MPC8541EEC
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MPC8541E PowerQUICC™ III Integrated Communications Processor Hardware Specification

The MPC8541E integrates a PowerPC™ processor core built on Power Architecture™ technology with system logic required for networking, telecommunications, and wireless infrastructure applications. The MPC8541E is a member of the PowerQUICC™ III family of devices that combine system-level support for industry-standard interfaces with processors that implement the embedded category of the Power Architecture technology. For functional characteristics of the processor, refer to the *MPC8555E PowerQUICC™ III Integrated Communications Processor Reference Manual*.

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Contents

1 Overview

The following section provides a high-level overview of the MPC8541E features. Figure 1 shows the major functional units within the MPC8541E.

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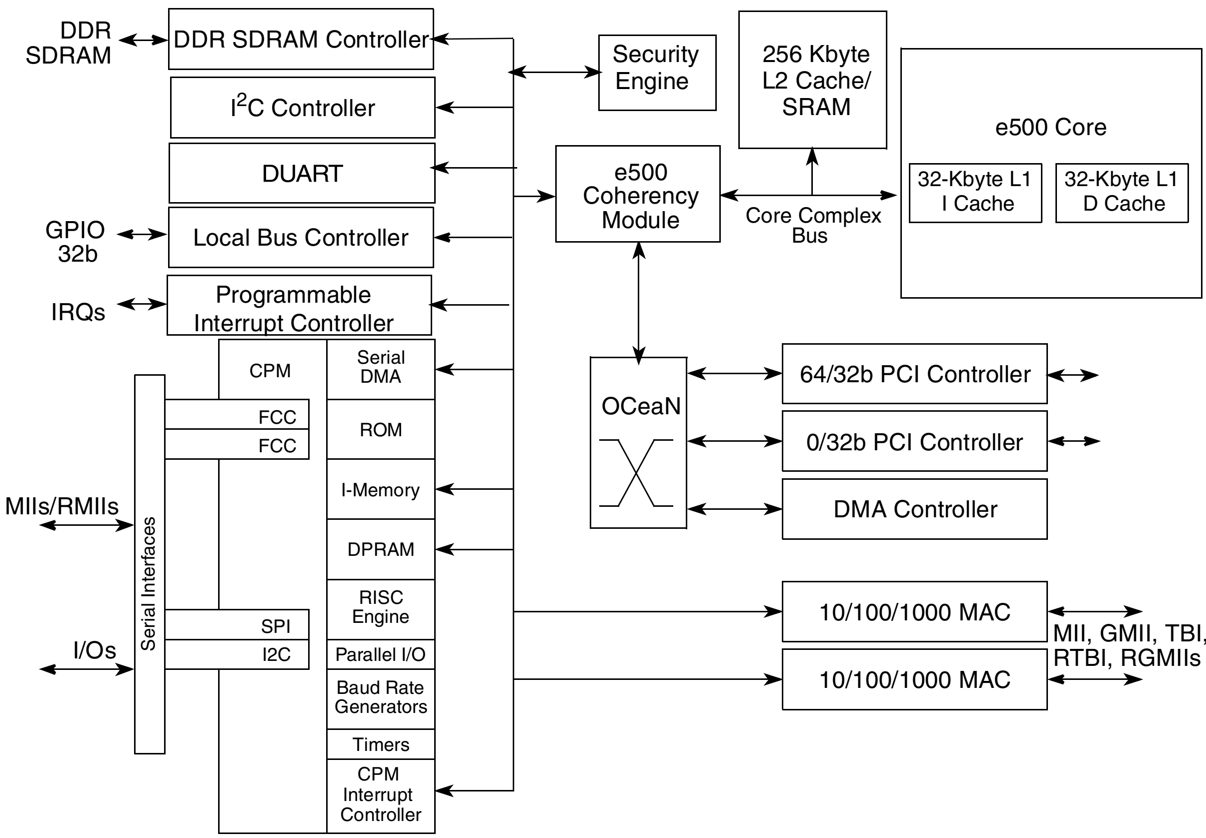


Figure 1. MPC8541E Block Diagram

1.1 Key Features

The following lists an overview of the MPC8541E feature set.

- Embedded e500 Book E-compatible core
  - High-performance, 32-bit Book E-enhanced core that implements the PowerPC architecture
  - Dual-issue superscalar, 7-stage pipeline design
  - 32-Kbyte L1 instruction cache and 32-Kbyte L1 data cache with parity protection
  - Lockable L1 caches—entire cache or on a per-line basis
  - Separate locking for instructions and data
  - Single-precision floating-point operations
  - Memory management unit especially designed for embedded applications
  - Enhanced hardware and software debug support
  - Dynamic power management
  - Performance monitor facility

- Security Engine is optimized to handle all the algorithms associated with IPSec, SSL/TLS, SRTP, IEEE Std 802.11i™, iSCSI, and IKE processing. The Security Engine contains 4 Crypto-channels, a Controller, and a set of crypto Execution Units (EUs). The Execution Units are:
  - Public Key Execution Unit (PKEU) supporting the following:
    - RSA and Diffie-Hellman
    - Programmable field size up to 2048-bits
    - Elliptic curve cryptography
    - F2m and F(p) modes
    - Programmable field size up to 511-bits
  - Data Encryption Standard Execution Unit (DEU)
    - DES, 3DES
    - Two key (K1, K2) or Three Key (K1, K2, K3)
    - ECB and CBC modes for both DES and 3DES
  - Advanced Encryption Standard Unit (AESU)
    - Implements the Rinjdael symmetric key cipher
    - Key lengths of 128, 192, and 256 bits.Two key
    - ECB, CBC, CCM, and Counter modes
  - ARC Four execution unit (AFEU)
    - Implements a stream cipher compatible with the RC4 algorithm
    - 40- to 128-bit programmable key
  - Message Digest Execution Unit (MDEU)
    - SHA with 160-bit or 256-bit message digest
    - MD5 with 128-bit message digest
    - HMAC with either algorithm
  - Random Number Generator (RNG)
  - 4 Crypto-channels, each supporting multi-command descriptor chains
    - Static and/or dynamic assignment of crypto-execution units via an integrated controller
    - Buffer size of 256 Bytes for each execution unit, with flow control for large data sizes
- High-performance RISC CPM
  - Two full-duplex fast communications controllers (FCCs) that support the following protocol:
    - IEEE Std 802.3™/Fast Ethernet (10/100)
  - Serial peripheral interface (SPI) support for master or slave
  - I^2C bus controller
  - General-purpose parallel ports—16 parallel I/O lines with interrupt capability
- 256 Kbytes of on-chip memory
  - Can act as a 256-Kbyte level-2 cache
  - Can act as a 256-Kbyte or two 128-Kbyte memory-mapped SRAM arrays
  - Can be partitioned into 128-Kbyte L2 cache plus 128-Kbyte SRAM
  - Full ECC support on 64-bit boundary in both cache and SRAM modes

- — SRAM operation supports relocation and is byte-accessible
- — Cache mode supports instruction caching, data caching, or both
- — External masters can force data to be allocated into the cache through programmed memory ranges or special transaction types (stashing).
- — Eight-way set-associative cache organization (1024 sets of 32-byte cache lines)
- — Supports locking the entire cache or selected lines
  - – Individual line locks set and cleared through Book E instructions or by externally mastered transactions
- — Global locking and flash clearing done through writes to L2 configuration registers
- — Instruction and data locks can be flash cleared separately
- — Read and write buffering for internal bus accesses

- Address translation and mapping unit (ATMU)
  - — Eight local access windows define mapping within local 32-bit address space
  - — Inbound and outbound ATMUs map to larger external address spaces
    - – Three inbound windows plus a configuration window on PCI
    - – Four inbound windows
    - – Four outbound windows plus default translation for PCI
- DDR memory controller
  - — Programmable timing supporting first generation DDR SDRAM
  - — 64-bit data interface, up to MHz data rate
  - — Four banks of memory supported, each up to 1 Gbyte
  - — DRAM chip configurations from 64 Mbits to 1 Gbit with x8/x16 data ports
  - — Full ECC support
  - — Page mode support (up to 16 simultaneous open pages)
  - — Contiguous or discontiguous memory mapping
  - — Sleep mode support for self refresh DDR SDRAM
  - — Supports auto refreshing
  - — On-the-fly power management using CKE signal
  - — Registered DIMM support
  - — Fast memory access via JTAG port
  - — 2.5-V SSTL2 compatible I/O
- Programmable interrupt controller (PIC)
  - — Programming model is compliant with the OpenPIC architecture
  - — Supports 16 programmable interrupt and processor task priority levels
  - — Supports 12 discrete external interrupts
  - — Supports 4 message interrupts with 32-bit messages
  - — Supports connection of an external interrupt controller such as the 8259 programmable interrupt controller

- Four global high resolution timers/counters that can generate interrupts
- Supports additional internal interrupt sources
- Supports fully nested interrupt delivery
- Interrupts can be routed to external pin for external processing
- Interrupts can be routed to the e500 core's standard or critical interrupt inputs
- Interrupt summary registers allow fast identification of interrupt source

• Two I^2C controllers (one is contained within the CPM, the other is a stand-alone controller which is not part of the CPM)
  - Two-wire interface
  - Multiple master support
  - Master or slave I^2C mode support
  - On-chip digital filtering rejects spikes on the bus
• Boot sequencer
  - Optionally loads configuration data from serial ROM at reset via the stand-alone I^2C interface
  - Can be used to initialize configuration registers and/or memory
  - Supports extended I^2C addressing mode
  - Data integrity checked with preamble signature and CRC
• DUART
  - Two 4-wire interfaces (RXD, TXD, RTS, CTS)
  - Programming model compatible with the original 16450 UART and the PC16550D
• Local bus controller (LBC)
  - Multiplexed 32-bit address and data operating at up to 166 MHz
  - Eight chip selects support eight external slaves
  - Up to eight-beat burst transfers
  - The 32-, 16-, and 8-bit port sizes are controlled by an on-chip memory controller
  - Three protocol engines available on a per chip select basis:
    - General purpose chip select machine (GPCM)
    - Three user programmable machines (UPMs)
    - Dedicated single data rate SDRAM controller
  - Parity support
  - Default boot ROM chip select with configurable bus width (8-, 16-, or 32-bit)
• Two Three-speed (10/100/1000)Ethernet controllers (TSECs)
  - Dual IEEE 802.3, 802.3u, 802.3x, 802.3z AC compliant controllers
  - Support for Ethernet physical interfaces:
    - 10/100/1000 Mbps IEEE 802.3 GMII
    - 10/100 Mbps IEEE 802.3 MII
    - 10 Mbps IEEE 802.3 MII

  - 1000 Mbps IEEE 802.3z TBI
  - 10/100/1000 Mbps RGMII/RTBI
- Full- and half-duplex support
- Buffer descriptors are backwards compatible with MPC8260 and MPC860T 10/100 programming models
- 9.6-Kbyte jumbo frame support
- RMON statistics support
- 2-Kbyte internal transmit and receive FIFOs
- MII management interface for control and status
- Programmable CRC generation and checking

- OCeaN switch fabric
  - Three-port crossbar packet switch
  - Reorders packets from a source based on priorities
  - Reorders packets to bypass blocked packets
  - Implements starvation avoidance algorithms
  - Supports packets with payloads of up to 256 bytes
- Integrated DMA controller
  - Four-channel controller
  - All channels accessible by both local and remote masters
  - Extended DMA functions (advanced chaining and striding capability)
  - Support for scatter and gather transfers
  - Misaligned transfer capability
  - Interrupt on completed segment, link, list, and error
  - Supports transfers to or from any local memory or I/O port
  - Selectable hardware-enforced coherency (snoop/no-snoop)
  - Ability to start and flow control each DMA channel from external 3-pin interface
  - Ability to launch DMA from single write transaction
- PCI Controllers
  - PCI 2.2 compatible
  - One 64-bit or two 32-bit PCI ports supported at 16 to 66 MHz
  - Host and agent mode support, 64-bit PCI port can be host or agent, if two 32-bit ports, only one can be an agent
  - 64-bit dual address cycle (DAC) support
  - Supports PCI-to-memory and memory-to-PCI streaming
  - Memory prefetching of PCI read accesses
  - Supports posting of processor-to-PCI and PCI-to-memory writes
  - PCI 3.3-V compatible

- — Selectable hardware-enforced coherency
- — Selectable clock source (SYSCLK or independent PCI_CLK)
- Power management
  - — Fully static 1.2-V CMOS design with 3.3- and 2.5-V I/O
  - — Supports power save modes: doze, nap, and sleep
  - — Employs dynamic power management
  - — Selectable clock source (sysclk or independent PCI_CLK)
- System performance monitor
  - — Supports eight 32-bit counters that count the occurrence of selected events
  - — Ability to count up to 512 counter specific events
  - — Supports 64 reference events that can be counted on any of the 8 counters
  - — Supports duration and quantity threshold counting
  - — Burstiness feature that permits counting of burst events with a programmable time between bursts
  - — Triggering and chaining capability
  - — Ability to generate an interrupt on overflow
- System access port
  - — Uses JTAG interface and a TAP controller to access entire system memory map
  - — Supports 32-bit accesses to configuration registers
  - — Supports cache-line burst accesses to main memory
  - — Supports large block (4-Kbyte) uploads and downloads
  - — Supports continuous bit streaming of entire block for fast upload and download
- IEEE Std 1149.1™-compatible, JTAG boundary scan
- 783 FC-PBGA package

2 Electrical Characteristics

This section provides the AC and DC electrical specifications and thermal characteristics for the MPC8541E. The MPC8541E is currently targeted to these specifications. Some of these specifications are independent of the I/O cell, but are included for a more complete reference. These are not purely I/O buffer design specifications.

2.1 Overall DC Electrical Characteristics

This section covers the ratings, conditions, and other characteristics.

2.1.1 Absolute Maximum Ratings

Table 1 provides the absolute maximum ratings.

Table 1. Absolute Maximum Ratings [1]

Characteristic		Symbol	Max Value	Unit	Notes
Core supply voltage		V_{DD}	–0.3 to 1.32 0.3 to 1.43 (for 1 GHz only)	V	
PLL supply voltage		AV_{DD}	–0.3 to 1.32 0.3 to 1.43 (for 1 GHz only)	V	
DDR DRAM I/O voltage		GV_{DD}	–0.3 to 3.63	V	
Three-speed Ethernet I/O, MII management voltage		LV_{DD}	–0.3 to 3.63 –0.3 to 2.75	V	
CPM, PCI, local bus, DUART, system control and power management, I^2C, and JTAG I/O voltage		OV_{DD}	–0.3 to 3.63	V	3
Input voltage	DDR DRAM signals	MV_{IN}	–0.3 to (GV_{DD} + 0.3)	V	2, 5
	DDR DRAM reference	MV_{REF}	–0.3 to (GV_{DD} + 0.3)	V	2, 5
	Three-speed Ethernet signals	LV_{IN}	–0.3 to (LV_{DD} + 0.3)	V	4, 5
	CPM, Local bus, DUART, SYSCLK, system control and power management, I^2C, and JTAG signals	OV_{IN}	–0.3 to (OV_{DD} + 0.3)1	V	5
	PCI	OV_{IN}	–0.3 to (OV_{DD} + 0.3)	V	6
Storage temperature range		T_{STG}	–55 to 150	°C	

Notes:
1. Functional and tested operating conditions are given in Table 2. Absolute maximum ratings are stress ratings only, and functional operation at the maximums is not guaranteed. Stresses beyond those listed may affect device reliability or cause permanent damage to the device.
2. **Caution:** MV_{IN} must not exceed GV_{DD} by more than 0.3 V. This limit may be exceeded for a maximum of 20 ms during power-on reset and power-down sequences.
3. **Caution:** OV_{IN} must not exceed OV_{DD} by more than 0.3 V. This limit may be exceeded for a maximum of 20 ms during power-on reset and power-down sequences.
4. **Caution:** LV_{IN} must not exceed LV_{DD} by more than 0.3 V. This limit may be exceeded for a maximum of 20 ms during power-on reset and power-down sequences.
5. (M,L,O)V_{IN} and MV_{REF} may overshoot/undershoot to a voltage and for a maximum duration as shown in Figure 2.
6. OV_{IN} on the PCI interface may overshoot/undershoot according to the PCI Electrical Specification for 3.3-V operation, as shown in Figure 3.

2.1.2 Power Sequencing

The MPC8541Erequires its power rails to be applied in a specific sequence in order to ensure proper device operation. These requirements are as follows for power up:

1. V_{DD}, AV_{DDn}
2. GV_{DD}, LV_{DD}, OV_{DD} (I/O supplies)

Items on the same line have no ordering requirement with respect to one another. Items on separate lines must be ordered sequentially such that voltage rails on a previous step must reach 90 percent of their value before the voltage rails on the current step reach ten percent of theirs.

NOTE

If the items on line 2 must precede items on line 1, please ensure that the delay does not exceed 500 ms and the power sequence is not done greater than once per day in production environment.

NOTE

From a system standpoint, if the I/O power supplies ramp prior to the V_{DD} core supply, the I/Os on the MPC8541E may drive a logic one or zero during power-up.

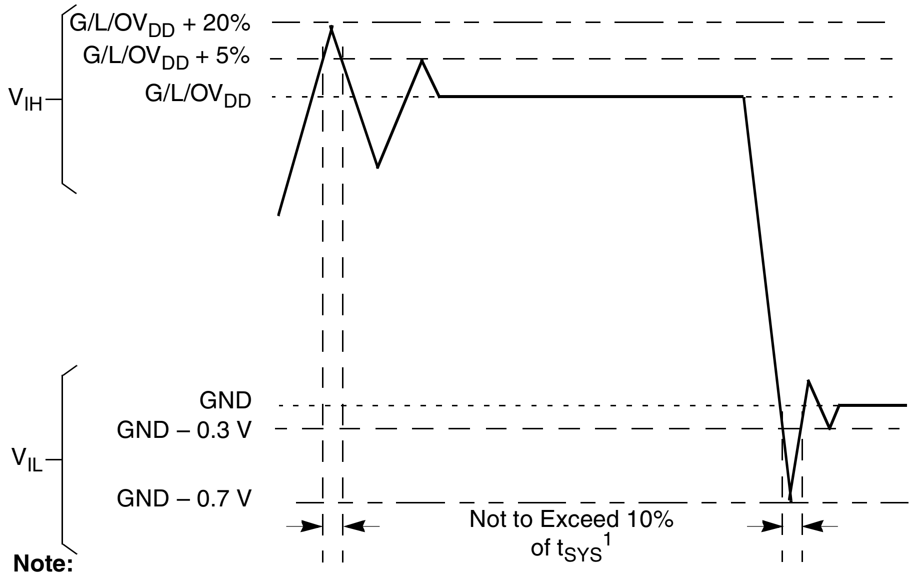
2.1.3 Recommended Operating Conditions

Table 2 provides the recommended operating conditions for the MPC8541E. Note that the values in Table 2 are the recommended and tested operating conditions. Proper device operation outside of these conditions is not guaranteed.

Table 2. Recommended Operating Conditions

Characteristic		Symbol	Recommended Value	Unit
Core supply voltage		V_{DD}	1.2 V ± 60 mV 1.3 V± 50 mV (for 1 GHz only)	V
PLL supply voltage		AV_{DD}	1.2 V ± 60 mV 1.3 V ± 50 mV (for 1 GHz only)	V
DDR DRAM I/O voltage		GV_{DD}	2.5 V ± 125 mV	V
Three-speed Ethernet I/O voltage		LV_{DD}	3.3 V ± 165 mV 2.5 V ± 125 mV	V
PCI, local bus, DUART, system control and power management, I^2C, and JTAG I/O voltage		OV_{DD}	3.3 V ± 165 mV	V
Input voltage	DDR DRAM signals	MV_{IN}	GND to GV_{DD}	V
	DDR DRAM reference	MV_{REF}	GND to GV_{DD}	V
	Three-speed Ethernet signals	LV_{IN}	GND to LV_{DD}	V
	PCI, local bus, DUART, SYSCLK, system control and power management, I^2C, and JTAG signals	OV_{IN}	GND to OV_{DD}	V
Die-junction Temperature		T_j	0 to 105	°C

Figure 2 shows the undershoot and overshoot voltages at the interfaces of the MPC8541E.



Note:
1. Note that t_{SYS} refers to the clock period associated with the SYSCLK signal.

Figure 2. Overshoot/Undershoot Voltage for $GV_{DD}/OV_{DD}/LV_{DD}$

The MPC8541E core voltage must always be provided at nominal 1.2 V (see Table 2 for actual recommended core voltage). Voltage to the processor interface I/Os are provided through separate sets of supply pins and must be provided at the voltages shown in Table 2. The input voltage threshold scales with respect to the associated I/O supply voltage. OV_{DD} and LV_{DD} based receivers are simple CMOS I/O circuits and satisfy appropriate LVCMOS type specifications. The DDR SDRAM interface uses a single-ended differential receiver referenced the externally supplied MV_{REF} signal (nominally set to $GV_{DD}/2$) as is appropriate for the SSTL2 electrical signaling standard.

Figure 3 shows the undershoot and overshoot voltage of the PCI interface of the MPC8541E for the 3.3-V signals, respectively.

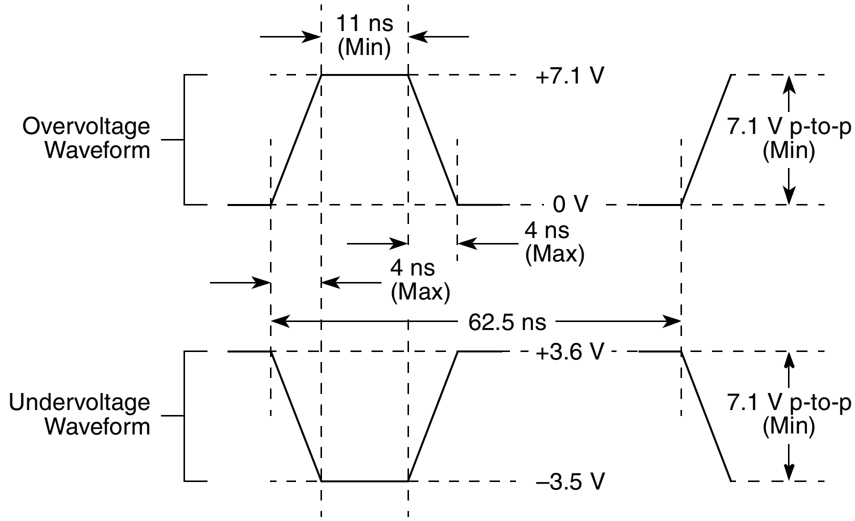


Figure 3. Maximum AC Waveforms on PCI interface for 3.3-V Signaling

2.1.4 Output Driver Characteristics

Table 3 provides information on the characteristics of the output driver strengths. The values are preliminary estimates.

Table 3. Output Drive Capability

Driver Type	Programmable Output Impedance (Ω)	Supply Voltage	Notes
Local bus interface utilities signals	25	OV_{DD} = 3.3 V	1
	42 (default)		
PCI signals	25		2
	42 (default)		
DDR signal	20	GV_{DD} = 2.5 V	
TSEC/10/100 signals	42	LV_{DD} = 2.5/3.3 V	
DUART, system control, I2C, JTAG	42	OV_{DD} = 3.3 V	

Notes:
1. The drive strength of the local bus interface is determined by the configuration of the appropriate bits in PORIMPSCR.
2. The drive strength of the PCI interface is determined by the setting of the $\overline{\text{PCI\_GNT1}}$ signal at reset.

3 Power Characteristics

The estimated typical power dissipation for this family of PowerQUICC III devices is shown in Table 4.

Table 4. Power Dissipation(1) (2)

CCB Frequency (MHz)	Core Frequency (MHz)	V_{DD}	Typical Power(3)(4) (W)	Maximum Power(5) (W)
200	400	1.2	4.4	6.1
	500	1.2	4.7	6.5
	600	1.2	5.0	6.8
267	533	1.2	4.9	6.7
	667	1.2	5.4	7.2
	800	1.2	5.8	8.6
333	667	1.2	5.5	7.4
	833	1.2	6.0	8.8
	1000(6)	1.3	9.0	12.2

Notes:

1. The values do not include I/O supply power (OV_{DD}, LV_{DD}, GV_{DD}) or AV_{DD}.
2. Junction temperature is a function of die size, on-chip power dissipation, package thermal resistance, mounting site (board) temperature, ambient temperature, air flow, power dissipation of other components on the board, and board thermal resistance. Any customer design must take these considerations into account to ensure the maximum 105 degrees junction temperature is not exceeded on this device.
3. Typical power is based on a nominal voltage of V_{DD} = 1.2V, a nominal process, a junction temperature of T_j = 105° C, and a Dhrystone 2.1 benchmark application.
4. Thermal solutions likely need to design to a value higher than Typical Power based on the end application, T_A target, and I/O power
5. Maximum power is based on a nominal voltage of V_{DD} = 1.2V, worst case process, a junction temperature of T_j = 105° C, and an artificial smoke test.
6. The nominal recommended V_{DD} = 1.3V for this speed grade.

Notes:

1.

2.

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4.

5.

6.

Table 5. Typical I/O Power Dissipation

Interface	Parameters	GV_{DD} (2.5 V)	OV_{DD} (3.3 V)	LV_{DD} (3.3 V)	LV_{DD} (2.5 V)	Unit	Comments
DDR I/O	CCB = 200 MHz	0.46	—	—	—	W	—
	CCB = 266 MHz	0.59	—	—	—	W	—
	CCB = 300 MHz	0.66	—	—	—	W	—
	CCB = 333 MHz	0.73	—	—	—	W	—
PCI I/O	64b, 66 MHz	—	0.14	—	—	W	—
	64b, 33 MHz	—	0.08	—	—	W	—
	32b, 66 MHz	—	0.07	—	—	W	Multiply by 2 if using two 32b ports
	32b, 33 MHz	—	0.04	—	—	W	
Local Bus I/O	32b, 167 MHz	—	0.30	—	—	W	—
	32b, 133 MHz	—	0.24	—	—	W	—
	32b, 83 MHz	—	0.16	—	—	W	—
	32b, 66 MHz	—	0.13	—	—	W	—
	32b, 33 MHz	—	0.07	—	—	W	—
TSEC I/O	MII	—	—	0.01	—	W	Multiply by number of interfaces used.
	GMII or TBI	—	—	0.07	—	W	
	RGMII or RTBI	—	—	—	0.04	W	
CPM - FCC	MII	—	0.015	—	—	W	—
	RMII	—	0.013	—	—	W	—
	HDLC 16 Mbps	—	0.009	—	—	W	—

4 Clock Timing

4.1 System Clock Timing

Table 6 provides the system clock (SYSCLK) AC timing specifications for the MPC8541E.

Table 6. SYSCLK AC Timing Specifications

Parameter/Condition	Symbol	Min	Typical	Max	Unit	Notes
SYSCLK frequency	f_{SYSCLK}	—	—	166	MHz	1
SYSCLK cycle time	t_{SYSCLK}	6.0	—	—	ns	—
SYSCLK rise and fall time	t_{KH}, t_{KL}	0.6	1.0	1.2	ns	2
SYSCLK duty cycle	t_{KHK}/t_{SYSCLK}	40	—	60	%	3
SYSCLK jitter	—	—	—	+/- 150	ps	4, 5

Notes:
1. **Caution:** The CCB to SYSCLK ratio and e500 core to CCB ratio settings must be chosen such that the resulting SYSCLK frequency, e500 (core) frequency, and CCB frequency do not exceed their respective maximum or minimum operating frequencies.
2. Rise and fall times for SYSCLK are measured at 0.6 and 2.7 V.
3. Timing is guaranteed by design and characterization.
4. This represents the total input jitter—short term and long term—and is guaranteed by design.
5. For spread spectrum clocking, guidelines are ±1% of the input frequency with a maximum of 60 kHz of modulation regardless of the input frequency.

4.2 TSEC Gigabit Reference Clock Timing

Table 7 provides the TSEC gigabit reference clock (EC_GTX_CLK125) AC timing specifications for the MPC8541E.

Table 7. EC_GTX_CLK125 AC Timing Specifications

Parameter/Condition	Symbol	Min	Typical	Max	Unit	Notes
EC_GTX_CLK125 frequency	f_{G125}	—	125	—	MHz	—
EC_GTX_CLK125 cycle time	t_{G125}	—	8	—	ns	—
EC_GTX_CLK125 rise time	t_{G125R}	—	—	1.0	ns	1
EC_GTX_CLK125 fall time	t_{G125F}	—	—	1.0	ns	1
EC_GTX_CLK125 duty cycle GMII, TBI RGMII, RTBI	t_{G125H}/t_{G125}	 45 47	—	 55 53	%	1, 2

Notes:
1. Timing is guaranteed by design and characterization.
2. EC_GTX_CLK125 is used to generate GTX clock for TSEC transmitter with 2% degradation. EC_GTX_CLK125 duty cycle can be loosened from 47/53% as long as PHY device can tolerate the duty cycle generated by GTX_CLK of TSEC.

4.3 Real Time Clock Timing

Table 8 provides the real time clock (RTC) AC timing specifications.

Table 8. RTC AC Timing Specifications

Parameter/Condition	Symbol	Min	Typical	Max	Unit	Notes
RTC clock high time	t_{RTCH}	2 x t_{CCB_CLK}	—	—	ns	—
RTC clock low time	t_{RTCL}	2 x t_{CCB_CLK}	—	—	ns	—

5 RESET Initialization

This section describes the AC electrical specifications for the RESET initialization timing requirements of the MPC8541E. Table 9 provides the RESET initialization AC timing specifications.

Table 9. RESET Initialization Timing Specifications

Parameter/Condition	Min	Max	Unit	Notes
Required assertion time of $\overline{\text{HRESET}}$	100	—	µs	—
Minimum assertion time for $\overline{\text{SRESET}}$	512	—	SYSCLKs	1
PLL input setup time with stable SYSCLK before HRESET negation	100	—	µs	—
Input setup time for POR configs (other than PLL config) with respect to negation of $\overline{\text{HRESET}}$	4	—	SYSCLKs	1
Input hold time for POR configs (including PLL config) with respect to negation of $\overline{\text{HRESET}}$	2	—	SYSCLKs	1
Maximum valid-to-high impedance time for actively driven POR configs with respect to negation of $\overline{\text{HRESET}}$	—	5	SYSCLKs	1

Notes:
1. SYSCLK is identical to the PCI_CLK signal and is the primary clock input for the MPC8541E. See the *MPC8555E PowerQUICC™ III Integrated Communications Processor Reference Manual* for more details.

Table 10 provides the PLL and DLL lock times.

Table 10. PLL and DLL Lock Times

Parameter/Condition	Min	Max	Unit	Notes
PLL lock times	—	100	µs	—
DLL lock times	7680	122,880	CCB Clocks	1, 2

Notes:
1. DLL lock times are a function of the ratio between the output clock and the platform (or CCB) clock. A 2:1 ratio results in the minimum and an 8:1 ratio results in the maximum.
2. The CCB clock is determined by the SYSCLK × platform PLL ratio.

6 DDR SDRAM

This section describes the DC and AC electrical specifications for the DDR SDRAM interface of the MPC8541E.

6.1 DDR SDRAM DC Electrical Characteristics

Table 11 provides the recommended operating conditions for the DDR SDRAM component(s) of the MPC8541E.

Table 11. DDR SDRAM DC Electrical Characteristics

Parameter/Condition	Symbol	Min	Max	Unit	Notes
I/O supply voltage	GV_{DD}	2.375	2.625	V	1
I/O reference voltage	MV_{REF}	$0.49 \times GV_{DD}$	$0.51 \times GV_{DD}$	V	2
I/O termination voltage	V_{TT}	$MV_{REF} - 0.04$	$MV_{REF} + 0.04$	V	3
Input high voltage	V_{IH}	$MV_{REF} + 0.18$	$GV_{DD} + 0.3$	V	—
Input low voltage	V_{IL}	–0.3	$MV_{REF} - 0.18$	V	—
Output leakage current	I_{OZ}	–10	10	μA	4
Output high current (V_{OUT} = 1.95 V)	I_{OH}	–15.2	—	mA	—
Output low current (V_{OUT} = 0.35 V)	I_{OL}	15.2	—	mA	—
MV_{REF} input leakage current	I_{VREF}	—	5	μA	—

Notes:
1. GV_{DD} is expected to be within 50 mV of the DRAM GV_{DD} at all times.
2. MV_{REF} is expected to be equal to $0.5 \times GV_{DD}$, and to track GV_{DD} DC variations as measured at the receiver. Peak-to-peak noise on MV_{REF} may not exceed ±2% of the DC value.
3. V_{TT} is not applied directly to the device. It is the supply to which far end signal termination is made and is expected to be equal to MV_{REF}. This rail should track variations in the DC level of MV_{REF}.
4. Output leakage is measured with all outputs disabled, $0 \text{ V} \leq V_{OUT} \leq GV_{DD}$.

Table 12 provides the DDR capacitance.

Table 12. DDR SDRAM Capacitance

Parameter/Condition	Symbol	Min	Max	Unit	Notes
Input/output capacitance: DQ, DQS, MSYNC_IN	C_{IO}	6	8	pF	1
Delta input/output capacitance: DQ, DQS	C_{DIO}	—	0.5	pF	1

Note:
1. This parameter is sampled. GV_{DD} = 2.5 V ± 0.125 V, f = 1 MHz, T_A = 25°C, $V_{OUT} = GV_{DD}/2$, V_{OUT} (peak to peak) = 0.2 V.

6.2 DDR SDRAM AC Electrical Characteristics

This section provides the AC electrical characteristics for the DDR SDRAM interface.

6.2.1 DDR SDRAM Input AC Timing Specifications

Table 13 provides the input AC timing specifications for the DDR SDRAM interface.

Table 13. DDR SDRAM Input AC Timing Specifications

At recommended operating conditions with GV_{DD} of 2.5 V ± 5%.

Parameter	Symbol	Min	Max	Unit	Notes
AC input low voltage	V_{IL}	—	MV_{REF} – 0.31	V	—
AC input high voltage	V_{IH}	MV_{REF} + 0.31	GV_{DD} + 0.3	V	—
MDQS—MDQ/MECC input skew per byte For DDR = 333 MHz For DDR ≤ 266 MHz	t_{DISKEW}	—	 750 1125	ps	1

Note:

1. Maximum possible skew between a data strobe (MDQS[n]) and any corresponding bit of data (MDQ[8n + {0...7}] if 0 <= n <= 7) or ECC (MECC[{0...7}] if n = 8).

6.2.2 DDR SDRAM Output AC Timing Specifications

Table 14 and Table 15 provide the output AC timing specifications and measurement conditions for the DDR SDRAM interface.

Table 14. DDR SDRAM Output AC Timing Specifications for Source Synchronous Mode

At recommended operating conditions with GV_{DD} of 2.5 V ± 5%.

Parameter	Symbol [1]	Min	Max	Unit	Notes
MCK[n] cycle time, (MCK[n]/$\overline{\text{MCK}}$[n] crossing)	t_{MCK}	6	10	ns	2
Skew between any MCK to ADDR/CMD 333 MHz 266 MHz 200 MHz	t_{AOSKEW}	 –1000 –1100 –1200	 200 300 400	ps	3
ADDR/CMD output setup with respect to MCK 333 MHz 266 MHz 200 MHz	t_{DDKHAS}	 2.8 3.45 4.6	—	ns	4
ADDR/CMD output hold with respect to MCK 333 MHz 266 MHz 200 MHz	t_{DDKHAX}	 2.0 2.65 3.8	—	ns	4
$\overline{\text{MCS}}$(n) output setup with respect to MCK 333 MHz 266 MHz 200 MHz	t_{DDKHCS}	 2.8 3.45 4.6	—	ns	4

Table 14. DDR SDRAM Output AC Timing Specifications for Source Synchronous Mode (continued)

At recommended operating conditions with GV_{DD} of 2.5 V ± 5%.

Parameter	Symbol [1]	Min	Max	Unit	Notes
$\overline{MCS}$(n) output hold with respect to MCK 333 MHz 266 MHz 200 MHz	t_{DDKHCX}	 2.0 2.65 3.8	—	ns	4
MCK to MDQS 333 MHz 266 MHz 200 MHz	t_{DDKHMH}	 –0.9 –1.1 –1.2	 0.3 0.5 0.6	ns	5
MDQ/MECC/MDM output setup with respect to MDQS 333 MHz 266 MHz 200 MHz	t_{DDKHDS}, t_{DDKLDS}	 900 900 1200	—	ps	6
MDQ/MECC/MDM output hold with respect to MDQS 333 MHz 266 MHz 200 MHz	t_{DDKHDX}, t_{DDKLDX}	 900 900 1200	—	ps	6
MDQS preamble start	t_{DDKHMP}	$-0.5 \times t_{MCK} - 0.9$	$-0.5 \times t_{MCK} + 0.3$	ns	7
MDQS epilogue end	t_{DDKLME}	–0.9	0.3	ns	7

Notes:

1. The symbols used for timing specifications follow the pattern of $t_{\text{(first two letters of functional block)(signal)(state) (reference)(state)}}$ for inputs and $t_{\text{(first two letters of functional block)(reference)(state)(signal)(state)}}$ for outputs. Output hold time can be read as DDR timing (DD) from the rising or falling edge of the reference clock (KH or KL) until the output went invalid (AX or DX). For example, t_{DDKHAS} symbolizes DDR timing (DD) for the time t_{MCK} memory clock reference (K) goes from the high (H) state until outputs (A) are setup (S) or output valid time. Also, t_{DDKLDX} symbolizes DDR timing (DD) for the time t_{MCK} memory clock reference (K) goes low (L) until data outputs (D) are invalid (X) or data output hold time.
2. All MCK/$\overline{MCK}$ referenced measurements are made from the crossing of the two signals ±0.1 V.
3. In the source synchronous mode, MCK/$\overline{MCK}$ can be shifted in 1/4 applied cycle increments through the Clock Control Register. For the skew measurements referenced for t_{AOSKEW} it is assumed that the clock adjustment is set to align the address/command valid with the rising edge of MCK.
4. ADDR/CMD includes all DDR SDRAM output signals except MCK/$\overline{MCK}$, $\overline{MCS}$, and MDQ/MECC/MDM/MDQS. For the ADDR/CMD setup and hold specifications, it is assumed that the Clock Control register is set to adjust the memory clocks by 1/2 applied cycle. The MCSx pins are separated from the ADDR/CMD (address and command) bus in the HW spec. This was separated because the MCSx pins typically have different loadings than the rest of the address and command bus, even though they have the same timings.
5. Note that t_{DDKHMH} follows the symbol conventions described in note 1. For example, t_{DDKHMH} describes the DDR timing (DD) from the rising edge of the MCK(n) clock (KH) until the MDQS signal is valid (MH). In the source synchronous mode, MDQS can launch later than MCK by 0.3 ns at the maximum. However, MCK may launch later than MDQS by as much as 0.9 ns. t_{DDKHMH} can be modified through control of the DQSS override bits in the TIMING_CFG_2 register. In source synchronous mode, this typically is set to the same delay as the clock adjust in the CLK_CNTL register. The timing parameters listed in the table assume that these two parameters have been set to the same adjustment value. See the *MPC8555E PowerQUICC™ III Integrated Communications Processor Reference Manual* for a description and understanding of the timing modifications enabled by use of these bits.
6. Determined by maximum possible skew between a data strobe (MDQS) and any corresponding bit of data (MDQ), ECC (MECC), or data mask (MDM). The data strobe should be centered inside of the data eye at the pins of the MPC8541E.
7. All outputs are referenced to the rising edge of MCK(n) at the pins of the MPC8541E. Note that t_{DDKHMP} follows the symbol conventions described in note 1.

Figure 4 shows the DDR SDRAM output timing for address skew with respect to any MCK.

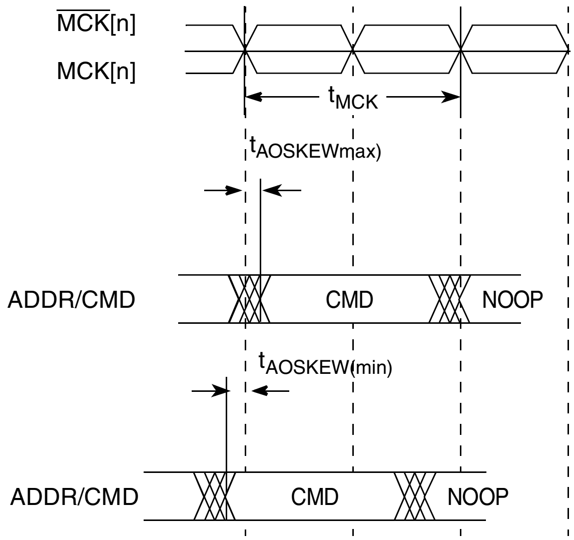

Figure 4. Timing Diagram for t_{AOSKEW} Measurement

Figure 5 shows the DDR SDRAM output timing diagram for the source synchronous mode.

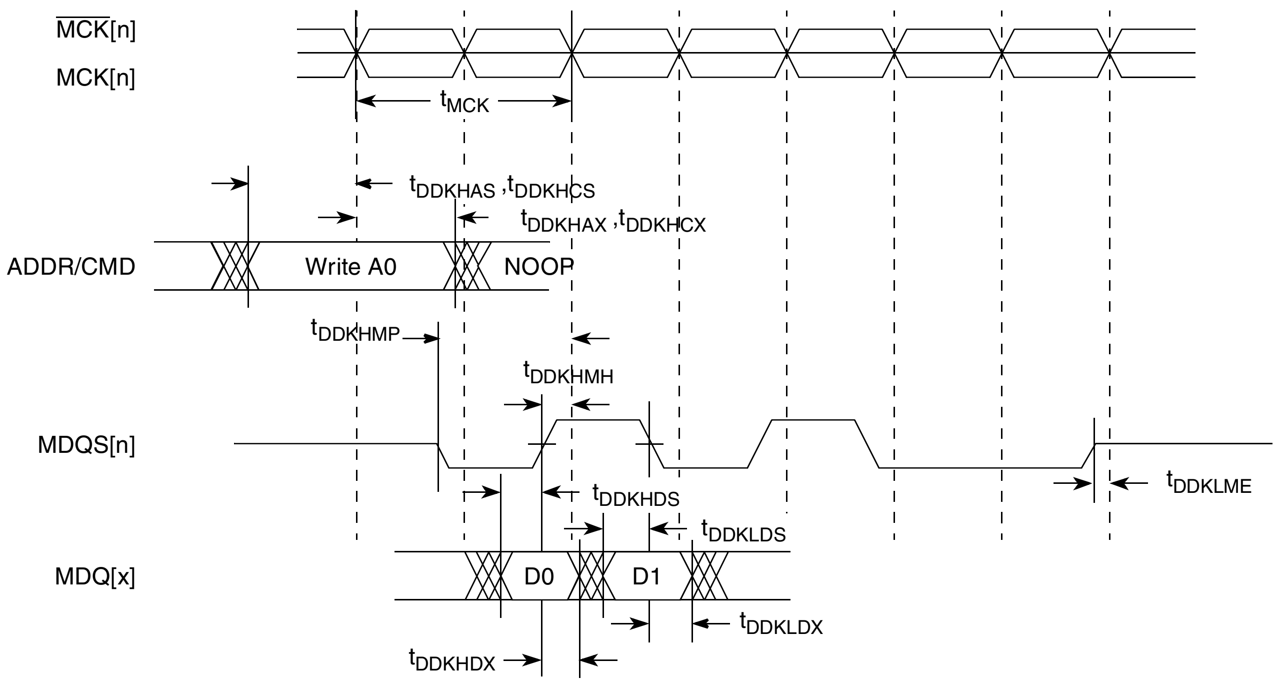

Figure 5. DDR SDRAM Output Timing Diagram for Source Synchronous Mode

Figure 6 provides the AC test load for the DDR bus.

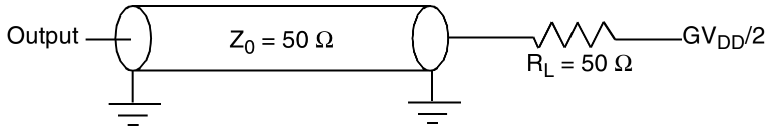

Figure 6. DDR AC Test Load

Table 15. DDR SDRAM Measurement Conditions

Symbol	DDR	Unit	Notes
V_{TH}	MV_{REF} ± 0.31 V	V	1
V_{OUT}	0.5 × GV_{DD}	V	2

Notes:
1. Data input threshold measurement point.
2. Data output measurement point.

7 DUART

This section describes the DC and AC electrical specifications for the DUART interface of the MPC8541E.

7.1 DUART DC Electrical Characteristics

Table 16 provides the DC electrical characteristics for the DUART interface of the MPC8541E.

Table 16. DUART DC Electrical Characteristics

Parameter	Symbol	Test Condition	Min	Max	Unit
High-level input voltage	V_{IH}	$V_{OUT} \geq V_{OH}$ (min) or $V_{OUT} \leq V_{OL}$ (max)	2	OV_{DD} + 0.3	V
Low-level input voltage	V_{IL}		–0.3	0.8	V
Input current	I_{IN}	V_{IN} [1] = 0 V or $V_{IN} = V_{DD}$	—	±5	μA
High-level output voltage	V_{OH}	OV_{DD} = min, I_{OH} = –100 μA	OV_{DD} – 0.2	—	V
Low-level output voltage	V_{OL}	OV_{DD} = min, I_{OL} = 100 μA	—	0.2	V

Note:
1. Note that the symbol V_{IN}, in this case, represents the OV_{IN} symbol referenced in Table 1 and Table 2.

7.2 DUART AC Electrical Specifications

Table 17 provides the AC timing parameters for the DUART interface of the MPC8541E.

Table 17. DUART AC Timing Specifications

Parameter	Value	Unit	Notes
Minimum baud rate	f_{CCB_CLK} / 1048576	baud	3
Maximum baud rate	f_{CCB_CLK} / 16	baud	1, 3
Oversample rate	16	—	2, 3

Notes:
1. Actual attainable baud rate is limited by the latency of interrupt processing.
2. The middle of a start bit is detected as the 8^{th} sampled 0 after the 1-to-0 transition of the start bit. Subsequent bit values are sampled each 16^{th} sample.
3. Guaranteed by design.

8 Ethernet: Three-Speed, MII Management

This section provides the AC and DC electrical characteristics for three-speed, 10/100/1000, and MII management.

8.1 Three-Speed Ethernet Controller (TSEC) (10/100/1000 Mbps)—GMII/MII/TBI/RGMII/RTBI Electrical Characteristics

The electrical characteristics specified here apply to all GMII (gigabit media independent interface), the MII (media independent interface), TBI (ten-bit interface), RGMII (reduced gigabit media independent interface), and RTBI (reduced ten-bit interface) signals except MDIO (management data input/output) and MDC (management data clock). The RGMII and RTBI interfaces are defined for 2.5 V, while the GMII and TBI interfaces can be operated at 3.3 V or 2.5 V. Whether the GMII, MII, or TBI interface is operated at 3.3 or 2.5 V, the timing is compliant with the IEEE 802.3 standard. The RGMII and RTBI interfaces follow the Hewlett-Packard reduced pin-count interface for Gigabit Ethernet Physical Layer Device Specification Version 1.2a (9/22/2000). The electrical characteristics for MDIO and MDC are specified in Section 8.3, "Ethernet Management Interface Electrical Characteristics."

8.1.1 TSEC DC Electrical Characteristics

All GMII, MII, TBI, RGMII, and RTBI drivers and receivers comply with the DC parametric attributes specified in Table 18 and Table 19. The potential applied to the input of a GMII, MII, TBI, RGMII, or RTBI receiver may exceed the potential of the receiver's power supply (for example, a GMII driver powered from a 3.6-V supply driving V_{OH} into a GMII receiver powered from a 2.5-V supply). Tolerance for dissimilar GMII driver and receiver supply potentials is implicit in these specifications. The RGMII and RTBI signals are based on a 2.5-V CMOS interface voltage as defined by JEDEC EIA/JESD8-5.

Table 18. GMII, MII, and TBI DC Electrical Characteristics

Parameter	Symbol	Conditions		Min	Max	Unit
Supply voltage 3.3 V	LV_{DD}	—		3.13	3.47	V
Output high voltage	V_{OH}	I_{OH} = –4.0 mA	LV_{DD} = Min	2.40	LV_{DD} + 0.3	V
Output low voltage	V_{OL}	I_{OL} = 4.0 mA	LV_{DD} = Min	GND	0.50	V
Input high voltage	V_{IH}	—	—	1.70	LV_{DD} + 0.3	V
Input low voltage	V_{IL}	—	—	–0.3	0.90	V
Input high current	I_{IH}	V_{IN} [1] = LV_{DD}		—	40	μA
Input low current	I_{IL}	V_{IN} [1] = GND		–600	—	μA

Note:
1. The symbol V_{IN}, in this case, represents the LV_{IN} symbol referenced in Table 1 and Table 2.

Table 19. GMII, MII, RGMII RTBI, and TBI DC Electrical Characteristics

Parameters	Symbol	Min	Max	Unit
Supply voltage 2.5 V	LV_{DD}	2.37	2.63	V
Output high voltage (LV_{DD} = Min, I_{OH} = –1.0 mA)	V_{OH}	2.00	LV_{DD} + 0.3	V
Output low voltage (LV_{DD} = Min, I_{OL} = 1.0 mA)	V_{OL}	GND – 0.3	0.40	V
Input high voltage (LV_{DD} = Min)	V_{IH}	1.70	LV_{DD} + 0.3	V
Input low voltage (LV_{DD} = Min)	V_{IL}	–0.3	0.70	V
Input high current (V_{IN} [1] = LV_{DD})	I_{IH}	—	10	μA
Input low current (V_{IN} [1] = GND)	I_{IL}	–15	—	μA

Note:
1. Note that the symbol V_{IN}, in this case, represents the LV_{IN} symbol referenced in Table 1and Table 2.

8.2 GMII, MII, TBI, RGMII, and RTBI AC Timing Specifications

The AC timing specifications for GMII, MII, TBI, RGMII, and RTBI are presented in this section.

8.2.1 GMII AC Timing Specifications

This section describes the GMII transmit and receive AC timing specifications.

8.2.2 GMII Transmit AC Timing Specifications

Table 20 provides the GMII transmit AC timing specifications.

Table 20. GMII Transmit AC Timing Specifications

At recommended operating conditions with LV_{DD} of 3.3 V ± 5%.

Parameter/Condition	Symbol [1]	Min	Typ	Max	Unit
GTX_CLK clock period	t_{GTX}	—	8.0	—	ns
GTX_CLK duty cycle	t_{GTXH}/t_{GTX}	40	—	60	%
GMII data TXD[7:0], TX_ER, TX_EN setup time	t_{GTKHDV}	2.5	—	—	ns
GTX_CLK to GMII data TXD[7:0], TX_ER, TX_EN delay	t_{GTKHDX}	0.5	—	5.0	ns
GTX_CLK data clock rise and fall times	t_{GTXR}[3], t_{GTXR}[2,4]	—	—	1.0	ns

Notes:

1. The symbols used for timing specifications herein follow the pattern $t_{(first\ two\ letters\ of\ functional\ block)(signal)(state)\ (reference)(state)}$ for inputs and $t_{(first\ two\ letters\ of\ functional\ block)(reference)(state)(signal)(state)}$ for outputs. For example, t_{GTKHDV} symbolizes GMII transmit timing (GT) with respect to the t_{GTX} clock reference (K) going to the high state (H) relative to the time date input signals (D) reaching the valid state (V) to state or setup time. Also, t_{GTKHDX} symbolizes GMII transmit timing (GT) with respect to the t_{GTX} clock reference (K) going to the high state (H) relative to the time date input signals (D) going invalid (X) or hold time. Note that, in general, the clock reference symbol representation is based on three letters representing the clock of a particular functional. For example, the subscript of t_{GTX} represents the GMII(G) transmit (TX) clock. For rise and fall times, the latter convention is used with the appropriate letter: R (rise) or F (fall).
2. Signal timings are measured at 0.7 V and 1.9 V voltage levels.
3. Guaranteed by characterization.
4. Guaranteed by design.

Figure 7 shows the GMII transmit AC timing diagram.

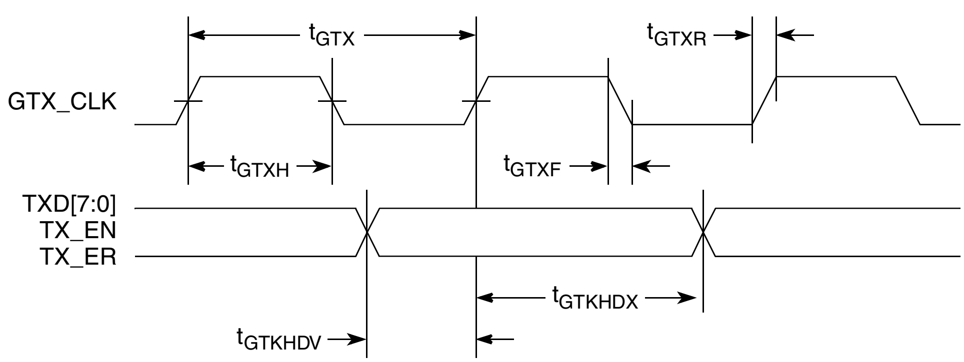

Figure 7. GMII Transmit AC Timing Diagram

8.2.2.1 GMII Receive AC Timing Specifications

Table 21 provides the GMII receive AC timing specifications.

Table 21. GMII Receive AC Timing Specifications

At recommended operating conditions with LV_{DD} of 3.3 V ± 5%.

Parameter/Condition	Symbol [1]	Min	Typ	Max	Unit
RX_CLK clock period	t_{GRX}	—	8.0	—	ns
RX_CLK duty cycle	t_{GRXH}/t_{GRX}	40	—	60	%
RXD[7:0], RX_DV, RX_ER setup time to RX_CLK	t_{GRDVKH}	2.0	—	—	ns
RXD[7:0], RX_DV, RX_ER hold time to RX_CLK	t_{GRDXKH}	0.5	—	—	ns
RX_CLK clock rise and fall time	t_{GRXR}, t_{GRXF} [2,3]	—	—	1.0	ns

Note:

1. The symbols used for timing specifications herein follow the pattern of $t_{\text{(first two letters of functional block)(signal)(state)(reference)(state)}}$ for inputs and $t_{\text{(first two letters of functional block)(reference)(state)(signal)(state)}}$ for outputs. For example, t_{GRDVKH} symbolizes GMII receive timing (GR) with respect to the time data input signals (D) reaching the valid state (V) relative to the t_{RX} clock reference (K) going to the high state (H) or setup time. Also, t_{GRDXKL} symbolizes GMII receive timing (GR) with respect to the time data input signals (D) went invalid (X) relative to the t_{GRX} clock reference (K) going to the low (L) state or hold time. Note that, in general, the clock reference symbol representation is based on three letters representing the clock of a particular functional. For example, the subscript of t_{GRX} represents the GMII (G) receive (RX) clock. For rise and fall times, the latter convention is used with the appropriate letter: R (rise) or F (fall).
2. Signal timings are measured at 0.7 V and 1.9 V voltage levels.
3. Guaranteed by design.

Figure 8 provides the AC test load for TSEC.

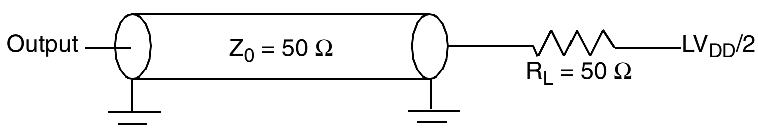

Figure 8. TSEC AC Test Load

Figure 9 shows the GMII receive AC timing diagram.

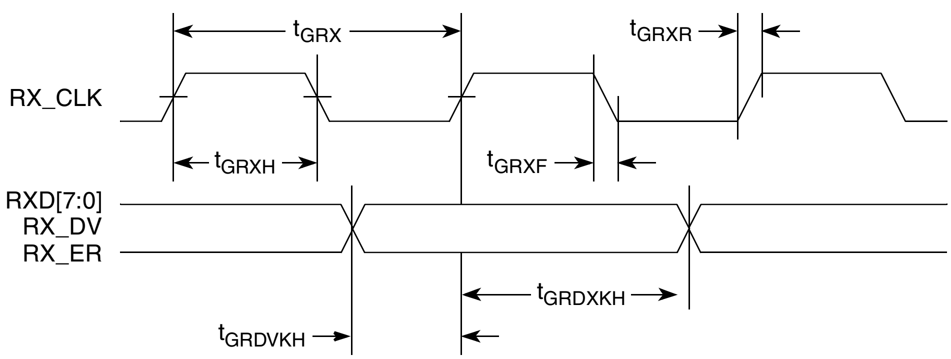

Figure 9. GMII Receive AC Timing Diagram

8.2.3 MII AC Timing Specifications

This section describes the MII transmit and receive AC timing specifications.

8.2.3.1 MII Transmit AC Timing Specifications

Table 22 provides the MII transmit AC timing specifications.

Table 22. MII Transmit AC Timing Specifications

At recommended operating conditions with LV_{DD} of 3.3 V ± 5%.

Parameter/Condition	Symbol [1]	Min	Typ	Max	Unit
TX_CLK clock period 10 Mbps	t_{MTX} [2]	—	400	—	ns
TX_CLK clock period 100 Mbps	t_{MTX}	—	40	—	ns
TX_CLK duty cycle	t_{MTXH}/t_{MTX}	35	—	65	%
TX_CLK to MII data TXD[3:0], TX_ER, TX_EN delay	t_{MTKHDX}	1	5	15	ns
TX_CLK data clock rise and fall time	t_{MTXR}, t_{MTXF} [2,3]	1.0	—	4.0	ns

Notes:

1. The symbols used for timing specifications herein follow the pattern of $t_{\text{(first two letters of functional block)(signal)(state)(reference)(state)}}$ for inputs and $t_{\text{(first two letters of functional block)(reference)(state)(signal)(state)}}$ for outputs. For example, t_{MTKHDX} symbolizes MII transmit timing (MT) for the time t_{MTX} clock reference (K) going high (H) until data outputs (D) are invalid (X). Note that, in general, the clock reference symbol representation is based on two to three letters representing the clock of a particular functional. For example, the subscript of t_{MTX} represents the MII(M) transmit (TX) clock. For rise and fall times, the latter convention is used with the appropriate letter: R (rise) or F (fall).
2. Signal timings are measured at 0.7 V and 1.9 V voltage levels.
3. Guaranteed by design.

Figure 10 shows the MII transmit AC timing diagram.

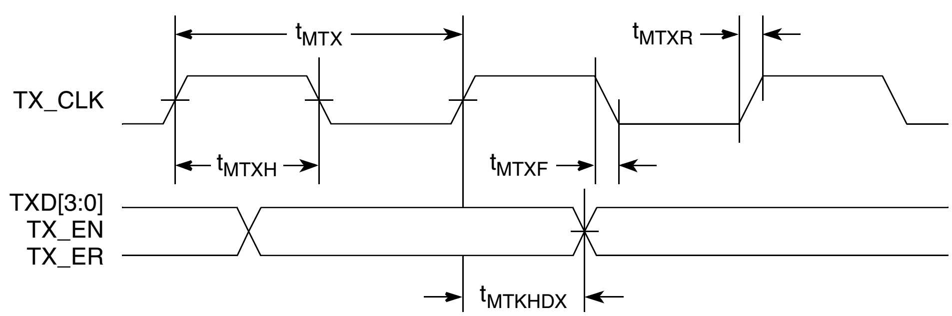

Figure 10. MII Transmit AC Timing Diagram