 1 ground
	Ground (sensor shield)	F3	O	Power	—		Sensor ground shield
	MAIN_RELAY	R1	O	Digital GPIO	Low	5A	Main relay control
Fuel Injection	CAM1_IN	E1	I	Analog Input	—	—	CAM sensor 1 input
	CAM2_IN	E2	I	Analog Input	—	—	CAM sensor 2 input
	INJ1	P2	O	Digital eTPU	Low	3A	Injector driver output to the solenoids, connected to the eTPU.
	INJ2	N1					
	INJ3	P1					
	INJ4	N2					
	FUEL_LEVEL	K1	I	Analog input	—	—	Fuel Level input
	FUEL_PUMP	R2	O	Digital PWM	Low	0.5A	Fuel pump relay control (PWM - can be generated either by the eMIOS or the eTPU depending on the exact requirements.
	PURGE_VALVE	P3	O	Digital	Low	1A	Purge valve control

Table continues on the next page...

Table 34. ECU Connector Signal Descriptions (continued)

Signal Group	Signal	Location	Direction[1]	Signal Type	Polarity	Current	Description
Ignition	IGN1	L2	O	Digital eTPU	Low	10A each	Ignition output to the spark plugs, connected to the eTPU.
	IGN2	L3					
	IGN3	M1					
	IGN4	L1					
	FAULT_LAMP	T3	O		Low	1A	Fault lamp output
	CPSM	Y3	I	Analog	—	—	Crank sensor negative input
	CPSP	X3	I	Analog	—	—	Crank sensor positive input
	IGN_SW	C1	I	Digital GPIO	High	20 mA	Ignition Switch input.
	KNOCK_NEG	F2	I	Analog	—	—	Knock sensor negative input
	KNOCK_POS	F1	I	Analog	—	—	Knock sensor positive input
	V_SPEED_IN	C3	I	Digital PWM			Vehicle speed input, connected to an eMIOS timer.
	TACH_OUT	T2	O	Digital PWM			Output to the tachometer
Intake Air	ETCA_1	W1	O	Digital PWM	High/ Low	1A or 5A	IACV (Idle Air Control Valve) motor coil 1 A
	ETCA_2	X2	O	Digital PWM	High/ Low	1A or 5A	IACV (Idle Air Control Valve) motor coil 2 A
	ETCB_1	X1	O	Digital PWM	High/ Low	1A or 5A	IACV (Idle Air Control Valve) motor coil 2 A / VVT1[2]
	ETCB_2	W2	O	Digital PWM	High/ Low	1A or 5A	IACV (Idle Air Control Valve) motor coil 2 B / VVT2[2]
	IACV_DUTY	N3	O	Digital	Low	3A	IACV (Idle Air Control Valve) duty control for valve, connected to a PWM
	INTAKE_PRESS	J1	I	Analog	—	—	Intake air pressure (MAP)
	INTAKE_TEMP	J2	I	Analog	—	—	Intake air temperature (IAT, TA)
	PEDAL_A	H1	I	Analog	—	—	Accelerator Pedal sensor input A
	PEDAL_B	H2	I	Analog	—	—	Accelerator Pedal sensor input B
	THRA_1	Y2	O	Digital PWM		5A	Electronic Throttle Control (ETC) output A
	THRA_2	Y1	O	Digital PWM		5A	Electronic Throttle Control (ETC) output A
	THR_POS_A	G1	I	Analog	—	—	Throttle Position Control input A.
	THR_POS_B	G2	I	Analog	—	—	Throttle Position Control input B

Table continues on the next page...

Table 34. ECU Connector Signal Descriptions (continued)

Signal Group	Signal	Location	Direction[1]	Signal Type	Polarity	Current	Description
Cooling	COOLANT_TEMP	K2	I	Analog	—	—	Coolant temperature input (ECT1)
	COOLANT_TEMP_OUT	S3	O	Digital PWM			Coolant temperature output
	COOLING_FAN	R3	O	Digital GPIO	Low	0.5A	Cooling fan 1 relay output (GPIO)
Oxygen Sensor	DOWN_O2	G3	I	Analog	—	—	Down stream oxygen sensor input (O2)
	DOWN_O2_HEAT	S2		Digital GPIO			Down stream oxygen sensor heater control (GPIO)
	UP_O2	H3	I	Analog	—	—	Up stream oxygen sensor input (O2)
	UP_O2_HEAT	S1	O	Digital GPIO			Up stream oxygen sensor heater control (GPIO)
Switch	BRAKE_SW	A3	I	Digital GPIO	High	20 mA	Brake switch input
	EPS_SW	B3		Digital GPIO	Low	20 mA	Power steering switch input
Communication	K_LINE	C2	Input/ Output	Digital eSCI	—	—	K Line communication interface
	CAN_A_L	A1	I/O	Digital CAN	—	—	Controller Area Network A low
	CAN_A_H	A2	I/O	Digital CAN	—	—	Controller Area Network A high
	CAN_B_L	D1	I/O	Digital CAN	—	—	Controller Area Network B low
	CAN_B_H	D2	I/O	Digital CAN	—	—	Controller Area Network B high
	RESERVED	D3, E3, J3, K3	—				Reserved for future definition and use.

1. As viewed by the ECU.
2. Variable Valve Timing

8.2 Printed Circuit Board Specifications

The following table shows the dimension specifications of the printer circuit board (PCB).

Table 35. PCB Specificaiotns

Property	Type
Board base material	FR-4
Number of layers	4

Table continues on the next page...

Table 35. PCB Specificaiotns (continued)

Property	Type
Board total thickness	1.6 mm
Board size	152 mm x 139 mm
Copper thickness (outside layers)	2 oz. (70 um)
Copper thickness (internal layers)	2 oz. (70 um)
Silkscreen side	Top only
Via type	Through hole
Hole type	Plated and non-plated
Surface type	ENIG

The following layer stack was used in the MPC563xM ECU Reference Design module.

Table 36. Layer Stack

Layer	Thickness	Description
Top layer	2 oz.	Primary routing layer. Most all of the components are mounted on the top side of the PCB
Core	6 mil	—
Internal plane 1	2 oz.	<<< used for ground??>>>
Core	6 mil	—
Internal plane 2	2 oz.	<<< used for power??>>>
Core	6 mil	—
Bottom layer	2 oz.	Routing layer and ground. Also used for mounting some discrete components.

8.3 Heat-sink details and specifications

To provide better thermal performance, an external heat-sink is mechanically connected to large traces on the printed circuit board to dissipate heat from the board and transfer the heat to a heat-sink built into the case. The heat-sink is located near the IGBT's and the two H-bridge devices (MC33932 and MC33926).

In hind-sight, the IBGT's do not generate as much heat as the MC33905 System Basis Chip (SBC). A better design would put the SBC closer to the heat-sink.

Table 37. Heat-sink Specifications

Parameter	Specification
Material	Aluminium
Metal thickness	3 mm
Dimension	See dimension drawing below

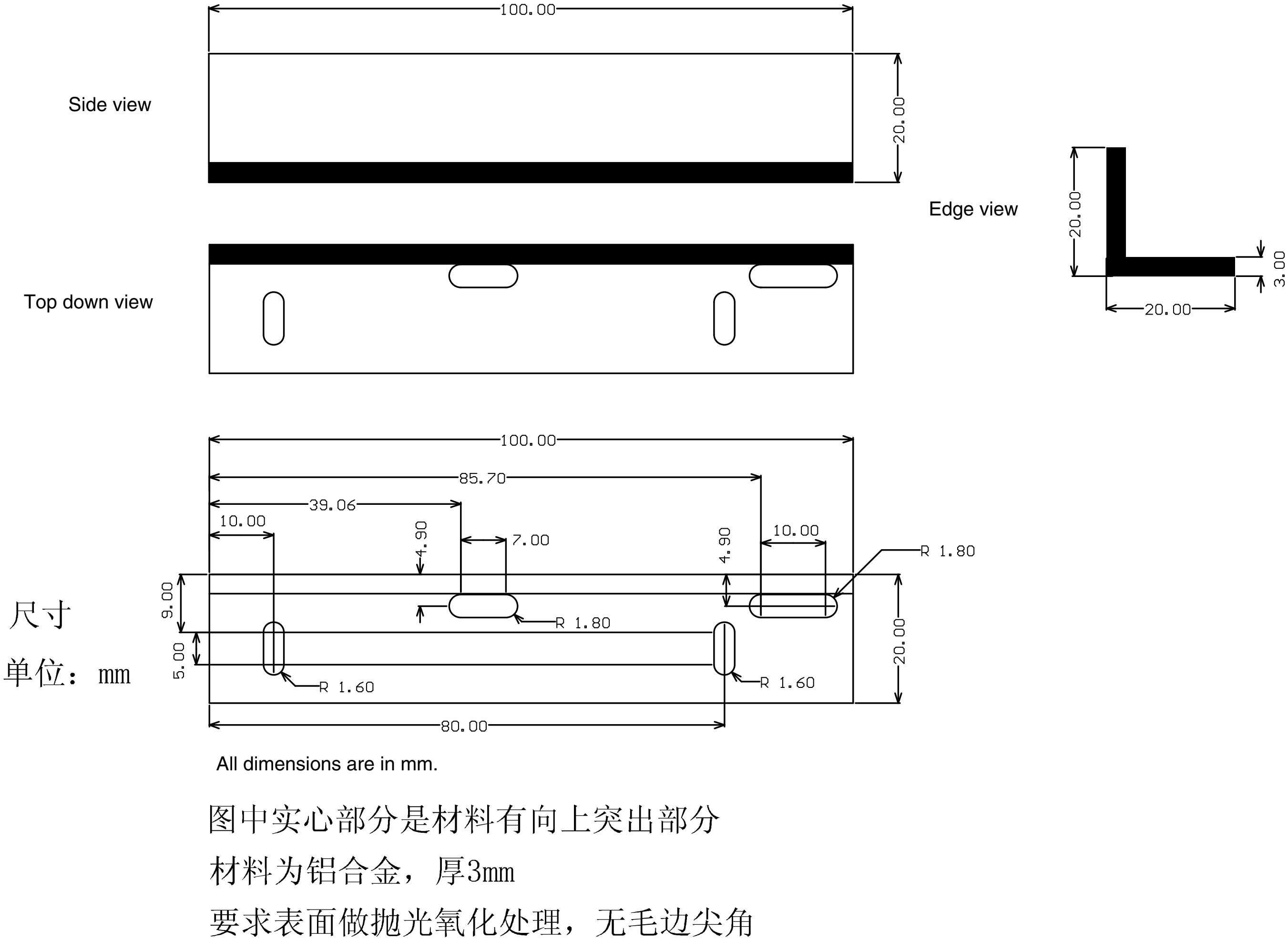

Figure 29. Heat-sink dimensional drawing

The heat-sink is physically connected with a two bolts with either thermal grease or a thermal pad. The mechanics of the housing and a spring bracket force the heat-sink mounted on the printed circuit board to be held against the heat-sink mounted in the case. This is shown in the picture below.

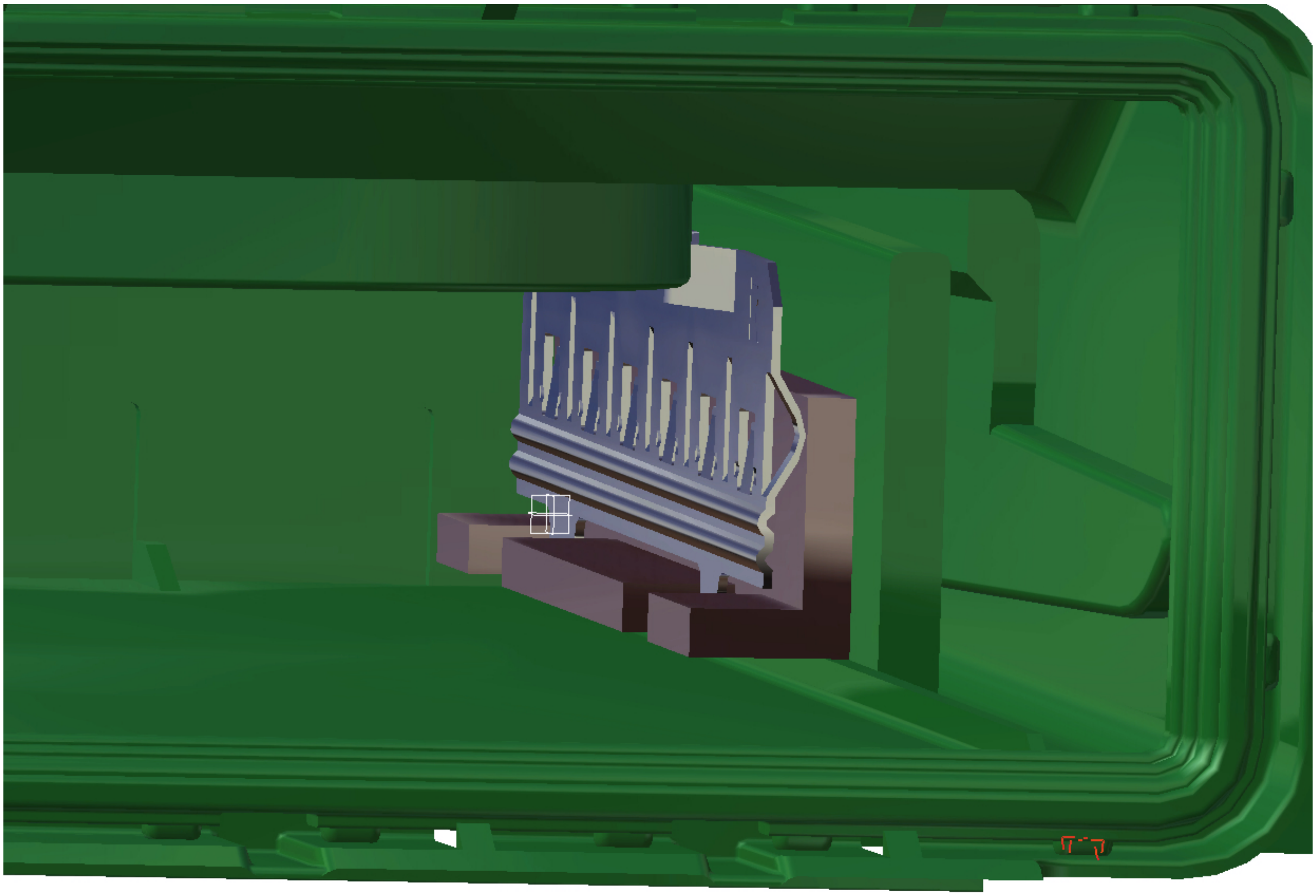

Figure 30. Case with spring bracket

9 Debug Features of the ECU

The MPC563xM ECU includes two types of connectors on the board for debug of the MPC563xM MCU. Only one can be used at a time. Either a 14-pin JTAG only connector can be used or the 38-pin Mictor Nexus connector can be used.

The JTAG connector allows minimal run control features such as starting MCU execution, downloading executable code into memory, modifying memory, programming flash, and other types of "stop" mode debug. The JTAG connector does allow for use of the Nexus read/write access feature to read or modify memory while the MCU core is running.

The 38-pin Mictor Nexus connector allows for all of the basic JTAG operations, but also allows advanced features such as real-time program trace.

The background debug mode (BDM) connector of the S08SG8 is documented in the S08SG8 section of this application note.

9.1 Nexus/JTAG debug interface

In all packages, the JTAG pins are implemented with multi-voltage (MULTV) pads. The MULTV pads must be powered by a 5 volt supply. The MULTV pads out a high voltage of only 3.3 volts when configured in the low voltage mode (when being used for JTAG or Nexus functions). When MULTV pads are configured as general purpose Input/output (GPIO), the pins output a standard CMOS 5 volt level.

NOTE

The Nexus pins on both the 176 and 208 packages must be powered directly from an external 3.3V supply. However, the JTAG pins are still powered by a 5V supply and use MULTV pads.

Table 38. JTAG pins and power supply

Pin	Pin Control Register (PCR)	Alternate Functions	Pad type	Power Supply
TCK	—	—	MULTV	VDDEH7[1]
TDI	232	eMIOS[5] or GPIO[232]	MULTV	VDDEH7[1]
TDO	228	eMIOS[6] or GPIO[228]	MULTV	VDDEH7[1]
TMS	—	—	MULTV	VDDEH7[1]
JCOMP	—	—	MULTV	VDDEH7[1]

1. VDDEH7 must be a 5 volt supply when using the JTAG pins. In the calibration package, this supply is named VDDE12.

The Nexus pins, however, implement different pad types depending on the package of the device. In the 144 PQFP package, the pins are implemented with MULTV pads and require a 5 volt power supply. However, on the 176 PQFP and the 208 MAPBGA packages, the pins are implemented with Fast pads. The fast pads require a 3.3V power supply that should be provided from an external power supply.

Table 39. Nexus pins and power supply

Signal	144 PQFP Package				176 PQFP and 208 MAPBGA			
	PCR	Alternate Functions	Pad Type	Power Supply	PCR	Alternate Functions	Pad Type	Power Supply
$\overline{\text{EVTI}}$	231	eTPU_A[2] or GPIO[231]	MULTV	VDDEH7[1]	345	CAL_ADDR[30]	Fast	VDDE7[2]
$\overline{\text{EVTO}}$	227	eTPU_A[4] or GPIO[227]	MULTV	VDDEH7[1]	344	CAL_$\overline{\text{EVTO}}$	Fast	VDDE7[2]
MCKO	219	GPIO[219]	MULTV	VDDEH7[1]	344	CAL_MCKO	Fast	VDDE7[2]
MDO[0]	220	eTPU_A[13] or GPIO[220]	MULTV	VDDEH7[1]	345	CAL_ADDR[16]	Fast	VDDE7[2]
MDO[1]	221	eTPU_A[19] or GPIO[221]	MULTV	VDDEH7[1]	345	CAL_ADDR[17]	Fast	VDDE7[2]
MDO[2]	222	eTPU_A[21] or GPIO[222]	MULTV	VDDEH7[1]	345	CAL_ADDR[18]	Fast	VDDE7[2]
MDO[3]	223	eTPU_A[25] or GPIO[223]	MULTV	VDDEH7[1]	345	CAL_ADDR[19]	Fast	VDDE7[2]
MDO[4:11]	—				345	CAL_ADDR[20:27]	Fast	VDDE7[2]
$\overline{\text{MESO}}$[0]	224	eTPU_A[27] or GPIO[224]	MULTV	VDDEH7[1]	345	CAL_ADDR[28]	Fast	VDDE7[2]
$\overline{\text{MESO}}$[0]	225	eTPU_A[29] or GPIO[225]	MULTV	VDDEH7[1]	345	CAL_ADDR[29]	Fast	VDDE7[2]

1. VDDEH7 must be a 5 volt supply when using the JTAG pins
2. This is not the same supply as VDDEH7. VDDE7 must be a 3.3V supply.

The MPC563xM Engine Reference Design uses the 144 PQFP package and therefore, powers the JTAG and Nexus debug signals to VDDEH7 (5 volts). However, since these pins use the MULTV pads in low swing mode, they will output a 3.3 volt level, therefore, the reference voltage (VREF signal on the debug connector) to the debug connector should be a 3.3 volt reference. The VRC33 signal (output of the 3.3 volt internal regulator) can be used as this reference point on the debug connectors. Debuggers must use less than 1 mA of current on the VREF pin (per the IEEE-ISTO 5001™-2003 standard).

9.2 MPC5600 JTAG connector

The figure below shows the pinout of the recommended JTAG connector to support the MPC5600 devices. If there is enough room allowed in the target system, a full Nexus connector is preferred over the simple 14-pin JTAG connector since it allows a higher degree of debug capability. It can be used as a minimum debug access or for BSDL board testing.

The recommended connector for the target system is the Tyco part number 2514-6002UB.

NOTE

This pinout is similar to the Freescale MCORE and DSP JTAG/OnCE connector definitions.

Table 40. Recommended JTAG connector pinout

Description	Pin	Pin	Description
TDI	1	2	GND
TDO	3	4	GND
TCK	5	6	GND
$\overline{\text{EVTI}}$[1]	7	8	—
$\overline{\text{RESET}}$	9	10	TMS
VREF	11	12	GND
$\overline{\text{RDY}}$[2]	13	14	JCOMP

1. $\overline{\text{EVTI}}$ is optional and was not included in the original (very early) definitions of the JTAG-only connector.
2. The $\overline{\text{RDY}}$ signal is not available on all packages or on all devices. Check the device pinout specification. In general it is not available in packages with 208 signals or less.

NOTE

Freescale recommends that a full Nexus connector be used for all tool debug connections, regardless of whether Nexus trace information is needed. Adapters for a JTAG class 1 14-pin connector (tool side) to the full Nexus MICTOR connectors (board side) are available from P&E Microcomputer Systems (http://www.pemicro.com), part number PE1906, and from Lauterbach (http://www.lauterbach.com), order number LA-3723 (CON-JTAG14-MICTOR). Lauterbach also has an adapter that will connect a MICTOR connector (tool side) to a 14-pin JTAG connector (board side). This adapter is order number LA-3725 (CON-MIC38-J14-5500).

9.3 MICTOR Connector Definition for the MPC5500 Family

The following table shows the complete signal usage for the MPC5500 full-port mode MICTOR connector. This uses the Vendor_IO pins 1–4 as MDO[11:8]. This connector may also be used for reduced-port mode (which only uses MDO[3:0]). While only one MICTOR is recommended, some tools may not support this configuration. For maximum tool compatibility, a second MICTOR may need to be added for the upper four MDO signals (MDO[11:8]).

Table 41. MPC5500 Family MICTOR Connector M38C

MPC5500 signal	Combined M38C or M38-2C						Combined M38C or M38-2C	MPC5500 signal
-	Reserved[1]	-	1	Ground	2	-	Reserved[1]	-
-	Reserved[1]	-	3		4	-	Reserved[1]	-
MDO9/GPIO80	VEN_IO0	Out	5		6	Out	CLOCKOUT	CLKOUT
BOOTCFG1/$\overline{IRQ3}$/ GPIO212	VEN_IO2	In	7		8	Out	VEN_IO3	MDO8/GPIO70
$\overline{RESET}$	/RESET	In	9		10	In	/EVTI	$\overline{EVTI}$
TDO	TDO	Out	11		12		VTREF	VDDE7
MDO10/GPIO81	VEN_IO4	Out	13		14	Out	/RDY	$\overline{RDY}$
TCK	TCK	In	15		16	Out	MDO7	MDO7/GPIO78
TMS	TMS	In	17	Ground	18	Out	MDO6	MDO6/GPIO77
TDI	TDI		19		20	Out	MDO5	MDO5/GPIO76
JCOMP	/TRST	In	21		22	Out	MDO4	MDO4/GPIO75
MDO11/GPIO82	VEN_IO1	Out	23	Ground	24	Out	MDO3	MDO3
$\overline{RSTOUT}$	TOOL_IO3	Out	25		26	Out	MDO2	MDO2
-[2]	TOOL_IO2		27		28	Out	MDO1	MDO1
-[2]	TOOL_IO1		29		30	Out	MDO0	MDO0
12 volts	UBATT		31		32	Out	/EVTO	$\overline{EVTO}$
12 volts	UBATT		33		34	Out	MCKO	MCKO
-[2]	TOOL_IO0		35		36	Out	/MSEO1	$\overline{MSEO1}$
VSTBY	VALTREF		37		38	Out	/MSEO0	$\overline{MSEO0}$

1. Pins 1 through 4 should be considered "reserved" and may be used by some logic analyzers as ground connections. If care is taken (and the proper cables are used), these pins could be used for customer I/O signals. However, check with the tool vendors used.
2. This optional Nexus signal is defined for use by tool vendors and has no defined connection to the MPC5500 family device.

Appendix A Schematic Appendix

This section contains a complete set of schematics for the MPC563xM Engine Control Unit Reference Design.

Appendix B MPC563xM Bill of Materials

Table B-1. MPC563xM ECU bill of materials

Quantity	Designator	Componant or Value	Description	Footprint	Part Number	Manufacturer	NE#	NW#
3	B1, B3, B5	MPZ2012S331A	Filter Bead	0805	—	—	—	—
5	C1, C2, C35, C37, C54	2.2nF	Capacitor	0805	—	—	—	—
6	C3, C4, C8, C26, C27, C42	1nF	Capacitor	0805	—	—	—	—
50	C5, C6, C7, C9, C10, C11, C12, C16, C17, C28, C29, C30, C43, C47, C48, C49, C50, C51, C55, C56, C60, C61, C65, C67, C69, C70, C79, C82, C84, C89, C90, C93, C100, C101, C102, C103, C108, C109, C112, C114, C115, C116, C117, C118, C119, C120, C121, C172, C181, C188	10nF	Capacitor	0603	—	—	—	—
2	C13, C14	470pF	Capacitor	0805	—	—	—	—
11	C15, C41, C155, C159, C162, C166, C168, C171, C174, C176, C182	1uF	Capacitor	0805	—	—	—	—

Table continues on the next page...

Table B-1. MPC563xM ECU bill of materials (continued)

Quantity	Designator	Componant or Value	Description	Footprint	Part Number	Manufacturer	NE#	NW#
36	C18, C22, C24, C25, C31, C33, C36, C39, C44, C45, C46, C52, C53, C57, C58, C59, C63, C64, C66, C68, C76, C77, C78, C86, C87, C99, C113, C122, C153, C170, C175, C179, C180, C189, C190, C191	100nF	Capacitor	0603	—	—	—	—
4	C19, C20, C71, C73	220pF	Capacitor	0805	—	—	—	—
1	C21	100uF 35V	Aluminum Electrolytic Capacitor	CAE-F	—	—	—	—
1	C23	47uF 35V	Aluminum Electrolytic Capacitor	CAE-D	—	—	—	—
1	C32	15nF	Capacitor	0805	—	—	—	—
1	C34	100pF	Capacitor	0805	—	—	—	—
2	C38, C40	22uF 16V	Capacitor	1210	—	—	—	—
10	C62, C154, C157, C158, C161, C165, C173, C177, C178, C194	10uF	Capacitor	1206	—	—	—	—
3	C80, C83, C85	33nF	Capacitor	0805	—	—	—	—
4	C94, C95, C96, C107	220nF	Capacitor	0805	—	—	—	—
4	C97, C98, C110, C111	5pF	Capacitor	0805	—	—	—	—
1	C124	100uF 50V	Aluminum Electrolytic Capacitor	CAE-G	—	—	—	—
1	C164	680nF	Capacitor	0805	—	—	—	—
2	C183, C184	12pF	Capacitor	0805	—	—	—	—
4	C185, R56, R59, R77	N/A	Capacitor, Resistor	0805	—	—	—	—

Table continues on the next page...

Table B-1. MPC563xM ECU bill of materials (continued)

Quantity	Designator	Componant or Value	Description	Footprint	Part Number	Manufacturer	NE#	NW#
3	D1, D2, D3	BAV199	Double Diode	SOT-23	—	—	—	—
1	D4	BAT54C	Double Diode	SOT-23	—	—	—	—
1	D5	BAT54S	Double Diode	SOT-23	—	—	—	—
1	D6	LED	LED	LED1208	—	—	—	—
1	D7	BZX84-C9V1	Zener Diode	SOT-23	—	—	—	—
1	D8	PESD24VL1BA	Bidirectional TVS	SOD-323	—	—	—	—
2	D9, D12	PESD1CAN	Double Bidirectional TVS for CAN	SOT-23	—	—	—	—
1	D10	SMCJ24CA	Bidirectional TVS	SMB	—	—	—	—
1	D11	MBRA140T3	Schottky Diode 3A 40V	SMA	—	—	—	—
1	D13	MBRA340T3	Schottky Diode 3A 40V	SMA	—	—	—	—
10	J1, J2, J3, J4, J5, J7, J8, J9, J10, J11	JUMPER3	Jumper 3-Pin	SIP3	—	—	—	—
1	J6	JUMPER	Jumper	JUMPER100	—	—	—	—
1	L1	B82789C223N2	EPCOS Common Mode Filter	B82789	—	—	—	—
1	P1	CINCH5810160005	CINCH 60-Pin Connector	CINCH-60-011	—	—	—	—
1	P2	BDM	Header, 6-Pin, Dual row	HAED3X2	—	—	—	—
1	P3	JTAG	JTAG Header, 14-Pin, Dual row	JTAG14	—	—	—	—
1	P4	NEXUS	Nexus Header, 38-Pin, Mictor	AMP767054-1	—	—	—	—

Table continues on the next page...

Table B-1. MPC563xM ECU bill of materials (continued)

Quantity	Designator	Componan t or Value	Descriptio n	Footprint	Part Number	Manufactur er	NE#	NW#
1	P5	SIP3	Header, 3-Pin, Single row	SIP3	—	—	—	—
5	Q1, Q2, Q3, Q6, Q23	MMUN2211 L	100mA Digital NPN Transistor	SMT3	—	—	—	—
4	Q4, Q5, Q12, Q13	NGD8201N	IGBT 20A 400V	DPAK-EP	—	—	—	—
2	Q7, Q8	BCP51	1A 45V PNP Bipolar Transistor	SOT-223	—	—	—	—
1	Q10	IRF7341	Dual N-Ch MOSFET 55V 3A	SO-8	—	—	—	—
1	Q19	BCP68	1A 20V NPN Bipolar Transistor	SOT-223	—	—	—	—
9	R1, R2, R3, R22, R37, R39, R50, R52, R72	10K	Resistor	0603	—	—	—	—
2	R4, R5	10K	Resistor	2512	—	—	—	—
4	R6, R7, R11, R24	100K	Resistor	0603	—	—	—	—
17	R8, R9, R10, R14, R23, R33, R45, R75, R76, R78, R88, R89, R95, R97, R100, R102, R104	10K	Resistor	0805	—	—	—	—
1	R12	120K	Resistor	0805	—	—	—	—
2	R13, R107	680K	Resistor	0805	—	—	—	—
1	R15	240K	Resistor	0805	—	—	—	—
8	R16, R17, R36, R71, R74, R85, R96, R101	20K	Resistor	0805	—	—	—	—
10	R18, R19, R20, R28, R29, R30, R31, R32, R34, R105	20K	Resistor	0603	—	—	—	—
4	R21, R108, R109, R110	1M	Resistor	0805	—	—	—	—

Table continues on the next page...

Table B-1. MPC563xM ECU bill of materials (continued)

Quantity	Designator	Component or Value	Description	Footprint	Part Number	Manufacturer	NE#	NW#
10	R25, R82, R84, R90, R91, R92, R94, R98, R99, R106	4.7K	Resistor	0805	—	—	—	—
3	R26, R35, R112	1K	Resistor	0805	—	—	—	—
1	R27	430R	Resistor	0805	—	—	—	—
2	R38, R73	120R	Resistor	0805	—	—	—	—
1	R40	15R	Resistor	0805	—	—	—	—
3	R41, R43, R48	200R	Resistor	0805	—	—	—	—
4	R42, R46, R47, R93	47K	Resistor	0805	—	—	—	—
3	R44, R61, R69	2.2K	Resistor	0805	—	—	—	—
4	R49, R51, R53, R62	4K	Resistor	0805	—	—	—	—
4	R54, R55, R60, R87	36K	Resistor	1206	—	—	—	—
2	R57, R58	0R	Resistor	0805	—	—	—	—
2	R63, R64	100R	Resistor	0805	—	—	—	—
5	R65, R67, R68, R80, R117	0R	Resistor	0603	—	—	—	—
1	R66	R020	Resistor	RES-SENSE-R020	—	—	—	—
1	R70	2.2K	Resistor	0603	—	—	—	—
1	R79	2K, 1%	Resistor	0805	—	—	—	—
2	R81, R86	N/A	Resistor	0603	—	—	—	—
1	R83	8R2	Resistor	2512	—	—	—	—
1	R103	1M	Resistor	0603	—	—	—	—
1	R111	330K, 1%	Resistor	0805	—	—	—	—
1	R113	24R	Resistor	2010	—	—	—	—
1	R114	39.2K	Resistor	0805	—	—	—	—
1	R115	100K, 1%	Resistor	0805	—	—	—	—
1	R116	10R	Resistor	0805	—	—	—	—
1	U1	MAX9924	Variable Reluctance Interface	uMAX-10	—	—	—	—
1	U2	LM2903	Dual Comparator	SO-8	—	—	—	—

Table continues on the next page...

Table B-1. MPC563xM ECU bill of materials (continued)

Quantity	Designator	Componant or Value	Description	Footprint	Part Number	Manufacturer	NE#	NW#
1	U3	MC33905SEK	SBC with High Speed CAN Interface	SO-32LD-EP	—	—	—	—
1	U4	MC33902	HS CAN Transceiver	SO-14	—	—	—	—
1	U6	MC33926	H-Bridge Driver	PQFN32-P80	—	—	—	—
1	U7	MC33932	Dual H-Bridge Driver	HSOP44	—	—	—	—
1	U8	MC33879	Octal Serial Switch	SO-32LD-EP	—	—	—	—
1	U9	MC33800	Engine Control IC	SO-54LD-PAD	—	—	—	—
1	U10	MC33810	Engine Control IC	SO-32LD-EP	—	—	—	—
1	U12	MC9S08SG8E2MTJ	Freescale 8-bit MCU	TSSOP20-P65	—	—	—	—
1	U13	MPC5634MMLQ80	Freescale 32-bit MCU	LQFP144	—	—	—	—
1	U16	MPXH9115[1]	Pressure Sensor	SSOP-8-C1317-04	—	—	—	—
1	X1	8MHz	Crystal Oscillator	XTAL-NX8045GB	—	—	—	—

1. The MPXH9115 is a lower cost alternative to the MPXHZ6115.

Appendix C MPC563xM ECU_Connector

Table C-1. MPC563xM ECU_Connector

Block	Pin Number	Function	I/O	Active Lo/High	Current Requirement	Description	MCU Pin Feature	MCU Pin Assignment
Power Supply	T1	Battery	PWR	—	—	—	—	—
	W3	Power ground	PWR	—	—	—	—	—
	M2	Ignition ground	PWR	—	—	—	—	—
	R1	Main relay control	O	Lo	0.5A	—	GPIO	—

Table continues on the next page...

Table C-1. MPC563xM ECU_Connector (continued)

Block	Pin Number	Function	I/O	Active Lo/ High	Current Requirement	Description	MCU Pin Feature	MCU Pin Assignment
Fuel injection	P2	Injection 1	O	Lo	3A	—	TPU	—
	N1	Injection 2	O	Lo	3A	—	TPU	—
	P1	Injection 3	O	Lo	3A	—	TPU	—
	N2	Injection 4	O	Lo	3A	—	TPU	—
	P3	Purge valve control	O	Lo	1A	—	PWM	—
	R2	Fuel pump relay control	O	Lo	0.5A	—	GPIO	—
	K1	Fuel level input	I	AN	—	—	AN	—
	E1	CAM sensor 1 input	I	AN	—	—	TIMER	—
	E2	CAM sensor 2 input	I	AN	—	For VVT	TIMER	—
Ignition	L2	Ignition 1	O	Lo	10A	—	TPU	—
	L3	Ignition 2	O	Lo	10A	—	TPU	—
	M1	Ignition 3	O	Lo	10A	—	TPU	—
	L1	Ignition 4	O	Lo	10A	—	TPU	—
	C1	Ignition on input	I	Hi	20mA	—	GPIO	—
	X3	Crank sensor positive input	I	AN	—	—	TPU	—
	Y3	Crank sensor negative input	I	AN	—	—	—	—
	F1	Knock sensor positive input	I	AN	—	—	AN	—
	F2	Knock sensor negative input	I	AN	—	—	—	—
	C3	Vehicle speed input	I	PWM	—	—	TIMER	—
	T2	Tach output	O	PWM	—	—	PWM	—
	T3	Fault lamp output	O	Lo	1A	—	GPIO	—

Table continues on the next page...

Table C-1. MPC563xM ECU_Connector (continued)

Block	Pin Number	Function	I/O	Active Lo/ High	Current Requirement	Description	MCU Pin Feature	MCU Pin Assignment
Intake Air	W1	IACV(Idle Air Control Valve) motor coil1 A	O	Hi/Lo	1A or 5A	Step motor	PWM	—
	X2	IACV motor coil1 B	O	Hi/Lo	1A or 5A	Step motor	PWM	—
	X1	IACV motor coil2 A / VVT1	O	Hi/Lo	1A or 5A	Step motor	PWM	—
	W2	IACV motor coil2 B / VVT2	O	Hi/Lo	1A or 5A	Step motor	PWM	—
	N3	IACV duty-control	O	Lo	3A	Valve	PWM	—
	G1	Throttle position input A	I	AN	—	—	AN	—
	G2	Throttle position input B	I	AN	—	—	AN	—
	J2	Intake air temperature	I	AN	—	IAT, TA	AN	—
	J1	Intake air pressure	I	AN	—	MAP	AN	—
	Y2	ETC(Electrical Throttle Control) output A	O	—	5A	—	PWM	—
	Y1	ETC(Electrical Throttle Control) output B	O	—	5A	—	PWM	—
	H1	Accelerator Pedal sensor input A	I	AN	—	—	AN	—
	H2	Accelerator Pedal sensor input B	I	AN	—	—	AN	—

Table continues on the next page...

Table C-1. MPC563xM ECU_Connector (continued)

Block	Pin Number	Function	I/O	Active Lo/ High	Current Requirement	Description	MCU Pin Feature	MCU Pin Assignment
Cooling	R3	Cooling fan 1 relay output	O	Lo	0.5A	—	GPIO	—
	K2	Coolant temperature 1 input	I	AN	—	ECT1	AN	—
	S3	Coolant temperature output	O	PWM	—	—	PWM	—
Oxygen Sensor	H3	Up stream oxygen sensor input	I	AN	—	O1	AN	—
	S1	Up stream oxygen sensor heat	O	—	—	—	GPIO	—
	G3	Down stream oxygen sensor input	I	AN	—	O2	AN	—
	S2	Down stream oxygen sensor heat	O	—	—	—	GPIO	—
Sensor Power	B1	5V sensor power supply 1	PWR	—	—	For all	—	—
	B2	5V sensor ground 1	PWR	—	—	For all	—	—
Switch	A3	Brake switch input	I	Hi	20mA	—	GPIO	—
	B3	Power steering switch input	I	Lo	20mA	—	GPIO	—
Communication	C2	K-line	I/O	—	—	—	SCI	—
	A2	CAN1 H	I/O	—	—	—	CAN	—
	A1	CAN1 L	I/O	—	—	—	CAN	—
	D2	CAN2 H	I/O	—	—	—	CAN	—
	D1	CAN2 L	I/O	—	—	—	CAN	—

Table continues on the next page...

Table C-1. MPC563xM ECU_Connector (continued)

Block	Pin Number	Function	I/O	Active Lo/ High	Current Requirement	Description	MCU Pin Feature	MCU Pin Assignment
Miscelleaneous	M3	Ignition ground 2	—	—	—	—	—	—
	F3	5V sensor ground shield	—	—	—	—	—	—
	—	5V sensor power supply 2	—	—	—	—	—	—
	—	5V sensor ground 2	—	—	—	—	—	—

Appendix D VRS Circuit

A discrete implementation of a Variable-Reluctance Sensor (VRS) interface has been implemented on the MPC4563xM ECU Reference Design. This circuit is a robust design that converts the signal from the VRS into a square wave logic signal. The circuit has a balanced input from a differential connection to the sensor using a twisted pair cable, or in extreme environments, a screened twisted pair cable. The minimum input voltage is 150 mVp-p, with a maximum 300Vp-p limited only by the power of the input resistors. The time constants are set for a 18 Hz minimum signal frequency over the production tolerance, temperature, and lifetime variation of the components used in the design. The maximum frequency exceeds practical requirements and maintains a relatively fixed phase shift of approximately 0.2 crank degrees at 200 Hz, and still under 0.5 crank degrees at over 20 kHz, or 20,000 revolutions per minute with a 60 tooth crank wheel with 2 missing teeth. To achieve noise immunity, an increasing minimum voltage is required as the RPM is raised.

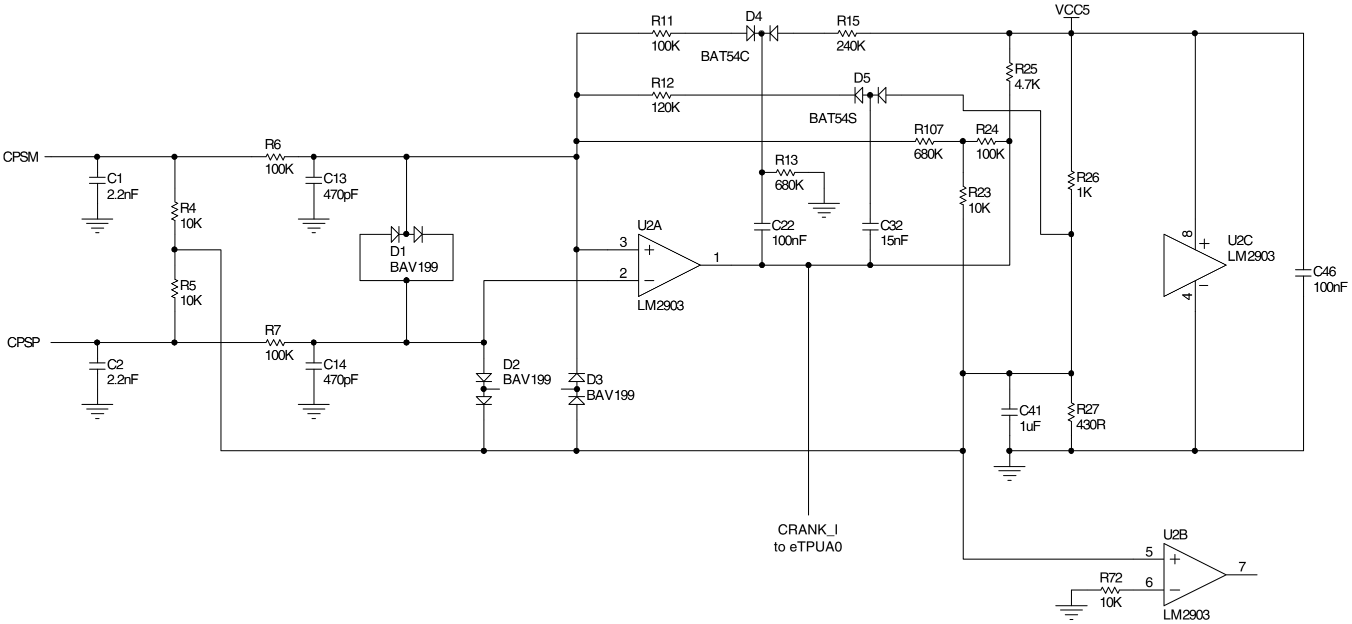

Figure D-1. Crank VRS filter schematic

This circuit applies a rising edge hysteresis, so for accurate timing, the crank sensor must be connected such that the falling voltage edge corresponds with the center of the trigger tooth. The crank position sensor positive output is connected to the negative input of the op-amp and the circuit is inverting.

A standard LM2903 comparator is used in this design and is designed to operate from a nominal 5 volt power supply. To allow for a single power supply, a virtual ground (at 1.5V) is created with a resistor divider circuit (1KΩ and 470 Ω), with a 1 µF filter capacitor.

This design provides ESD protection with a 2.2 µF on each of the inputs from the VRS. This provides protection for the other components from a human body model static discharge of 2kV. These capacitors should be high voltage components (what voltage rating). In addition, these capacitors have a capacitive loading of approximately 1.1 nF. The resistive load on the sensor is 20KΩ (two 10KΩ resistors connected to the virtual ground). A resistive load is required to prevent the inductance of the sensor "ringing" with the capacitive load. In the extreme condition of a 300Vp-p signal (106Vrms) this requires that the resistor be able to handle 280mW, so the package size selection is important for these resistors.

The typical comparator can handle a positive voltage of up to 30V. Therefore, clamp diodes are included on the inputs to protect against positive over-shoot as well as negative overshoot voltage conditions. The diodes shown clamp to the virtual ground.

Appendix E Additional MPC563xM Hardware Topics

Although this document is primarily documentation of the MPC563xM Engine Control Unit Reference Design, much of the information contained within this document is applicable to any MPC563xM system design. However, since the MPC563xM ECU doesn't use all packages or even all features of the device, this appendix lists information that may be helpful when designing other types of systems.

E.1 Pin Overview

Since there are many different requirements for the input and output signals of the MCUs, several types of pin types are used. The following table summarizes the types of pins/pads available on the MCUs. Information on the pad types and signal multiplexing is available in the device Reference Manual and the device Data Sheet. This section helps interpret this information.

NOTE

This document uses the terms pins, balls, and pads interchangeably when referencing the external signals of the device.

Table E-1. Pad Types

Pad type	Abbreviation	Description
Slow Speed pads	S or Slow	Most of the peripheral signals are slow (or medium if available depending on the device definition) speed pads, such as the eMIOS, and the eTPU. The Slow speed pads have slew rate control and may implement digital input circuitry, digital output circuitry or both. Slow pads can be powered by 3.3 or 5.0 volts.
Medium Speed pads	MH or Medium	Most of the peripheral signals are medium (or medium if available depending on the device definition) speed pads, such as the eMIOS, and the eTPU. The Medium speed pads have slew rate control and may implement digital input circuitry, digital output circuitry or both. Medium pads can be powered by 3.3 or 5.0 volts.

Table continues on the next page...

Table E-1. Pad Types (continued)

Pad type	Abbreviation	Description
Analog pads	AE or Analog	The Analog pads are low leakage and have no digital input or output circuitry. Some Analog pins (analog pads that support being used as a differential analog signal) also contain pull up and pull down resistors incorporated into the pad that can be independently selected.
Fast pads	F or Fast	The fast pads are digital pads that allow high speed signals. Generally, these are used for the external bus interface.
Multiple Voltage pads	MULTV	Multiple voltage pads support multiple voltages. These are typically used on pins that support 5V general purpose Input/Output functions, as well as debug functions (selectable) that are powered by 5 volts, but only drive to a 3 volt level.

Each of these pad types have programmable features that are controlled in a pin or pad configuration register (PCR). All pins, except single purpose pins without special properties that need to be controlled, on the device have a PCR. In a few cases, some signals are grouped together and a PCR controls multiple pins. The PCR is identified by the GPIO number. The PCR controls the pin function, direction, and other capabilities of the pin.

E.1.1 Handling unused pins

In some applications, not all pins of the device may be needed. Good CMOS handling practices state that all unused pins should be tied off and not left floating. On the MCU, unused digital pins can be left open in the target system. Almost all pins have internal pull devices (either pullup or pulldown devices[5]). For unused digital pins, it is recommended that software disable both the input buffers and the output buffers of the pads in the Pad Control Register for the pins. In addition, the weak pulldown device should be enabled. This keeps the pad in a safe state under all conditions.

For analog pins, it is recommended that they be pulled down to VSSA (the analog return path to the MCU).

E.1.2 Injection current and maximum pin voltages

All pins implement protection diodes that protect against electrostatic discharge (ESD). In many cases, both digital and analog pins need to be connected to voltages that are higher than the operating voltage of the device pin. In addition to providing protection from ESD, these diode structures will also clamp the voltage to a diode drop above the supply of that pin segment. This is permissible, as long as the current injection is limited as defined in the device specification. Current can be limited by adding a series resistor on the signal. The input protection diodes will keep the voltage at the pin to a safe level (per the absolute maximum ratings of the device) as long as it is less than the maximum injection current specification.

The maximum voltages are shown in the following table. Only the primary supplies are listed. See the device Data Sheet for the complete specifications and latest values. This table lists the DC maximum voltage and an accumulated amount of AC time that signals can go above the DC maximum voltage. Each over-voltage duration must be accumulated over the lifetime of the device and meet these specifications.

5. Technically, these devices are not resistors. They are active weak transistors that pull the input up or down.

Symbol	Parameter	Condition	Maximum Voltage (DC)	Maximum voltage (limited time)	Maximum cumulative limited time
V_{DD}	All 1.2V supplies		1.32V	2V	10 hours
V_{DDE}	All 3.3V supplies		3.6V	5.3V	10 hours
V_{DDEH}	All 5.0V supplies		5.5V	6.8V	10 hours
V_{IN}	DC input voltage	V_{DDEH} Powered I/O pads	V_{DDEH} + 0.3V	V_{DDEH} + 2.0V	60 hours
		V_{DDE} Powered I/O pads	V_{DDE} + 0.3V	V_{DDE} + 2.0V	60 hours
		V_{DDA} Powered I/O pads	V_{DDA} + 0.3V	V_{DDA} + 2.0V	60 hours

Additional circuits on the pins can be enabled only by fast ESD transients. In normal operation, these circuits have no effect on the pin characteristics and are triggered by fast high voltage transients. To prevent turning on these circuits during normal power-up sequences, the ramp rate of the power supplies (all external supplies, 5V, and if the internal regulators are not used, 3.3V and 1.2V) should not exceed 25 V/ms.

Below is an extract from the MPC563xM Data Sheet revision 8 dated February 2011. These specifications may change. Consult the latest revision of the data sheet to determine if there have been updates to these specifications.

Table E-3. Injection currents allowed

Pin type	Maximum inject current allowed
Absolute Maximum Digital Input Current	±3 mA[1]
Absolute Maximum Input Current, Analog Pins	±3 mA[2]

1. Total injection current for all pins must not exceed 25 mA at maximum operating voltage.
2. Total injection current for all analog input pins must not exceed 15 mA.

The figure below shows a typical digital pin and the protection diodes. Controls for all of the pad options are controlled in the Pad/Pin Configuration Register for the pin.

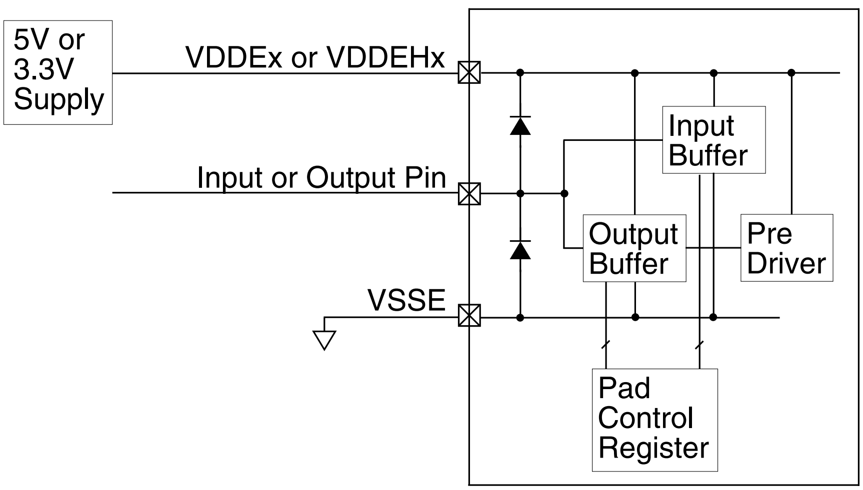

Figure E-1. Typical input protection

The value of a series resistor to limit the injected current can be calculated simply. For a 1 mA injection current limit, a 20K Ω resistor provides a protection of a 20 V DC injection current:

DC_{max} = 20 kΩ/1 mA = 20 V

This voltage is sufficient for signals that are connected to a typical 12 V battery.

E.1.3 Understanding pin multiplexing

A majority of the Input/Output pins[6] on the MCU have multiple functions that are selectable by software, [7]. The figure below shows a typical excerpt from the MPC567xF data sheet, but other devices have similar table, for the ball multiplexing of the different functions. This table shows the different functions that are available on each pin.

Primary functions are listed First

Secondary functions are alternate functions

GPIO/PCR[1]	Signal Name[2]	P/A/G[3]	Function[4]	Function Summary	Direction	Pad Type[5]	Voltage[6]	State during RESET[7]	State after RESET[8]	Package Location	
										416	516
119	ETPUA5_ETPUA17_GPIO119	P	ETPUA5	eTPU A channel	I/O	MH	V_{DDEH1}	—/WKPCFG	—/WKPCFG	K3	H1
		A1	ETPUA17	eTPU A channel (output only)	O						
		A2	—	—	—						
		G	GPIO119	GPIO	I/O						
120	ETPUA6_ETPUA18_GPIO120	P	ETPUA6	eTPU A channel	I/O	MH	V_{DDEH1}	—/WKPCFG	—/WKPCFG	K4	K5
		A1	ETPUA18	eTPU A channel (output only)	O						
		A2	—	—	—						
		G	GPIO120	GPIO	I/O						

GPIO functions are listed Last

Function not implemented on this device

Figure E-2. Typical Device Pin Multiplexing

The first example shown above shows the ETPUA5_ETPUA17_GPIO pin. It can function as either enhanced Timing Processing Unit instantiation A (eTPU A) channel 5, eTPU A channel 17, or as a General Purpose Input/Output. In this particular case, the GPIO and the eTPU A Channel 5 can be used either as an input to the eTPU or GPIO, or can be used as an output. However, if the eTPU A Channel 17 function is selected, it can only be used as an output.

NOTE

In some cases, whether a channel can be an input or an output depends on the individual device definition. These should be checked carefully when designing a board. Although the internal signal to the eTPU A for channel 17 can either be input or an output, this particular pin can only support channel 17 being an output in this example. Other modules such as enhanced Modular Input/Output Subsystem (eMIOS) may also have this restriction. In particular, even though the eMIOS, channels are all orthogonal[8] on the MPC567xF and MPC5676R, the input of some channels can only come from the Deserial/Serial Peripheral Interface (DSPI) and cannot be defined to come directly from a pin. This functionality of each pin needs to be reviewed with the particular device Reference Manual and Data Sheet.

Other information is shown in the above table extract is important when designing a board. These other fields are:

- **Pad Type**: This column of the table contains the pad type of the ball/pin. This is required to understand the characteristics of the pin/ball.

6. Ball grid array (BGA) packages have balls instead of pins. Pins are used on packages that have pins for signals. Pads refers to the bonding pad on the physical die that is contained inside the package. These terms are typically used interchangeably. The actual correct term depends on the package type.
7. In some cases, hardware overrides the software settings. Consult the device reference manual and data sheet.
8. On some devices, the eMIOS channels are orthogonal, that is every channel has the same functional capabilities. This is not true on all devices. Some devices (such as the MPC5634M) only support a subset of the eMIOS functions are supported on some channels.

- **Voltage**: The voltage column of the table lists the power supply that powers the pin. All of the pins are broken up into separate power segments such that the input and output voltages for the pins match the voltage of the circuits connected to the pins. On some devices that support more than one DSPI module, one of the DSPI can be set to operate at a different voltage level than the others. This allows one DSPI to handle 5 volt peripheral devices and another DPSI to have 3.3 volt peripheral devices.
- **State During Reset and State After Reset**: The columns for the state of the pin during and after reset could be important in the design of the system. The user needs to ensure that these states do not cause any issues with external circuitry, such as turning on a motor during reset.
- **Package Location:** These columns show the ball map location of the signal. (Note that the 324 package of the MPC567xF was not available at the time this table was originally created and therefore is not shown on this extract.)

E.2 208 MAP BGA and 176 QFP pin differences between devices

Although the 208 MAPBGA and 176 QFP packages are not used in the MPC563xM Engine Reference Design, this information is listed for information for customers that may substitute the MAPBGA or the 176 package in their designs.

The larger packages (176 and 208) allow additional pins to be available. The additional pins are shown in the following table. Some of the functions are not available on the MPC5632M or the MPC5633M, in the same packages.

Table E-4. 208 MAP and 176 PQFP addiitonal signals and function differences between devices

	MPC5632M	MPC5633M	MPC5634M
eMIOS[1]	No	No	Yes
eMIOS[13]	No	No	Yes
eMIOS[15]	No	No	Yes
GPIO[98]	No	No	Yes
GPIO[99]	No	No	Yes
GPIO[206]	No	No	Yes
GPIO[207]	No	No	Yes
AN[36]	No	No	Yes
AN[37]	No	No	Yes

Some additional I/O pins are gained by moving the Nexus functions to different die pads, thus freeing up the additional shared functions. See additional information about the functions available in Table 39

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Japan
0120 191014 or +81 3 5437 9125
support.japan@freescale.com

Asia/Pacific:
Freescale Semiconductor China Ltd.
Exchange Building 23F
No. 118 Jianguo Road
Chaoyang District
Beijing 100022
China
+86 10 5879 8000
support.asia@freescale.com

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