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Hardware Design Guide

MPC560xP devices

Contents

1 Introduction

The MPC560xP microcontrollers are members of the 32-bit Qorivva microcontroller family built on the Power Architecture® technology. The devices are targeted at the chassis and safety market segment, especially the Electrical Hydraulic Power Steering, low end Electrical Power Steering and Airbag applications.

The purpose of this document is to describe hardware design considerations when developing hardware for the MPC560xP family of microcontrollers: 5604P, 5603P, 5602P, 5601P. It will cover topics such as clock generation, decoupling, Voltage regulator and power considerations. Detailed reference design schematics and descriptions of the main components are also contained within this document. Some general hardware recommendations are also provided.

2 Power Supply

The MPC5604P has a single main/input voltage supply which can be either 5 V or 3.3 V with a specified tolerance of ±10% this is converted using the internal VREG to 1.2V ±10% for the core logic. The user is not permitted to supply the core logic via an external 1.2 V supply, they must always use the on-chip voltage regulator (VREG).

The internal regulator has 3 different domains:

- Low Voltage Domain for 1.2 V output to the core
- High Voltage Domain for 5 V supply
- High Voltage Domain for 3.3 V supply

MPC5604P has 6 different pin supply voltages:

Symbol	Description
VDD_HV_REG	Voltage regulator supply voltage
VDD_LV_COR	1.2v Core supply
VDD_HV_IO	Input/Output supply voltage
VDD_HV_ADC	ADC supply and high voltage reference
VDD_HV_OSC	Crystal oscillator amplifier supply voltage
VDD_HV_FL	Code and data flash supply voltage

HV: High Voltage external power supply for voltage regulator module. These pins must be connected to the power supply (3.3 V or 5 V).

LV: Low Voltage (1.2 V) internal power supply for the Core, PLL. This voltage is generated by the internal voltage regulator with external connections available for stability decoupling capacitors. It is further split into three main domains to ensure noise isolation between critical LV modules within the device: Core, Flash , PLL

HV_ADC dedicated to the Analog to Digital Converter functions.

2.1 Voltage Regulator

The voltage regulator on the MPC560xP converts the main input supply 3.3 V or 5.0 V ±10% to 1.2 V core logic level. The internal voltage regulator requires an external capacitance to be connected to the device in order to provide a stable 1.2 V low voltage digital supply to the device.

2.2 Ballast Transistor

The internal VREG requires an external NPN ballast transistor (BCP56, BCP68, BCX68 or BC817) to be connected as given in Figure 1. The NPN provides a stable low voltage digital supply to the device and serves as the main current source for the device.

Table 2. Recommended Ballast Transistors

Part	Manufacturer	Recommended derivative
BCP68	ON semi	BCP68
	Infineon	BCP68-10
	NXP	BCP68-10; BCP68-25
	Fairchild	BCP68-10; BCP68-25
BCX68	Infineon	BCX68-10;BCX68-16; BCX68-25
	Fairchild	BCX68
BC817	Infineon	BC817-16; BC817-25; BC817SU
	NXP	BC817-16; BC817-25
	Fairchild	BC817-16;BC817-25; BC817-40
BCP56	ON semi	BCP56-10
	Infineon	BCP56-10; BCP56-16
	NXP	BCP56-10; BCP56-16
	Fairchild	BCP56
	ST	BCP56-16

The ballast transistor provides regulator stability. Stability refers to the way which the regulator reacts to changes in the load. An unstable circuit may enter a state of continuous oscillation.

Figure 1 represents a typical example of the ballast transistor circuitry.

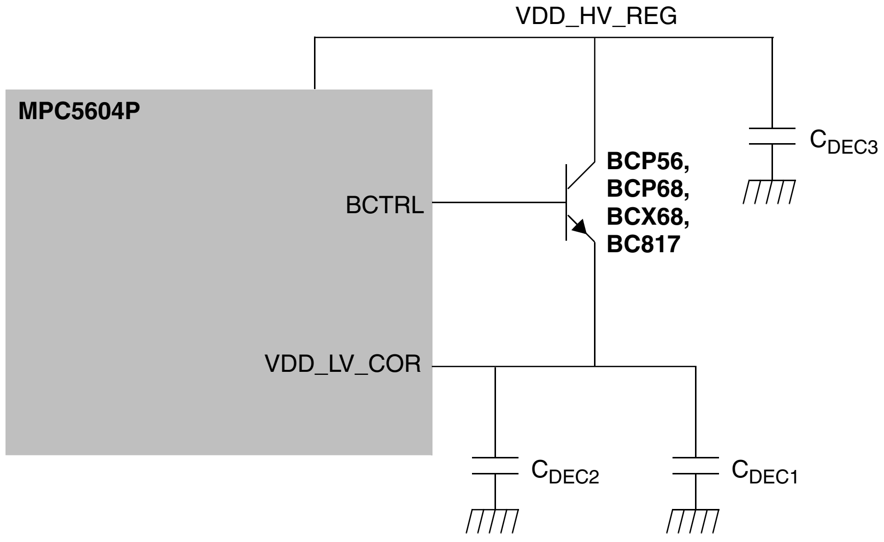


Figure 1. Configuration without base resistor

BCTRL - (Voltage Regulator external NPN Ballast base control pin) controls the current on the base of the transistor. The current is increased to raise the voltage on the VDD and decreases to lower the voltage. The gain of the transistor controls the maximum current available on the supply pin. The gain should be high enough to allow for startup and low enough to prevent the regulator becoming unstable.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{DD\_LV\_REGCOR}$	Output voltage under maximum load run supply current configuration	Post-trimming	1.15	-	1.32	V
C_{DEC1}	External decoupling/ stability ceramic capacitor	4 capacitances	40	56	-	µF
R_{REG}	Resulting ESR of all four C_{DEC1}	Absolute maximum value between 100 kHz and 10 MHz	-	-	45	mΩ

Table continues on the next page...

C_{DEC2}	External decoupling/ stability ceramic capacitor	4 capacitances of 100 nF each	400	-	-	nF
C_{DEC3}	External decoupling/ stability ceramic capacitor on $V_{DD\_HV\_REG}$	-	40	-	-	μF

2.3 Capacitors

The ballast transistor requires capacitors to be added for decoupling and stability. The number of capacitors is not important — only the overall capacitance value and the overall ESR value are important.

- C1 – The capacitance on V_{DD_LV} is determined by the stability requirement of the regulator. It is recommended that the 40μF value is split between the $V_{DD\_LV\_COR}$ / $V_{SS\_LV\_COR}$ pair pins, 4x10μF capacitors placed as close as possibly to the MCU pins.
- C2 – The 4 x100nF decoupling capacitors are required to filter high frequency noise and smooth the 5 V input signal, again these should be placed as close as possible to the MCU pins.
- C3 – The 40μF capacitance value is required to meet the voltage drop on the collector and transient requirements, especially during power-up. It is recommended to place the 40μF capacitor as close as possible to the ballast transistor collector pin.

47 μF cap can be added to the V_{DD} 5V as a bulk capacitance to reduce ripple from the input supply (optional).

The bypass capacitors serve two purposes:

• To provide (normally dominant) pole to ensure loop stability

• Used as a charge tank for load demand changes. This means if for example load suddenly drops, the cap on the collector will consume the current until the regulator has adapted to the new situation (and vice versa)

NOTE

Required capacitor values listed in the table include a de-rating factor of 40%, covering tolerance, temperature, and aging effects. These factors are taken into account to assure proper operation under worst case conditions. X7R type materials are recommended for all capacitors, based on ESR characteristics.

2.4 Additional design option

The output stage for the power transistor is a class A stage, PMOS power device, loaded with a bit current towards ground. Thus only the current source towards ground can remove charge in the base of the power transistor, so the turn off delay is not acceptable. Adding an external resistor base to ground improves the situation and decreases the max available base current. Using this approach it is possible to reduce load capacitance from 40μF to 20μF as shown in Figure 2. This is achieved through the addition of an external 20 kΩ resistor added to the base of the transistor. Addition of this pull-down resistor reduces the response rate of the regulation loop, and therefore reduces the amount of reserve required to respond to changes in the load. This option may reduce component cost.

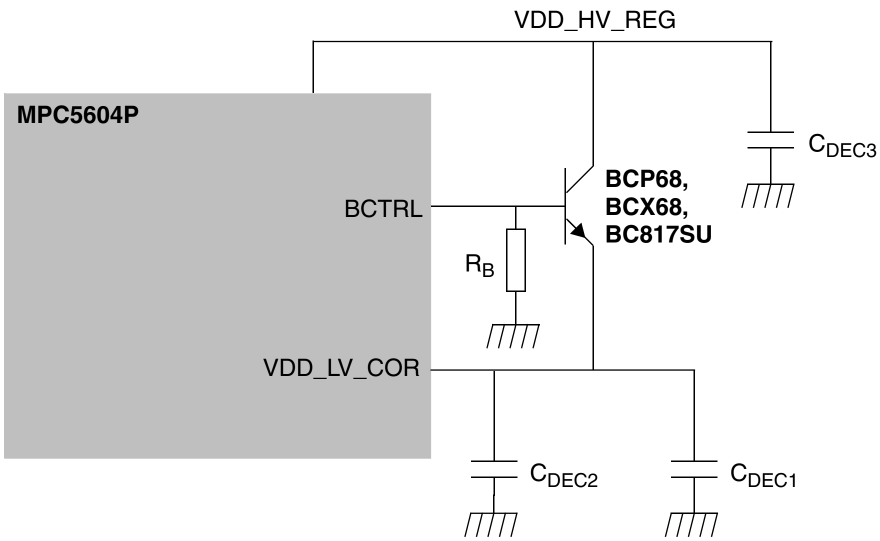


Figure 2. Configuration with base resistor

Note: For 5601P and 5602P the 20k base resistor has been integrated into the MCU and additional component is not required.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VDD_LV_REG COR	Output voltage under maximum load run supply current configuration	Post-trimming	1.15	-	1.32	V
R_B	External resistance on bipolar junction transistor (BJT) base	Bipolar BCP68 or BCX68 or BC817. Three capacitance s of 10µF	19.5	30	-	µF
R_{REG}	Resulting ESR of either one or all three CDEC1	Absolute maximum value between 100 kHz and 10 MHz	-	-	45	mΩ
C_{DEC1}	External decoupling/ stability ceramic capacitor	Bipolar BCP68 or BCX68 or BC817SU Three capacitances of 10 µF	19.5	30	-	µF
		Bipolar BC817 One capacitance of 22 µF	14.3	22	-	

Table continues on the next page...

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
C_{DEC2}	External decoupling/ stability ceramic capacitor	Four capacitances of 440 nF each	1200	1760	-	nF
C_{DEC3}	External decoupling/ stability ceramic capacitor on $V_{DD\_HV\_REG}$	Two capacitances of 10 µF each	2 x 10µF	-	-	µF

3 Clock Circuity

The MPC5604P has 4 clock sources.

- IRC— internal RC oscillator
- XOSC — external oscillator clock
- FMPLL_0 - 64 Mhz PLL (max) for System clock
- FMPLL_1 - 120 Mhz PLL (max) for Motor control peripherals

The IRC is internal and does not have to be considered from a hardware design perspective. The FMPLL is described in Section 3.1.

The XOSC external crystal oscillator works in a range from 4 MHz to 40 MHz. The crystal oscillator circuit includes an internal oscillator driver and an external crystal circuitry. It provides an output clock that can be provided to PLL or used as a reference clock to specific modules depending on system requirements.

Referring to the schematic of the on-chip oscillator (Figure 3: Reference oscillator circuit), the key items are described in the following section. The oscillator circuit provides a reference clock signal to the on-chip PLL. The oscillator circuit consists of:

- the crystal
- two capacitors
- The external bias resistor (R1) is not required as there is an internal bias resistor within the recommended crystals. However, it is recommended to leave space for one on the PCB to accommodate different crystal configurations in the future.

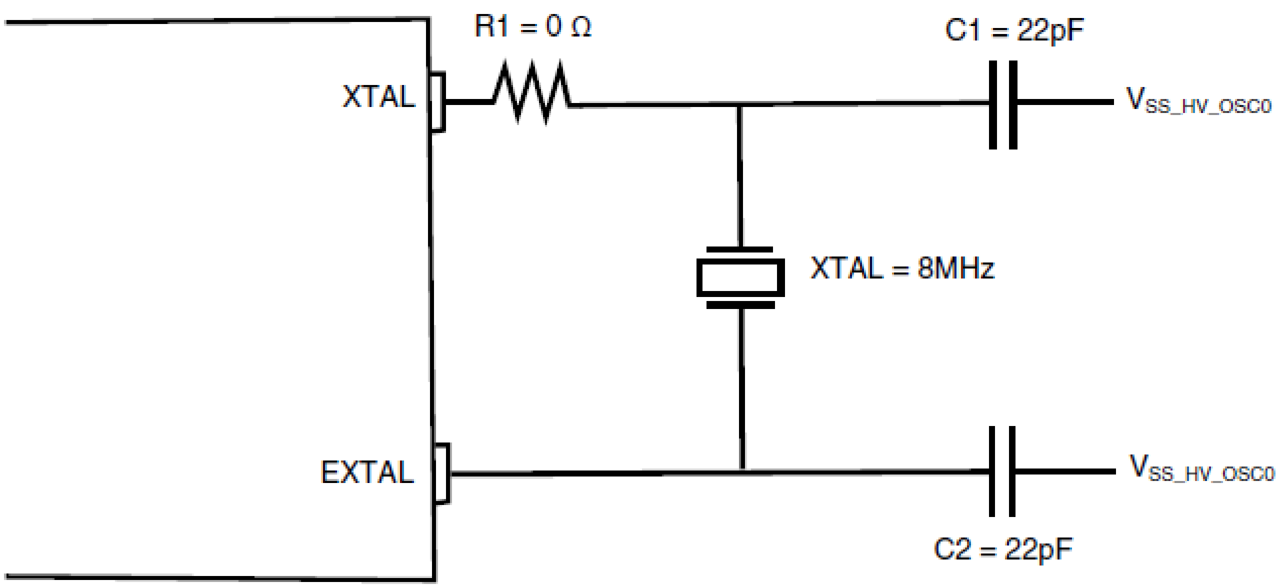


Figure 3. External crystal circuit

The load capacitors are dependent on the specifications of the crystal and on the board capacitance. It is recommended to have the crystal manufacturer evaluate the crystal on the evaluation board / PCB.

3.1 Frequency Modulated PLL (FMPLL)

The FMPLL allows the user to generate high speed system clocks from a 4MHz to 40MHz input clock. Futhermore, the FMPLL supports programmable frequency modulation of the system clock. The PLL has the following major features:

- Input clock frequency from an 4MHz to 40MHz
- Voltage controlled oscillator (VCO) range from 256MHz to 512MHz
- Reduced frequency divider (RFD) for reduced frequency operation without forcing the PLL to re-lock
- Frequency modulated PLL
  - Modulation enabled/disabled through software
  - Triangle wave modulation
- Programmable modulation depth (±0.25% to ±4% deviation from center frequency)
  - Programmable modulation frequency dependent on reference frequency
- Self-clocked mode (SCM) operation
- Input supply : same as core supply : 1.2V

The MPC56xx devices can use either the on-chip oscillator with an external crystal or an external reference clock as the reference clock to the device. This reference is qualified in multiple manners before the PLL will begin lock operation. The “pre” FMPLL circuitry consists of an automatic level-controlled amplifier, a comparator, a loss of clock detector, and a predivider.

3.2 Approved crystals

Following is a list of crystals that have been tested and approved by Freescale. If you wish to use a crystal not on this list please work with the crystal manufacturer to ensure compatibility.

Table 5. Approved crystals

Nominal frequency	Crystal info	Crystal equivalent series resistance ESR	Crystal motional capacitance (CI) fF	Crystal motional inductance (LI) mH	Load on xtalin/ xtalout C1=C2(pF)	Shunt capacitance b/w xtalout and xtalin C0(pF)
4.0	NX8045GB	300	2.68	591.0	21.0	2.93
8.0	NX5032GA	300	2.46	160.7	17.0	3.01
10.0	NX5032GA	150	2.93	86.6	15.0	2.91
12.0	NX5032GA	120	3.11	56.5	15.0	2.93
16.0	NX5032GA	120	3.90	25.3	10.0	3.00
40.0	NX5032GA	50	6.18	2.56	8.0	3.49

the CERALOCK resonators listed below have also been approved for use on all MPC560xP devices based on the e200z0 core.

Table 6. Approved resonators

Part number	vibration	Fr[kHz[	Fa[kHz]	Fa-Fr(dF) [kHz]	Ra[ohm]	R1[ohm]	L1[mH]	C1[pF]	Co[pF]	Qm	CL1(Nominal)pF	CL2(nominal)pF
CSTCR4M00G53-R0	Fundamental	3929.50	4163.25	233.75	372.41	12.78	0.84443	1.94268	15.85730	1630.93	15	15
CSTCR4M00G55-R0	Fundamental	3898.00	4123.00	225.00	465.03	11.38	0.88244	1.88917	15.90537	1899.77	39	39

4 Analogue to Digital Convertor (ADC)

The ADC module has an independent A/D converter supply and reference voltage which allows for an isolated analog voltage supply input pin VDD_HV_ADC, resulting in a low noise voltage source. The VDD_HV_ADC must be at the same voltage as the digital voltage supply VDD_HV, in addition to the VSS_HV_ADC analog ground in for further supply isolation.

Analog signals should not run parallel to clock or any noisy signals such as XTAL and EXTAL and should cross at right angles if necessary.

Symbol	Description
VDD_HV_AD0	ADC0 supply and high reference voltage
VSS_HV_AD0	ADC0 ground and low reference voltage
VDD_HV_AD1	ADC1 supply and high reference voltage
VSS_HV_AD1	ADC1 ground and low reference voltage

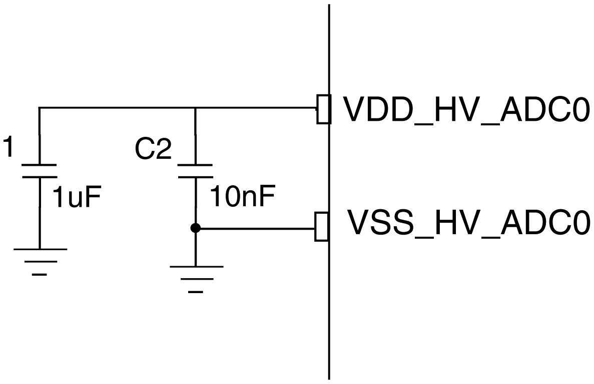
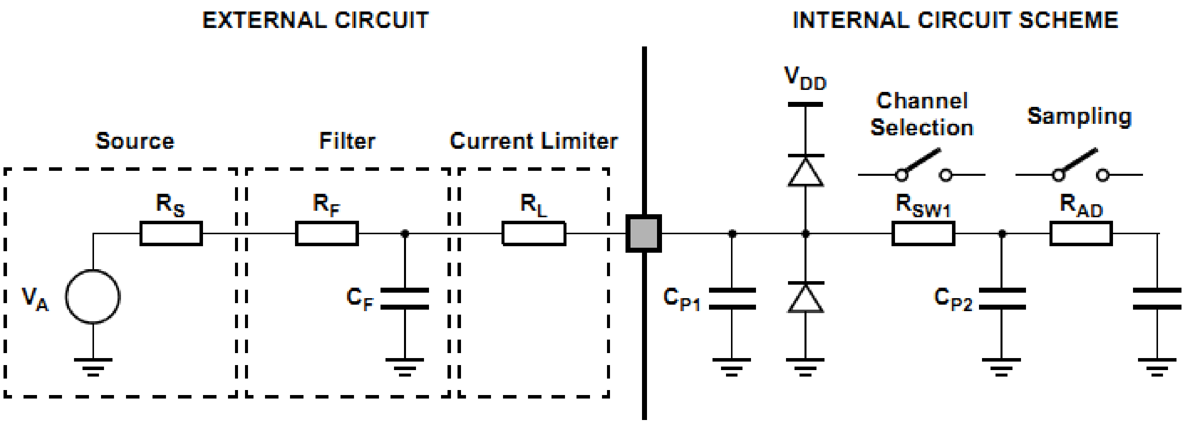


Figure 4. ADC voltage supply connection

To preserve the accuracy of the A/D converter, it is necessary that analog input pins have low AC impedance. Placing a capacitor with good high frequency characteristics at the input pin of the device can be effective: the capacitor should be as large as possible, ideally infinite. This capacitor contributes to attenuating the noise present on the input pin; further, it sources charge during the sampling phase, when the analog signal source is a high-impedance source.

A real filter can typically be obtained by using a series resistance with a capacitor on the input pin (simple RC filter). The RC filtering may be limited according to the value of source impedance of the transducer or circuit supplying the analog signal to be measured. The filter at the input pins must be designed taking into account the dynamic characteristics of the input signal (bandwidth) and the equivalent input impedance of the ADC itself. For more information read MPC560xP datasheet.



R_S Source Impedance
R_F Filter Resistance
C_F Filter Capacitance
R_L Current Limiter Resistance
R_{SW1} Channel Selection Switch Impedance
R_{AD} Sampling Switch Impedance
C_P Pin Capacitance (two contributions, C_{P1} and C_{P2})
C_S Sampling Capacitance

Figure 5. Input equivalent circuit

5 Recommended debug connectors and connector pin out definitions

The table below shows the recommended connectors for different applications for the MPC560xP.

Table 8. Recommended connectors

Connector style	Target system part number	Connector type
14-pin BERG JTAG only	3M 2514-6002UB	JTAG-only configuration
25-position (2 × 25, 50-pin) Samtec	Samtec ASP-148422-01	Full Nexus configuration

NOTE

Whichever connector is chosen, "keep-out" areas may be required by some tools. Consult the preferred tool vendor to determine any area that must remain clear around the debug connector. Some tool vendors may include an extension cable to minimize "keep-out" areas, but use of an extension will degrade the signal. In many cases, this degradation will be insignificant, but the amount of degradation depends on many factors, including clock frequency and target board layout.

5.1 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 9. 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).

6 MPC56xx high-speed parallel trace connector

For high-speed trace applications, the MICTOR-38 connector is not optimized for best signal integrity when using more than eight Message Data Out signals (MDO). Twelve MDO pins push the capability of the connector from a signal integrity standpoint. When moving to devices that support the full 16-bit MDO, a Samtec ERF8 series connector is highly recommended. The part number of the Samtec connector is shown in the following table.

Table 10. Recommended high-speed parallel trace connector part number

Connector	Part number (Samtec)	Style	Description
HP50	ASP-148422-01	Samtec ERF8 series, 25 position by 2 row	Vertical mount for MCU module

The Samtec ERF8 series of connectors is intended for high-speed applications requiring a minimal footprint with a reliable, latching connection. The recommended connector has two rows of twenty-five contacts each with a spacing of 0.8 mm. The connector provides isolation between the high-speed trace signals and the low-speed JTAG and control signals. It also provides ample ground connections to ensure signal integrity.

The following picture is courtesy of Samtec U.S.A (http://www.samtec.com/search/NEXUS.aspx).

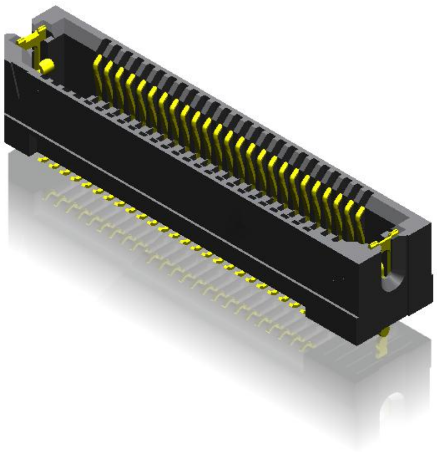


Figure 6. HP50 (ASP-148422-01) connector

Table 11 shows the recommended pinout for the Samtec connector.

Table 11. MPC56xx high-speed parallel trace connector

Position	Signal	Direction[1]	Pin number	Pin number	Direction[1]	Signal	IEEE-5001-2011 GEN_IO signal name
	GND [2]					GND[2]	
1	$\overline{\text{MSEO0}}$	Out	1	2	Out[3]	VREF	
2	$\overline{\text{MSEO1}}$	Out	3	4	In	TCK	
3	GND		5	6	In	TMS	
4	MDO0	Out	7	8	In	TDI	
5	MDO1	Out	9	10	Out	TDO	
6	GND		11	12	In	JCOMP	
7	MDO2	Out	13	14	Out	$\overline{\text{RDY}}$	
8	MDO3	Out	15	16	In	$\overline{\text{EVTI}}$	
9	GND		17	18	Out	$\overline{\text{EVTO}}$	
10	MCKO	Out	19	20	In	$\overline{\text{RESET}}$	
11	MDO4	Out	21	22	Out	$\overline{\text{RSTOUT}}$	GEN_IO0
12	GND		23	24		GND	
13	MDO5	Out	25	26	Out	CLKOUT	
14	MDO6	Out	27	28	In/Out	TD/WDT	GEN_IO1
15	GND		29	30		GND	
16	MDO7	Out	31	32	In/Out	DAI1	GEN_IO2
17	MDO8	Out	33	34	In/Out	DAI2	GEN_IO3
18	GND		35	36		GND	
19	MDO9	Out	37	38		ARBREQ	GEN_IO4
20	MDO10	Out	39	40		ARBGRT	GEN_IO5
21	GND		41	42		GND	
22	MDO11	Out	43	44	Out	MDO13	
23	MDO12	Out	45	46	Out	MDO14	
24	GND		47	48		GND	
25	MDO15	Out	49	50		N/C[4]	
	GND[2]					GND[2]	

1. Viewed from the MCU.
2. The connector locking mechanism provides additional ground connections on each end of the connector.
3. This is an output from the connector standpoint. It may or may not be from the MCU.
4. No connection — should be left open. Reserved for MDO16 on devices with more than sixteen MDO signals (future compatibility). In some applications this may be used as an SRAM voltage detect to determine when voltage for a standby SRAM is disconnected.

7 Minimum external circuitry

In general, other than the connector, no additional circuitry is required for the Nexus/JTAG debug circuitry. The MPC5600 devices include internal pull devices that ensure the pins remain in a safe state; however, if there is additional circuitry connected to the Nexus/JTAG pins, or long traces that could be affected by other signals (due to crosstalk from high-current or high-speed signals), a minimum number of external pull resistors can be added to insure proper operation under all conditions.

Table 12. Optional minimum debug port external resistors

Nexus/JTAG signal	Resistor direction and value	Description
JCOMP	10 kΩ pulldown	Holds debug port in reset and prevents any debug commands from interfering with the normal operation of the MCU.
$\overline{\text{RESET}}$	4.7 kΩ pullup	The $\overline{\text{RESET}}$ input should be driven from an open collector output; therefore, it requires a pullup resistor for the MCU.
TD/WDT[1]	10 kΩ pulldown	With no tool attached, this signal should be held low and may or may not be connected to a pin of the MCU, depending on the system definition.
$\overline{\text{EVTI}}$	10 kΩ pullup	A pullup resistor prevents debug mode from being forced after reset if debug mode is enabled (JCOMP = high). It also prevents breakpoints from being forced if debug mode is enabled. **NOTE:** In almost all situations, a resistor is not required on this signal.

1. This is an optional signal and is not actually required for the MCU.

In addition to the pullup and pulldown resistors, some systems may want to use buffers between the Nexus/JTAG connector inputs and the MCU. This will prevent over-voltage conditions from causing damage to the MCU signals. Normal systems should not require this circuitry, but it is helpful in systems that can be exposed to improper connections that provide voltages that are outside the operating conditions of the MCU. A common circuit to use is the Texas Instruments SN74CBTLV3861[1]. This device is a bus switch that implements a bidirectional interface between two terminals with less than 5 Ω of resistance. It should be powered by the same supply that powers the debug port. The device enable should be connected to ground for the interface to be enabled whenever the debug port on the MCU is powered. This circuit provides a high impedance to the tool when the debug port is powered off.

NOTE

It is recommended that at least the reduced port configuration Nexus signals be made available (somewhere) on production boards. This facilitates debugging of new boards and analysis of errors in software, even on boards that have restricted space and normally provide a JTAG-only connection. If the Nexus signals are available on the production board, an adapter could be built to provide a Nexus connection on boards that do not have a complete footprint for one of the standard Nexus connectors. Likewise, the JTAG connector does not have to be populated on production boards and could even utilize a smaller connector footprint that could be used with an adapter to the standard debug connections.

1. SN74CBTLV3861-Q1 is automotive qualified if required.

8 Example communication peripheral connections

There are a wide range of peripheral pins available on the MCU. Many of these have fairly standard definitions for their use. This section provides example connections for some of the most commonly used communications peripherals, such as LIN, CAN, Ethernet, and RS-232 communication interfaces.

Table 13 summarizes the maximum communication speed and general overview information for the different types of interfaces.

Table 13. Communication module comparison

Common name	Standard	Distributed timebase	Speed (maximum supported)	Channels	Time triggered	Arbitration
RS-232D	EIA RS-232 revision D	No	115.2 kbit/s	Single	No	None (optional flow control)
LIN	LIN 1.0, LIN 2.0, and LIN 2.1[1]	No	100 kbit/s[2]	Single	No	None (master/ slave)
CAN	Bosch 2.0B ISO11898	No	1 Mbit/s[3]	Single	No (additional function)	CSMA (Carrier Sense Multiple Access)
Ethernet	IEEE 802.3	No[4]	100 Mbit/s	Single	No	CSMA/CD

1. Many Freescale devices only support the LIN 1.0 and 2.0 standards. LIN2.1 requires a different sampling scheme.
2. Typical speed is 10 or 20 Kbps, but supports a fast mode of 100 Kbps.
3. Two different speed classes are supported by CAN, a fast (250K to 1M bps) and a low speed CAN (5K to 125K bps).
4. Distributed timebase is not native by IEEE802.3 but there is hardware support for a PTP protocol that allows a distributed timebase to be used.

In a typical system, the battery reverse bias and over-voltage protection may be shared between all of the communication devices in the target system. Figure 7 shows a typical protection.

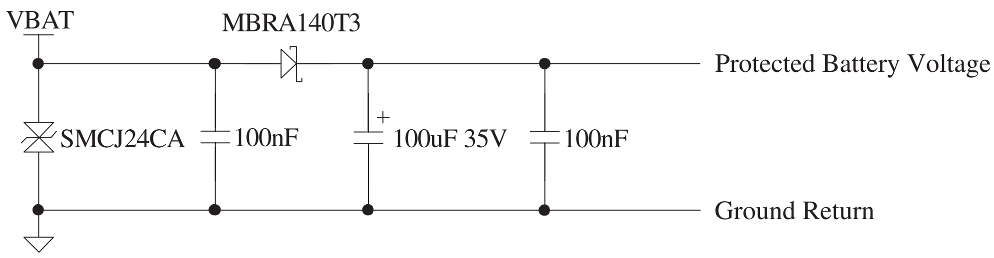


Figure 7. Typical protection circuit

8.1 Example RS-232 interface for LINFlex

The RS-232 (TIA/EIA-232-F) standard is a fairly common interface that was once available on nearly all computers. While this interface is disappearing, adapters are available to allow the use of RS-232 peripherals through other interfaces, such as USB. RS-232 was intended to be a very low-cost, low-performance interface. This interface was originally specified with signal voltages of +12 V and –12 V typically. However, this has been lowered to a typical minimum voltage of +5 V and –5 V in recent years.

Figure 8 shows the typical connections between the serial port of an MCU and the MAX3232-EP RS-232D transceiver from Texas Instruments (http://www.ti.com/). The transceiver operates from either a 3.3-V or a 5-V supply and includes two charge pumps to generate the required output voltages. This device contains two transmit drivers and two receivers. The charge pumps require four external capacitors.

NOTE

The commercial grade MAX3232 device is not rated for the full automotive temperature of -40 to +125° C and is not intended for automotive applications. This circuit should not be used or populated in a production module intended for automotive use. However, in many cases, the RS-232 interface is intended only as a development interface; therefore, the commercial device can be used for prototyping purposes. TI does offer a device option with an operating temperature range of –40 to +85° C. TI has an enhanced version of the device, MAX3232-EP, that is intended for aerospace, medical, and defense applications. This version is available with an operating temperature range of –55 to +125° C.

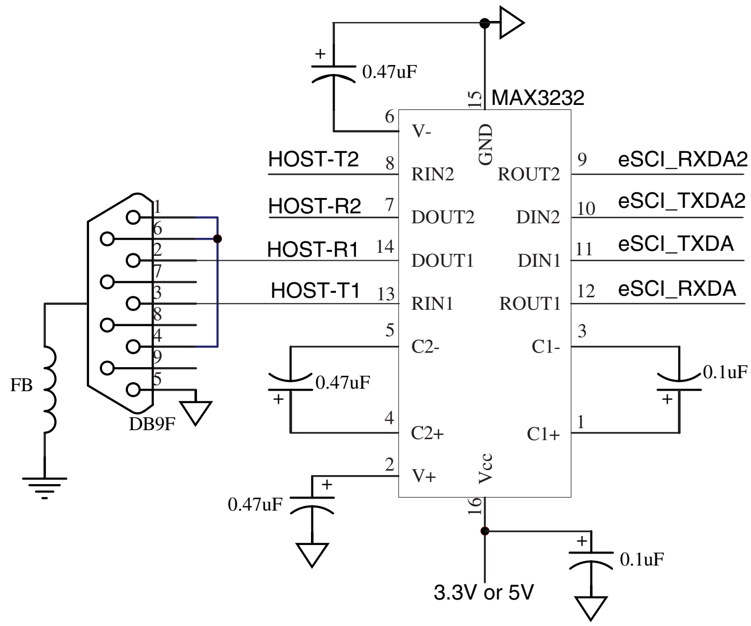


Figure 8. Typical LINFlex to RS-232D circuit

Table 14. Typical RS-232D connector definition

6 Connect to pin 1 and 4	**1** Connect to pin 4 and 6
7 N/C	**2** RS-232 TX (transmit)
8 N/C	**3** RS-232 RX (receive)
9 N/C	**4** Connect to pin 1 and 6
	5 GND

NOTE

N/C pins are not connected.

The connector's shell should be connected through a ferrite bead to ground.

8.2 CAN interface circuitry

Controller Area Network (CAN) is commonly used in almost all automotive applications to allow communication between various microchips in the car.

The number of CAN modules on-chip vary from device to device. A separate CAN transceiver is required for each CAN module, although some CAN transceivers may have more than one on a single chip.

Freescale CAN modules conform to CAN protocol specification version 2.0B, and the transceivers shown in this Hardware design guide comply with ISO11898 physical layer standard.

Typically, CAN is used at either a low speed (5 Kbps to 125 Kbps) or a high speed (250 Kbps to 1 Mbps). Power train applications typically use a high speed (HS) CAN interface to communicate between the engine control unit and the transmission control unit. Body and chassis applications typically use a low speed (LS) CAN interface. In the dashboard of a vehicle, there is typically a gateway device that interfaces between HS and LS CAN networks.

Popular CAN transceivers include the NXP devices in the table below. Example TJA1050 HS and TJA1054 LS circuits are shown in this Hardware design guide .

Table 15. NXP CAN transceiver comparison

	TJA1050	TJA1054	TJA1040	TJA1041
Bit-rate (Kbps)	1000	125	1000	1000
Modes of operation	Normal, listen only	Normal, standby, sleep	Normal, standby	Normal, listen only, standby, sleep

8.2.1 High-speed CAN TJA1050 interface

Figure 9 shows the typical connections for the physical interface between the MCU and the CAN bus for HS applications using the NXP TJA1050 HS CAN transceiver.

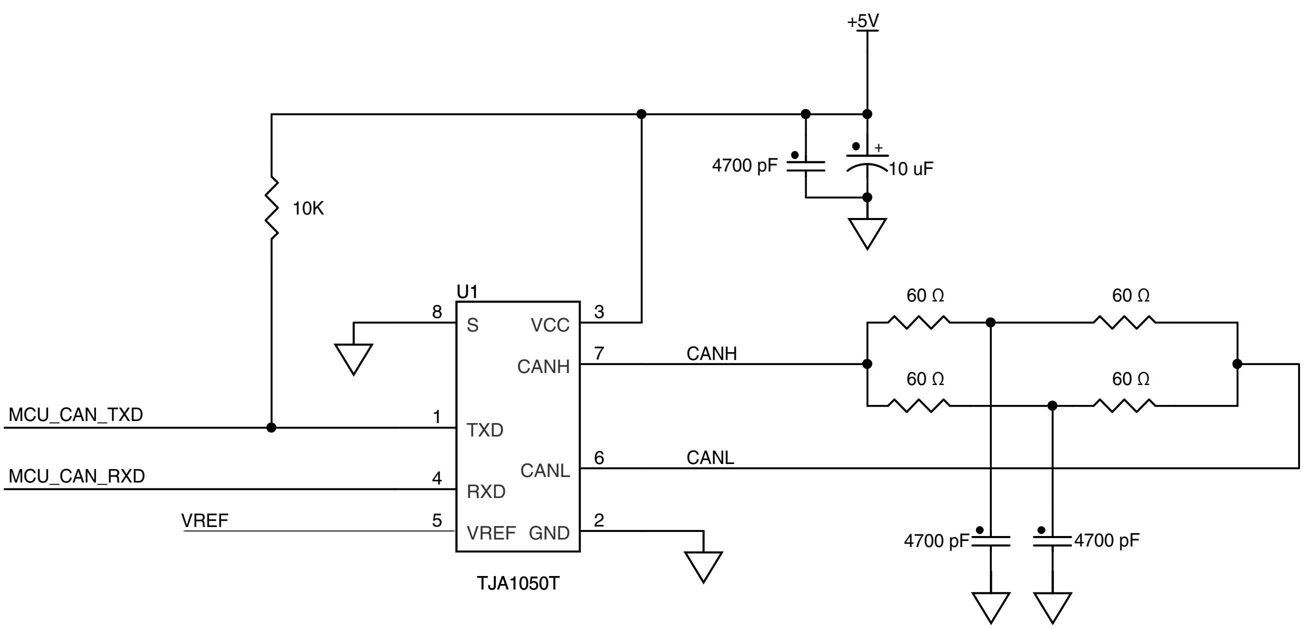


Figure 9. Typical high-speed CAN circuit using TJA1050

NOTE

Decoupling shown as an example only.

TXD/RXD pullup/pulldown may be required, depending on device implementation.

Table 16. TJA1050 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 TXD	CAN transmit data input from the MCU.
2	GND	Output	Ground	Ground	Ground return termination.
3	VCC	Input		5 V	Voltage supply input (5 V).
4	RXD	Output	Receive Data	MCU CAN RXD	CAN receive data output to the MCU.
5	VREF	Output	Reference voltage Output	Not used	Mid-supply output voltage. This is typically not used in many systems, but can be used if voltage translation needs to be done between the CAN transceiver and the MCU.
6	CANL	Input/ Output	CAN Bus Low	CAN Bus Connector	CAN bus low pin.
7	CANH	Input/ Output	CAN Bus High	CAN Bus Connector	CAN bus high pin.
8	S	Input	Select	Grounded or MCU GPIO	Select for high-speed mode or silent mode. Silent mode disables the transmitter, but keeps the rest of the device active. This may be used in the case of an error condition.

8.2.2 Low-speed CAN TJA1054 interface

Figure 10 shows the typical connections for the physical interface between the MCU and the CAN bus for LS applications using the NXP TJA1054 LS CAN transceiver. Optionally, the standby and enable pins can be connected to MCU GPIO pins for additional control of the physical interface.

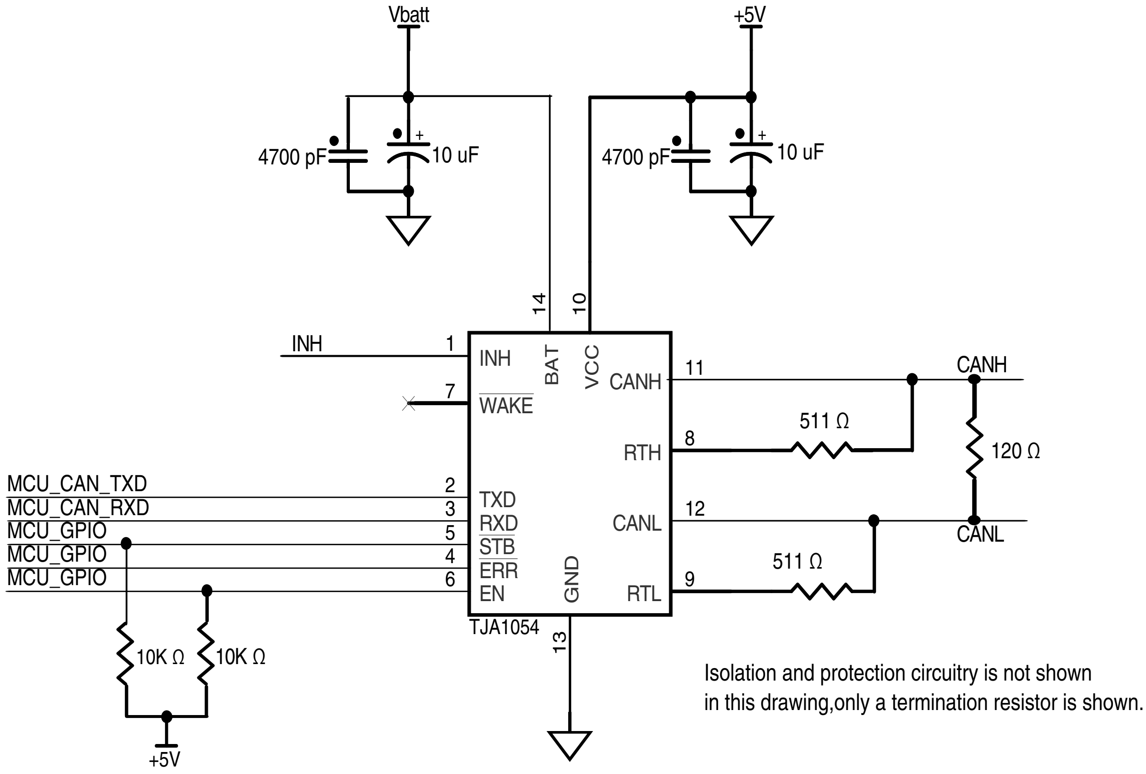


Figure 10. Typical low-speed CAN circuit using TJA1054

NOTE

Decoupling shown as an example only.

STB and EN should be pulled high for Normal mode. These signals can optionally be connected to MCU GPIO pins to allow MCU control of the the physical interface.

Table 17. TJA1054 pin definitions and example system connections

Pin number	Pin name	Pin direction	Full pin name	MCU or system connection	Description
1	INH	Input	Inhibit	Typically not connected	Inhibit output for control of an external power supply regulator if a wake up occurs.
2	TXD	Input	Transmit Data	MCU CAN TXD	CAN transmit data input from the MCU.
3	RXD	Output	Receive Data	MCU CAN RXD	CAN receive data output to the MCU.
4	ERR	Output	Error	MCU GPIO	The error signal indicates a bus failure in normal operating mode or a wake up is detected in standby or sleep modes.
5	STB	Input	Voltage Supply for IO	MCU GPIO	Standby input for device. It is also used in conjunction with the EN pin to determine the mode of the transceiver.

Table continues on the next page...

Table 17. TJA1054 pin definitions and example system connections (continued)

Pin number	Pin name	Pin direction	Full pin name	MCU or system connection	Description
6	EN	Input	Enable	MCU GPIO	Enable input for the device. It is also used in conjunction with the STB pin to determine the mode of the transceiver.
7	$\overline{\text{WAKE}}$	Input	Wake	Typically not connected	Wake input (active low), both falling and rising edges are detected.
8	RTH	Input	Termination Resistor High	Resistor to CANH	Termination resistor for the CAN bus high[1]
9	RTL	Input	Termination Resistor Low	Resistor to CANL	Termination resistor for the CAN bus low[1]
10	VCC	Input	Voltage Supply	5 volts	Digital IO supply voltage, 5 volts.
11	CANH	Output	CAN Bus High	CAN Bus Connector	CAN bus high pin.
12	CANL	Input/ Output	CAN Bus Low	CAN Bus Connector	CAN bus low pin.
13	Ground	Output	Ground	Ground	Ground return termination path.
14	BAT	Input	Standby	Battery voltage	Battery supply pin, nominally 12 V.

1. This allows the transceiver to control the CAN bus impedance under an error condition.

8.2.3 Recommended CAN connector

Generally, DB9 connectors are used for evaluation boards to connect CAN modules together, whereas there are various connectors used for production hardware. Figure 11 and Table 18 show a typical example of the connector pinout. A male type connector is used on the evaluation board and a female type cable connects with it.

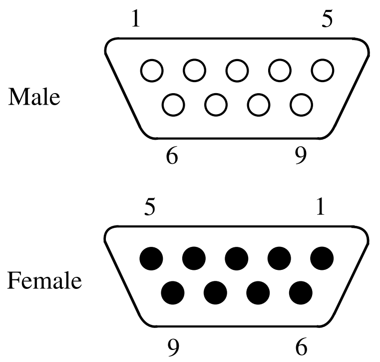


Figure 11. DB9 Connector Types

Table 18. DB9 connector mapping

Pin number	Signal name
1	N/C
2	CAN_L
3	GND
4	N/C
5	CAN_SHIELD (OPTIONAL)
6	GND
7	CAN_H
8	N/C
9	CAN_V+ (OPTIONAL)

NOTE

The metal shell of the connector should be connected through a ferrite bead to the chassis ground.

9 Pin Overview

Since there are many different requirements for the input and output signals of the MCU, several types of pin types are used. The following table summarizes the types of pins/pads available on the MCU. 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 19. Pad Types

Pad type	Abbreviation	Description
Slow Speed pads	Slow	Most of the peripheral signals are slow (or medium if available depending on the device definition) speed pads. 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 volts.
Medium Speed pads	Medium	Most of the peripheral signals are medium (or medium if available depending on the device definition) speed pads. 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 volts.
Fast pads	Fast	The fast pads are digital pads that allow high speed signals. Generally, these are used for the external bus interface.

Each of these pad types have programmable features that are controlled in a pin or pad configuration register (PCR). All pin, 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.

9.1 Pad slew rate

The slow, medium and high speed pads implement a slew rate control (SRC) selection in the Pad Configuration Register (PCR). Slew rate is used to slow down the time it takes for the signal to switch from a low to a high or from a high to a low.

The table below shows the different slew rate settings that are available.

Table 20. Slew Rate settings

Pad type	Load drive (pF)	Frequency of Operation (MHz) (max)	Slope at rising/falling edge (ns) (min/max)
Slow Speed Pad	25	4	4/40
	50	2	6/50
	100	2	10/75
	200	2	14/100
Medium Speed Pad	25	40	2/12
	50	20	4/25
	100	13	8/40
	200	7	14/70

Table continues on the next page...

Table 20. Slew Rate settings (continued)

Pad type	Load drive (pF)	Frequency of Operation (MHz) (max)	Slope at rising/falling edge (ns) (min/max)
Fast Speed Pad	25	72	1/4
	50	55	1.5/7
	100	40	3/12
	200	25	5/18

9.2 Injection Current

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.

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 MPC5604P Data Sheet revision 7 dated 04/2011. These specifications may change. Consult the latest revision of the data sheet to determine if there have been updates to these specifications.

NOTE

Applying signals to pins (~3.3V) during power-off (VDD ~0V) must be considered as a kind of overload conditions. Series resistors between signal sources and pins may be needed to limit injection current.

NOTE

Any overload conditions (positive or negative voltage out of V_{IH} and V_{IL} spec applied to the pins) should be avoided.

Table 21. Absolute maximum ratings

Symbol	Parameter	Min	Max	Unit
V_{IN}	Voltage on any pin with respect to ground (V_{SS_HV})	$V_{SS\_HV\_IO}$-0.3	$V_{DD\_HV\_IO}$+0.3	V
I_{INJPAD}	Input current on any pin during overload condition	-10	10	mA
I_{INJSUM}	Absolute sum of all input currents during overload condition	-50	50	mA

Table 22. ADC conversion characteristics

Symbol	Parameter	Conditions	Value			Unit
			Min	Typ	Max	
I_{INJ}	Input current injection	Current injection on one ADC input, different from the converted one. Remains within TUE specification	-5		5	mA
TUE	Total unadjusted error without current injection	-	-2.5	-	3	LSB
TUE	Total unadjusted error with current injection	-	-3	-	3	LSB

NOTE

In case overload condition can not be avoided, injection current specification (I_{INJPAD}, I_{INJSUM}, I_{INJ}) can be applied which limits the current at internal clamp by using an external series resistor, however, current injection should be minimized because it causes degradation of ADC accuracy.

9.3 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[2]). 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 ball. 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).

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

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