



REALTEK

RTL8101E-GR

INTEGRATED FAST ETHERNET CONTROLLER FOR PCI EXPRESS™ APPLICATIONS

DATASHEET

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USING THIS DOCUMENT

This document is intended for the software engineer’s reference and provides detailed programming information.

Though every effort has been made to ensure that this document is current and accurate, more information may have become available subsequent to the production of this guide. In that event, please contact your Realtek representative for additional information that may help in the development process.

REVISION HISTORY

| Revision | Release Date | Summary |
|----------|--------------|---|
| 1.0 | 2005/11/11 | First release. |
| 1.1 | 2006/04/07 | Changed Figure 1, Pin Assignments, Page 3. Changed Table 6, Reference, Page 5. Changed Table 8, Power & Ground, Page 6. |
| 1.2 | 2007/05/05 | Changed ESR data (Table 13, page 15). Added Table 14, page 16. |

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1. General Description

The Realtek RTL8101E Fast Ethernet controller combines an IEEE 802.3 10/100Base-T compliant Media Access Controller (MAC), PCI Express bus controller, and embedded memory. With state-of-the-art DSP technology and mixed-mode signal technology, the RTL8101E offers high-speed transmission over CAT 5 UTP cable or CAT 3 UTP (10Mbps only) cable. Functions such as Crossover Detection & Auto-Correction, polarity correction, adaptive equalization, cross-talk cancellation, echo cancellation, timing recovery, and error correction are implemented to provide robust transmission and reception capability at high speeds.

The device supports the PCI Express 1.0a bus interface for host communications with power management and is compliant with the IEEE 802.3u specification for 10/100Mbps Ethernet. It also supports an auxiliary power auto-detect function, and will auto-configure related bits of the PCI power management registers in PCI configuration space.

Advanced Configuration Power management Interface (ACPI)—power management for modern operating systems that are capable of Operating System-directed Power Management (OSPM)—is supported to achieve the most efficient power management possible. PCI Message Signaled Interrupt (MSI) is also supported.

In addition to the ACPI feature, remote wake-up (including AMD Magic Packet™, Re-LinkOk, and Microsoft® Wake-up frame) is supported in both ACPI and APM (Advanced Power Management) environments. To support WOL from a deep power down state (e.g., D3cold, i.e. main power is off and only auxiliary exists), the auxiliary power source must be able to provide the needed power for the RTL8101E.

The RTL8101E is fully compliant with Microsoft® NDIS5 (IP, TCP, UDP) Checksum and Segmentation Task-offload features, and supports IEEE 802 IP Layer 2 priority encoding and IEEE 802.1Q Virtual bridged Local Area Network (VLAN). The above features contribute to lowering CPU utilization, especially benefiting performance when in operation on a network server.

The device also features next-generation interconnect PCI Express technology. PCI Express is a high-bandwidth, low-pin-count, serial interconnect technology that offers significant improvements in performance over conventional PCI and also maintains software compatibility with existing PCI infrastructure.

The RTL8101E is suitable for multiple market segments and emerging applications, such as desktop, mobile, workstation, server, communications platforms, and embedded applications.

2. Features

- Integrated 10/100 transceiver
- Auto-Negotiation with Next Page capability
- Supports PCI Express™ 1.0a
- Supports pair swap/polarity/skew correction
- Crossover Detection & Auto-Correction
- Wake-on-LAN and remote wake-up support
- Microsoft® NDIS5 Checksum Offload (IP, TCP, UDP) and Largesend Offload support
- Supports Full Duplex flow control (IEEE 802.3x)
- Fully compliant with IEEE 802.3, IEEE 802.3u, IEEE 802.3ab
- Supports IEEE 802.1P Layer 2 Priority Encoding
- Supports IEEE 802.1Q VLAN tagging
- Serial EEPROM
- Transmit/Receive on-chip buffer support
- Supports power down/link down power saving
- Supports PCI Message Signaled Interrupt (MSI)
- 64-pin QFN package

3. System Applications

- Fast Ethernet on Motherboard, Notebook, or Embedded system

4. Pin Assignments

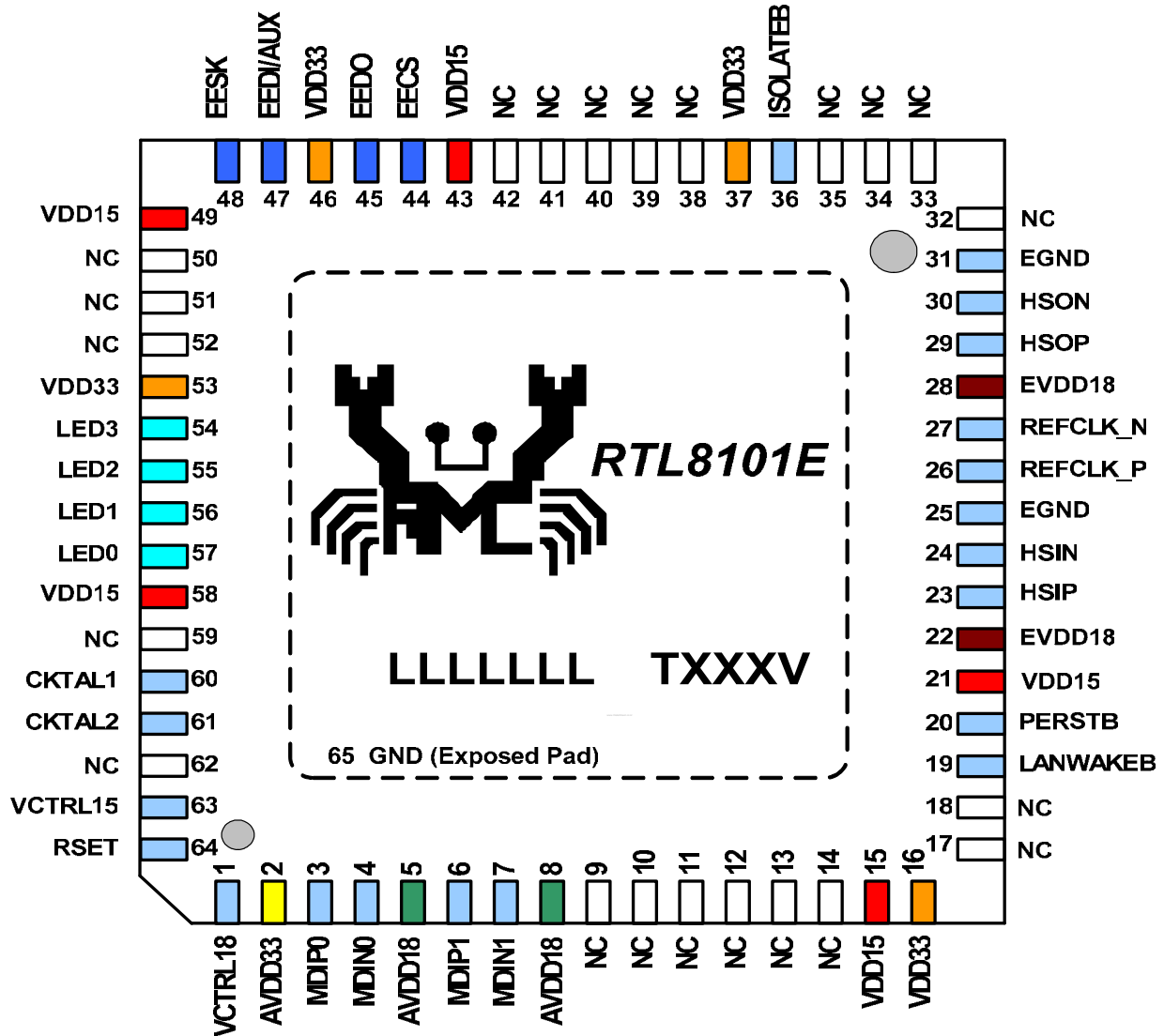


Figure 1. Pin Assignments

4.1. Package Identification

‘Green’ package is indicated by a ‘G’ in the location marked ‘T’ in Figure 1.

5. Pin Descriptions

The signal type codes below are used in the following tables:

| | |
|--|----------------------------|
| I: Input | S/T/S: Sustained Tri-State |
| O: Output | O/D: Open Drain |
| T/S: Tri-State bi-directional input/output pin | |

5.1. Power Management/Isolation

Table 1. Power Management/Isolation

| Symbol | Type | Pin No | Description |
|----------|------|--------|---|
| LANWAKEB | O/D | 19 | Power Management Event: Open drain, active low. Used to reactivate the PCI Express slot's main power rails and reference clocks. |
| ISOLATEB | I | 36 | Isolate Pin: Active low. Used to isolate the RTL8101E from the PCI Express bus. The RTL8101E will not drive its PCI Express outputs (excluding LANWAKEB) and will not sample its PCI Express input as long as the Isolate pin is asserted. |

5.2. PCI Express Interface

Table 2. PCI Express Interface

| Symbol | Type | Pin No | Description |
|----------|------|--------|---|
| REFCLK_P | I | 26 | PCI Express Differential Reference Clock Source: 100MHz \pm 300ppm. |
| REFCLK_N | I | 27 | |
| HSOP | O | 29 | PCI Express Transmit Differential Pair. |
| HSOIN | O | 30 | |
| HSIP | I | 23 | PCI Express Receive Differential Pair. |
| HSIN | I | 24 | |
| PERSTB | I | 20 | PCI Express Reset Signal: Active low. When the PERSTB is asserted at power-on state, the RTL8101E returns to a pre-defined reset state and is ready for initialization and configuration after the de-assertion of the PERSTB. |

5.3. EEPROM

Table 3. EEPROM

| Symbol | Type | Pin No | Description |
|----------|------|--------|---|
| EESK | O | 48 | Serial data clock. |
| EEDI/AUX | O/I | 47 | EEDI: Output to serial data input pin of EEPROM. AUX: Input pin to detect if Aux. Power exists or not on initial power-on. This pin should be connected to EEPROM. To support wakeup from ACPI D3cold or APM power-down, this pin must be pulled high to Aux. Power via a resistor. If this pin is not pulled high to Aux. Power, the RTL8101E assumes that no Aux. Power exists. |
| EEDO | I | 45 | Input from serial data output pin of EEPROM. |
| EECS | O | 44 | EECS: EEPROM chip select. |

5.4. Transceiver Interface

Table 4. Transceiver Interface

| Symbol | Type | Pin No | Description |
|--------|------|--------|--|
| MDIP0 | I/O | 3 | In MDI mode, this pair acts as the BI_DA+/- pair, and is the transmit pair in 10Base-T and 100Base-TX. |
| MDIN0 | I/O | 4 | In MDI crossover mode, this pair acts as the BI_DB+/- pair, and is the receive pair in 10Base-T and 100Base-TX. |
| MDIP1 | I/O | 6 | In MDI mode, this pair acts as the BI_DB+/- pair, and is the receive pair in 10Base-T and 100Base-TX. |
| MDIN1 | I/O | 7 | In MDI crossover mode, this pair acts as the BI_DA+/- pair, and is the transmit pair in 10Base-T and 100Base-TX. |

5.5. Clock

Table 5. Clock

| Symbol | Type | Pin No | Description |
|--------|------|--------|----------------------------------|
| CKTAL1 | I | 60 | Input of 25MHz clock reference. |
| CKTAL2 | O | 61 | Output of 25MHz clock reference. |

5.6. Reference

Table 6. Reference

| Symbol | Type | Pin No | Description |
|--------|------|--------|---|
| RSET | I | 64 | Reference. External resistor reference. |

5.7. LEDs

Table 7. LEDs

| Symbol | Type | Pin No | Description | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------|---------|-------------|---|---------|-------------|----|----|----|------|-------|------------|----|------------|------|---------|-------------|------|-------------|------|--------|------|----|------|------|----|----|------|----|
| LED0 | O | 57 | <table border="1"> <thead> <tr> <th>LEDS1-0</th> <th>00</th> <th>01</th> <th>10</th> <th>11</th> </tr> </thead> <tbody> <tr> <td>LED0</td> <td>Tx/Rx</td> <td>LINK10/ACT</td> <td>Tx</td> <td>LINK10/ACT</td> </tr> <tr> <td>LED1</td> <td>LINK100</td> <td>LINK100/ACT</td> <td>LINK</td> <td>LINK100/ACT</td> </tr> <tr> <td>LED2</td> <td>LINK10</td> <td>FULL</td> <td>Rx</td> <td>FULL</td> </tr> <tr> <td>LED3</td> <td>NA</td> <td>NA</td> <td>FULL</td> <td>NA</td> </tr> </tbody> </table> | LEDS1-0 | 00 | 01 | 10 | 11 | LED0 | Tx/Rx | LINK10/ACT | Tx | LINK10/ACT | LED1 | LINK100 | LINK100/ACT | LINK | LINK100/ACT | LED2 | LINK10 | FULL | Rx | FULL | LED3 | NA | NA | FULL | NA |
| LEDS1-0 | 00 | 01 | | 10 | 11 | | | | | | | | | | | | | | | | | | | | | | | |
| LED0 | Tx/Rx | LINK10/ACT | | Tx | LINK10/ACT | | | | | | | | | | | | | | | | | | | | | | | |
| LED1 | LINK100 | LINK100/ACT | | LINK | LINK100/ACT | | | | | | | | | | | | | | | | | | | | | | | |
| LED2 | LINK10 | FULL | | Rx | FULL | | | | | | | | | | | | | | | | | | | | | | | |
| LED3 | NA | NA | FULL | NA | | | | | | | | | | | | | | | | | | | | | | | | |
| LED1 | O | 56 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| LED2 | O | 55 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| LED3 | O | 54 | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note 1: During power down mode, the LED signals are logic high.

Note 2: LEDS1-0's initial value comes from the 93C46. If there is no 93C46, the default value of the (LEDS1, LEDS0) = (1, 1).

5.8. Power & Ground

Table 8. Power & Ground

| Symbol | Type | Pin No | Description |
|---------|-------|--------------------|---|
| VDD33 | Power | 16, 37, 46, 53 | Digital 3.3V power supply. |
| VDD15 | Power | 15, 21, 43, 49, 58 | Digital 1.5V power supply. |
| AVDD18 | Power | 5, 8 | Analog 1.8V power supply. |
| EVDD18 | Power | 22, 28 | Analog 1.8V power supply. |
| AVDD33 | Power | 2 | Analog 3.3V power supply. |
| EGND | Power | 25, 31 | Analog Ground. |
| GND | Power | 65 | Ground.(Exposed Pad) |
| VCTRL15 | O | 63 | 1.5 voltage output supplies power to VDD15 power pin. |
| VCTRL18 | O | 1 | 1.8 voltage output supplies power to AVDD18 and EVDD18 power pin. |

Note: Refer to the most updated schematic circuit for correct configuration.

5.9. NC (Not Connected) Pins

Table 9. NC (Not Connected) Pins

| Symbol | Type | Pin No | Description |
|--------|------|---|----------------|
| NC | | 9, 10, 11, 12, 13, 14, 17, 18, 32, 33, 34, 35, 38, 39, 40, 41, 42, 50, 51, 52, 59, 62 | Not Connected. |

6. Functional Description

6.1. *PCI Express Bus Interface*

The RTL8101E complies with PCI Express Base Specification Revision 1.0a, and runs at a 2.5GHz signaling rate with X1 link width, i.e., one transmit and one receive differential pair. The RTL8101E supports four types of PCI Express messages: interrupt messages, error messages, power management messages, and hot-plug messages. To ease PCB layout constraints, PCI Express lane polarity reversal and link reversal are also supported.

6.1.1. PCI Express Transmitter

The RTL8101E's PCI Express block receives digital data from the Ethernet interface and performs data scrambling with Linear Feedback Shift Register (LFSR) and 8B/10B coding technology into 10-bit code groups. Data scrambling is used to reduce the possibility of electrical resonance on the link, and 8B/10B coding technology is used to benefit embedded clocking, error detection, and DC balance by adding an overhead to the system through the addition of 2 extra bits. The data code groups are passed through its serializer for packet framing. The generated 2.5Gbps serial data is transmitted onto the PCB trace to its upstream device via a differential driver.

6.1.2. PCI Express Receiver

The RTL8101E's PCI Express block receives 2.5Gbps serial data from its upstream device to generate parallel data. The receiver's PLL circuits are re-synchronized to maintain bit and symbol lock. Through 8B/10B decoding technology and data descrambling, the original digital data is recovered and passed to the RTL8101E's internal Ethernet MAC to be transmitted onto the Ethernet media.

6.2. *LED Functions*

The RTL8101E supports four LED signals in four different configurable operation modes. The following sections describe the various LED actions.

6.2.1. Link Monitor

The Link Monitor senses link integrity, such as LINK10, LINK100, LINK10/100, LINK10/ACT, or LINK100/ACT. Whenever link status is established, the specific link LED pin is driven low. Once a cable is disconnected, the link LED pin is driven high, indicating that no network connection exists.

6.2.2. Rx LED

In 10/100Mbps mode, blinking of the Rx LED indicates that receive activity is occurring.

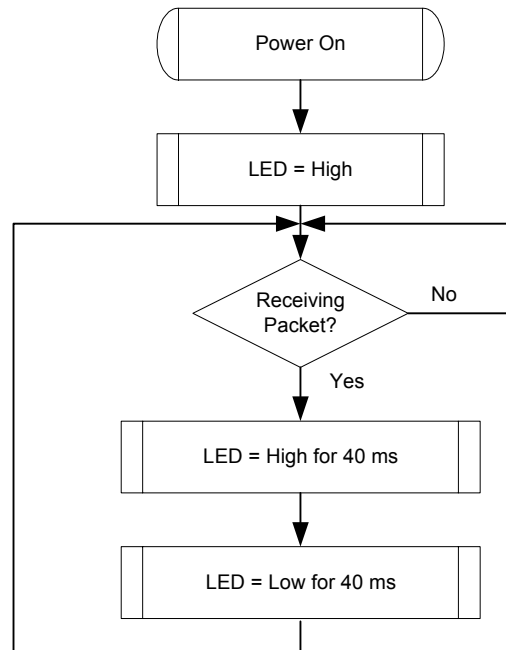


Figure 2. Rx LED

6.2.3. Tx LED

In 10/100Mbps mode, blinking of the Tx LED indicates that transmit activity is occurring.

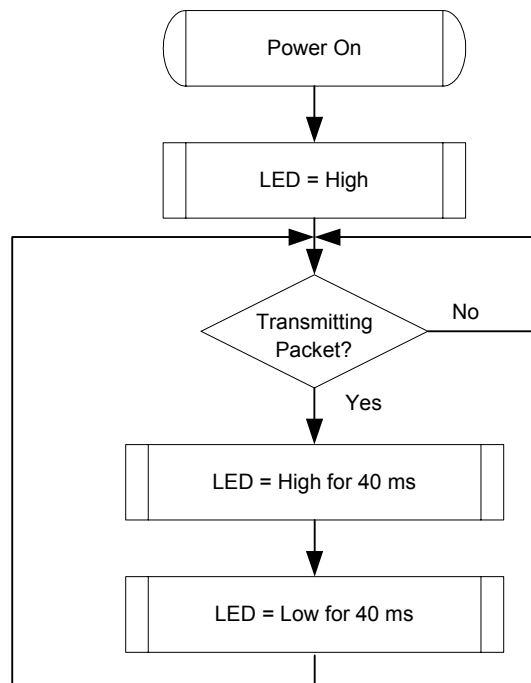


Figure 3. Tx LED

6.2.4. Tx/Rx LED

In 10/100Mbps mode, blinking of the Tx/Rx LED indicates that both transmit and receive activity is occurring.

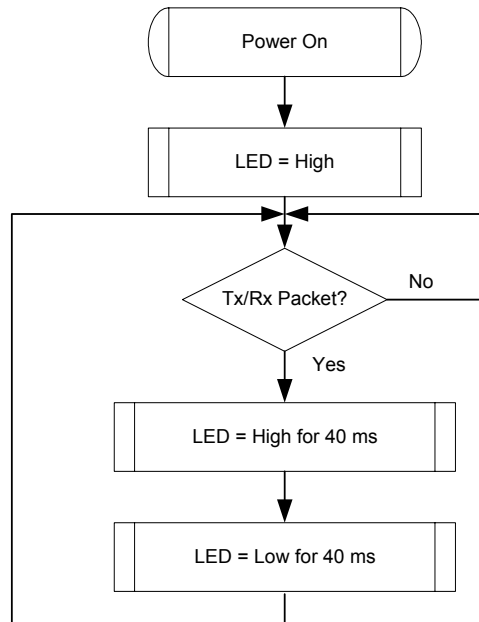


Figure 4. Tx/Rx LED

6.2.5. LINK/ACT LED

In 10/100Mbps mode, blinking of the LINK/ACT LED indicates that the RTL8101E is linked and operating properly. When this LED is high for extended periods, it indicates that a link problem exists.

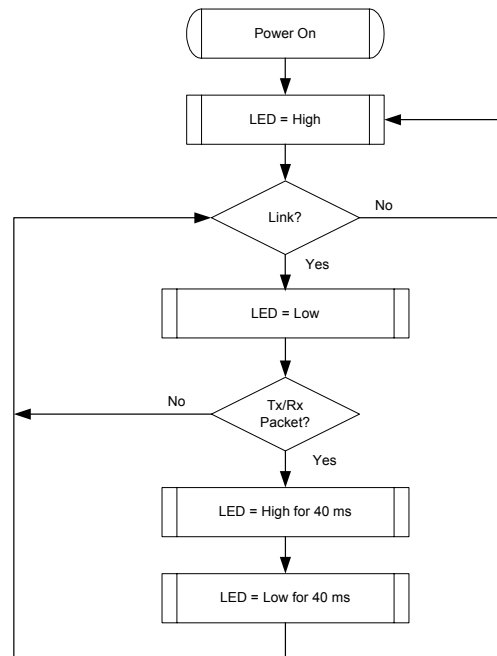


Figure 5. LINK/ACT LED

6.3. PHY Transceiver

6.3.1. PHY Transmitter

Based on state-of-the-art DSP technology and mixed-mode signal processing technology, the RTL8101E operates at 10/100Mbps over standard CAT.5 UTP cable (100Mbps), and CAT.3 UTP cable (10Mbps).

MII (100Mbps) Mode

The transmitted 4-bit nibbles (TXD[3:0]) from the MAC, clocked at 25MHz (TXC), are converted into 5B symbol code through 4B/5B coding technology, then through scrambling and serializing, are converted to 125Mhz NRZ and NRZI signals. After that, the NRZI signals are passed to the MLT3 encoder, then to the D/A converter and transmitted onto the media.

MII (10Mbps) Mode

The transmitted 4-bit nibbles (TXD[3:0]) from the MAC, clocked at 2.5MHz (TXC), are serialized into 10Mbps serial data. The 10Mbps serial data is converted into a Manchester-encoded data stream and is transmitted onto the media by the D/A converter.

6.3.2. PHY Receiver

MII (100Mbps) Mode

The MLT3 signal is processed with an ADC, equalizer, BLW (Baseline Wander) correction, timing recovery, MLT3 and NRZI decoder, descrambler, 4B/5B decoder, and is then presented to the MII interface in 4-bit-wide nibbles at a clock speed of 25MHz.

MII (10Mbps) Mode

The received differential signal is converted into a Manchester-encoded stream first. Next, the stream is processed with a Manchester decoder and is de-serialized into 4-bit-wide nibbles. The 4-bit nibbles are presented to the MII interface at a clock speed of 2.5MHz.

6.4. EEPROM Interface

The RTL8101E requires the attachment of an external EEPROM. The 93C46/93C56 is a 1K-bit/2K-bit EEPROM. The EEPROM interface permits the RTL8101E to read from, and write data to, an external serial EEPROM device.

Values in the external EEPROM allow default fields in PCI configuration space and I/O space to be overridden following a power-on or software EEPROM auto-load command. The RTL8101E will auto-load values from the EEPROM. If the EEPROM is not present, the RTL8101E initialization uses default values for the appropriate Configuration and Operational Registers. Software can read and write to the EEPROM using bit-bang accesses via the 9346CR Register, or using PCI VPD (Vital Product Data). The interface consists of EESK, EECS, EEDO, and EEDI.

The correct EEPROM (i.e. 93C46/93C56) must be used in order to ensure proper LAN function.

Table 10. EEPROM Interface

| EEPROM | Description |
|----------|--|
| EECS | 93C46/93C56 chip select. |
| EESK | EEPROM serial data clock. |
| EEDI/Aux | Input data bus/Input pin to detect whether Aux. Power exists on initial power-on. This pin should be connected to EEPROM. To support wakeup from ACPI D3cold or APM power-down, this pin must be pulled high to Aux. Power via a resistor. If this pin is not pulled high to Aux. Power, the RTL8101E assumes that no Aux. Power exists. |
| EEDO | Output data bus. |

6.5. Power Management

The RTL8101E complies with ACPI (Rev 1.0, 1.0b, 2.0), PCI Power Management (Rev 1.1), PCI Express Active State Power Management (ASPM), and Network Device Class Power Management Reference Specification (V1.0a), such as to support an Operating System-directed Power Management (OSPM) environment.

The RTL8101E can monitor the network for a Wakeup Frame, a Magic Packet, or a Re-LinkOk, and notify the system via a PCI Express Power Management Event (PME) Message, Beacon, or LANWAKEB pin when such a packet or event occurs. Then the system can be restored to a normal state to process incoming jobs.

When the RTL8101E is in power down mode (D1 ~ D3):

- The Rx state machine is stopped. The RTL8101E monitors the network for wakeup events such as a Magic Packet, Wakeup Frame, and/or Re-LinkOk, in order to wake up the system. When in power down mode, the RTL8101E will not reflect the status of any incoming packets in the ISR register and will not receive any packets into the Rx on-chip buffer.
- The on-chip buffer status and packets that have already been received into the Rx on-chip buffer before entering power down mode are held by the RTL8101E.
- Transmission is stopped. PCI Express transactions are stopped. The Tx on-chip buffer is held.
- After being restored to D0 state, the RTL8101E transmits data that was not moved into the Tx on-chip buffer during power down mode. Packets that were not transmitted completely last time are re-transmitted.

The D3cold_support_PME bit (bit15, PMC register) and the Aux_I_b2:0 bits (bit8:6, PMC register) in PCI configuration space depend on the existence of Aux power (bit15, PMC) = 1.

If EEPROM D3cold_support_PME bit (bit15, PMC) = 0, the above 4 bits are all 0's.

Example:

If EEPROM D3c_support_PME = 1:

- If aux. power exists, then PMC in PCI config space is the same as EEPROM PMC (if EEPROM PMC = C2 F7, then PCI PMC = C2 F7)
- If aux. power is absent, then PMC in PCI config space is the same as EEPROM PMC except the above 4 bits are all 0's (if EEPROM PMC = C2 F7, then PCI PMC = 02 76)

In the above case, if wakeup support is desired when main power is off, it is suggested that the EEPROM PMC be set to C2 F7 (Realtek EEPROM default value).

If EEPROM D3c_support_PME = 0:

- If aux. power exists, then PMC in PCI config space is the same as EEPROM PMC (if EEPROM PMC = C2 77, then PCI PMC = C2 77)
- If aux. power is absent, then PMC in PCI config space is the same as EEPROM PMC except the above 4 bits are all 0's (if EEPROM PMC = C2 77, then PCI PMC = 02 76)

In the above case, if wakeup support is not desired when main power is off, it is suggested that the EEPROM PMC be set to 02 76.

Link Wakeup occurs only when the following conditions are met:

- The LinkUp bit (CONFIG3#4) is set to 1, the PMEn bit (CONFIG1#0) is set to 1, and the corresponding wake-up method (message, beacon, or LANWAKEB) can be asserted in the current power state.

Magic Packet Wakeup occurs only when the following conditions are met:

- The destination address of the received Magic Packet is acceptable to the RTL8101E, e.g., a broadcast, multicast, or unicast packet addressed to the current RTL8101E adapter.
- The received Magic Packet does not contain a CRC error.
- The Magic bit (CONFIG3#5) is set to 1, the PMEn bit (CONFIG1#0) is set to 1, and the corresponding wake-up method (message, beacon, or LANWAKEB) can be asserted in the current power state.
- The Magic Packet pattern matches, i.e. $6 * FFh + MISC$ (can be none) + $16 * DID$ (Destination ID) in any part of a valid Ethernet packet.

A Wakeup Frame event occurs only when the following conditions are met:

- The destination address of the received Wakeup Frame is acceptable to the RTL8101E, e.g., a broadcast, multicast, or unicast address to the current RTL8101E adapter.
- The received Wakeup Frame does not contain a CRC error.
- The PMEn bit (CONFIG1#0) is set to 1.
- The 16-bit CRC^A of the received Wakeup Frame matches the 16-bit CRC of the sample Wakeup Frame pattern given by the local machine's OS. Or, the RTL8101E is configured to allow direct packet wakeup, e.g., a broadcast, multicast, or unicast network packet.

Note: 16-bit CRC: The RTL8101E supports two normal wakeup frames (covering 64 mask bytes from offset 0 to 63 of any incoming network packet) and three long wakeup frames (covering 128 mask bytes from offset 0 to 127 of any incoming network packet).

The corresponding wake-up method (message, beacon, or LANWAKEB) is asserted only when the following conditions are met:

- The PMEn bit (bit0, CONFIG1) is set to 1.
- The PME_En bit (bit8, PMCSR) in PCI Configuration Space is set to 1.
- The RTL8101E may assert the corresponding wake-up method (message, beacon, or LANWAKEB) in the current power state or in isolation state, depending on the PME_Support (bit15-11) setting of the PMC register in PCI Configuration Space.
- A Magic Packet, LinkUp, or Wakeup Frame has been received.
- Writing a 1 to the PME_Status (bit15) of the PMCSR register in the PCI Configuration Space clears this bit and causes the RTL8101E to stop asserting the corresponding wake-up method (message, beacon, or LANWAKEB) (if enabled).

When the RTL8101E is in power down mode, e.g., D1-D3, the IO and MEM accesses to the RTL8101E are disabled. After a PERSTB assertion, the device's power state is restored to D0 automatically if the original power state was D3_{cold}. There is almost no hardware delay at the device's power state transition. When in ACPI mode, the device does not support PME (Power Management Enable) from D0 (this is the Realtek default setting of the PMC register auto-loaded from EEPROM). The setting may be changed from the EEPROM, if required.

6.6. Vital Product Data (VPD)

Bit 31 of the Vital Product Data (VPD) capability structure in the RTL8101E's PCI Configuration Space is used to issue VPD read/write commands and is also a flag used to indicate whether the transfer of data between the VPD data register and the 93C46/93C56 has completed or not.

Write VPD register: (write data to the 93C46/93C56)

Set the flag bit to 1 at the same time the VPD address is written to write VPD data to EEPROM. When the flag bit is reset to 0 by the RTL8101E, the VPD data (4 bytes per VPD access) has been transferred from the VPD data register to EEPROM.

Read VPD register: (read data from the 93C46/93C56)

Reset the flag bit to 0 at the same time the VPD address is written to retrieve VPD data from EEPROM. When the flag bit is set to 1 by the RTL8101E, the VPD data (4 bytes per VPD access) has been transferred from EEPROM to the VPD data register.

Note1: Refer to the PCI 2.2 Specifications for further information.

Note2: The VPD address must be a DWORD-aligned address as defined in the PCI 2.2 Specifications. VPD data is always consecutive 4-byte data starting from the VPD address specified.

Note3: Realtek reserves offset 40h to 7Fh in EEPROM, mainly for VPD data to be stored.

Note4: The VPD function of the RTL8101E is designed to be able to access the full range of the 93C46/93C56 EEPROM.

7. Characteristics

7.1. Absolute Maximum Ratings

WARNING: Absolute maximum ratings are limits beyond which permanent damage may be caused to the device, or device reliability will be affected. All voltages are specified reference to GND unless otherwise specified.

Table 11. Absolute Maximum Ratings

| Symbol | Description | Minimum | Maximum | Unit |
|----------------|---------------------|---------|------------------------------------|------|
| VDD33, AVDD33 | Supply Voltage 3.3V | -0.5 | 4.6 | V |
| AVDD18, EVDD18 | Supply Voltage 1.8V | -0.5 | 2.1 | V |
| VDD15 | Supply Voltage 1.5V | -0.5 | 2 | V |
| DCinput | Input Voltage | -0.5 | Corresponding Supply Voltage + 0.5 | V |
| DCoutput | Output Voltage | -0.5 | Corresponding Supply Voltage + 0.5 | V |
| | Storage Temperature | -55 | +125 | °C |

* Refer to the most updated schematic circuit for correct configuration.

7.2. Recommended Operating Conditions

Table 12. Recommended Operating Conditions

| Description | Pins | Minimum | Typical | Maximum | Unit |
|------------------------------------|----------------|---------|---------|---------|------|
| Supply Voltage VDD | VDD33, AVDD33 | 3.0 | 3.3 | 3.6 | V |
| | AVDD18, EVDD18 | 1.62 | 1.8 | 1.98 | V |
| | VDD15 | 1.35 | 1.5 | 1.65 | V |
| Ambient Temperature T _A | - | 0 | - | 70 | °C |
| Maximum Junction Temperature | - | - | - | 125 | °C |

* Refer to the most updated schematic circuit for correct configuration.

7.3. Crystal Requirements

Table 13. Crystal Requirements

| Symbol | Description/Condition | Minimum | Typical | Maximum | Unit |
|-----------------------------|---|---------|---------|---------|------|
| F _{ref} | Parallel resonant crystal reference frequency, fundamental mode, AT-cut type. | - | 25 | - | MHz |
| F _{ref} Stability | Parallel resonant crystal frequency stability, fundamental mode, AT-cut type. T _a =25°C. | -50 | - | +50 | ppm |
| F _{ref} Tolerance | Parallel resonant crystal frequency tolerance, fundamental mode, AT-cut type. T _a =-20°C ~+70°C. | -30 | - | +30 | ppm |
| F _{ref} Duty Cycle | Reference clock input duty cycle. | 40 | - | 60 | % |
| C _L | Load Capacitance. | - | - | - | pF |
| ESR | Equivalent Series Resistance. | - | - | 30 | Ω |
| DL | Drive Level. | - | - | 0.5 | mW |

7.4. Transformer Characteristics

Table 14. Transformer Characteristics

| Parameter | Transmit End | Receive End |
|-------------------|-------------------|-------------------|
| Turn Ratio | 1:1 CT | 1:1 |
| Inductance (min.) | 350 μ H @ 8mA | 350 μ H @ 8mA |

Note: The Auto-Crossover Detection Function requires a transformer with symmetrical TX/RX and Choke after transformer placement, i.e. Pulse Engineer H1251 (refer to the suggested RTL8101E Schematic which is available for download at www.realtek.com.tw).

7.5. Thermal Characteristics

Table 15. Thermal Characteristics

| Parameter | Minimum | Maximum | Units |
|-------------------------------|---------|---------|-------|
| Storage Temperature | -55 | +125 | °C |
| Ambient Operating Temperature | 0 | 70 | °C |

7.6. DC Characteristics

Table 16. DC Characteristics

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Units |
|----------------|--|--------------------|-------------|---------|-------------|---------|
| VDD33, AVDD33 | 3.3V Supply Voltage | - | 3.0 | 3.3 | 3.6 | V |
| AVDD18, EVDD18 | 1.8V Supply Voltage | - | 1.62 | 1.8 | 1.98 | V |
| VDD15 | 1.5V Supply Voltage | - | 1.35 | 1.5 | 1.65 | V |
| Voh | Minimum High Level Output Voltage | Ioh = -8mA | 0.9 * VDD33 | - | VDD33 | V |
| Vol | Maximum Low Level Output Voltage | Iol = 8mA | - | - | 0.1 * VDD33 | V |
| Vih | Minimum High Level Input Voltage | - | 0.5 * VDD33 | - | VDD33+0.5 | V |
| Vil | Maximum Low Level Input Voltage | - | -0.5 | - | 0.3 * VDD33 | V |
| Iin | Input Current | Vin = VDD33 or GND | -1.0 | - | 1.0 | μ A |
| Icc33 | Average Operating Supply Current from 3.3V | - | - | TBD | - | mA |
| Icc18 | Average Operating Supply Current from 1.8V | - | - | TBD | - | mA |
| Icc15 | Average Operating Supply Current from 1.5V | - | - | TBD | - | mA |

* Refer to the most updated schematic circuit for correct configuration.

7.7. AC Characteristics

7.7.1. Serial EEPROM Interface Timing

93C46(64*16)/93C56(128*16)

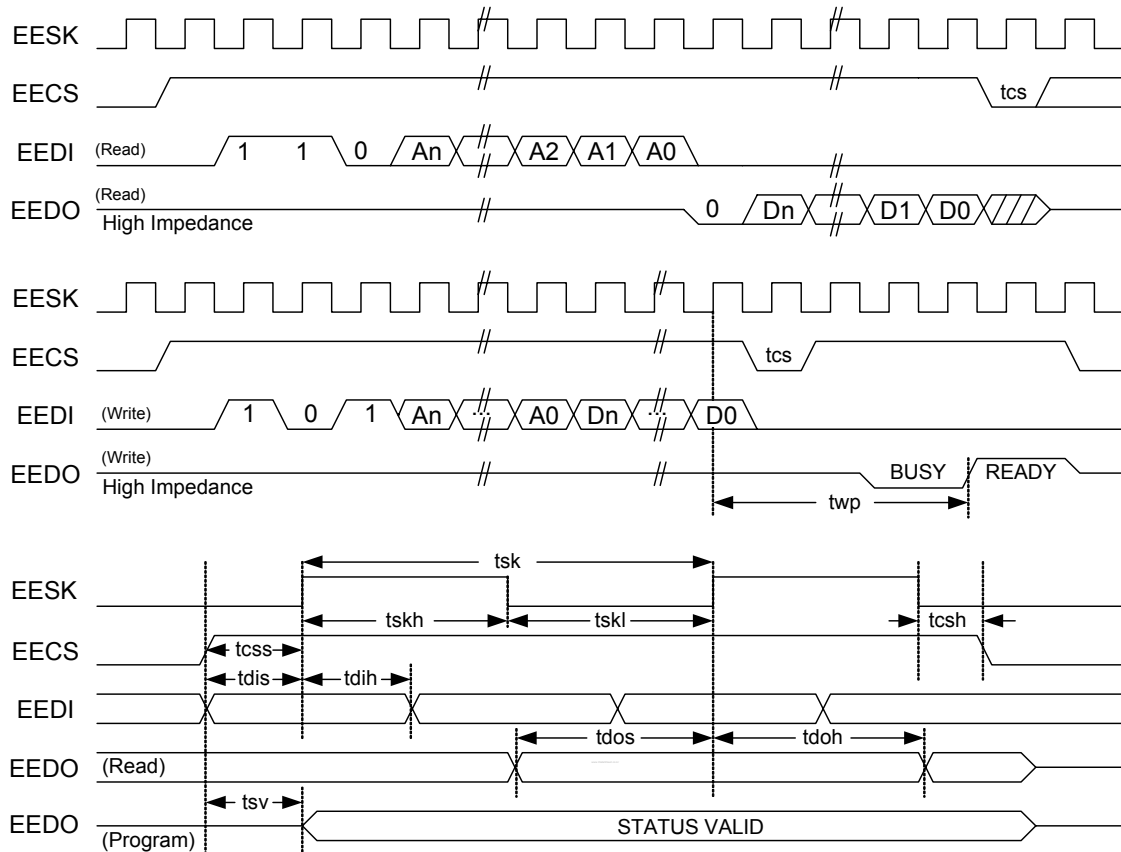


Figure 6. Serial EEPROM Interface Timing

Table 17. EEPROM Access Timing Parameters

| Symbol | Parameter | EEPROM Type | Min. | Max. | Unit |
|--------|---------------------|-------------|------|------|------|
| tcs | Minimum CS Low Time | 9346 | 1000 | - | ns |
| twp | Write Cycle Time | 9346 | - | 10 | ms |
| tsk | SK Clock Cycle Time | 9346 | 4 | - | μs |
| tskh | SK High Time | 9346 | 1000 | - | ns |
| tskl | SK Low Time | 9346 | 1000 | - | ns |
| tcsh | CS Hold Time | 9346 | 0 | - | ns |
| tcshs | CS Setup Time | 9346 | 200 | - | ns |
| tdis | DI Setup Time | 9346 | 400 | - | ns |
| tdih | DI Hold Time | 9346 | 400 | - | ns |
| tdos | DO Setup Time | 9346 | 2000 | - | ns |
| tdoh | DO Hold Time | 9346 | - | 2000 | ns |
| tsv | CS to Status Valid | 9346 | - | 1000 | ns |

7.8. PCI Express Bus Parameters

7.8.1. Differential Transmitter Parameters

Table 18. Differential Transmitter Parameters

| Symbol | Parameter | Min | Typical | Max | Units |
|---|--|--------|---------|----------|-------|
| UI | Unit Interval ² | 399.88 | 400 | 400.12 | ps |
| V _{TX-DIFFP-P} | Differential Peak to Peak Output Voltage | 0.800 | - | 1.2 | V |
| V _{TX-DE-RATIO} | De-Emphasized Differential Output Voltage (Ratio) | -3.0 | -3.5 | -4.0 | dB |
| T _{TX-EYE} | Minimum Tx Eye Width | 0.70 | - | - | UI |
| T _{TX-EYE-MEDIAN-to-MAX-JITTER} | Maximum time between the jitter median and maximum deviation from the median | - | - | 0.15 | UI |
| T _{TX-RISE, T_{TX-FALL}} | D+/D- Tx Output Rise/Fall Time | 0.125 | - | - | UI |
| V _{TX-CM-ACp} | RMS AC Peak Common Mode Output Voltage | | - | 20 | mV |
| V _{TX-CM-DCACTIVE-IDLEDELTA} | Absolute Delta of DC Common Mode Voltage During L0 and Electrical Idle | 0 | - | 100 | mV |
| V _{TX-CM-DCLINE-DELTA} | Absolute Delta of DC Common Mode Voltage between D+ and D- | 0 | - | 25 | mV |
| V _{TX-IDLE-DIFFP} | Electrical Idle Differential Peak Output Voltage | 0 | - | 20 | mV |
| V _{TX-RCV-DETECT} | The amount of voltage change allowed during Receiver Detection | - | - | 600 | mV |
| V _{TX-DC-CM} | The TX DC Common Mode Voltage | 0 | - | 3.6 | V |
| I _{TX-SHORT} | TX Short Circuit Current Limit | | - | 90 | mA |
| T _{TX-IDLE-MIN} | Minimum time spent in Electrical Idle | 50 | - | - | UI |
| T _{TX-IDLE-SETTO-IDLE} | Maximum time to transition to a valid Electrical Idle after sending an Electrical Idle ordered set | - | - | 20 | UI |
| T _{TX-IDLE-TOTO-DIFF-DATA} | Maximum time to transition to valid TX specifications after leaving an Electrical Idle condition | - | - | 20 | UI |
| RL _{TX-DIFF} | Differential Return Loss | 12 | - | - | dB |
| RL _{TX-CM} | Common Mode Return Loss | 6 | - | - | dB |
| Z _{TX-DIFF-DC} | DC Differential TX Impedance | 80 | 100 | 120 | Ω |
| Z _{TX-DC} | Transmitter DC Impedance | 40 | - | - | Ω |
| L _{TX-SKEW} | Lane-to-Lane Output Skew | - | - | 500+2 UI | ps |
| C _{TX} | AC Coupling Capacitor | 75 | - | 200 | nF |
| T _{crosslink} | Crosslink Random Timeout | 0 | - | 1 | ms |

Notel: Refer to PCI Express Base Specification, rev.1.0a, for correct measurement environment setting of each parameter.

Note2: The data rate can be modulated with an SSC (Spread Spectrum Clock) from +0 to -0.5% of the nominal data rate frequency, at a modulation rate in the range not exceeding 30 kHz – 33 kHz. The +/- 300 ppm requirement still holds, which requires the two communicating ports be modulated such that they never exceed a total of 600 ppm difference.

7.8.2. Differential Receiver Parameters

Table 19. Differential Receiver Parameters

| Symbol | Parameter | Min. | Typical | Max. | Units |
|-----------------------------------|--|--------|---------|--------|----------|
| UI | Unit Interval | 399.88 | 400 | 400.12 | ps |
| $V_{RX-DIFFp-p}$ | Differential Input Peak to Peak Voltage | 0.175 | - | 1.200 | V |
| T_{RX-EYE} | Minimum Receiver Eye Width | 0.4 | - | - | UI |
| $T_{RX-EYE-MEDIAN-to-MAX-JITTER}$ | Maximum time between the jitter median and maximum deviation from the median | - | - | 0.3 | UI |
| $V_{RX-CM-ACp}$ | AC Peak Common Mode Input Voltage | - | - | 150 | mV |
| $RL_{RX-DIFF}$ | Differential Return Loss | 15 | - | - | dB |
| RL_{RX-CM} | Common Mode Return Loss | 6 | - | - | dB |
| $Z_{RX-DIFF-DC}$ | DC Differential Input Impedance | 80 | 100 | 120 | Ω |
| Z_{RX-DC} | DC Input Impedance | 40 | 50 | 60 | Ω |
| $Z_{RX-HIGH-IMP-DC}$ | Powered Down DC Input Impedance | 200 k | - | - | Ω |
| $V_{RX-IDLE-DET-DIFFp-p}$ | Electrical Idle Detect Threshold | 65 | - | 175 | mV |
| $T_{RX-IDLE-DET-DIFFENTERTIME}$ | Unexpected Electrical Idle Enter Detect Threshold Integration Time | - | - | 10 | ms |
| $L_{RX-SKEW}$ | Total Skew | - | - | 20 | ns |

Note: Refer to PCI Express Base Specification, rev.1.0a, for correct measurement environment setting of each parameter.

7.8.3. REFCLK Parameters

Table 20. REFCLK Parameters

| Symbol | Parameter | 100MHz Input | | Units |
|--------------------------|---|-------------------|----------------------|-------|
| | | Min | Max | |
| T_{absmin} | Absolute min. DIF CLK Period | 9.872 | - | ns |
| T_{rise} | Rise Time | 175 | 700 | ps |
| T_{fall} | Fall Time | 175 | 700 | ps |
| $h\Delta T_{rise}$ | Rise Time Variation | - | 125 | ps |
| ΔT_{fall} | Fall Time Variation | - | 125 | ps |
| Rise/Fall Matching | | - | 20 | % |
| V_{high} | Voltage High (typical 0.71V) | 660 | 850 | mV |
| V_{low} | Voltage Low (typical 0.0V) | -150 | - | mV |
| $V_{cross absolute}$ | Absolute Crossing Point Voltages | 250 | 550 | mV |
| $V_{cross relative}$ | Relative Crossing Point Voltages | Note ² | Note ² | V |
| Total ΔV_{cross} | Total Variation of V_{cross} over all edges | - | 140 | mV |
| $T_{ccjitter}$ | Cycle to Cycle Jitter | - | 125 | ps |
| Duty Cycle | | 45 | 55 | % |
| V_{ovs} | Maximum Voltage (Overshoot) | - | $V_{high avg} + 0.3$ | V |
| V_{uds} | Minimum Voltage (Undershoot) | - | -0.3 | V |
| V_{rb} | Ringback Voltage | 0.2 | N/A | V |

Note1: Refer to PCI Express Base Specification, rev.1.0a, for correct measurement environment setting of each parameter.

Note2: $V_{cross relative Min} = 0.5(V_{high avg} - 0.710) + 0.250$, $V_{cross relative Max} = 0.5(V_{high avg} - 0.710) + 0.550$. The crossing point must meet the absolute and relative crossing point specifications simultaneously.

Note3: The nominal single-ended swing for each clock is 0 to 0.7V with a nominal frequency of 100MHz \pm 300 PPM.

Note4: The reference clocks may support spread spectrum clocking. The minimum clock period cannot be violated.

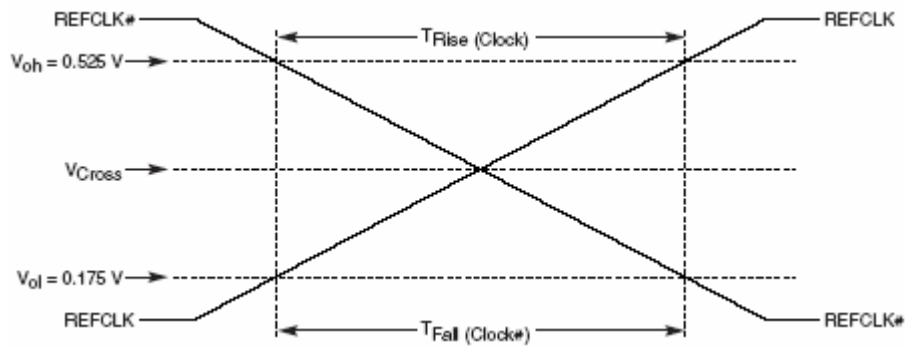


Figure 7. REFCLK Single-Ended Measurement Points for T_{rise} and T_{fall}

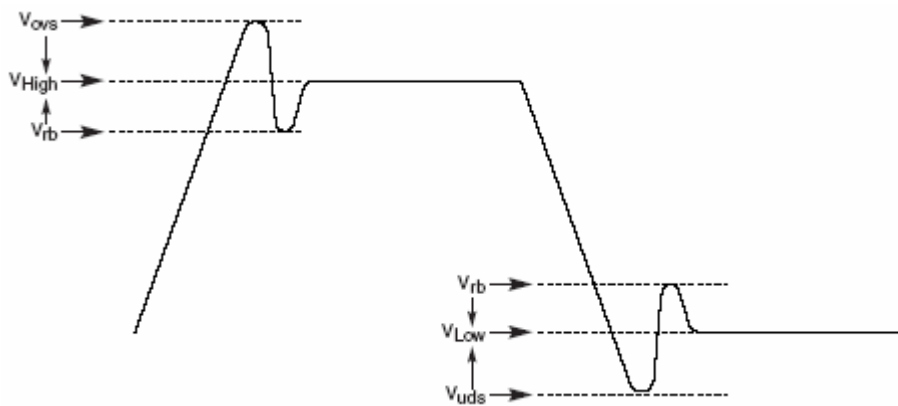


Figure 8. REFCLK Single-Ended Measurement Points for V_{ovs} , V_{uds} , and V_{rb}

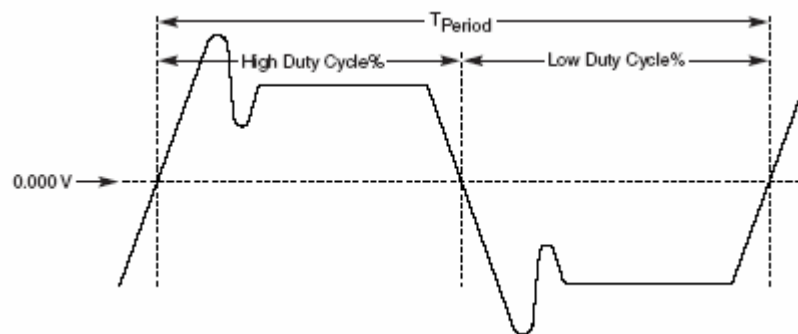
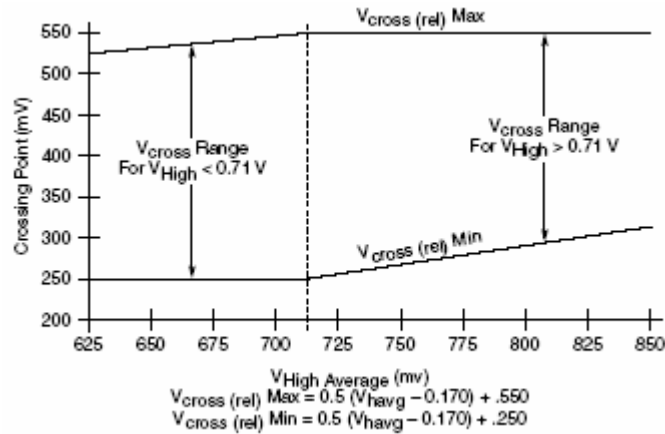


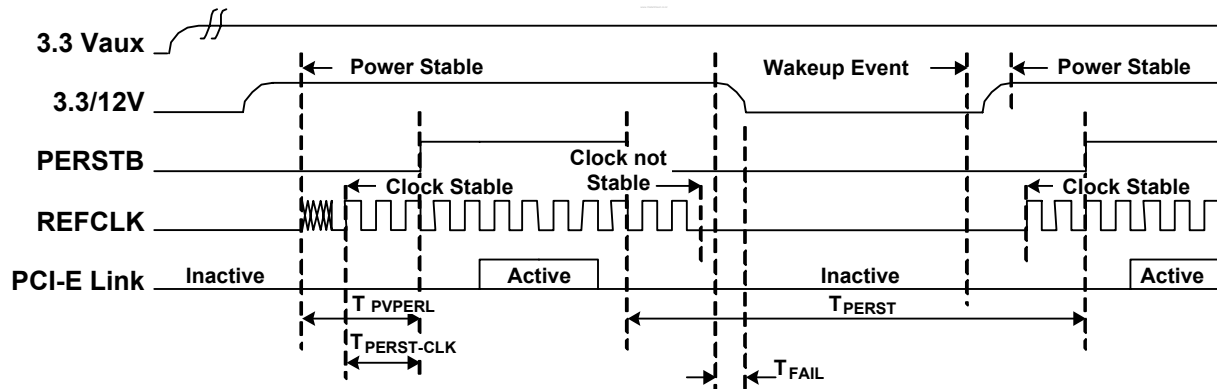
Figure 9. REFCLK Differential Measurement Points for T_{period} , Duty Cycle, and Jitter


Figure 10. REFCLK V_{cross} Range

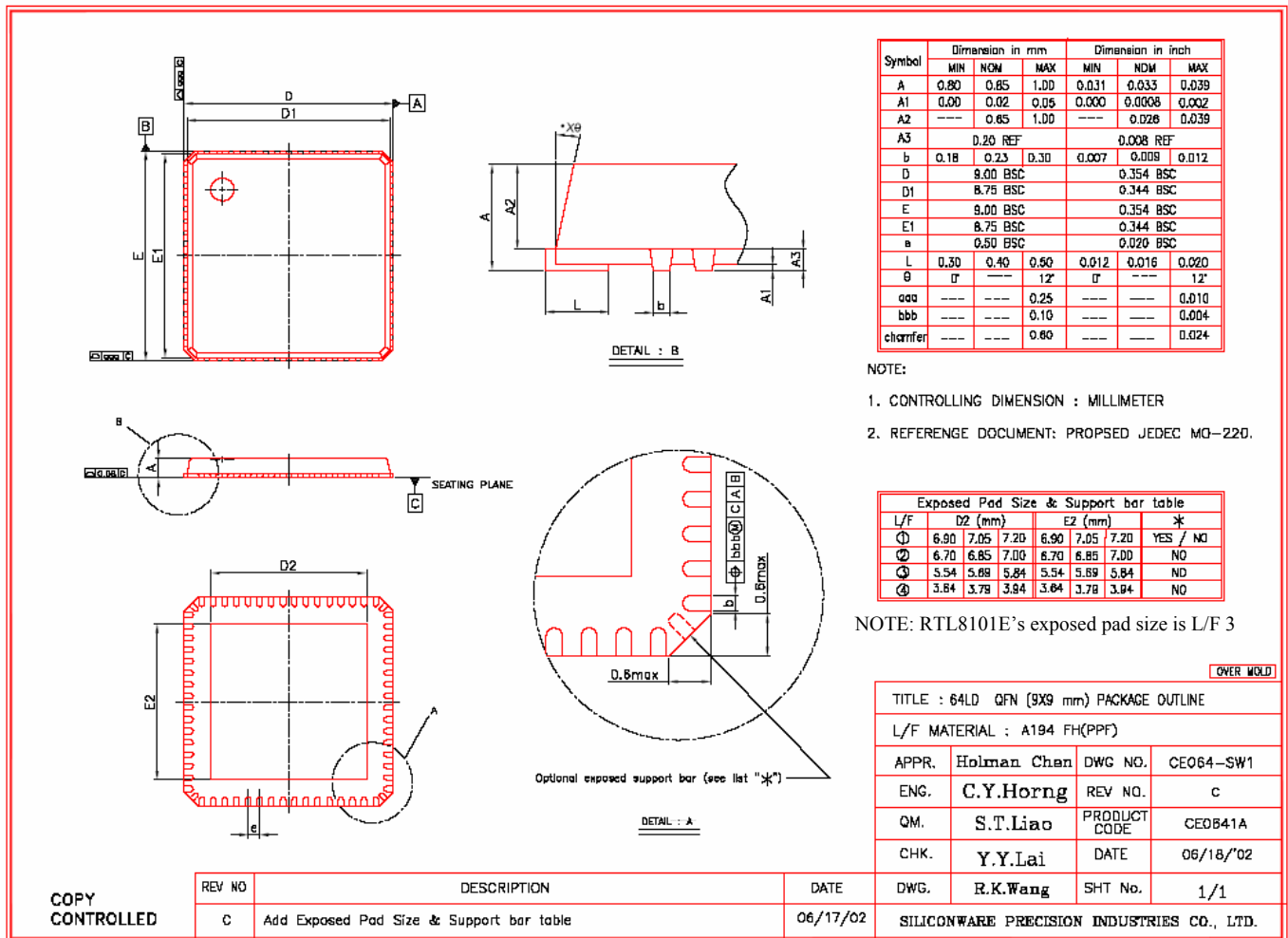
7.8.4. Auxiliary Signal Timing Parameters

Table 21. Auxiliary Signal Timing Parameters

| Symbol | Parameter | Min | Max | Units |
|-----------------|---------------------------------------|-----|-----|---------|
| T_{PVPERL} | Power stable to PERSTB inactive | 100 | - | ms |
| $T_{PERST-CLK}$ | REFCLK stable before PERSTB inactive | 100 | - | μ s |
| T_{PERST} | PERSTB active time | 100 | - | μ s |
| T_{FAIL} | Power level invalid to PWRGD inactive | - | 500 | ns |
| T_{WKRF} | LANWAKEB rise – fall time | - | 100 | ns |


Figure 11. Auxiliary Signal Timing

8. Mechanical Dimensions



9. Ordering Information

Table 22. Ordering Information

| Part Number | Package | Status |
|-------------|----------------------------|------------|
| RTL8101E-GR | 64-Pin QFN 'Green' package | Production |

Note: See page 3 for package ID information.

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