

REALTEK

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RTL8111D-GR
RTL8111DL-GR
RTL8111D-VB-GR
RTL8111DL-VB-GR
RTL8111DL-VB-CG

INTEGRATED GIGABIT ETHERNET CONTROLLER FOR PCI EXPRESS APPLICATIONS

DATASHEET

(CONFIDENTIAL: Development Partners Only)

Rev. 1.8

21 July 2010

Track ID: JATR-2265-11



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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.

REVISION HISTORY

| Revision | Release Date | Summary |
|----------|--------------|---|
| 1.0 | 2008/05/13 | First release. |
| 1.1 | 2008/07/03 | Revised section 6.2.6, page 12. Added section 9.2, page 37. Added section 9.3, page 37. |
| 1.2 | 2008/07/29 | Updated licensing information. |
| 1.3 | 2008/08/08 | Added Deep Slumber Mode (DSM) power saving to features list on page 2. |
| 1.4 | 2008/08/29 | Revised Figure 2, page 4 (Pin23). |
| 1.5 | 2009/01/07 | Switching regulator output revised from 1.2V to 1.05V. Revised Table 19 Crystal Requirements, page 27, Drive Level value. |
| 1.6 | 2009/03/10 | Added RTL8111D-VB-GR & RTL8111DL-VB-GR product numbers. Added Deep Slumber Mode (DSM) V2 Feature on page 2. Added section 6.9 Deep Slumber Mode (DSM) V1 & V2, page 19. |
| 1.7 | 2009/08/14 | Revised section 5.7 LEDs, page 7. Revised section 6.2.6 Customizable LED Configuration, page 12. Revised section 6.5 EEPROM Interface, page 14. Revised section 7 Switching Regulator, page 20. Revised section 9.2 RTL8111DL & RTL8111DL-VB (48-Pin LQFP), page 37. Revised section 9.3 Mechanical Dimensions Notes (RTL8111DL/RTL8111DL-VB 48-Pin), page 37. |
| 1.8 | 2010/07/21 | Added RTL8111DL-VB-CG product number. |

Table of Contents

| | |
|--|-----------|
| 1. GENERAL DESCRIPTION | 1 |
| 2. FEATURES | 2 |
| 3. SYSTEM APPLICATIONS | 2 |
| 4. PIN ASSIGNMENTS | 3 |
| 4.1. RTL8111D & RTL8111D-VB (64-PIN QFN) | 3 |
| 4.2. PACKAGE IDENTIFICATION..... | 3 |
| 4.3. RTL8111DL & RTL8111DL-VB (48-PIN LQFP)..... | 4 |
| 4.4. PACKAGE IDENTIFICATION..... | 4 |
| 5. PIN DESCRIPTIONS | 5 |
| 5.1. POWER MANAGEMENT/ISOLATION | 5 |
| 5.2. PCI EXPRESS INTERFACE | 5 |
| 5.3. TRANSCEIVER INTERFACE..... | 6 |
| 5.4. CLOCK | 6 |
| 5.5. REGULATOR AND REFERENCE..... | 6 |
| 5.6. EEPROM | 7 |
| 5.7. LEDs | 7 |
| 5.8. POWER AND GROUND | 8 |
| 5.9. GPIO PINS | 8 |
| 5.10. TEST PINS | 8 |
| 5.11. NC PINS | 8 |
| 6. FUNCTIONAL DESCRIPTION | 9 |
| 6.1. PCI EXPRESS BUS INTERFACE..... | 9 |
| 6.1.1. PCI Express Transmitter | 9 |
| 6.1.2. PCI Express Receiver..... | 9 |
| 6.2. LED FUNCTIONS..... | 9 |
| 6.2.1. Link Monitor..... | 9 |
| 6.2.2. Rx LED..... | 10 |
| 6.2.3. Tx LED | 10 |
| 6.2.4. Tx/Rx LED..... | 11 |
| 6.2.5. LINK/ACT LED | 11 |
| 6.2.6. Customizable LED Configuration | 12 |
| 6.3. PHY TRANSCEIVER | 13 |
| 6.3.1. PHY Transmitter..... | 13 |
| 6.3.2. PHY Receiver | 13 |
| 6.4. NEXT PAGE | 14 |
| 6.5. EEPROM INTERFACE..... | 14 |
| 6.6. POWER MANAGEMENT..... | 15 |
| 6.7. VITAL PRODUCT DATA (VPD)..... | 17 |
| 6.8. RECEIVE-SIDE SCALING (RSS) | 18 |
| 6.8.1. Receive-Side Scaling (RSS) Initialization | 18 |
| 6.8.2. RSS Operation | 19 |
| 6.9. DEEP SLUMBER MODE (DSM) V1 & V2..... | 19 |
| 7. SWITCHING REGULATOR | 20 |
| 7.1. INDUCTOR AND CAPACITOR PARTS LIST..... | 20 |
| 7.2. MEASUREMENT CRITERIA..... | 21 |
| 7.3. EFFICIENCY MEASUREMENT | 25 |
| 7.4. POWER SEQUENCE | 26 |

| | | |
|------------|--|-----------|
| 8. | CHARACTERISTICS..... | 27 |
| 8.1. | ABSOLUTE MAXIMUM RATINGS | 27 |
| 8.2. | RECOMMENDED OPERATING CONDITIONS | 27 |
| 8.3. | CRYSTAL REQUIREMENTS..... | 27 |
| 8.4. | OSCILLATOR REQUIREMENTS | 28 |
| 8.5. | THERMAL CHARACTERISTICS..... | 28 |
| 8.6. | DC CHARACTERISTICS..... | 28 |
| 8.7. | AC CHARACTERISTICS..... | 29 |
| 8.7.1. | <i>Serial EEPROM Interface Timing</i> | 29 |
| 8.8. | PCI EXPRESS BUS PARAMETERS..... | 30 |
| 8.8.1. | <i>Differential Transmitter Parameters</i> | 30 |
| 8.8.2. | <i>Differential Receiver Parameters</i> | 31 |
| 8.8.3. | <i>REFCLK Parameters</i> | 31 |
| 8.8.4. | <i>Auxiliary Signal Timing Parameters</i> | 35 |
| 9. | MECHANICAL DIMENSIONS..... | 36 |
| 9.1. | RTL8111D & RTL8111D-VB (64-PIN QFN) | 36 |
| 9.2. | RTL8111DL & RTL8111DL-VB (48-PIN LQFP)..... | 37 |
| 9.3. | MECHANICAL DIMENSIONS NOTES (RTL8111DL/RTL8111DL-VB 48-PIN)..... | 37 |
| 10. | ORDERING INFORMATION | 38 |

List of Tables

| | |
|--|----|
| TABLE 1. POWER MANAGEMENT/ISOLATION | 5 |
| TABLE 2. PCI EXPRESS INTERFACE | 5 |
| TABLE 3. TRANSCEIVER INTERFACE | 6 |
| TABLE 4. CLOCK | 6 |
| TABLE 5. REGULATOR AND REFERENCE | 6 |
| TABLE 6. EEPROM | 7 |
| TABLE 7. LEDs | 7 |
| TABLE 8. POWER AND GROUND | 8 |
| TABLE 9. GPIO PINS | 8 |
| TABLE 10. TEST PINS | 8 |
| TABLE 11. NC PINS | 8 |
| TABLE 12. LED SELECT (IO REGISTER OFFSET 18H~19H)..... | 12 |
| TABLE 13. CUSTOMIZED LEDs | 12 |
| TABLE 14. EEPROM INTERFACE | 14 |
| TABLE 15. INDUCTOR AND CAPACITOR PARTS LIST | 20 |
| TABLE 16. POWER SEQUENCE PARAMETER | 26 |
| TABLE 17. ABSOLUTE MAXIMUM RATINGS | 27 |
| TABLE 18. RECOMMENDED OPERATING CONDITIONS | 27 |
| TABLE 19. CRYSTAL REQUIREMENTS | 27 |
| TABLE 20. OSCILLATOR REQUIREMENTS | 28 |
| TABLE 21. THERMAL CHARACTERISTICS | 28 |
| TABLE 22. DC CHARACTERISTICS | 28 |
| TABLE 23. EEPROM ACCESS TIMING PARAMETERS | 29 |
| TABLE 24. DIFFERENTIAL TRANSMITTER PARAMETERS | 30 |
| TABLE 25. DIFFERENTIAL RECEIVER PARAMETERS | 31 |
| TABLE 26. REFCLK PARAMETERS | 31 |
| TABLE 27. AUXILIARY SIGNAL TIMING PARAMETERS | 35 |
| TABLE 28. ORDERING INFORMATION | 38 |

List of Figures

| | | |
|------------|--|----|
| FIGURE 1. | RTL8111D & RTL8111D-VB (64-PIN QFN) PIN ASSIGNMENTS | 3 |
| FIGURE 2. | RTL8111DL & RTL8111DL-VB (48-PIN LQFP) PIN ASSIGNMENTS | 4 |
| FIGURE 3. | RX LED..... | 10 |
| FIGURE 4. | TX LED..... | 10 |
| FIGURE 5. | TX/RX LED..... | 11 |
| FIGURE 6. | LINK/ACT LED..... | 11 |
| FIGURE 7. | INPUT VOLTAGE OVERSHOOT <4V (GOOD)..... | 21 |
| FIGURE 8. | INPUT VOLTAGE OVERSHOOT >4V (BAD)..... | 21 |
| FIGURE 9. | CERAMIC 22 μ F 1210 (X5R) (GOOD)..... | 22 |
| FIGURE 10. | CERAMIC 22 μ F 0805 (Y5V) (BAD)..... | 22 |
| FIGURE 11. | ELECTROLYTIC 100 μ F (RIPPLE TOO HIGH)..... | 23 |
| FIGURE 12. | 4R7GTSD32 (GOOD) | 24 |
| FIGURE 13. | 1 μ H BEAD (BAD) | 24 |
| FIGURE 14. | SWITCHING REGULATOR EFFICIENCY MEASUREMENT CHECKPOINT | 25 |
| FIGURE 15. | POWER SEQUENCE | 26 |
| FIGURE 16. | SERIAL EEPROM INTERFACE TIMING..... | 29 |
| FIGURE 17. | SINGLE-ENDED MEASUREMENT POINTS FOR ABSOLUTE CROSS POINT AND SWING | 33 |
| FIGURE 18. | SINGLE-ENDED MEASUREMENT POINTS FOR DELTA CROSS POINT | 33 |
| FIGURE 19. | SINGLE-ENDED MEASUREMENT POINTS FOR RISE AND FALL TIME MATCHING | 33 |
| FIGURE 20. | DIFFERENTIAL MEASUREMENT POINTS FOR DUTY CYCLE AND PERIOD | 34 |
| FIGURE 21. | DIFFERENTIAL MEASUREMENT POINTS FOR RISE AND FALL TIME | 34 |
| FIGURE 22. | DIFFERENTIAL MEASUREMENT POINTS FOR RINGBACK..... | 34 |
| FIGURE 23. | REFERENCE CLOCK SYSTEM MEASUREMENT POINT AND LOADING | 35 |
| FIGURE 24. | AUXILIARY SIGNAL TIMING..... | 35 |

1. General Description

The Realtek RTL8111D(L)/RTL8111D(L)-VB Gigabit Ethernet controllers combine a triple-speed IEEE 802.3 compliant Media Access Controller (MAC) with a triple-speed Ethernet transceiver, PCI Express bus controller, and embedded memory. With state-of-the-art DSP technology and mixed-mode signal technology, the RTL8111D(L)/RTL8111D(L)-VB offers high-speed transmission over CAT 5 UTP cable or CAT 3 UTP (10Mbps only) cable. Functions such as Crossover Detection and 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 RTL8111D(L)/RTL8111D(L)-VB supports the PCI Express 1.1 bus interface for host communications with power management, and is compliant with the IEEE 802.3u specification for 10/100Mbps Ethernet and the IEEE 802.3ab specification for 1000Mbps 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. The RTL8111D(L)/RTL8111D(L)-VB features embedded One-Time-Programmable (OTP) memory to replace the external EEPROM (93C46/93C56/93C66).

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 MSI (Message Signaled Interrupt) and MSI-X are also supported.

In addition to the ACPI feature, remote wake-up (including AMD Magic Packet™ 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 RTL8111D(L)/RTL8111D(L)-VB.

The RTL8111D(L)/RTL8111D(L)-VB is fully compliant with Microsoft® NDIS5, NDIS6(IPv4, IPv6, TCP, UDP) Checksum and Segmentation Task-offload (Large send and Giant send) 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 RTL8111D(L)/RTL8111D(L)-VB supports Receive Side Scaling (RSS) to hash incoming TCP connections and load-balance received data processing across multiple CPUs. RSS improves the number of transactions per second and number of connections per second, for increased network throughput.

The device also features inter-connect 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 device embeds an adaptive equalizer in the PCIe PHY for ease of system integration and excellent link quality. The equalizer enables the length of the PCB traces to reach 40 inches.

The RTL8111D(L)/RTL8111D(L)-VB is suitable for multiple market segments and emerging applications, such as desktop, mobile, workstation, server, communications platforms, and embedded applications.

The RTL8111D(L)/RTL8111D(L)-VB supports the Deep Slumber Mode (DSM) power saving V1/V2 feature. See the separate DSM application notes for details.

2. Features

- Integrated 10/100/1000 transceiver
- Auto-Negotiation with Next Page capability
- Supports PCI Express 1.1
- Supports pair swap/polarity/skew correction
- Crossover Detection & Auto-Correction
- Wake-on-LAN and remote wake-up support
- Microsoft[®] NDIS5, NDIS6 Checksum Offload (IPv4, IPv6, TCP, UDP) and Segmentation Task-offload (Large send v1 and Large send v2) support
- Supports Full Duplex flow control (IEEE 802.3x)
- Supports jumbo frame to 9K bytes
- 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
- Embedded OTP memory can replace the external EEPROM
- Serial EEPROM
- Transmit/Receive on-chip buffer support
- Supports power down/link down power saving
- Built-in Switching regulator
- Supports PCI MSI (Message Signaled Interrupt) and MSI-X
- Supports quad core Receive-Side Scaling (RSS)
- Embeds an adaptive equalizer in PCI Express PHY (PCB traces to reach 40 inches)
- Supports Deep Slumber Mode (DSM) power saving V1/V2 features (V2 for RTL8111D(L)-VB only)
- Customized LEDs
- Packages
 - ◆ 64-pin QFN ‘Green’ package (RTL8111D & RTL8111D-VB)
 - ◆ 48-pin LQFP ‘Green’ package (RTL8111DL & RTL8111DL-VB)

3. System Applications

- PCI Express Gigabit Ethernet on Motherboard, Notebook, or Embedded system

4. Pin Assignments

4.1. RTL8111D & RTL8111D-VB (64-Pin QFN)

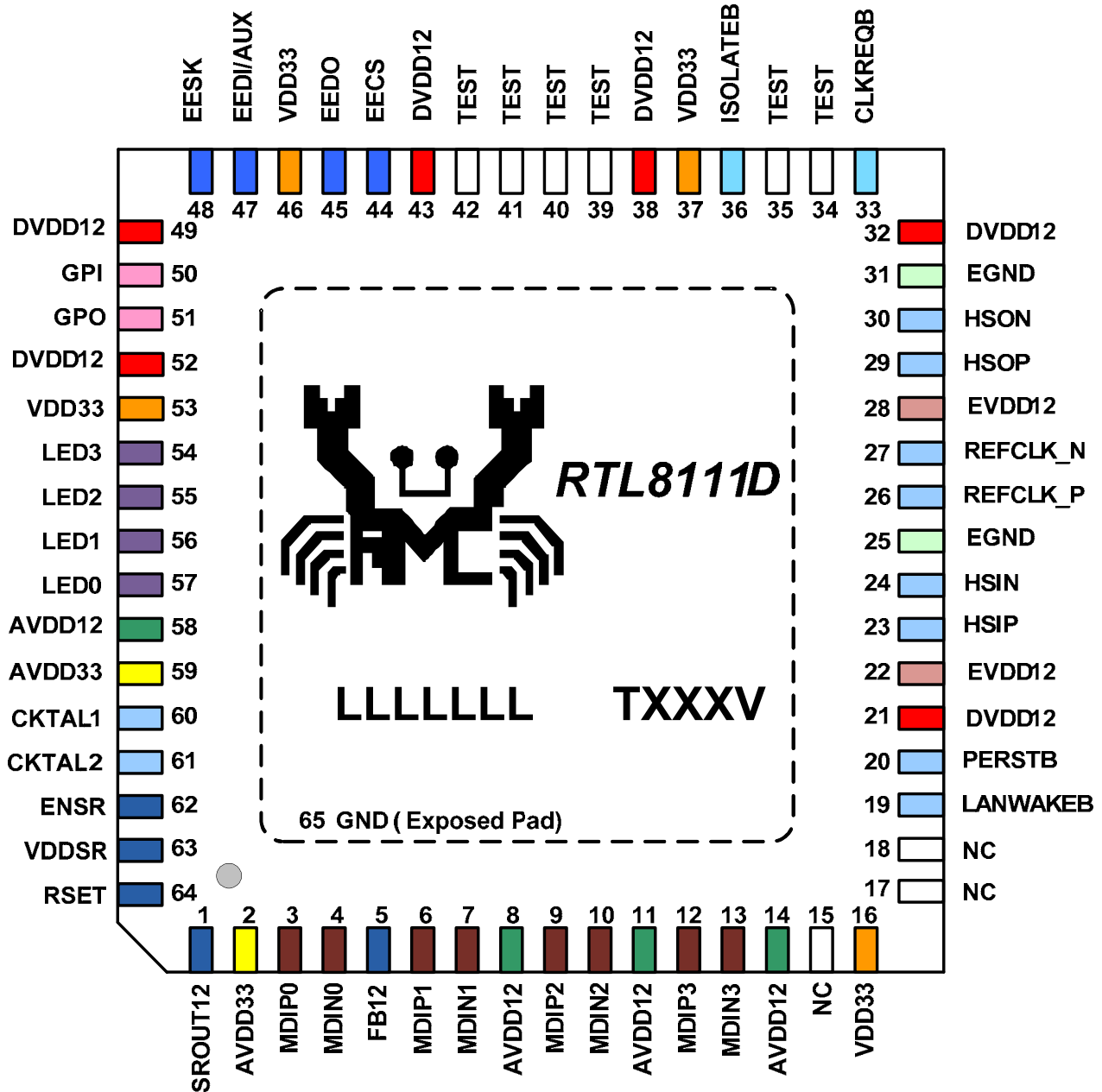


Figure 1. RTL8111D & RTL8111D-VB (64-Pin QFN) Pin Assignments

4.2. Package Identification

‘Green’ package is indicated by a ‘G’ in the location marked ‘T’ in Figure 1. The version number is shown in the location marked ‘V’.

4.3. RTL8111DL & RTL8111DL-VB (48-Pin LQFP)

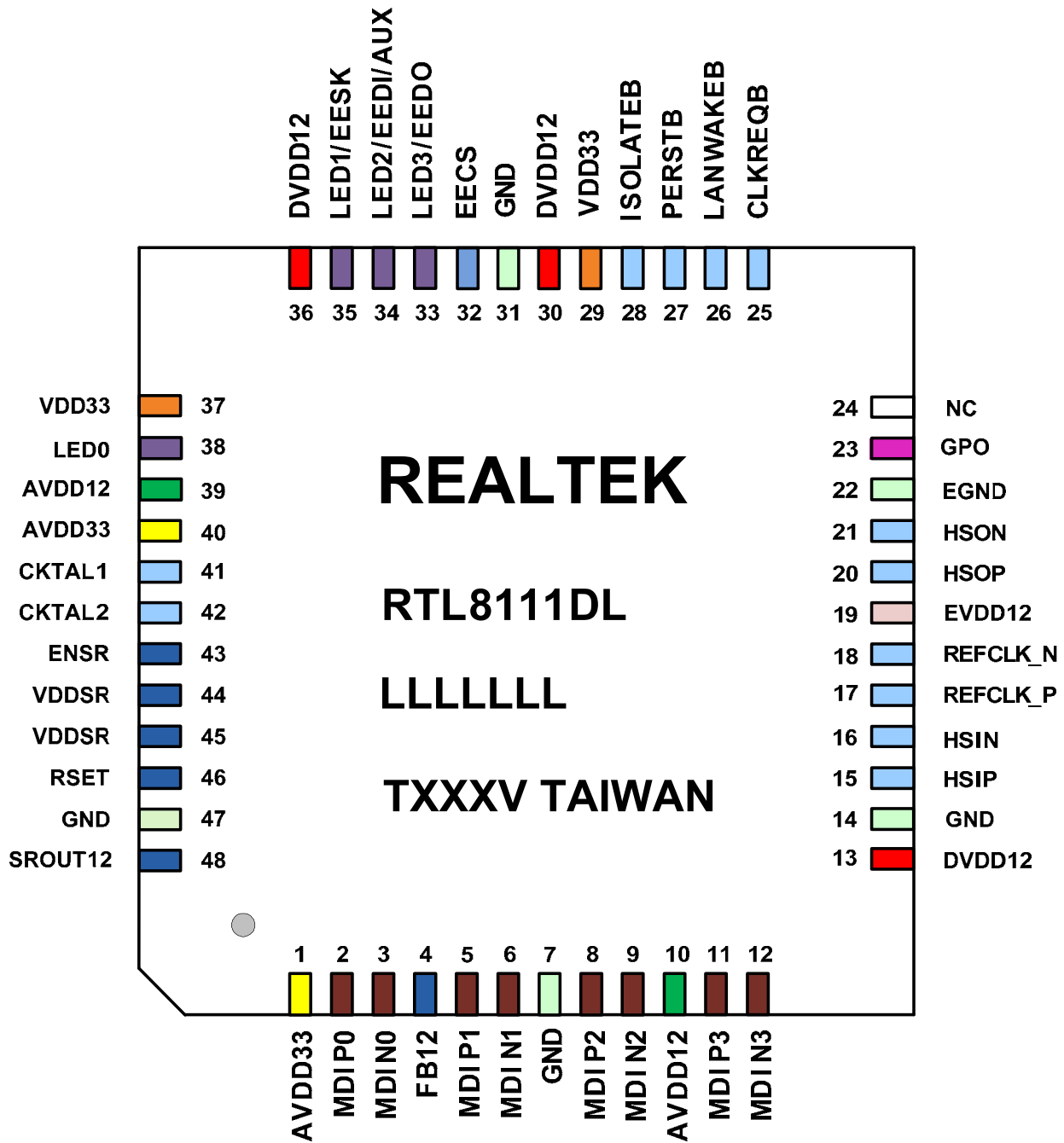


Figure 2. RTL8111DL & RTL8111DL-VB (48-Pin LQFP) Pin Assignments

4.4. Package Identification

‘Green’ package is indicated by a ‘G’ in the location marked ‘T’ in Figure 2. The version number is shown in the location marked ‘V’.

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 P: Power

5.1. Power Management/Isolation

Table 1. Power Management/Isolation

| Symbol | Type | Pin No (64-pin) | Pin No (48-pin) | Description |
|----------|------|--------------------|--------------------|---|
| LANWAKEB | O/D | 19 | 26 | Power Management Event: Open drain, active low. Used to reactivate the PCI Express slot's main power rails and reference clocks. |
| ISOLATEB | I | 36 | 28 | Isolate Pin: Active low. Used to isolate the RTL8111D(L)/RTL8111D(L)-VB from the PCI Express bus. The RTL8111D(L)/RTL8111D(L)-VB 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 (64-pin) | Pin No (48-pin) | Description |
|----------|------|--------------------|--------------------|---|
| REFCLK_P | I | 26 | 17 | PCI Express Differential Reference Clock Source: 100MHz ± 300ppm. |
| REFCLK_N | I | 27 | 18 | |
| HSOP | O | 29 | 20 | PCI Express Transmit Differential Pair. |
| HSOIN | O | 30 | 21 | |
| HSIP | I | 23 | 15 | PCI Express Receive Differential Pair. |
| HSIN | I | 24 | 16 | |
| PERSTB | I | 20 | 27 | PCI Express Reset Signal: Active low. When the PERSTB is asserted at power-on state, the RTL8111D(L)/RTL8111D(L)-VB returns to a pre-defined reset state and is ready for initialization and configuration after the de-assertion of the PERSTB. |
| CLKREQB | O/D | 33 | 25 | Reference Clock Request Signal. This signal is used by the RTL8111D(L)/RTL8111D(L)-VB to request starting of the PCI Express reference clock. |

5.3. Transceiver Interface

Table 3. Transceiver Interface

| Symbol | Type | Pin No (64-pin) | Pin No (48-pin) | Description |
|--------|------|--------------------|--------------------|--|
| MDIP0 | IO | 3 | 2 | In MDI mode, this is the first pair in 1000Base-T, i.e., the BI_DA+/- pair, and is the transmit pair in 10Base-T and 100Base-TX. |
| MDIN0 | IO | 4 | 3 | In MDI crossover mode, this pair acts as the BI_DB+/- pair, and is the receive pair in 10Base-T and 100Base-TX. |
| MDIP1 | IO | 6 | 5 | In MDI mode, this is the second pair in 1000Base-T, i.e., the BI_DB+/- pair, and is the receive pair in 10Base-T and 100Base-TX. |
| MDIN1 | IO | 7 | 6 | In MDI crossover mode, this pair acts as the BI_DA+/- pair, and is the transmit pair in 10Base-T and 100Base-TX. |
| MDIP2 | IO | 9 | 8 | In MDI mode, this is the third pair in 1000Base-T, i.e., the BI_DC+/- pair. |
| MDIN2 | IO | 10 | 9 | In MDI crossover mode, this pair acts as the BI_DD+/- pair. |
| MDIP3 | IO | 12 | 11 | In MDI mode, this is the fourth pair in 1000Base-T, i.e., the BI_DD+/- pair. |
| MDIN3 | IO | 13 | 12 | In MDI crossover mode, this pair acts as the BI_DC+/- pair. |

5.4. Clock

Table 4. Clock

| Symbol | Type | Pin No (64-pin) | Pin No (48-pin) | Description |
|--------|------|--------------------|--------------------|----------------------------------|
| CKTAL1 | I | 60 | 41 | Input of 25MHz Clock Reference. |
| CKTAL2 | O | 61 | 42 | Output of 25MHz Clock Reference. |

5.5. Regulator and Reference

Table 5. Regulator and Reference

| Symbol | Type | Pin No (64-pin) | Pin No (48-pin) | Description |
|---------|------|--------------------|--------------------|---|
| SROUT12 | O | 1 | 48 | Switching Regulator 1.05V Output. Connect to 5 μ H inductor. |
| FB12 | I | 5 | 4 | Feedback Pin for Switching Regulator. |
| ENSR | I | 62 | 43 | 3.3V: Enable switching regulator. 0V: Disable switching regulator. |
| VDDSR | P | 63 | 44, 45 | Digital 3.3V Power Supply for Switching Regulator. |
| RSET | I | 64 | 46 | Reference. External resistor reference. |

Note: See section 7, page 20 for switching regulator layout.

5.6. EEPROM

Table 6. EEPROM

| Symbol | Type | Pin No (64-pin) | Pin No (48-pin) | Description |
|----------|------|-----------------|-----------------|---|
| EESK | O | 48 | 35 | Serial Data Clock. |
| EEDI/AUX | O/I | 47 | 34 | 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 RTL8111D(L)/RTL8111D(L)-VB assumes that no Aux. Power exists. |
| EEDO | I | 45 | 33 | Input from Serial Data Output Pin of EEPROM. |
| EECS | O | 44 | 32 | EECS: EEPROM chip select. |

5.7. LEDs

Table 7. LEDs

| Symbol | Type | Pin No (64-pin) | Pin No (48-pin) | Description | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------|----------|---------------------|-----------------|---|-----------------|----|----|----|----|------|-------|-------|----|----------------|------|---------|---------------------|------|-----------------|------|--------|----------------|----|----------------|------|----------|----------|----------------|------------------|
| LED0 | O | 57 | 38 | <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>TX/RX</td> <td>TX</td> <td>LINK10/ ACT</td> </tr> <tr> <td>LED1</td> <td>LINK100</td> <td>LINK10/ 100/1000</td> <td>LINK</td> <td>LINK100/ ACT</td> </tr> <tr> <td>LED2</td> <td>LINK10</td> <td>LINK10/ 100</td> <td>RX</td> <td>FULL DUPLEX</td> </tr> <tr> <td>LED3</td> <td>LINK1000</td> <td>LINK1000</td> <td>FULL DUPLEX</td> <td>LINK1000 /ACT</td> </tr> </tbody> </table> | LEDS1-0 | 00 | 01 | 10 | 11 | LED0 | TX/RX | TX/RX | TX | LINK10/ ACT | LED1 | LINK100 | LINK10/ 100/1000 | LINK | LINK100/ ACT | LED2 | LINK10 | LINK10/ 100 | RX | FULL DUPLEX | LED3 | LINK1000 | LINK1000 | FULL DUPLEX | LINK1000 /ACT |
| LEDS1-0 | 00 | 01 | 10 | | 11 | | | | | | | | | | | | | | | | | | | | | | | | |
| LED0 | TX/RX | TX/RX | TX | | LINK10/ ACT | | | | | | | | | | | | | | | | | | | | | | | | |
| LED1 | LINK100 | LINK10/ 100/1000 | LINK | | LINK100/ ACT | | | | | | | | | | | | | | | | | | | | | | | | |
| LED2 | LINK10 | LINK10/ 100 | RX | | FULL DUPLEX | | | | | | | | | | | | | | | | | | | | | | | | |
| LED3 | LINK1000 | LINK1000 | FULL DUPLEX | LINK1000 /ACT | | | | | | | | | | | | | | | | | | | | | | | | | |
| LED1 | O | 56 | 35 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| LED2 | O | 55 | 34 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| LED3 | O | 54 | 33 | | | | | | | | | | | | | | | | | | | | | | | | | | |

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

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

When implementing dual color LEDs and EEPROM at the same time:

Pin33, Pin34, and Pin35 of the RTL8111DL are shared pins. Follow the RTL8111DL Reference design (version 1.07 or later) to select 2 pins from these 3 shared pins for a dual color LED circuit. Otherwise, the RTL8111DL EEPROM may not function.

5.8. Power and Ground

Table 8. Power and Ground

| Symbol | Type | Pin No (64-pin) | Pin No (48-pin) | Description |
|--------|------|------------------------|--------------------|-----------------------------|
| VDD33 | P | 16, 37, 46, 53 | 29, 37 | Digital 3.3V Power Supply. |
| DVDD12 | P | 21, 32, 38, 43, 49, 52 | 13, 30, 36 | Digital 1.05V Power Supply. |
| AVDD12 | P | 8, 11, 14, 58 | 10, 39 | Analog 1.05V Power Supply. |
| EVDD12 | P | 22, 28 | 19 | Analog 1.05V Power Supply. |
| AVDD33 | P | 2, 59 | 1, 40 | Analog 3.3V Power Supply. |
| EGND | P | 25, 31 | 22 | Analog Ground. |
| GND | P | 65 | 7, 14, 31, 47 | Ground (Exposed Pad). |

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

5.9. GPIO Pins

Table 9. GPIO Pins

| Symbol | Type | Pin No (64-pin) | Pin No (48-pin) | Description |
|--------|------|--------------------|--------------------|---|
| GPI | I | 50 | - | General Purpose Input Pin. |
| GPO | O | 51 | 23 | General Purpose Output Pin. This pin reflects the link up or link down state. High: Link up Low: Link down |

5.10. Test Pins

Table 10. Test Pins

| Symbol | Type | Pin No (64-pin) | Pin No (48-pin) | Description |
|--------|------|------------------------|--------------------|----------------------------|
| Test | - | 34, 35, 39, 40, 41, 42 | - | Realtek Internal Use Only. |

5.11. NC Pins

Table 11. NC Pins

| Symbol | Type | Pin No (64-pin) | Pin No (48-pin) | Description |
|--------|------|--------------------|--------------------|----------------|
| NC | - | 15, 17, 18 | 24 | Not Connected. |

6. Functional Description

6.1. *PCI Express Bus Interface*

The RTL8111D(L)/RTL8111D(L)-VB complies with PCI Express Base Specification Revision 1.1, and runs at a 2.5GHz signaling rate with X1 link width, i.e., one transmit and one receive differential pair. The RTL8111D(L)/RTL8111D(L)-VB 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 RTL8111D(L)/RTL8111D(L)-VB'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 RTL8111D(L)/RTL8111D(L)-VB'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 de-scrambling, the original digital data is recovered and passed to the RTL8111D(L)/RTL8111D(L)-VB's internal Ethernet MAC to be transmitted onto the Ethernet media.

6.2. *LED Functions*

The RTL8111D(L)/RTL8111D(L)-VB 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, LINK1000, LINK10/100/1000, LINK10/ACT, LINK100/ACT, or LINK1000/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 10/100/1000Mbps mode, blinking of the Rx LED indicates that receive activity is occurring.

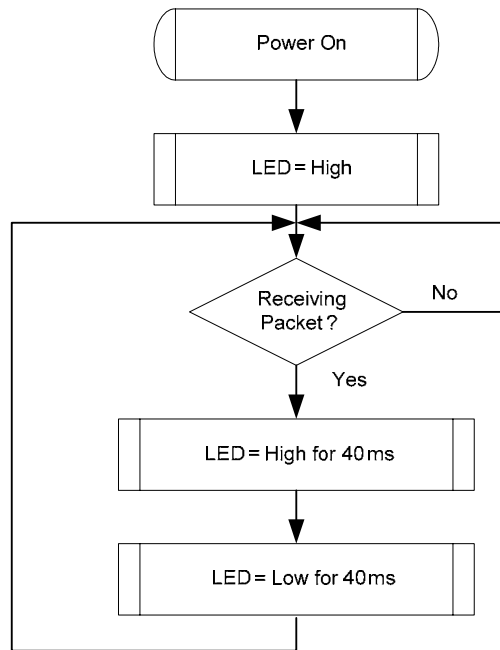


Figure 3. Rx LED

6.2.3. Tx LED

In 10/100/1000Mbps mode, blinking of the Tx LED indicates that transmit activity is occurring.

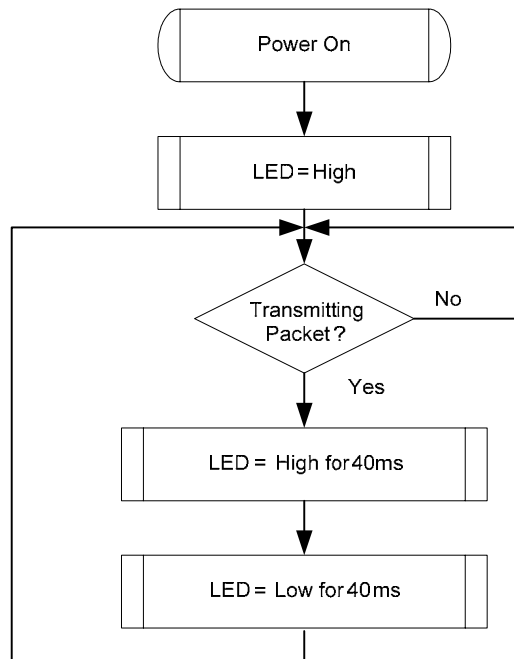


Figure 4. Tx LED

6.2.4. Tx/Rx LED

In 10/100/1000Mbps mode, blinking of the Tx/Rx LED indicates that both transmit and receive activity is occurring.

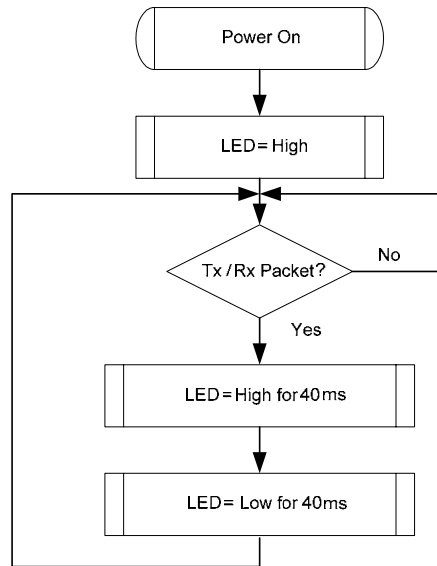


Figure 5. Tx/Rx LED

6.2.5. LINK/ACT LED

In 10/100/1000Mbps mode, blinking of the LINK/ACT LED indicates that the RTL8111D(L)/RTL8111D(L)-VB is linked and operating properly. When this LED is high for extended periods, it indicates that a link problem exists.

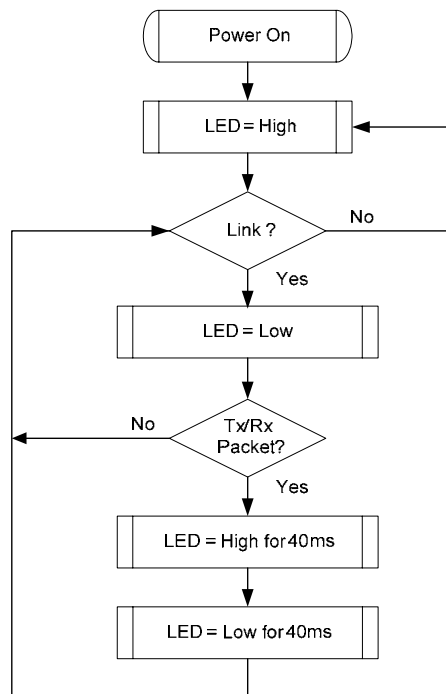


Figure 6. LINK/ACT LED

6.2.6. Customizable LED Configuration

The RTL8111D(L)/RTL8111D(L)-VB supports customizable LED operation modes via IO register offset 18h~19h. Table 12 describes the different LED actions.

Table 12. LED Select (IO Register Offset 18h~19h)

| Bit | Symbol | RW | Description |
|-------|---------|----|------------------------|
| 15:12 | LEDSEL3 | RW | LED Select for PINLED3 |
| 11:8 | LEDSEL2 | RW | LED Select for PINLED2 |
| 7:4 | LEDSEL1 | RW | LED Select for PINLED1 |
| 3:0 | LEDSEL0 | RW | LED Select for PINLED0 |

When implementing customized LEDs:

1. Set IO register offset 0x55 bit 6 to 1h to enable the customized LED function
2. Configure IO register offset 18h~19h to support your own LED signals. For example, if the value in the IO offset 0x18 is 0x8EC1h (1000111011000001b), the LED actions are:
 - LED 0: On only in 10M mode, with no blinking during TX/RX
 - LED 1: On only in 1000M mode, with TX/RX blinking
 - LED 2: On only in 100M/1000M mode, with TX/RX blinking
 - LED 3: On only in full duplex mode

Table 13. Customized LEDs

| | LINK | | | ACT/Full |
|-------|----------|-----------|------------|----------|
| Speed | Link 10M | Link 100M | Link 1000M | - |
| LED 0 | Bit 0 | Bit 1 | Bit 2 | Bit 3 |
| LED 1 | Bit 4 | Bit 5 | Bit 6 | Bit 7 |
| LED 2 | Bit 8 | Bit 9 | Bit 10 | Bit 11 |
| LED 3 | Bit 12 | Bit 13 | Bit 14 | Bit 15 |

| LED Pin | ACT=0 | ACT=1 |
|---------|--------------------------------------|------------------------------------|
| LINK=0 | Floating | LED On when in Full Duplex Mode |
| LINK>0 | LED On when Selected Speed is Linked | LED Blinks on Selected Speed TX/RX |

Note1: ACT means blinking TX and RX. LINK indicates Link 10M and Link 100M.

Note2: There are two special modes:

Mode A: LED OFF Mode → Set all bits to 0.

Mode B: TX/RX Mode → Set LED 0=0, and either LED 1, LED 2, or LED 3 >0.

LED 0 = Blinking on TX/RX.

LED 1 = Follow Customized LED rule.

LED 2 = Follow Customized LED rule.

LED 3 = Follow Customized LED rule.

6.3. PHY Transceiver

6.3.1. PHY Transmitter

Based on state-of-the-art DSP technology and mixed-mode signal processing technology, the RTL8111D(L)/RTL8111D(L)-VB operates at 10/100/1000Mbps over standard CAT.5 UTP cable (100/1000Mbps), and CAT.3 UTP cable (10Mbps).

GMII (1000Mbps) Mode

The RTL8111D/RTL8111D-VB's PCS layer receives data bytes from the MAC through the GMII interface and performs the generation of continuous code-groups through 4D-PAM5 coding technology. These code groups are passed through a waveform-shaping filter to minimize EMI effects, and are transmitted onto the 4-pair CAT5 cable at 125MBaud/s through a D/A converter.

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

GMII (1000Mbps) Mode

Input signals from the media pass through the sophisticated on-chip hybrid circuit to separate the transmitted signal from the input signal for effective reduction of near-end echo. Afterwards, the received signal is processed with state-of-the-art technology, e.g., adaptive equalization, BLW (Baseline Wander) correction, cross-talk cancellation, echo cancellation, timing recovery, error correction, and 4D-PAM5 decoding. Then, the 8-bit-wide data is recovered and is sent to the GMII interface at a clock speed of 125MHz. The Rx MAC retrieves the packet data from the receive MII/GMII interface and sends it to the Rx Buffer Manager.

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. Next Page

If 1000Base-T mode is advertised, three additional Next Pages are automatically exchanged between the two link partners. Users can set PHY Reg4.15 to 1 to manually exchange extra Next Pages via Reg7 and Reg8 as defined in IEEE 802.3ab.

6.5. EEPROM Interface

The RTL8111D(L)/RTL8111D(L)-VB requires the attachment of an external EEPROM. The 93C46/93C56/93C66 is a 1K-bit/2K-bit EEPROM. The EEPROM interface permits the RTL8111D(L)/RTL8111D(L)-VB to read from, and write data to, an external serial EEPROM device.

Note: The RTL8111DL/RTL8111DL-VB only supports 93C46 EEPROM.

Values in the internal eFUSE memory or 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 RTL8111D(L)/RTL8111D(L)-VB will auto-load values from the eFUSE or EEPROM. If the EEPROM is not present and eFUSE auto-load is bypassed, the RTL8111D(L)/RTL8111D(L)-VB 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., 93C46/93C56/93C66) must be used in order to ensure proper LAN function.

Table 14. EEPROM Interface

| EEPROM | Description |
|---------------|--|
| EECS | 93C46/93C56/93C66 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 RTL8111D(L)/RTL8111D(L)-VB assumes that no Aux. Power exists. |
| EEDO | Output Data Bus. |

6.6. Power Management

The RTL8111D(L)/RTL8111D(L)-VB 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 RTL8111D(L)/RTL8111D(L)-VB can monitor the network for a Wakeup Frame, a Magic Packet, 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 RTL8111D(L)/RTL8111D(L)-VB is in power down mode (D1 ~ D3):

- The Rx state machine is stopped. The RTL8111D(L)/RTL8111D(L)-VB monitors the network for wakeup events such as a Magic Packet and Wakeup Frame in order to wake up the system. When in power down mode, the RTL8111D(L)/RTL8111D(L)-VB 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 RTL8111D(L)/RTL8111D(L)-VB.
- Transmission is stopped. PCI Express transactions are stopped. The Tx on-chip buffer is held.
- After being restored to D0 state, the RTL8111D(L)/RTL8111D(L)-VB 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 D3_{cold}_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. If aux. power is absent, the above 4 bits are all 0 in binary.

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 = C3 FF, then PCI PMC = C3 FF)
- 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 = C3 FF, then PCI PMC = 03 7E)

In the above case, if wakeup support is desired when main power is off, it is suggested that the EEPROM PMC be set to C3 FF (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 = C3 7F, then PCI PMC = C3 7F)
- 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 = C3 7F, then PCI PMC = 03 7E)

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 03 7E.

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

- The destination address of the received Magic Packet is acceptable to the RTL8111D(L)/RTL8111D(L)-VB, e.g., a broadcast, multicast, or unicast packet addressed to the current RTL8111D(L)/RTL8111D(L)-VB.
- 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 RTL8111D(L)/RTL8111D(L)-VB, e.g., a broadcast, multicast, or unicast address to the current RTL8111D(L)/RTL8111D(L)-VB.
- 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 RTL8111D(L)/RTL8111D(L)-VB is configured to allow direct packet wakeup, e.g., a broadcast, multicast, or unicast network packet.

Note: 16-bit CRC: The RTL8111D(L)/RTL8111D(L)-VB supports eight long wakeup frames (covering 128 mask bytes from offset 0 to 127 of any incoming network packet).

The corresponding wake-up method (message 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 RTL8111D(L)/RTL8111D(L)-VB may assert the corresponding wake-up method (message 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 RTL8111D(L)/RTL8111D(L)-VB to stop asserting the corresponding wake-up method (message or LANWAKEB) (if enabled).

When the RTL8111D(L)/RTL8111D(L)-VB is in power down mode, e.g., D1-D3, the IO and MEM accesses to the RTL8111D(L)/RTL8111D(L)-VB 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.

6.7. Vital Product Data (VPD)

Bit 31 of the Vital Product Data (VPD) capability structure in the RTL8111D/RTL8111D-VB'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 93C46/93C56/93C66 has completed or not.

Write VPD register: (write data to the 93C46/93C56/93C66)

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 RTL8111D/RTL8111D-VB, 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 93C46/93C56/93C66)

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 RTL8111D/RTL8111D-VB, the VPD data (4 bytes per VPD access) has been transferred from EEPROM to the VPD data register.

Note1: Refer to the PCI 2.3 Specifications for further information.

Note2: The VPD address must be a DWORD-aligned address as defined in the PCI 2.3 Specifications. VPD data is always consecutive 4-byte data starting from the VPD address specified.

Note3: Realtek reserves offset 60h to 7Fh in EEPROM mainly for VPD data to be stored.

Note4: The VPD function of the RTL8111D(L)/RTL8111D(L)-VB is designed to be able to access the full range of the 93C46/93C56/93C66 EEPROM.

6.8. Receive-Side Scaling (RSS)

The RTL8111D(L)/RTL8111D(L)-VB is compliant with the Network Driver Interface Specification (NDIS) 6.0 Receive-Side Scaling (RSS) technology for the Microsoft Windows family of operating systems. RSS allows packet receive-processing from a network adapter to be balanced across the number of available computer processors, increasing performance on multi CPU platforms.

6.8.1. Receive-Side Scaling (RSS) Initialization

During RSS initialization, the Windows operating system will inform the RTL8111D(L)/RTL8111D(L)-VB that it should store the following parameters: hash function, hash type, hash bits, indirection table, BaseCPUNumber, and the secret hash key.

Hash Function

The default hash function is the Toeplitz hash function.

Hash Type

The hash types indicate which field of the packet needs to be hashed to get the hash result. There are several combinations of these fields, mainly, TCP/IPv4, IPv4, TCP/IPv6, IPv6, and IPv6 extension headers.

- TCP/IPv4 requires hash calculations over the IPv4 source address, the IPv4 destination address, the source TCP port and the destination TCP port.
- IPv4 requires hash calculations over the IPv4 source address and the IPv4 destination address.
- TCP/IPv6 requires hash calculations over the IPv6 source address, the IPv6 destination address, the source TCP port and the destination TCP port.
- IPv6 requires hash calculations over the IPv6 source address and the IPv6 destination address
(Note: The RTL8111D(L)/RTL8111D(L)-VB does not support the IPv6 extension header hash type in RSS).

Hash Bits

Hash bits are used to index the hash result into the indirection table

Indirection Table

The Indirection Table stores values that are added to the BaseCPUNumber to enable RSS interrupts to be restricted from some CPUs. The OS will update the Indirection Table to rebalance the load.

BaseCPUNumber

The lowest number CPU to use for RSS. BaseCPUNumber is added to the result of the indirection table lookup.

Secret hash key

The key used in the Toeplitz function. For different hash types, the key size is different.

6.8.2. RSS Operation

After the parameters are set, the RTL8111D(L)/RTL8111D(L)-VB will start hash calculation on each incoming packet and forward each packet to its correct queue according to the hash result. If the incoming packet is not in the hash type, it will be forwarded to the primary queue. The hash result plus the BaseCPUNumber will be indexed into the indirection table to get the correct CPU number. The RTL8111D(L)/RTL8111D(L)-VB uses three methods to inform the system of incoming packets: inline interrupt, MSI, and MSIX. Periodically the OS will update the indirection table to rebalance the load across the CPUs.

6.9. Deep Slumber Mode (DSM) V1 & V2

The RTL8111D(L)/RTL8111D(L)-VB supports Link Down power saving mode via communication with the BIOS and external circuitry. Note that DSMv2 is a simplified implementation of DSMv1, and is only supported in the RTL8111D(L)-VB. Refer to the separate DSM application note for details.

7. Switching Regulator

The RTL8111D(L)/RTL8111D(L)-VB incorporates a state-of-the-art switching regulator that requires a well-designed PCB layout in order to achieve good power efficiency and lower the output voltage ripple and input overshoot. Note that the switching regulator 1.05V output pin (SROUT12) must be connected only to DVDD12 and AVDD12 (do not provide this power source to other devices).

Note: Refer to the separate Layout Guide for details.

7.1. Inductor and Capacitor Parts List

Table 15. Inductor and Capacitor Parts List

| Inductor Type | Inductance | ESR at 1MHz (mΩ) | Max IDC (mA) | Output Ripple (mV) |
|---------------|------------|------------------|--------------|--------------------|
| 4R7GTSD32 | 4.7μH | 712 | 1100 | 12.6 |
| 6R8GTSD32 | 6.8μH | 784 | 900 | 12 |
| 6R8GTSD53 | 6.8μH | 737 | 1510 | 10.4 |

Note 1: The ESR is equivalent to RDC or DCR. Lower ESR inductor values will promote a higher efficiency switching regulator.

Note 2: The power inductor used by the switching regulator must be able to withstand 600mA of current.

Note 3: Typically, if the power inductor's ESR at 1MHz is below 0.8Ω, the switching regulator efficiency will be above 75%. However the actual switching regulator efficiency should be measured according to the method described in section 7.3 Efficiency Measurement, page 25.

| Capacitor Type | Capacitance | ESR at 1MHz (mΩ) | Output Ripple (mV) |
|----------------|-------------|------------------|--------------------|
| 22μF 1210 TDK | 21.5μF | 33.53 | 9.6 |
| 22μF 1210 X5R | 22.15μF | 34.11 | 10.4 |

Note: Capacitors (C18 & C82) are suggested to be ceramic due to their low ESR value. Lower ESR values will yield lower output voltage ripple.

7.2. Measurement Criteria

In order for the switching regulator to operate properly, the input and output voltage measurement criteria must be met. From the input side, the voltage overshoot cannot exceed 4V; otherwise the chip may be damaged. Note that the voltage signal must be measured directly at the VDDSR pin, not at the capacitor. In order to reduce the input voltage overshoot, the C82 and C83 must be placed close to the VDDSR pin. The following figures show what a good input voltage and a bad one look like.

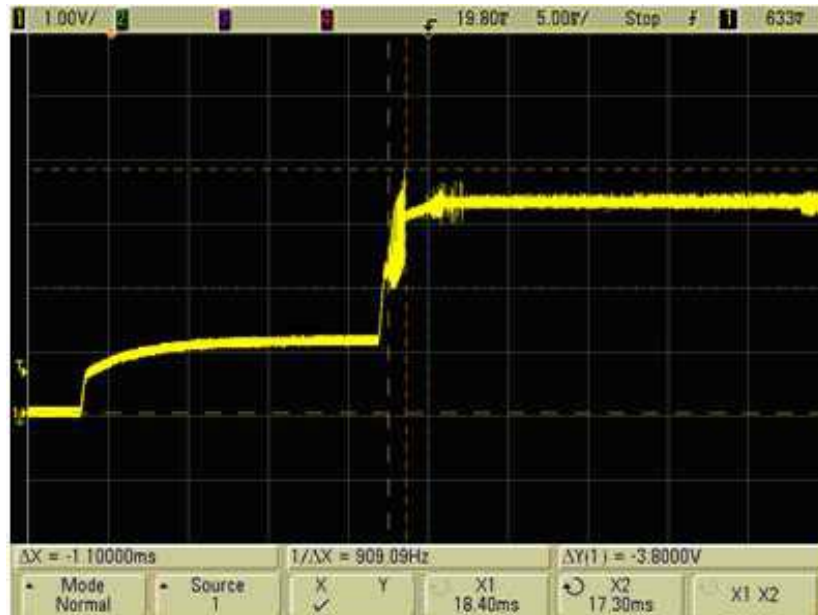


Figure 7. Input Voltage Overshoot <4V (Good)



Figure 8. Input Voltage Overshoot >4V (Bad)

From the output side measured at the SROUT12 pin, the voltage ripple must be within 100mV. Choosing different types and values of output capacitor (C18, C19) and power inductor (L20) will seriously affect the efficiency and output voltage ripple of switching regulators. The following figures show the effects of different types of capacitors on the switching regulator's output voltage.

The blue square wave signal (top row) is measured at the output the SROUT12 pin before the power inductor (L20). The yellow signal (second row) is measured after the power inductor (L20), and shows there is a voltage ripple. The green signal (lower row) is the current. Data in the following figures was measured at gigabit speed.



Figure 9. Ceramic 22 μ F 1210 (X5R) (Good)

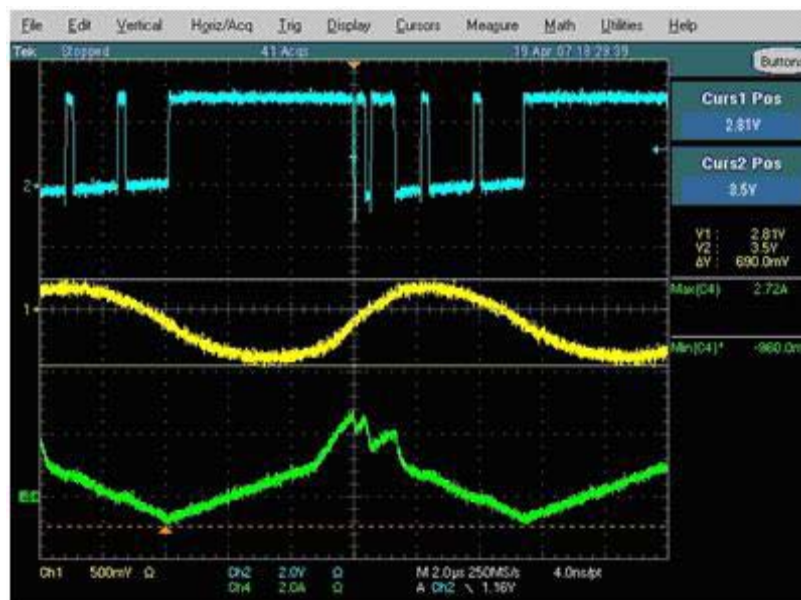


Figure 10. Ceramic 22 μ F 0805 (Y5V) (Bad)

A ceramic 22 μ F (X5R) will have a lower voltage ripple compared to the electrolytic 100 μ F. The key to choosing a proper output capacitor is to choose the lowest ESR to reduce the output voltage ripple. Choosing a ceramic 22 μ F 0805 (Y5V) in this case will cause malfunction of the switching regulator. Placing several Electrolytic capacitors in parallel will help lower the output voltage ripple.



Figure 11. Electrolytic 100 μ F (Ripple Too High)

The following figures show how different inductors affect the SROUT12 pin output waveform. The typical waveform should look like Figure 12, which has a square waveform with a dip at the falling edge and the rising edge. If the inductor is not carefully chosen, the waveform may look like Figure 13, where the waveform looks like a distorted square. This will cause insufficient current supply and will undermine the stability of the system at gigabit speed. Data in the following figures was measured at gigabit speed.

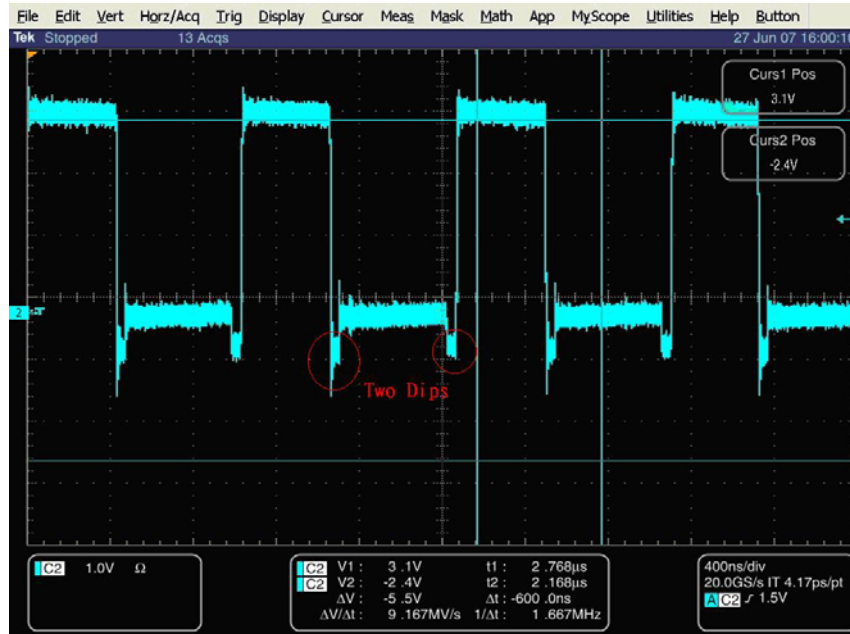


Figure 12. 4R7GTSD32 (Good)

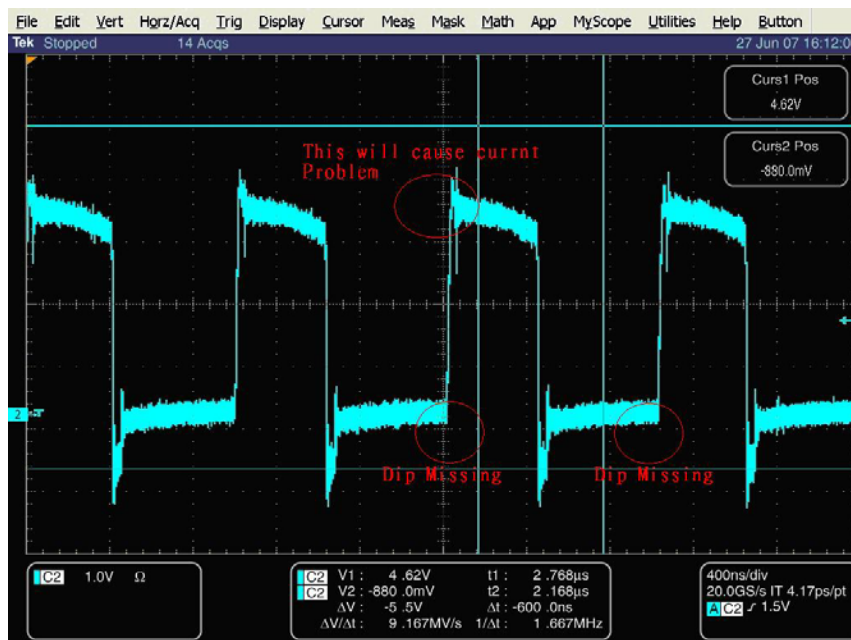


Figure 13. 1 μ H Bead (Bad)

7.3. Efficiency Measurement

The efficiency of the switching regulator is designed to be above 75% in gigabit traffic mode. It is very important to choose a suitable inductor before Gerber certification, as the Inductor ESR value will affect the efficiency of the switching regulator. An inductor with a lower ESR value will result in a higher efficiency switching regulator.

The efficiency of the switching regulator is easily measured using the following method.

Figure 14 shows two checkpoints, checkpoint A (CP_A) and checkpoint B (CP_B). The switching regulator input current (Icpa) should be measured at CP_A, and the switching regulator output current (Icpb) should be measured at CP_B.

To determine efficiency, apply the following formula:

$$\text{Efficiency} = V_{cpb} \cdot I_{cpb} / V_{cpa} \cdot I_{cpa}$$

Where V_{cpb} is 1.05V; V_{cpa} is 3.3V. The measurements should be performed in gigabit traffic mode.

For example: The inductor used in the evaluation board is a GOTREND GTSD32-4R7M:

- The ESR value @ 1MHz is approximately 0.712ohm
- The measured I_{cpa} is 101mA at CP_A
- The measured I_{cpb} is 263mA at CP_B

These values are measured in gigabit traffic mode, so the efficiency of the GOTREND GTSD32-4R7M can be calculated as follows:

$$\text{Efficiency} = (1.05V \cdot 263mA) / (3.3V \cdot 101mA) = 0.823 = 82.3\%$$

We strongly recommend that when choosing an inductor for the switching regulator, the efficiency should be measured, and that the inductor should yield an efficiency rating higher than 75%. If the efficiency does not meet this requirement, there may be risk to the switching regulator reliability in the long run.

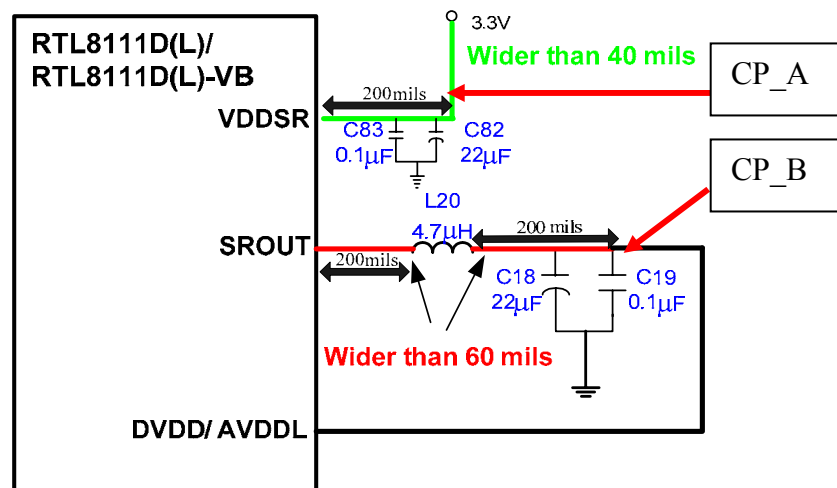


Figure 14. Switching Regulator Efficiency Measurement Checkpoint

7.4. Power Sequence

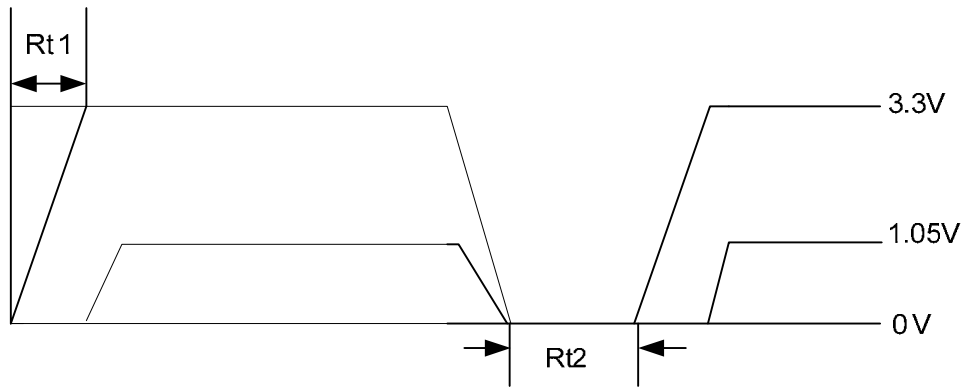


Figure 15. Power Sequence

Table 16. Power Sequence Parameter

| Symbol | Description | Min | Typical | Max | Units |
|--------|----------------|-----|---------|-----|-------|
| Rt1 | 3.3V Rise Time | 1 | - | 100 | ms |
| Rt2 | 3.3V Fall Time | 200 | - | - | ms |

Note 1: The RTL8111D(L)/RTL8111D(L)-VB does not support fast 3.3V rising. The 3.3V rise time must be controlled over 1ms. If the rise time is too short it will induce a peak voltage in PIN63, which may cause permanent damage to the switching regulator.

Note 2: If there is any action that involves consecutive ON/OFF toggling of the switching-regulator source (3.3V), the design must make sure the OFF state of both the switching-regulator source (3.3V) and output (1.05V) reach 0V, and the time period between the consecutive ON/OFF toggling action must be longer than 200ms.

8. Characteristics

8.1. 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 17. Absolute Maximum Ratings

| Symbol | Description | Minimum | Maximum | Unit |
|----------------|----------------------|---------|------------------------------------|------|
| VDD33, AVDD33 | Supply Voltage 3.3V | -0.3 | +0.30 | V |
| AVDD12, DVDD12 | Supply Voltage 1.05V | -0.3 | +0.12 | V |
| EVDD12 | Supply Voltage 1.05V | -0.3 | +0.12 | V |
| DCinput | Input Voltage | -0.3 | Corresponding Supply Voltage + 0.5 | V |
| DCoutput | Output Voltage | -0.3 | Corresponding Supply Voltage + 0.5 | V |
| N/A | Storage Temperature | -55 | +125 | °C |

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

8.2. Recommended Operating Conditions

Table 18. Recommended Operating Conditions

| Description | Pins | Minimum | Typical | Maximum | Unit |
|-------------------------------------|----------------|---------|---------|---------|------|
| Supply Voltage VDD | VDD33, AVDD33 | 2.97 | 3.3 | 3.63 | V |
| | AVDD12, DVDD12 | 1.0 | 1.05 | 1.09 | V |
| | EVDD12 | 1.0 | 1.05 | 1.09 | V |
| Ambient Operating Temperature T_A | - | 0 | - | 70 | °C |
| Maximum Junction Temperature | - | - | - | 125 | °C |

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

8.3. Crystal Requirements

Table 19. 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. $T_a = 0^\circ\text{C} \sim +70^\circ\text{C}$. | -30 | - | +30 | ppm |
| F_{ref} Tolerance | Parallel resonant crystal frequency tolerance, fundamental mode, AT-cut type. $T_a = 25^\circ\text{C}$. | -50 | - | +50 | ppm |
| F_{ref} Duty Cycle | Reference Clock Input Duty Cycle. | 40 | - | 60 | % |
| ESR | Equivalent Series Resistance. | - | - | 30 | Ω |
| DL | Drive Level. | - | - | 0.3 | mW |

Note: The CLK source can come from other places in the system, but it must accord with the parameters above.

8.4. Oscillator Requirements

Table 20. Oscillator Requirements

| Parameter | Condition | Minimum | Typical | Maximum | Unit |
|----------------------|--|---------|---------|---------|--------------------|
| Frequency | - | - | 25 | - | MHz |
| Frequency Stability | $T_a = 0^{\circ}\text{C} \sim +70^{\circ}\text{C}$ | -30 | - | +30 | ppm |
| Frequency Tolerance | $T_a = 25^{\circ}\text{C}$ | -50 | - | +50 | ppm |
| Duty Cycle | - | 40 | - | 60 | % |
| Jitter | - | - | - | 50 | ps |
| Vp-p | - | 3.15 | 3.3 | 3.45 | V |
| Rise Time | - | - | - | 10 | ns |
| Fall Time | - | - | - | 10 | ns |
| Operation Temp Range | - | 0 | - | 70 | $^{\circ}\text{C}$ |

Note: The CLK source can come from other places in the system, but it must accord with the parameters above.

8.5. Thermal Characteristics

Table 21. Thermal Characteristics

| Parameter | Minimum | Maximum | Units |
|-------------------------------|---------|---------|--------------------|
| Storage Temperature | -55 | +125 | $^{\circ}\text{C}$ |
| Ambient Operating Temperature | 0 | 70 | $^{\circ}\text{C}$ |

8.6. DC Characteristics

Table 22. DC Characteristics

| Symbol | Parameter | Conditions | Minimum | Typical | Maximum | Units |
|-----------------|---|-------------------------------------|--------------------------|---------|--------------------------|---------------|
| VDD33, AVDD33 | 3.3V Supply Voltage | - | 2.97 | 3.3 | 3.63 | V |
| DVDD12, AVDD12 | 1.05V Supply Voltage | - | 1.0 | 1.05 | 1.09 | V |
| EVDD12 | 1.05V Supply Voltage | - | 1.0 | 1.05 | 1.09 | V |
| V _{oh} | Minimum High Level Output Voltage | $I_{oh} = -4\text{mA}$ | $0.9 \cdot \text{VDD33}$ | - | VDD33 | V |
| V _{ol} | Maximum Low Level Output Voltage | $I_{ol} = 4\text{mA}$ | 0 | - | $0.1 \cdot \text{VDD33}$ | V |
| V _{ih} | Minimum High Level Input Voltage | - | 2.0 | - | - | V |
| V _{il} | Maximum Low Level Input Voltage | - | - | - | 0.8 | V |
| I _{in} | Input Current | Vin = VDD33 or GND | 0 | - | 0.5 | μA |
| Icc33 | Average Operating Supply Current from 3.3V | At 1Gbps with heavy network traffic | - | 66 | - | mA |
| Icc12 | Average Operating Supply Current from 1.05V | At 1Gbps with heavy network traffic | - | 272 | - | mA |

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

8.7. AC Characteristics

8.7.1. Serial EEPROM Interface Timing

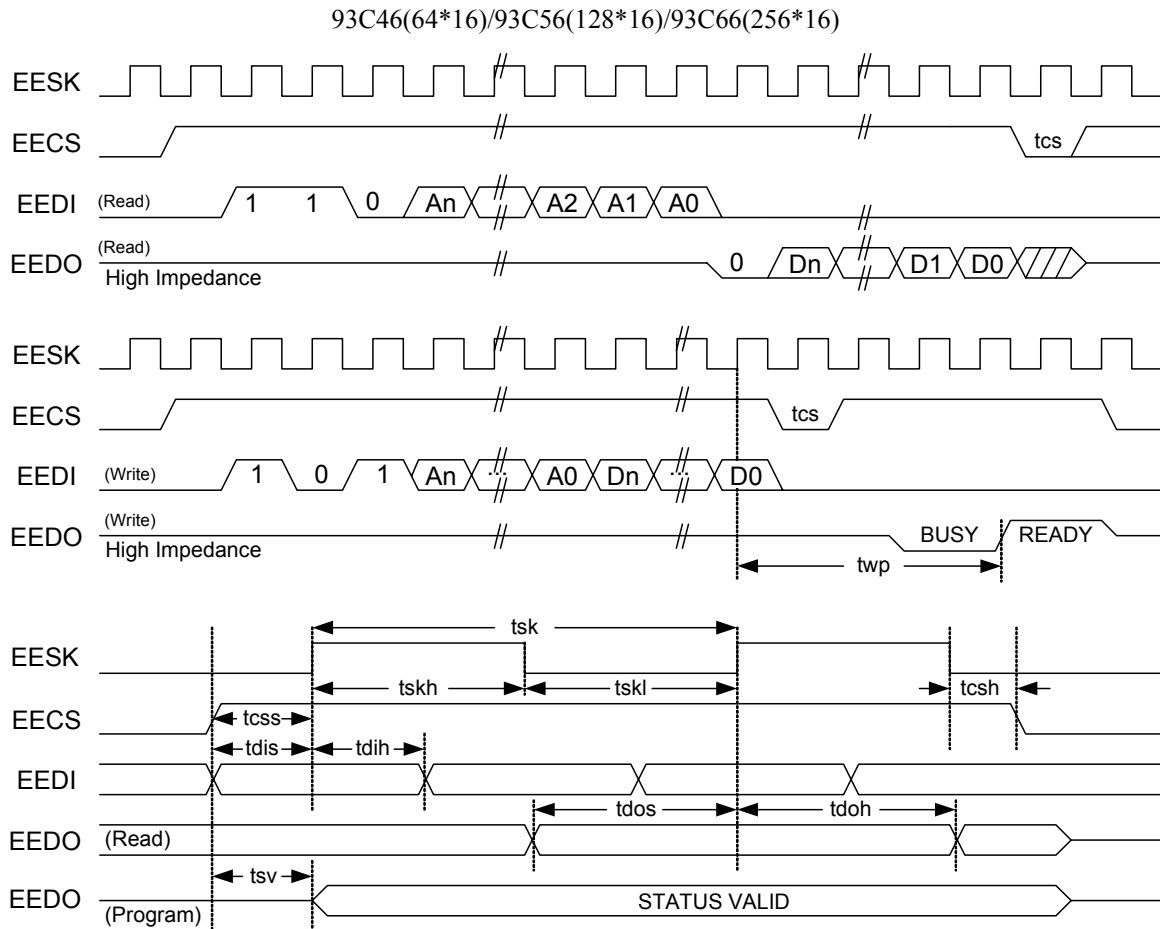


Figure 16. Serial EEPROM Interface Timing

Table 23. EEPROM Access Timing Parameters

| Symbol | Parameter | EEPROM Type | Min. | Max. | Unit |
|--------|---------------------|----------------|------|------|------|
| tcs | Minimum CS Low Time | 9346/9356/9366 | 1000 | - | ns |
| twp | Write Cycle Time | 9346/9356/9366 | - | 10 | ms |
| tsk | SK Clock Cycle Time | 9346/9356/9366 | 4 | - | μs |
| tskh | SK High Time | 9346/9356/9366 | 1000 | - | ns |
| tskl | SK Low Time | 9346/9356/9366 | 1000 | - | ns |
| tcss | CS Setup Time | 9346/9356/9366 | 200 | - | ns |
| tcsh | CS Hold Time | 9346/9356/9366 | 0 | - | ns |
| tdis | DI Setup Time | 9346/9356/9366 | 400 | - | ns |
| tdih | DI Hold Time | 9346/9356/9366 | 400 | - | ns |
| tdos | DO Setup Time | 9346/9356/9366 | 2000 | - | ns |
| tdoh | DO Hold Time | 9346/9356/9366 | - | 2000 | ns |
| tsv | CS to Status Valid | 9346/9356/9366 | - | 1000 | ns |

8.8. PCI Express Bus Parameters

8.8.1. Differential Transmitter Parameters

Table 24. Differential Transmitter Parameters

| Symbol | Parameter | Min | Typical | Max | Units |
|-----------------------------------|--|--------|---------|------------|----------|
| UI | Unit Interval | 399.88 | 400 | 400.12 | ps |
| $V_{TX-DIFFp-p}$ | Differential Peak to Peak Output Voltage | 0.800 | - | 1.05 | 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 | 0.75 | - | - | UI |
| $T_{TX-EYE-MEDIAN-t0-MAX-JITTER}$ | Maximum Time between The Jitter Median and Maximum Deviation from The Median | - | - | 0.125 | 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 | 10 | - | - | dB |
| RL_{TX-CM} | Common Mode Return Loss | 6 | - | - | dB |
| $Z_{TX-DIFF-DC}$ | DC Differential Tx Impedance | 80 | 100 | 120 | 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 |

Note1: Refer to PCI Express Base Specification, rev.1.1, 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 30kHz – 33kHz. The $\pm 300ppm$ requirement still holds, which requires the two communicating ports be modulated such that they never exceed a total of 600ppm difference.

8.8.2. Differential Receiver Parameters

Table 25. 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 | - | 1.05 | 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 | 10 | - | - | 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 | 200k | - | - | 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.1.1, for correct measurement environment setting of each parameter.

8.8.3. REFCLK Parameters

Table 26. REFCLK Parameters

| Symbol | Parameter | 100MHz Input | | Units | Note |
|-------------------|---|--------------|--------|-------|-----------|
| | | Min | Max | | |
| Rise Edge Rate | Rising Edge Rate | 0.6 | 4.0 | V/ns | 2, 3 |
| Fall Edge Rate | Falling Edge Rate | 0.6 | 4.0 | V/ns | 2, 3 |
| V_{IH} | Differential Input High Voltage | +150 | - | mV | 2 |
| V_{IL} | Differential Input Low Voltage | - | -150 | mV | 2 |
| V_{CROSS} | Absolute Crossing Point Voltage | +250 | +550 | mV | 1, 4, 5 |
| $V_{CROSS DELTA}$ | Variation of V_{CROSS} Over All Rising Clock Edges | - | +140 | mV | 1, 4, 9 |
| V_{RB} | Ring-Back Voltage Margin | -100 | +100 | mV | 2, 12 |
| T_{STABLE} | Time before V_{RB} is Allowed | 500 | - | ps | 2, 12 |
| $T_{PERIOD AVG}$ | Average Clock Period Accuracy | -300 | +2800 | ppm | 2, 10, 13 |
| $T_{PERIOD ABS}$ | Absolute Period (Including Jitter and Spread Spectrum) | 9.847 | 10.203 | ns | 2, 6 |
| $T_{CCJITTER}$ | Cycle to Cycle Jitter | - | 150 | ps | 2 |
| V_{MAX} | Absolute Maximum Input Voltage | - | +1.15 | V | 1, 7 |
| V_{MIN} | Absolute Minimum Input Voltage | - | -0.3 | V | 1, 8 |

| Symbol | Parameter | 100MHz Input | | Units | Note |
|--------------------|--|--------------|-----|-------|-------|
| | | Min | Max | | |
| Duty Cycle | Duty Cycle | 40 | 60 | % | 2 |
| Rise-Fall Matching | Rising Edge Rate (REFCLK+) to Falling Edge Rate (REFCLK-) Matching | - | 20 | % | 1, 14 |
| Z _{C-DC} | Clock Source DC Impedance | 40 | 60 | Ω | 1, 11 |

Note1: Measurement taken from single-ended waveform.

Note2: Measurement taken from differential waveform.

Note3: Measured from -150mV to +150mV on the differential waveform (derived from REFCLK+ minus REFCLK-). The signal must be monotonic through the measurement region for rise and fall time. The 300mV measurement window is centered on the differential zero crossing. See Figure 20, page 34.

Note4: Measured at crossing point where the instantaneous voltage value of the rising edge of REFCLK+ equals the falling edge of REFCLK-. See Figure 17, page 33.

Note5: Refers to the total variation from the lowest crossing point to the highest, regardless of which edge is crossing. Refers to all crossing points for this measurement. See Figure 17, page 33.

Note6: Defines as the absolute minimum or maximum instantaneous period. This includes cycle to cycle jitter, relative ppm tolerance, and spread spectrum modulation. See Figure 19, page 33.

Note7: Defined as the maximum instantaneous voltage including overshoot. See Figure 17, page 33.

Note8: Defined as the minimum instantaneous voltage including undershoot. See Figure 17, page 33.

Note9: Defined as the total variation of all crossing voltages of Rising REFCLK+ and Falling REFCLK-. This is the maximum allowed variance in VCROSS for any particular system. See Figure 17, page 33.

Note10: Refer to Section 4.3.2.1 of the PCI Express Base Specification, Revision 1.1 for information regarding ppm considerations.

Note11: System board compliance measurements must use the test load card described in Figure 23, page 35. REFCLK+ and REFCLK- are to be measured at the load capacitors CL. Single ended probes must be used for measurements requiring single ended measurements. Either single ended probes with math or differential probe can be used for differential measurements. Test load CL=2pF.

Note12: T_{STABLE} is the time the differential clock must maintain a minimum ±150mV differential voltage after rising/falling edges before it is allowed to droop back into the V_{RB} ±100mV differential range. See Figure 22, page 34.

Note13: PPM refers to parts per million and is a DC absolute period accuracy specification. 1ppm is 1/1,000,000th of 100.000000MHz exactly, or 100Hz. For 300ppm then we have an error budget of 100Hz/ppm*300ppm=30kHz. The period is to be measured with a frequency counter with measurement window set to 100ms or greater. The ±300ppm applies to systems that do not employ Spread Spectrum or that use common clock source. For systems employing Spread Spectrum there is an additional 2500ppm nominal shift in maximum period resulting from the 0.5% down spread resulting in a maximum average period specification of +2800ppm.

Note14: Matching applies to rising edge rate for REFCLK+ and falling edge rate for REFCLK-. It is measured using a ±75mV window centered on the median cross point where REFCLK+ rising meets REFCLK- falling. The median cross point is used to calculate the voltage thresholds the oscilloscope is to use for the edge rate calculations. The Rise Edge Rate of REFCLK+ should be compared to the Fall Edge Rate of REFCLK-; the maximum allowed difference should not exceed 20% of the slowest edge rate. See Figure 18, page 33.

Note15: Refer to PCI Express Card Electromechanical Specification, rev.1.1, for correct measurement environment setting of each parameter.

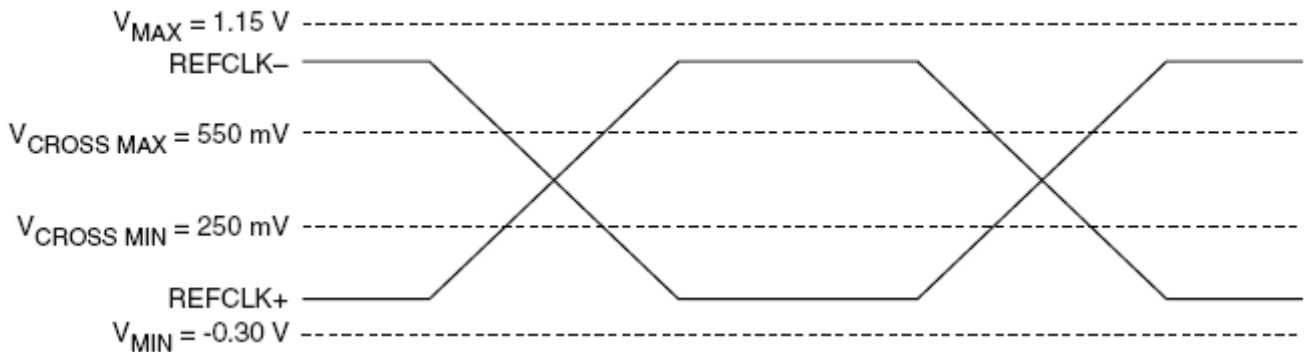


Figure 17. Single-Ended Measurement Points for Absolute Cross Point and Swing

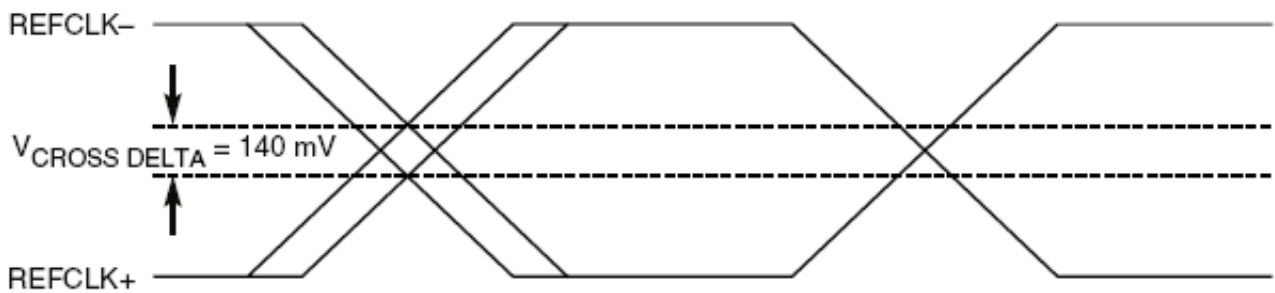


Figure 18. Single-Ended Measurement Points for Delta Cross Point

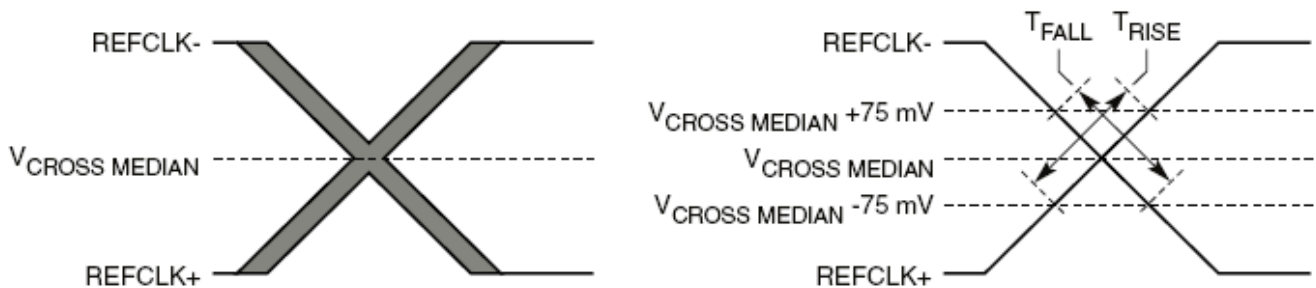


Figure 19. Single-Ended Measurement Points for Rise and Fall Time Matching

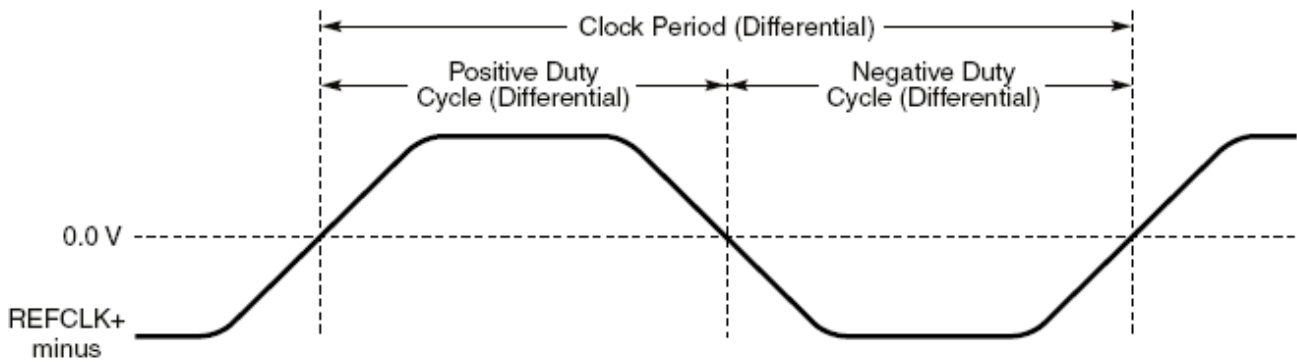


Figure 20. Differential Measurement Points for Duty Cycle and Period

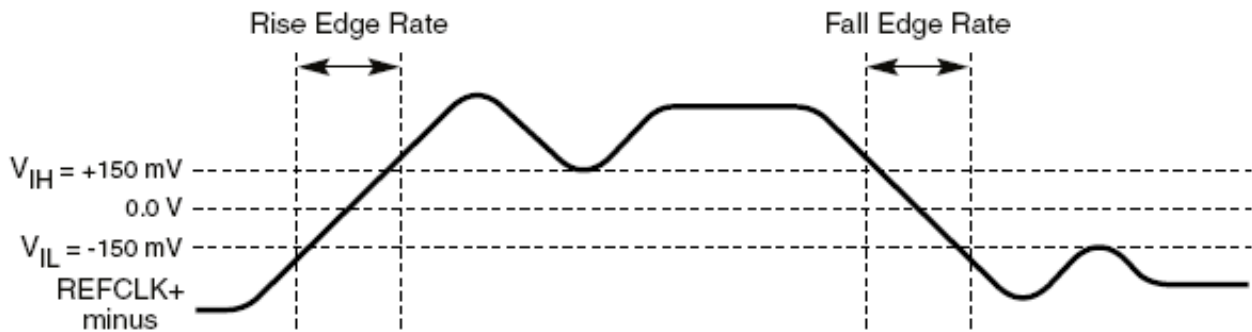


Figure 21. Differential Measurement Points for Rise and Fall Time

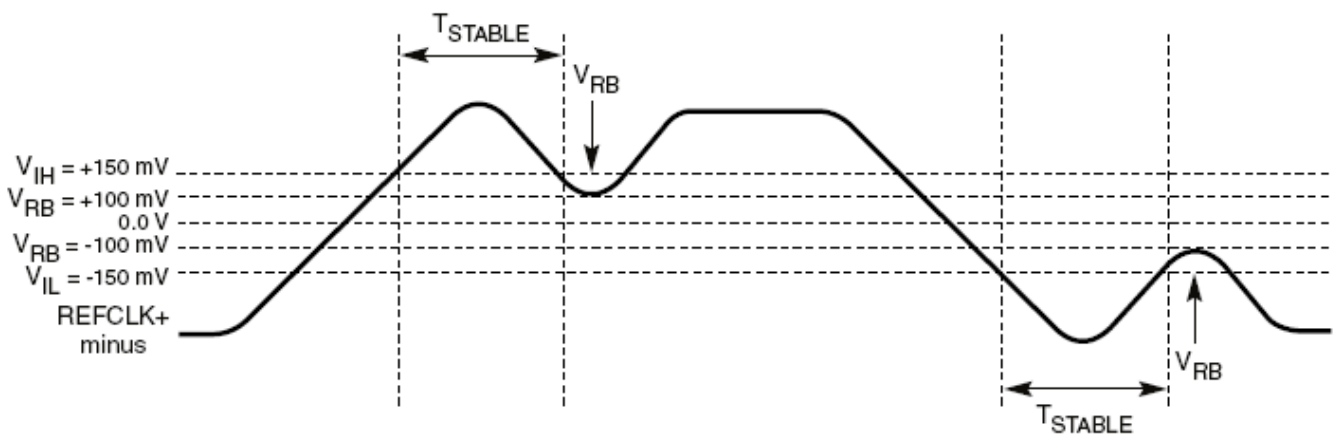


Figure 22. Differential Measurement Points for Ringback

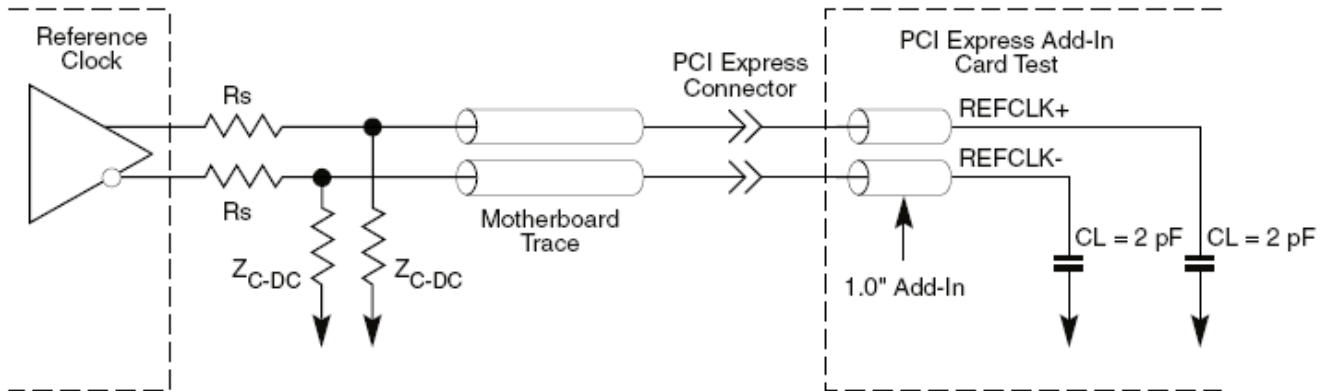


Figure 23. Reference Clock System Measurement Point and Loading

8.8.4. Auxiliary Signal Timing Parameters

Table 27. 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 |

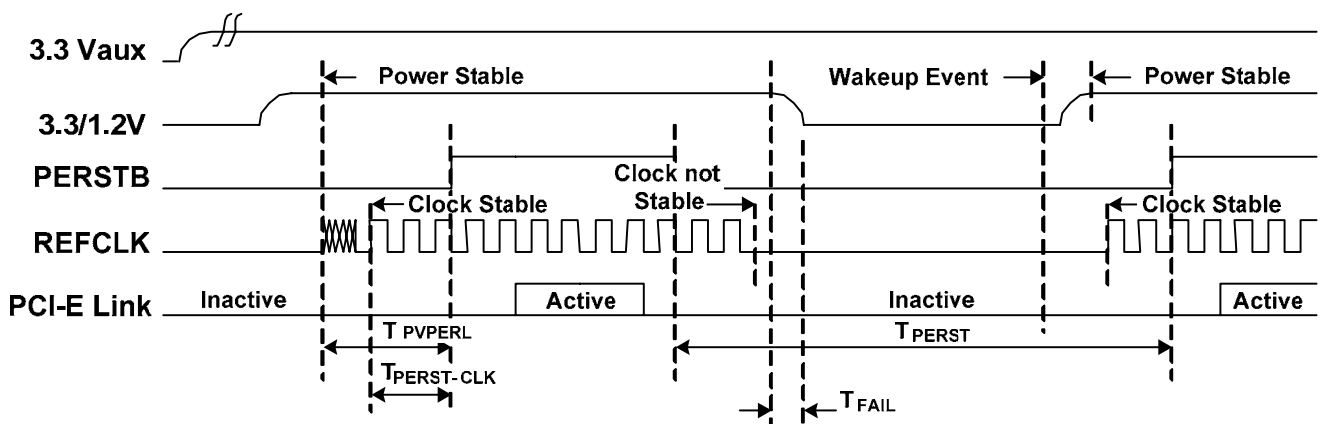
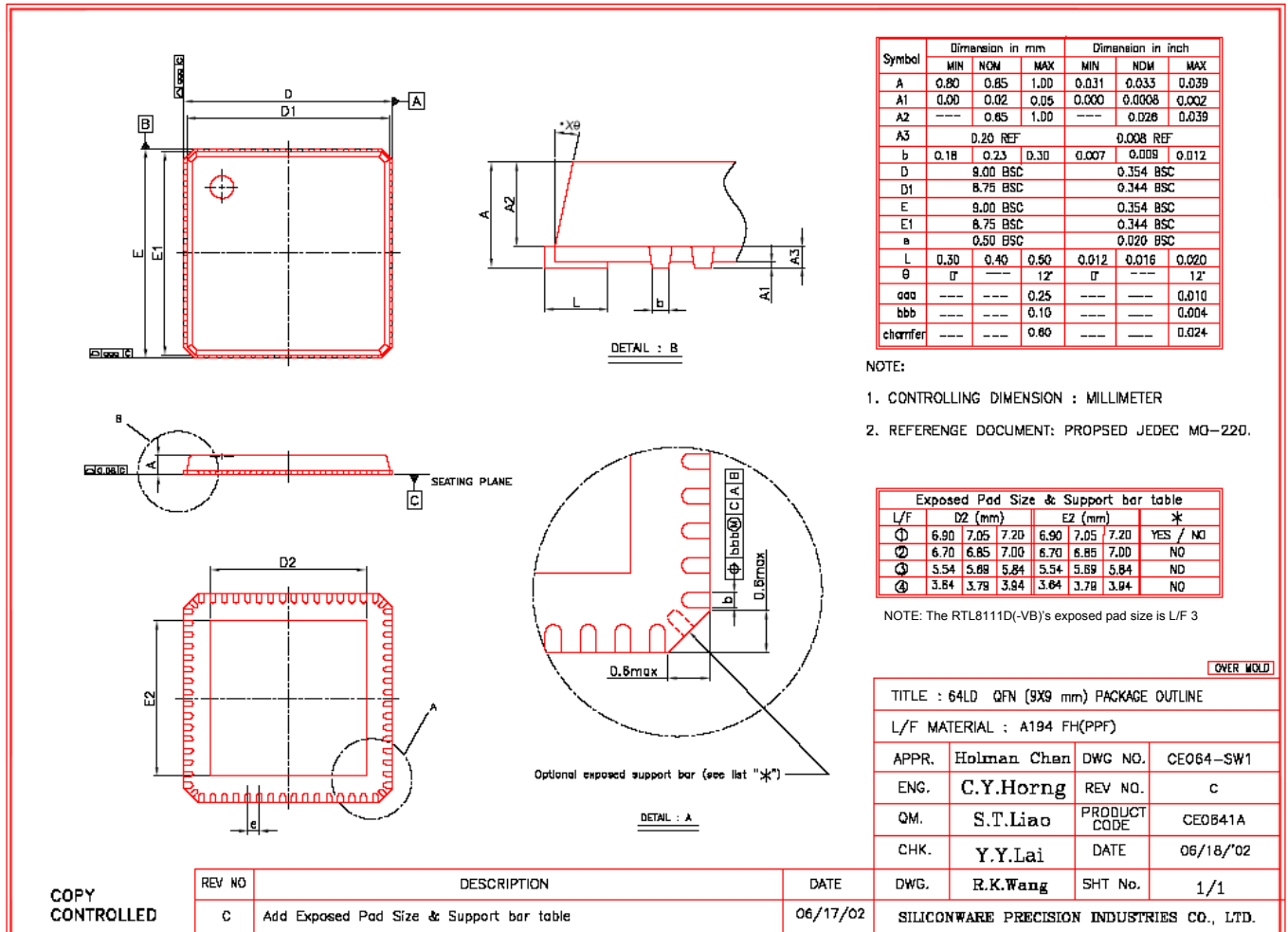


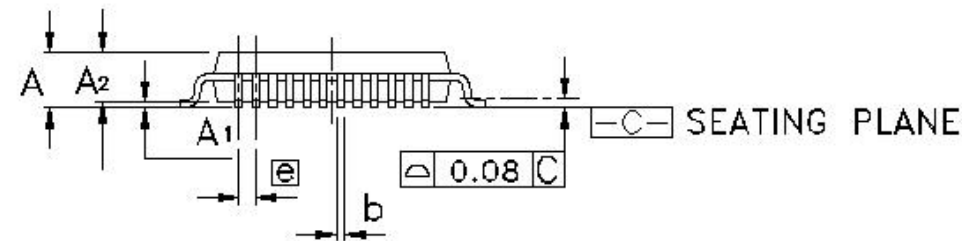
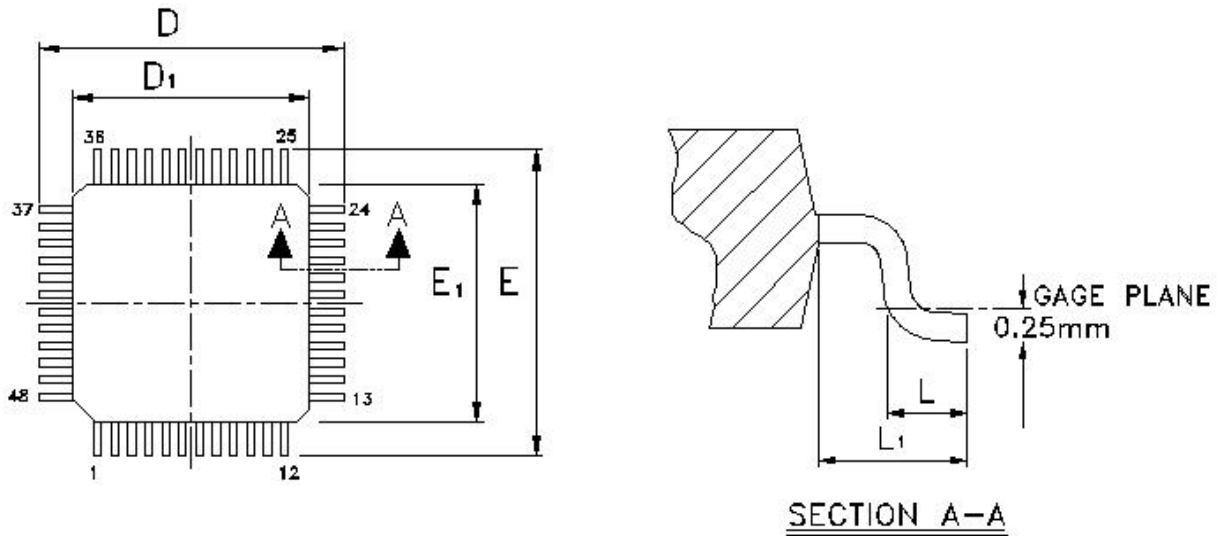
Figure 24. Auxiliary Signal Timing

9. Mechanical Dimensions

9.1. RTL8111D & RTL8111D-VB (64-Pin QFN)



9.2. RTL8111DL & RTL8111DL-VB (48-Pin LQFP)



9.3. Mechanical Dimensions Notes (RTL8111DL/RTL8111DL-VB 48-Pin)

| Symbol | Dimension in Inchs | | | Dimension in Millimeters | | |
|--------|--------------------|-------|-------|--------------------------|------|------|
| | Min | Nom | Max | Min | Nom | Max |
| A | - | - | 0.063 | - | - | 1.60 |
| A1 | 0.002 | 0.004 | 0.006 | 0.00 | 0.1 | 0.15 |
| A2 | 0.053 | 0.055 | 0.057 | 1.30 | 1.40 | 1.45 |
| b | 0.007 | 0.009 | 0.011 | 0.15 | 0.22 | 0.27 |
| D/E | 0.354 BSC | | | 9.00 BSC | | |
| D1/E1 | 0.276 BSC | | | 7.00 BSC | | |
| e | 0.020 BSC | | | 0.50 BSC | | |
| L | 0.018 | 0.024 | 0.030 | 0.45 | 0.60 | 0.75 |
| L1 | 0.039 REF | | | 1.00 REF | | |

Note 1: CONTROLLING DIMENSION: MILLIMETER (mm).

Note 2: REFERENCE DOCUMENT: JEDEC MS-026.

10. Ordering Information

Table 28. Ordering Information

| Part Number | Package | Status |
|--------------------|--|---------------|
| RTL8111D-GR | 64-Pin QFN 'Green' Package with Au Bonding | Production |
| RTL8111DL-GR | 48-Pin LQFP 'Green' Package with Au Bonding | Production |
| RTL8111D-VB-GR | 64-Pin QFN 'Green' Package with Au Bonding; Version B Silicon | Production |
| RTL8111DL-VB-GR | 48-Pin LQFP 'Green' Package with Au Bonding; Version B Silicon | Production |
| RTL8111DL-VB-CG | 48-Pin LQFP 'Green' Package with Cu Bonding; Version B Silicon | Production |

Note: See page 3 and page 4 for package identification information.

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