

REALTEK

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RTL8251CN-VB-GR

INTEGRATED 10/100/1000 GIGABIT ETHERNET TRANSCEIVER

DATASHEET

(CONFIDENTIAL: Development Partners Only)

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REALTEK

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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	2009/10/01	First release.

Table of Contents

1. GENERAL DESCRIPTION.....	1
2. FEATURES.....	2
3. SYSTEM APPLICATIONS.....	2
4. PIN ASSIGNMENTS	3
4.1. PACKAGE IDENTIFICATION.....	3
5. PIN DESCRIPTIONS	4
5.1. TRANSCEIVER INTERFACE.....	4
5.2. CLOCK	4
5.3. RGMII.....	5
5.4. MANAGEMENT INTERFACE.....	5
5.5. RESET	5
5.6. MODE SELECTION	6
5.7. LED DEFAULT SETTINGS	6
5.8. REGULATOR AND REFERENCE.....	6
5.9. POWER AND GROUND	7
5.10. NOT CONNECTED	7
6. FUNCTION DESCRIPTION	8
6.1. TRANSMITTER.....	8
6.1.1. RGMII (1000Mbps) Mode.....	8
6.1.2. RGMII (100Mbps) Mode.....	8
6.1.3. RGMII (10Mbps) Mode.....	8
6.2. RECEIVER.....	8
6.2.1. RGMII (1000Mbps) Mode.....	8
6.2.2. RGMII (100Mbps) Mode.....	9
6.2.3. RGMII (10Mbps) Mode.....	9
6.3. HARDWARE CONFIGURATION	9
6.4. LED AND PHY ADDRESS CONFIGURATION	10
6.5. MAC/PHY INTERFACE	11
6.5.1. RGMII.....	11
6.5.2. Management Interface.....	11
6.6. AUTO-NEGOTIATION.....	12
6.6.1. Auto-Negotiation Priority Resolution.....	15
6.6.2. Auto-Negotiation Master/Slave Resolution	15
6.6.3. Auto-Negotiation PAUSE/ASYMMETRIC PAUSE Resolution	16
6.7. Crossover Detection and Auto-Correction	17
6.8. LED CONFIGURATION.....	18
6.9. POLARITY CORRECTION	19
6.10. POWER	19
7. REGISTER DESCRIPTIONS.....	20
7.1. REGISTER MAPPING AND DEFINITIONS.....	20
7.2. REGISTER TABLE	21
7.2.1. BMCR (Basic Mode Control Register, Address 0x00)	21
7.2.2. BMSR (Basic Mode Status Register, Address 0x01).....	22
7.2.3. PHYID1 (PHY Identifier Register 1, Address 0x02)	23

7.2.4.	PHYID2 (PHY Identifier Register 2, Address 0x03)	24
7.2.5.	ANAR (Auto-Negotiation Advertising Register, Address 0x04)	24
7.2.6.	ANLPAR (Auto-Negotiation Link Partner Ability Register, Address 0x05)	25
7.2.7.	ANER (Auto-Negotiation Expansion Register, Address 0x06)	25
7.2.8.	ANNPTR (Auto-Negotiation Next Page Transmit Register, Address 0x07)	26
7.2.9.	ANNPRR (Auto-Negotiation Next Page Receive Register, Address 0x08)	26
7.3.	GBCR (1000BASE-T CONTROL REGISTER, ADDRESS 0x09)	27
7.3.1.	GBSR (1000Base-T Status Register, Address 0x0A)	28
7.3.2.	GBESR (1000Base-T Extended Status Register, Address 0x0F)	28
7.3.3.	PHYCR (PHY Specific Control Register, Address 0x10)	29
7.3.4.	PHYSR (PHY Specific Status Register, Address 0x11)	29
7.3.5.	INER (Interrupt Enable Register, Address 0x12)	30
7.3.6.	INSR (Interrupt Status Register, Address 0x13)	30
7.3.7.	RXERC (Receive Error Counter, Address 0x15)	31
7.3.8.	LEDCR (LED Control Register, Address 0x18)	31
7.3.9.	PAGSEL (Page Select Register, Address 0x1F)	31
8.	SWITCHING REGULATOR.....	32
8.1.	PCB LAYOUT	32
8.2.	INDUCTOR AND CAPACITOR PARTS LIST	33
8.3.	MEASUREMENT CRITERIA	34
8.4.	TYPICAL SWITCHING REGULATOR PCB LAYOUT	38
8.5.	EFFICIENCY MEASUREMENT	39
8.6.	POWER SEQUENCE	40
9.	APPLICATION DIAGRAM	40
10.	CHARACTERISTICS.....	41
10.1.	ABSOLUTE MAXIMUM RATINGS	41
10.2.	RECOMMENDED OPERATING CONDITIONS	41
10.3.	CRYSTAL REQUIREMENTS	41
10.4.	OSCILLATOR REQUIREMENTS	42
10.5.	DC CHARACTERISTICS	42
10.6.	AC CHARACTERISTICS	43
10.6.1.	MDC/MDIO Timing	43
10.6.2.	RGMII Timing	43
10.6.3.	RGMII Timing Modes	44
11.	MECHANICAL DIMENSIONS (6MM X 6MM).....	45
12.	ORDERING INFORMATION.....	46

List of Tables

TABLE 1. TRANSCEIVER INTERFACE	4
TABLE 2. CLOCK	4
TABLE 3. RGMII	5
TABLE 4. MANAGEMENT INTERFACE	5
TABLE 5. RESET	5
TABLE 6. MODE SELECTION	6
TABLE 7. LED DEFAULT SETTINGS	6
TABLE 8. REGULATOR AND REFERENCE	6
TABLE 9. POWER AND GROUND	7
TABLE 10. NOT CONNECTED	7
TABLE 11. CONFIG PINS VS. CONFIGURATION REGISTER	9
TABLE 12. CONFIGURATION REGISTER DEFINITION	9
TABLE 13. TYPICAL MDIO FRAME FORMAT	11
TABLE 14. 1000BASE-T BASE AND NEXT PAGES BIT ASSIGNMENTS	13
TABLE 15. LED REGISTER TABLE	18
TABLE 16. LED CONFIGURATION TABLE	18
TABLE 17. REGISTER MAPPING AND DEFINITIONS	20
TABLE 18. BMCR (BASIC MODE CONTROL REGISTER, ADDRESS 0x00)	21
TABLE 19. BMSR (BASIC MODE STATUS REGISTER, ADDRESS 0x01)	22
TABLE 20. PHYID1 (PHY IDENTIFIER REGISTER 1, ADDRESS 0x02)	23
TABLE 21. PHYID2 (PHY IDENTIFIER REGISTER 2, ADDRESS 0x03)	24
TABLE 22. ANAR (AUTO-NEGOTIATION ADVERTISING REGISTER, ADDRESS 0x04)	24
TABLE 23. ANLPAR (AUTO-NEGOTIATION LINK PARTNER ABILITY REGISTER, ADDRESS 0x05)	25
TABLE 24. ANER (AUTO-NEGOTIATION EXPANSION REGISTER, ADDRESS 0x06)	25
TABLE 25. ANNPTR (AUTO-NEGOTIATION NEXT PAGE TRANSMIT REGISTER, ADDRESS 0x07)	26
TABLE 26. ANNPRR (AUTO-NEGOTIATION NEXT PAGE RECEIVE REGISTER, ADDRESS 0x08)	26
TABLE 27. GBCR (1000BASE-T CONTROL REGISTER, ADDRESS 0x09)	27
TABLE 28. GBSR (1000BASE-T STATUS REGISTER, ADDRESS 0x0A)	28
TABLE 29. GBESR (1000BASE-T EXTENDED STATUS REGISTER, ADDRESS 0x0F)	28
TABLE 30. PHYCR (PHY SPECIFIC CONTROL REGISTER, ADDRESS 0x10)	29
TABLE 31. PHYSR (PHY SPECIFIC STATUS REGISTER, ADDRESS 0x11)	29
TABLE 32. INER (INTERRUPT ENABLE REGISTER, ADDRESS 0x12)	30
TABLE 33. INSR (INTERRUPT STATUS REGISTER, ADDRESS 0x13)	30
TABLE 34. RXERC (RECEIVE ERROR COUNTER, ADDRESS 0x15)	31
TABLE 35. LEDCR (LED CONTROL REGISTER, ADDRESS 0x18)	31
TABLE 36. PAGSEL (PAGE SELECT REGISTER, ADDRESS 0x1F)	31
TABLE 37. INDUCTOR AND CAPACITOR PARTS LIST	33
TABLE 38. POWER SEQUENCE PARAMETER	40
TABLE 39. ABSOLUTE MAXIMUM RATINGS	41
TABLE 40. RECOMMENDED OPERATING CONDITIONS	41
TABLE 41. CRYSTAL REQUIREMENTS	41
TABLE 42. OSCILLATOR REQUIREMENTS	42
TABLE 43. DC CHARACTERISTICS	42
TABLE 44. MDC/MDIO MANAGEMENT TIMING PARAMETERS	43
TABLE 45. RGMII TIMING PARAMETERS	43
TABLE 46. ORDERING INFORMATION	46

List of Figures

FIGURE 1. PIN ASSIGNMENTS.....	3
FIGURE 2. LED AND PHY ADDRESS CONFIGURATION	10
FIGURE 3. TYPICAL MDC/MDIO READ TIMING.....	11
FIGURE 4. TYPICAL MDC/MDIO WRITE TIMING	12
FIGURE 5. SWITCHING REGULATOR APPLICATION.....	32
FIGURE 6. INPUT VOLTAGE OVERSHOOT <4V (GOOD).....	34
FIGURE 7. INPUT VOLTAGE OVERSHOOT >4V (BAD).....	34
FIGURE 8. CERAMIC 22 μ F 1210(X5R) (GOOD).....	35
FIGURE 9. CERAMIC 22 μ F 0805(Y5V) (BAD).....	35
FIGURE 10. ELECTROLYTIC 100 μ F (RIPPLE TOO HIGH).....	36
FIGURE 11. 4R7GTSD32 (GOOD).....	37
FIGURE 12. 1 μ H BEAD (BAD).....	37
FIGURE 13. TYPICAL SWITCHING REGULATOR PCB LAYOUT (TOP LAYER).....	38
FIGURE 14. TYPICAL SWITCHING REGULATOR PCB LAYOUT (BOTTOM LAYER)	38
FIGURE 15. SWITCHING REGULATOR EFFICIENCY MEASUREMENT CHECKPOINT	39
FIGURE 16. POWER SEQUENCE.....	40
FIGURE 17. APPLICATION DIAGRAM	40
FIGURE 18. MDC/MDIO MANAGEMENT TIMING PARAMETERS	43
FIGURE 19. RGMII TIMING MODES	44

1. General Description

The Realtek RTL8251CN-VB-GR is a highly integrated Ethernet transceiver that complies with 10Base-T, 100Base-TX, and 1000Base-T IEEE 802.3 standards. It provides all the necessary physical layer functions to transmit and receive Ethernet packets over CAT 5 UTP cable or CAT 3 UTP (10Mbps only) cable.

The RTL8251CN-VB uses state-of-the-art DSP technology and an Analog Front End (AFE) to enable high-speed data transmission and reception over UTP cable. Functions such as Crossover Detection & Auto-Correction, polarity correction, adaptive equalization, cross-talk cancellation, echo cancellation, timing recovery, and error correction are implemented in the RTL8251CN-VB to provide robust transmission and reception capabilities at 10Mbps, 100Mbps, or 1000Mbps.

Data transfer between MAC and PHY is via the Reduced Gigabit Media Independent Interface (RGMI) for 1000Base-T, 10Base-T, and 100Base-TX.

2. Features

- 1000Base-T IEEE 802.3ab Compliant
- 100Base-TX IEEE 802.3u Compliant
- 10Base-T IEEE 802.3 Compliant
- IEEE 802.3 Compliant RGMII
- Supports Auto-Negotiation
- Supports Parallel Detection
- Crossover Detection & Auto-Correction
- Automatic polarity correction
- Transmit wave-shaping
- DSP processing
- Internal hybrids for 1000Base-T
- Baseline Wander Correction
- Support Interrupt function
- Supports half/full duplex operation
- Transmission rate up to 1Gbps over industry standard CAT.5 UTP cable with BER less than 10^{-10} in 1000Base-T
- The design transceiver capability target is up to 120M for CAT.5 cable in 1000Base-T
- Supports 3.3V or 2.5V signaling for RGMII
- Supports 25MHz external crystal or OSC
- Provides 125MHz clock source for MAC
- Provides 2 network status LEDs
- Supports Link Down power saving
- Built-in switching regulator
- 48-pin QFN
- 0.11 μ m process with very low power consumption

3. System Applications

Network Interface Adapter, MAU (Media Access Unit), CNR (Communication and Network Riser), ACR (Advanced Communication Riser), Ethernet hub, and Ethernet switch.

In addition, it can be used in any embedded system with an Ethernet MAC that needs a UTP physical connection.

4. Pin Assignments

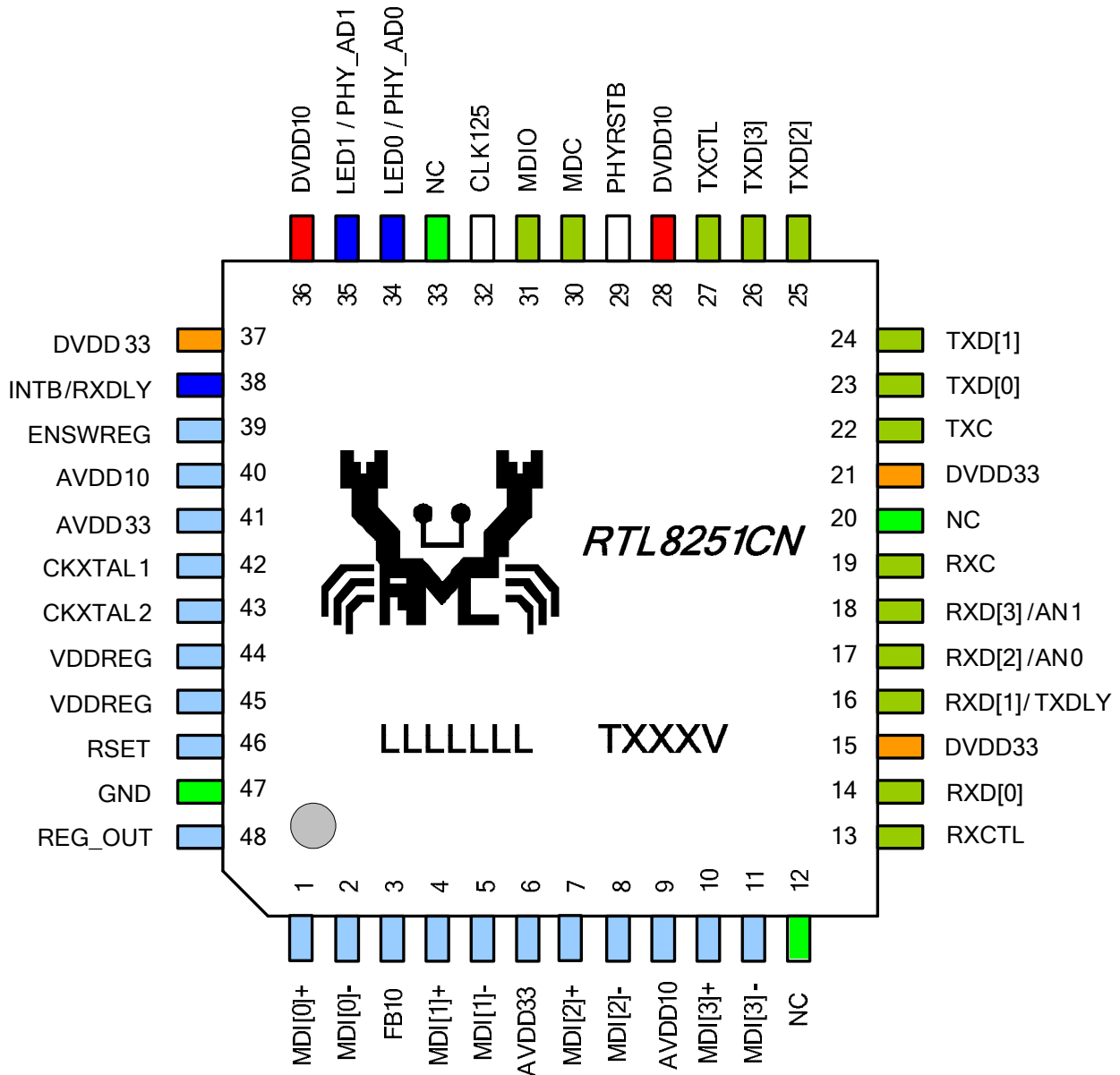


Figure 1. Pin Assignments

4.1. Package Identification

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

5. Pin Descriptions

Note that some pins have multiple functions. Refer to the Pin Assignments figure on page 3 for a graphical representation.

5.1. Transceiver Interface

Table 1. Transceiver Interface

Pin No.	Pin Name	Type	Description
1	MDI[0]+	IO	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.
2	MDI[0]–	IO	In MDI crossover mode, this pair acts as the BI_DB+/- pair, and is the receive pair in 10Base-T and 100Base-TX.
4	MDI[1]+	IO	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.
5	MDI[1]–	IO	In MDI crossover mode, this pair acts as the BI_DA+/- pair, and is the transmit pair in 10Base-T and 100Base-TX.
7	MDI[2]+	IO	In MDI mode, this is the third pair in 1000Base-T, i.e., the BI_DC+/- pair.
8	MDI[2]–	IO	In MDI crossover mode, this pair acts as the BI_DD+/- pair.
10	MDI[3]+	IO	In MDI mode, this is the fourth pair in 1000Base-T, i.e., the BI_DD+/- pair.
11	MDI[3]–	IO	In MDI crossover mode, this pair acts as the BI_DC+/- pair.

5.2. Clock

Table 2. Clock

Pin No.	Pin Name	Type	Description
42	CKXTAL1	I	25MHz Crystal Input. If a 25MHz oscillator is used, connect CKXTAL1 to the oscillator's output (see section 10.3 Crystal Requirements, page 41 for clock source specifications).
43	CKXTAL2	O	25MHz Crystal Output. Must be left open when an external 25MHz oscillator drives CKXTAL2.
32	CLK125	O	125MHz Reference Clock Generated from Internal PLL.

5.3. RGMII

Table 3. RGMII

Pin No.	Pin Name	Type	Description
22	TXC	I	The transmit reference clock will be 125MHz, 25MHz, or 2.5MHz depending on speed.
23	TXD[0]	I	Transmit Data. Data is transmitted from MAC to PHY via TXD[3:0].
24	TXD[1]	I	
25	TXD[2]	I	
26	TXD[3]	I	
27	TXCTL	I	Receive Control Signal from the MAC.
19	RXC	O	The continuous receive reference clock will be 125MHz, 25MHz, or 2.5MHz, and is derived from the received data stream.
14	RXD[0]	O	Receive Data. Data is transmitted from PHY to MAC via RXD[3:0].
16	RXD[1]	O	
17	RXD[2]	O	
18	RXD[3]	O	
13	RXCTL	O	Transmit Control Signal to the MAC.
16	TXDLY	I	RGMII Transmit Clock Timing Control. 1: Add 2ns delay to TXC for TXD latching
38	RXDLY	I	RGMII Receiver Clock Timing Control. 1: Add 2ns delay to RXC for RXD latching

5.4. Management Interface

Table 4. Management Interface

Pin No.	Pin Name	Type	Description
30	MDC	I	Management Data Clock.
31	MDIO	IO	Input/Output of Management Data.
38	INTB	O	Interrupt. Active low.

5.5. Reset

Table 5. Reset

Pin No.	Pin Name	Type	Description
29	PHYRSTB	I	Hardware Reset. Active low.

5.6. Mode Selection

Table 6. Mode Selection

Pin No.	Pin Name	Type	Description
34	PHY_AD0	I	PHY Configuration.
35	PHY_AD1	I	
17	AN0	I	
18	AN1	I	

Note: See section 6.3 Hardware Configuration, page 9 for details.

5.7. LED Default Settings

Table 7. LED Default Settings

Pin No.	Pin Name	Type	Description
34	LED0	O	Blinking=Transmitting or Receiving.
35	LED1	O	Low=Link Up (Any speed) High=Link Down (Any speed) <i>Note: High/Low active depends on hardware configuration setting.</i>

Note: See section 6.8 LED Configuration, page 18 for details.

5.8. Regulator and Reference

Table 8. Regulator and Reference

Pin No.	Pin Name	Type	Description
46	RSET	I	Reference. External Resistor Reference.
44, 45	VDDREG	Power	3.3V Power Supply for Switching Regulator.
48	REG_OUT	O	Switching Regulator 1.05V Output. Connect to a 4.7 μ H inductor.
3	FB10	I	Feedback Pin for Switching Regulator.
39	ENSWREG	I	3.3V: Enable switching regulator. 0V: Disable switching regulator.

5.9. Power and Ground

Table 9. Power and Ground

Pin No.	Pin Name	Type	Description
15, 21, 37	DVDD33	Power	Digital Power. 3.3V.
15, 21	DVDD33	Power	RGMI I Power Pins, For 3.3 or 2.5V RGMI I/O.
28, 36	DVDD10	Power	Digital Power. 1.05V.
6, 41	AVDD33	Power	Analog Power. 3.3V.
9, 40	AVDD10	Power	Analog Power. 1.05V.
47	GND	Ground	Ground. Exposed Pad (E-Pad) is Analog and Digital Ground (see section 11 Mechanical Dimensions (6mm x 6mm), page 45).

5.10. Not Connected

Table 10. Not Connected

Pin No.	Pin Name	Type	Description
12, 20, 33	NC	-	Not Connected.

6. Function Description

6.1. *Transmitter*

Based on state-of-the-art DSP technology and mixed-mode signal processing technology, the RTL8251CN-VB is capable of operating at 10/100/1000Mbps link speed over standard CAT.5 UTP cable and CAT.3 UTP cable (10Mbps).

6.1.1. **RGMII (1000Mbps) Mode**

The RTL8251CN-VB's PCS layer receives data bytes from the MAC through the RGMII interface and performs generation of continuous code-groups through 4D-PAM5 coding technology. These code groups are passed through a waveform-shaping filter to minimize EMI effect, and are transmitted onto the 4-pair CAT5 cable at 125MBaud/s through a D/A converter.

6.1.2. **RGMII (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 signal are passed to the MLT3 encoder, then to the D/A converter and transmitted onto the media.

6.1.3. **RGMII (10Mbps) Mode**

The transmit 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.

6.2. *Receiver*

6.2.1. **RGMII (1000Mbps) Mode**

Input signals from the media first pass through the on-chip sophisticated hybrid circuit to subtract 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, such as 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 RGMII interface at a clock speed of 125MHz. The Rx MAC retrieves the packet data from the receive RGMII interface and sends it to the Rx Buffer Manager.

6.2.2. RGMII (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 RGMII interface in 4-bit-wide nibbles at a clock speed of 25MHz.

6.2.3. RGMII (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 RGMII interface at a clock speed of 2.5MHz.

6.3. Hardware Configuration

The operation speed, interface mode, and PHY address can be set by the CONFIG pins. The respective value mapping of CONFIG with the configurable vector is listed in Table 11. To set the CONFIG pins, an external pull-high or pull-low via resistor is required.

Table 11. CONFIG Pins vs. Configuration Register

Pin	Pin Name
LED0	PHYAD[0]
LED1	PHYAD[1]
RXD2	AN[0]
RXD3	AN[1]

Table 12. Configuration Register Definition

Configuration	Description
PHYAD[1:0]	PHY Address. PHYAD sets the PHY address for the device. <i>Note: PHYAD[:]=0 can support all PHY addresses. It can automatically remember the first MAC address.</i>
AN[1:0]	Auto-Negotiation (NWay) Configuration. AN[1:0] controls the setting of Auto-Negotiation enable/disable, speed, and duplex setting. 00: 10Base-T Full Duplex 01: 100base-Tx Half Duplex 10: 100base-Tx Full Duplex 11: NWay. Advertise all capabilities

6.4. LED and PHY Address Configuration

In order to reduce the pin count on the RTL8251CN-VB, the LED pins are duplexed with the PHY address pins. As the PHYAD strap options share the LED output pins, the external combinations required for strapping and LED usage must be considered in order to avoid contention. Specifically, when the LED outputs are used to drive LEDs directly, the active state of each output driver is dependent on the logic level sampled by the corresponding PHYAD input upon power-up/reset. For example, as Figure 2 (left-side) shows, if a given PHYAD input is resistively pulled high then the corresponding output will be configured as an active low driver. On the right side, we can see that if a given PHYAD input is resistively pulled low then the corresponding output will be configured as an active high driver. The PHY address configuration pins should not be connected to GND or VCC directly, but must be pulled high or low through a resistor (e.g., 4.7K Ω). If no LED indications are needed, the components of the LED path (LED+510 Ω) can be removed.

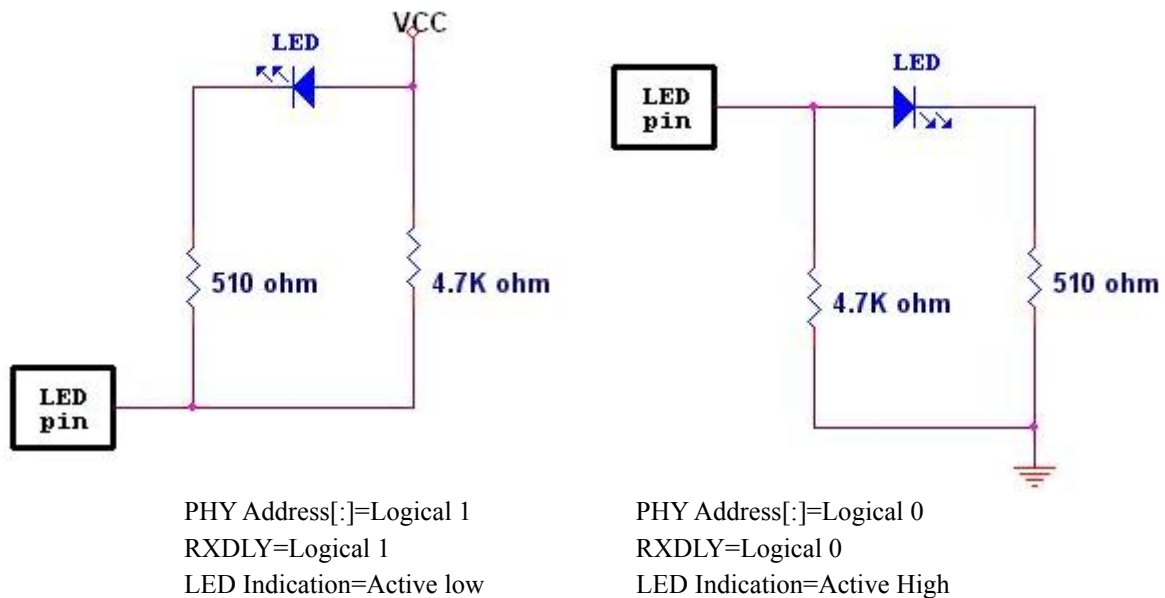


Figure 2. LED and PHY Address Configuration

6.5. MAC/PHY Interface

The RTL8251CN-VB supports industry standards and is suitable for most off-the-shelf MACs with a RGMII interface.

6.5.1. RGMII

In 1000Base-T mode (RGMII interface is selected), TXC and RXC sources are 125MHz. TXC will always be generated by the MAC and RXC will always be generated by the PHY. TXD[3:0] and RXD[3:0] signals are used for data transitions on rising edge and on falling edge of clock.

6.5.2. Management Interface

The management interface provides access to the internal registers through the MDC and MDIO pins as described in IEEE 802.3u section 22. The MDC signal, provided by the MAC, is the management data clock reference to the MDIO signal. The MDIO is the management data input/output and is a bi-directional signal that runs synchronously to MDC. The MDIO pin needs a 1.5k Ohm pull-up resistor to maintain the MDIO high during idle and turnaround.

Preamble suppression is the default setting of the RTL8251CN-VB after power-on. However, there still must be at least one idle bit between operations.

Up to 32bits, the RTL8251CN-VB can share the same MDIO line. In switch/router applications, each port should be assigned a unique address during the hardware reset sequence, and it can only be addressed via that unique PHY address. For detailed information on the RTL8251CN-VB management registers, see section 7 Register Descriptions, page 20.

Table 13. Typical MDIO Frame Format

Management Serial Protocol	<idle><start><op code><PHY addr.><reg. addr.><turnaround><data><idle>
Read	<idle><01><10><AAAA><RRRR><Z0><xxxx xxxx xxxx xxxx><idle>
Write	<idle><01><01><AAAA><RRRR><10><xxxx xxxx xxxx xxxx><idle>

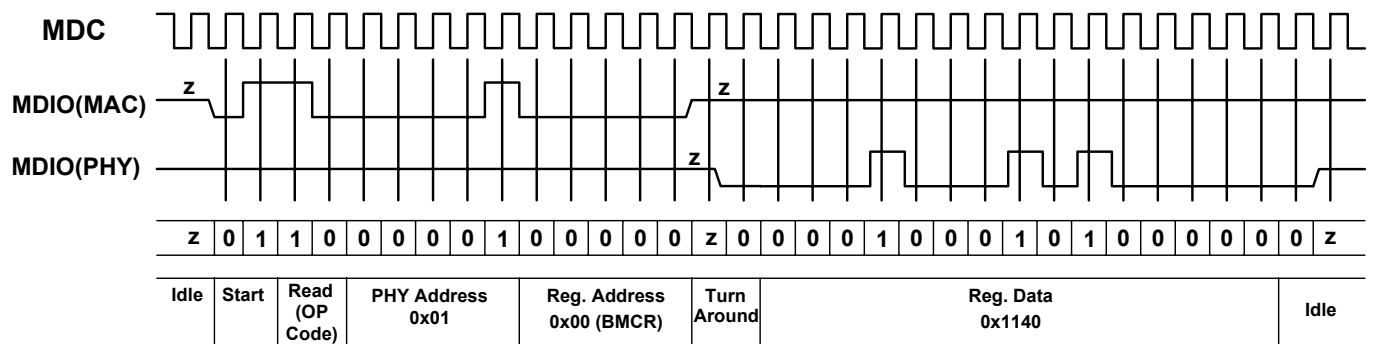


Figure 3. Typical MDC/MDIO Read Timing

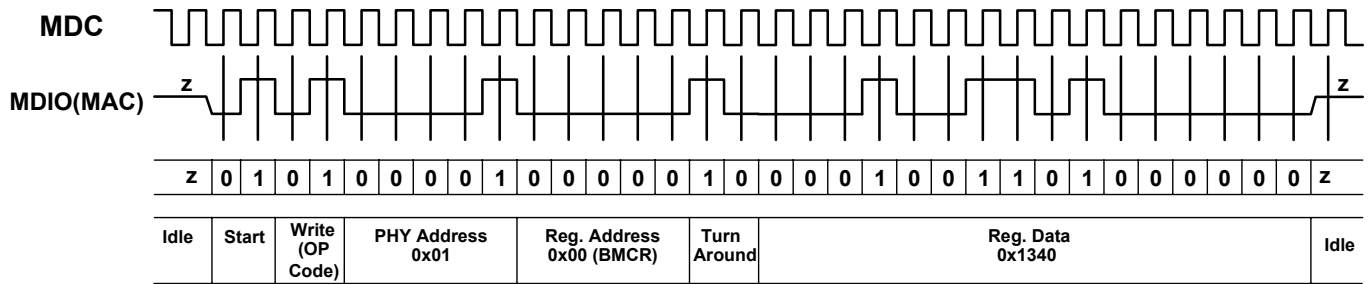


Figure 4. Typical MDC/MDIO Write Timing

6.6. Auto-Negotiation

Auto-Negotiation is a mechanism to determine the fastest connection between two link partners. For copper media applications, it was introduced in IEEE 802.3u for Ethernet and Fast Ethernet, and then in IEEE 802.3ab to address extended functions for Gigabit Ethernet. It performs the following:

- Auto-Negotiation Priority Resolution
- Auto-Negotiation Master/Slave Resolution
- Auto-Negotiation PAUSE/ASYMMETRIC PAUSE Resolution
- Crossover Detection & Auto-Correction Resolution

Upon de-assertion of a hardware reset, the RTL8251CN-VB can be configured to have auto-negotiation enabled, or be forced to operate in 10Base-T, 100Base-TX, or 1000Base-T mode via the CONFIG pins (see section 6.3 Hardware Configuration, page 9). If the RTL8251CN-VB is configured to operate only in 1000Base-T mode, then auto-negotiation is still enabled with only 1000Base-T mode advertised.

The auto-negotiation process is initiated automatically upon any of the following:

- Power-up
- Hardware reset
- Software reset (register 0.15)
- Restart auto-negotiation (register 0.9)
- Transition from power down to power up (register 0.11)
- Entering the link fail state

Table 14. 1000Base-T Base and Next Pages Bit Assignments

Bit	Name	Bit Description	Register Location
Base Page			
D15	NP	Next Page. 1: Indicates that Next Pages follow 0: Indicates that no Next Pages follow	-
D14	Ack	Acknowledge. 1: Indicates that a device has successfully received its link partner's Link Code Word (LCW)	-
D13	RF	Remote Fault. 1: Indicates to its link partner that a device has encountered a fault condition	-
D[12:5]	A[7:0]	Technology Ability Field. Indicates to its link partner the supported technologies specific to the selector field value.	Register 4.[12:5] Table 22, page 24.
D[4:0]	S[4:0]	Selector Field. Always 00001. Indicates to its link partner that it is an IEEE 802.3 device.	Register 4.[4:0] Table 22, page 24.
PAGE 0 (Message Next Page)			
M15	NP	Next Page. 1: Indicates that Next Pages follow 0: Indicates that no Next Pages follow	-
M14	Ack	Acknowledge. 1: Indicates that a device has successfully received its link partner's Link Code Word (LCW)	-
M13	MP	Message Page. 1: Indicates to its link partner that this is a message page, not an unformatted page.	-
M12	Ack2	Acknowledge 2. 1: Indicates to its link partner that a device has the ability to comply with the message.	-
M11	T	Toggle. Used by the NWay arbitration function to ensure synchronization with its link partner during Next Page exchange.	-
M[10:0]	-	1000Base-T Message Code. Always 8.	-
PAGE 1 (Unformatted Next Page)			
U15	NP	Next Page. 1: Indicates that Next Pages follow 0: Indicates that no Next Pages follow	-
U14	Ack	Acknowledge. 1: Indicates that a device has successfully received its link partner's Link Code Word (LCW)	-
U13	MP	Message Page. 1: Indicates to its link partner that this is a message page, not an unformatted page.	-

Bit	Name	Bit Description	Register Location
U12	Ack2	Acknowledge 2. 1: Indicates to its link partner that a device has the ability to comply with the message.	-
U11	T	Toggle. Used by the NWay arbitration function to ensure synchronization with its link partner during Next Page exchange.	-
U[10:5]	-	Reserved. Transmit as 0	-
U4	-	1000Base-T Half Duplex. 1: Half duplex 0: No half duplex	RGMII register 9.8 (GBCR) Table 27, page 27.
U3	-	1000Base-T Full Duplex. 1: Full duplex 0: No full duplex	RGMII register 9.8 (GBCR) Table 27, page 27.
U2	-	1000Base-T Port Type Bit. 1: Multi-port device 0: Single-port device	RGMII register 9.8 (GBCR) Table 27, page 27.
U1	-	1000Base-T Master-Slave Manual Configuration Value. 1: Master 0: Slave This bit is ignored if bit 9.12=0	RGMII register 9.8 (GBCR) Table 27, page 27.
U0	-	1000Base-T Master-Slave Manual Configuration Enable. 1: Manual Configuration Enable This bit is intended to be used for manual selection in Master-Slave mode, and is to be used in conjunction with bit 9.11	RGMII register 9.8 (GBCR) Table 27, page 27.
PAGE 2 (Unformatted Next Page)			
U15	NP	Next Page. 1: Indicates that Next Pages follow 0: Indicates that no Next Pages follow	-
U14	Ack	Acknowledge. 1: Indicates that a device has successfully received its link partner's Link Code Word (LCW)	-
U13	MP	Message Page. 1: Indicates to its link partner that this is a message page, not an unformatted page	-
U12	Ack2	Acknowledge 2. 1: Indicates to its link partner that a device has the ability to comply with the message	-
U11	T	Toggle. Used by the NWay arbitration function to ensure synchronization with its link partner during Next Page exchange.	-
U[10:0]	-	1000Base-T Master-Slave Seed Bit[10:0]	Master-Slave Seed Value SB[10:0]

6.6.1. Auto-Negotiation Priority Resolution

Upon the start of auto-negotiation, to advertise its capabilities each station transmits a 16-bit packet called a Link Code Word (LCW), within a burst of 17 to 33 Fast Link Pulses (FLP). A device capable of auto-negotiation transmits and receives the FLPs. The receiver must identify three identical LCWs before the information is authenticated and used in the arbitration process. The devices decode the base LCW and select capabilities with the highest common denominator supported by both devices.

To advertise 1000Base-T capability, both link partners, sharing the same link medium, should engage in Next Page (1000Base-T Message Page, Unformatted Page 1, and Unformatted Page 2) exchange.

Auto-negotiation ensures that the highest priority protocol will be selected as the link speed based on the following priorities advertised through the Link Code Word (LCW) exchange. Refer to IEEE 802.3 Clause 28 for detailed information.

1. 1000Base-T Full Duplex (highest priority)
2. 1000Base-T Half Duplex
3. 100Base-Tx Full Duplex
4. 100Base-Tx Half Duplex
5. 10Base-T Full Duplex
6. 10Base-T Half Duplex (lowest priority)

6.6.2. Auto-Negotiation Master/Slave Resolution

To establish a valid 1000Base-T link, the Master/Slave mode of both link partners should be resolved through the auto-negotiation process:

- Master Priority
 - Multi-port > Single port
 - Manual > Non-manual
- Determination of Master/Slave configuration from LCW
 - Manual_MASTER=U0*U1
 - Manual_SLAVE=U0*!U1
 - Single-port device=!U0*!U2
 - Multi-port device=!U0*U2

Where: U0 is bit 0 of the Unformatted Page 1
U1 is bit 1 of the Unformatted Page 1
U2 is bit 2 of the Unformatted Page 1

- Where there are two stations with the same configuration, the one with higher Master-Slave seed SB[10:0] in the unformatted page 2 shall become Master.
- Master-Slave configuration process resolution:
 - Successful: Bit 10.15 Master-Slave Configuration Fault is set to logical 0, and bit 10.14 is set to logical 1 for Master resolution, or set to logical 0 for Slave resolution.
 - Unsuccessful: Auto-Negotiation restarts.
 - Fault detect: Bit 10.15 is set to logical 1 to indicate that a configuration fault has been detected. Auto-Negotiation restarts automatically. This happens when both stations are set to manual Master mode or manual Slave mode, or after seven attempts to configure the Master-Slave relationship through the seed method has failed.

6.6.3. Auto-Negotiation PAUSE/ASYMMETRIC PAUSE Resolution

Auto-negotiation is also used to determine the flow control capability between link partners. Flow control is a mechanism that can force a busy transmitting link partner to stop transmitting in a full duplex environment by sending special MAC control frames. In IEEE 802.3u, a PAUSE control frame had already been defined. However, in IEEE 802.3ab, a new ASY-PAUSE control frame was defined; if the MAC can only generate PAUSE frames but is not able to respond to PAUSE frames generated by the link partner, then it is called ASYMMETRIC PAUSE.

PAUSE/ASYMMETRIC PAUSE capability can be configured by setting the ANAR bits 10 and 11 (Table 22, page 24). Link partner PAUSE capabilities can be determined from ANLPAR bits 10 and 11 (Table 23, page 25). A PHY layer device such as the RTL8251CN-VB is not directly involved in PAUSE resolution, but simply advertises and reports PAUSE capabilities during the Auto-Negotiation process. The MAC is responsible for final PAUSE/ASYMMETRIC PAUSE resolution after a link is established, and is responsible for correct flow control actions thereafter.

6.7. Crossover Detection and Auto-Correction

Ethernet needs a crossover mechanism between both link partners to cross the transmit signal to the receiver when the medium is twisted-pair cable (e.g., CAT.3 or CAT.5 UTP). Crossover Detection & Auto-Correction Configuration eliminates the need for crossover cables between devices, such as two PC's connected to each other with a CAT.3 or CAT.5 Ethernet cable. The basic concept is to assume the initial default setting is MDI mode, and then check the link status. If no link is established after a certain time, change to MDI Crossover mode and repeat the process until a link is established. An 11-bit pseudo-random timer is applied to decide the mode change time interval.

Crossover Detection & Auto-Correction is not a part of the Auto-Negotiation process, but it utilizes the process to exchange the MDI/MDI Crossover configuration. If the RTL8251CN-VB is configured to only operate in 100Base-TX or only in 10Base-T mode, then Auto-Negotiation is disabled only if the Crossover Detection & Auto-Correction function is also disabled. If Crossover Detection & Auto-Correction are enabled, then Auto-Negotiation is enabled and the RTL8251CN-VB advertises only 100Base-TX mode or 10Base-T mode. If the speed of operation is configured manually and Auto-Negotiation is still enabled because the Crossover Detection & Auto-Correction function is enabled, then the duplex advertised is as follows:

1. If CONFIG is set to half duplex, then only half duplex is advertised.
2. If CONFIG is set to full duplex, then both full and half duplex are advertised.

If the user wishes to advertise only full duplex at a particular speed with the Crossover Detection & Auto-Correction function enabled, then Auto-Negotiation should be enabled (register 0.12) with the appropriate advertising capabilities set in registers 4 or 9. The Crossover Detection & Auto-Correction function may be enabled/disabled by setting (register 16.6) manually.

After initial configuration following a hardware reset, Auto-Negotiation can be enabled and disabled via register 0.12, speed via registers 0.13, 0.6, and duplex via register 0.8. The abilities that are advertised can be changed via registers 4 and 9. Changes to registers 0.12, 0.13, 0.6, and 0.8 do not take effect unless at least one of the following events occurs:

- Software reset (register 0.15)
- Restart of Auto-Negotiation (register 0.9)
- Transition from power-down to power-up (register 0.11)

Registers 4 and 9 are internally latched once each time Auto-Negotiation enters the ABILITY DETECT state in the arbitration state machine (IEEE 802.3). Hence a write into register 4 or 9 has no effect once the RTL8251CN-VB begins to transmit Fast Link Pulses.

Register 7 is treated in a similar manner as 4 and 9 during additional Next Page exchanges. Once the RTL8251CN-VB completes Auto-Negotiation, it updates the various statuses in registers 1, 5, 6, and 10. The speed, duplex, page received, and Auto-Negotiation completed statuses are also available in registers 17 and 19.

6.8. LED Configuration

The RTL8251CN-VB supports two LED pins, suitable for multiple types of applications that can directly drive the LEDs. The output of these pins is determined by setting the corresponding bits in Page2 register 26. To change the register page, see note below and Table 15 and Table 16.

Note: To switch to Page2, Register 26, set Register 31 Data=0002. After setting, switch to the PHY's Page0 (Register 31 Data=0000).

Table 15. LED Register Table

	LINK Speed			Active (Tx/Rx)
	10Mbps	100Mbps	1000Mbps	
LED0	Reg26 Bit0	Reg26 Bit1	Reg26 Bit2	Reg26 Bit3
LED1	Reg26 Bit4	Reg26 Bit5	Reg26 Bit6	Reg26 Bit7

Table 16. LED Configuration Table

Pin	LINK Bit			Active (Tx/Rx) Bit	Description
	10	100	1000		
LED	0	0	0	0	N/A
	0	0	0	1	Active
	0	0	1	0	Link 1000
	0	0	1	1	Link 1000+Active
	0	1	0	0	Link 100
	0	1	0	1	Link 100+Active
	0	1	1	0	Link 100/1000
	0	1	1	1	Link 100/1000+Active
	1	0	0	0	Link 10
	1	0	0	1	Link 10+Active
	1	0	1	0	Link 10/1000
	1	0	1	1	Link 10/1000+Active
	1	1	0	0	Link 10/100
	1	1	0	1	Link 10/100+Active
	1	1	1	0	Link 10/100/1000
	1	1	1	1	Link 10/100/1000+Active

6.9. Polarity Correction

The RTL8251CN-VB automatically corrects polarity errors on the receive pairs in 1000Base-T and 10Base-T modes. In 100Base-TX mode polarity is irrelevant. In 1000Base-T mode, receive polarity errors are automatically corrected based on the sequence of idle symbols. Once the descrambler is locked, the polarity is also locked on all pairs. The polarity becomes unlocked only when the receiver loses lock. In 10Base-T mode, polarity errors are corrected based on the detection of validly spaced link pulses. The detection begins during the MDI crossover detection phase and locks when the 10Base-T link is up. The polarity becomes unlocked when the link is down.

6.10. Power

The RTL8251CN-VB implements a voltage regulator to generate operating power. The system vendor needs to supply a 3.3V, 1A steady power source. The RTL8251CN-VB converts the 3.3V steady power source to 1.05V via a switching regulator.

Another possible implementation is to use an external regulator to generate 1.0V. Be sure that the regulator meets the required current rate.

The RTL8251CN-VB implements an option for the RGMII power pins. The standard I/O voltage of the RGMII interface is 3.3V, with support for 2.5V to lower EMI. The 2.5V power source for RGMII is from an external regulator.

7. Register Descriptions

7.1. Register Mapping and Definitions

Table 17. Register Mapping and Definitions

Offset	Access	Name	Description
0	RW	BMCR	Basic Mode Control Register.
1	RO	BMSR	Basic Mode Status Register.
2	RO	PHYID1	PHY Identifier Register 1.
3	RO	PHYID2	PHY Identifier Register 2.
4	RW	ANAR	Auto-Negotiation Advertising Register.
5	RW	ANLPAR	Auto-Negotiation Link Partner Ability Register.
6	RW	ANER	Auto-Negotiation Expansion Register.
7	RW	ANNPTR	Auto-Negotiation Next Page Transmit Register.
8	RW	ANNPRR	Auto-Negotiation Next Page Receive Register.
9	RW	GBCR	1000Base-T Control Register.
10	RO	GBSR	1000Base-T Status Register.
11~14	RO	RSVD	Reserved.
15	RO	GBESR	1000Base-T Extended Status Register.
16	RW	PHYCR	PHY Specific Control Register.
17	RO	PHYSR	PHY Specific Status Register.
18	RW	INER	Interrupt Enable Register.
19	RO	INSR	Interrupt Status Register.
21	RO	RXERC	Receive Error Counter.
24	RW	LEDCR	LED Control Register.
25	RO	RSVD	Reserved.
27~30	RO	RSVD	Reserved.
31	RW	PAGSEL	Page Select Register.
26/Page2	RW	LEDCR	LED Control Register.

Note: To switch to Page2, Register 26, set Register 31 Data=0002. After setting, switch to the PHY's Page0 (Register 31 Data=0000).

7.2. Register Table

7.2.1. BMCR (Basic Mode Control Register, Address 0x00)

Table 18. BMCR (Basic Mode Control Register, Address 0x00)

Bit	Name	RW	Default	Description															
0.15	Reset	RW, SC ¹	0	Reset. 1: PHY reset 0: Normal operation															
0.14	Loopback	RW	0	Loopback Mode for 10M & 100M. 1: Enable loopback mode 0: Disable loopback mode The loopback function enables RGMII transmit data to be routed to the RGMII receive data path.															
0.13	Speed[0]	RW	0	Speed Select Bit 0. In forced mode, i.e., when Auto-Negotiation is disabled, bits 6 and 13 determine device speed selection. <table><tr><th>Speed[1]</th><th>Speed[0]</th><th>Speed Enabled</th></tr><tr><td>1</td><td>1</td><td>Reserved</td></tr><tr><td>1</td><td>0</td><td>Reserved</td></tr><tr><td>0</td><td>1</td><td>100Mbps</td></tr><tr><td>0</td><td>0</td><td>10Mbps</td></tr></table>	Speed[1]	Speed[0]	Speed Enabled	1	1	Reserved	1	0	Reserved	0	1	100Mbps	0	0	10Mbps
Speed[1]	Speed[0]	Speed Enabled																	
1	1	Reserved																	
1	0	Reserved																	
0	1	100Mbps																	
0	0	10Mbps																	
0.12	ANE	RW	1	Auto-Negotiation Enable. 1: Enable Auto-Negotiation 0: Disable Auto-Negotiation															
0.11	PWD	RW	0	Power Down. 1: Power down (only Management Interface and logic active, link is down) 0: Normal operation															
0.10	Isolate	RW	0	Isolate. 1: RGMII interface is isolated; the serial management interface (MDC, MDIO) is still active. When this bit is asserted, the RTL8251CN-VB ignores TXD[3:0], and TXCLT inputs, and presents a high impedance on TXC, RXC, RXCLT, RXD[3:0]. 0: Normal operation															
0.9	Restart_AN	RW, SC	0	Restart Auto-Negotiation. 1: Restart Auto-Negotiation 0: Normal operation															
0.8	Duplex	RW	1	Duplex Mode. 1: Full Duplex operation 0: Half Duplex operation This bit is valid only in force mode, i.e., NWay is disabled.															

Bit	Name	RW	Default	Description
0.7	Collision Test	RW	0	Collision Test. 1: Collision test enabled 0: Normal operation When set, this bit will cause the COL signal to be asserted in response to the assertion of TXEN within 512-bit times. The COL signal will be de-asserted within 4-bit times in response to the de-assertion of TXEN.
0.6	Speed[1]	RW	1	Speed Select Bit 1. Refer to bit 0.13.
0.5:0	RSVD	RO	000000	Reserved.

Note 1: SC: Self-cleared

Note 2: The power-on duplex, speed, and ANE values take on the values set by external pins AN[3:0] on hardware reset only. A write to these registers has no effect unless any one of the following also occurs: Software reset (0.15) is asserted, Restart_AN (0.9) is asserted, or PWD (0.11) transitions from power down to normal operation.

Note 3: When the RTL8251CN-VB is switched from power down to normal operation, a software reset and restart auto-negotiation is performed, even if bits Reset (0.15) and Restart_AN (0.9) are not set by the user.

Note 4: Auto-Negotiation is enabled when speed is set to 1000Base-T. Crossover Detection & Auto-Correction takes precedence over Auto-Negotiation disable (0.12=0). If ANE is disabled, speed and duplex capabilities are advertised by 0.13, 0.6, and 0.8. Otherwise, register 4.8:5 and 9.9:8 take effect.

Note 5: Auto-Negotiation automatically restarts after hardware or software reset regardless of whether or not the restart bit (0.9) is set.

7.2.2. BMSR (Basic Mode Status Register, Address 0x01)

Table 19. BMSR (Basic Mode Status Register, Address 0x01)

Bit	Name	RW	Default	Description
1.15	100Base-T4	RO	0	100Base-T4 Capability. The RTL8251CN-VB does not support 100Base-T4 mode. This bit should always be 0.
1.14	100Base-TX (full)	RO	1	100Base-TX Full Duplex Capability. 1: Device is able to perform 100Base-TX in full duplex mode 0: Device is not able to perform 100Base-TX in full duplex mode
1.13	100Base-TX (half)	RO	1	100Base-TX Half Duplex Capability. 1: Device is able to perform 100Base-TX in half duplex mode 0: Device is not able to perform 100Base-TX in half duplex mode
1.12	10Base-T (full)	RO	1	10Base-T Full Duplex Capability. 1: Device is able to perform 10Base-T in full duplex mode. 0: Device is not able to perform 10Base-T in full duplex mode.
1.11	10Base-T (half)	RO	1	10Base-T Half Duplex Capability. 1: Device is able to perform 10Base-T in half duplex mode 0: Device is not able to perform 10Base-T in half duplex mode
1.10	100Base-T2 (full)	RO	0	100Base-T2 Full Duplex Capability. The RTL8251CN-VB does not support 100Base-T2 mode and this bit should always be 0.

Bit	Name	RW	Default	Description
1.9	100Base-T2 (half)	RO	0	100Base-T2 Half Duplex Capability. The RTL8251CN-VB does not support 100Base-T2 mode. This bit should always be 0.
1.8	1000Base-T Extended Status	RO	1	1000Base-T Extended Status Register. 1: Device supports Extended Status Register 0x0F (15) 0: Device does not support Extended Status Register 0x0F This register is read-only and is always set to 1.
1.7	RSVD	RO	0	Reserved.
1.6	Preamble Suppression	RO	1	Preamble Suppression Capability (Permanently On). The RTL8251CN-VB always accepts transactions with preamble suppressed.
1.5	Auto-Negotiation Complete	RO	0	Auto-Negotiation Complete. 1: Auto-Negotiation process complete, and contents of registers 5, 6, 8, and 10 are valid 0: Auto-Negotiation process not complete
1.4	Remote Fault	RC*	0	Remote Fault. 1: Remote fault condition detected (cleared on read or by reset). Indication or notification of remote fault from Link Partner 0: No remote fault condition detected
1.3	Auto-Negotiation Ability	RO	1	Auto Configured Link. 1: Device is able to perform Auto-Negotiation 0: Device is not able to perform Auto-Negotiation
1.2	Link Status	RO	0	Link Status. 1: Linked 0: Not Linked This register indicates whether the link was lost since the last read. For the current link status, either read this register twice or read register bit 17.10 Link Real Time.
1.1	Jabber Detect	RC	0	Jabber Detect. 1: Jabber condition detected 0: No Jabber occurred
1.0	Extended Capability	RO	1	1: Extended register capabilities, always 1

Note: RC: Read-cleared after read.

7.2.3. PHYID1 (PHY Identifier Register 1, Address 0x02)

Table 20. PHYID1 (PHY Identifier Register 1, Address 0x02)

Bit	Name	RW	Default	Description
2.15:0	OUI_MSB	RO	0000000000011100	Organizationally Unique Identifier Bit 3:18. Always 0000000000011100.

Note: Realtek OUI is 0x000732.

7.2.4. PHYID2 (PHY Identifier Register 2, Address 0x03)

Table 21. PHYID2 (PHY Identifier Register 2, Address 0x03)

Bit	Name	RW	Default	Description
3.15:10	OUI_LSB	RO	110010	Organizationally Unique Identifier Bit 19:24. Always 110010.
3.9:4	Model Number	RO	010001	Always 010001.
3.3:0	Revision Number	RO	0010	Revision Number

7.2.5. ANAR (Auto-Negotiation Advertising Register, Address 0x04)

Table 22. ANAR (Auto-Negotiation Advertising Register, Address 0x04)

Bit	Name	RW	Default	Description
4.15	NextPage	RW	0	1: Additional next pages exchange desired 0: No additional next pages exchange desired
4.14	RSVD	RO	0	Reserved.
4.13	Remote Fault	RW	0	1: Set Remote Fault bit 0: No remote fault detected
4.12	RSVD	RO	0	Reserved.
4.11	Asymmetric PAUSE	RW	0	1: Advertise support of asymmetric pause 0: No support of asymmetric pause
4.10	PAUSE	RW	0	1: Advertise support of pause frames 0: No support of pause frames
4.9	100Base-T4	RO	1	1: 100Base-T4 support 0: 100Base-T4 not supported
4.8	100Base-TX (Full)	RW	1	1: Advertise support of 100Base-TX full-duplex mode 0: Not advertised
4.7	100Base-TX (Half)	RW	1	1: Advertise support of 100Base-TX half-duplex mode 0: Not advertised
4.6	10Base-T (Full)	RW	1	1: Advertise support of 10Base-TX full-duplex mode 0: Not advertised
4.5	10Base-T (Half)	RW	1	1: Advertise support of 10Base-TX full-duplex mode 0: Not advertised
4.4:0	Selector Field	RO	00001	Indicates the RTL8251CN-VB Supports IEEE 802.3

Note 1: The setting of Register 4 has no effect unless NWay is restarted or the link goes down.

Note 2: If 1000Base-T is advertised, then the required next pages are automatically transmitted. Register 4.15 should be set to 0 if no additional next pages are needed.

7.2.6. ANLPAR (Auto-Negotiation Link Partner Ability Register, Address 0x05)

Table 23. ANLPAR (Auto-Negotiation Link Partner Ability Register, Address 0x05)

Bit	Name	RW	Default	Description
5.15	Next Page	RO	0	Next Page Indication. Received Code Word Bit 15.
5.14	ACK	RO	0	Acknowledge. Received Code Word Bit 14.
5.13	Remote Fault	RO	0	Remote Fault indicated by Link Partner. Received Code Word Bit 13.
5.12:5	Technology Ability Field	RO	00000000	Received Code Word Bit 12:5.
5.4:0	Selector Field	RO	00000	Received Code Word Bit 4:0.

Note: Register 5 is not valid until the Auto-Negotiation complete bit 1.5 indicates completed.

7.2.7. ANER (Auto-Negotiation Expansion Register, Address 0x06)

Table 24. ANER (Auto-Negotiation Expansion Register, Address 0x06)

Bit	Name	RW	Default	Description
6.15:5	RSVD	RO	0x000	Reserved.
6.4	Parallel Detection Fault	RC	0	1: A fault has been detected via the Parallel Detection function 0: A fault has not been detected via the Parallel Detection function
6.3	Link Partner Next Pageable	RO	0	1: Link Partner supports Next Page exchange 0: Link Partner does not support Next Page exchange
6.2	Local Next Pageable	RO	1	1: Local Device is able to send Next Page Always 1.
6.1	Page Received	RC	0	1: A New Page (new LCW) has been received 0: A New Page has not been received
6.0	Link Partner Auto-Negotiation capable	RO	0	1: Link Partner supports Auto-Negotiation 0: Link Partner does not support Auto-Negotiation

Note: Register 6 is not valid until the Auto-Negotiation complete bit 1.5 indicates completed.

7.2.8. ANNPTR (Auto-Negotiation Next Page Transmit Register, Address 0x07)

Table 25. ANNPTR (Auto-Negotiation Next Page Transmit Register, Address 0x07)

Bit	Name	RW	Default	Description
7.15	Next Page	RW	0	Next Page Indication. 0: No more next pages to send 1: More next pages to send Transmit Code Word Bit 15.
7.14	RSVD	RO	0	Transmit Code Word Bit 14.
7.13	Message Page	RW	1	Message Page. 0: Unformatted Page 1: Message Page Transmit Code Word Bit 13.
7.12	Acknowledge 2	RW	0	Acknowledge2. 0: Local device has no ability to comply with the message received 1: Local device has the ability to comply with the message received Transmit Code Word Bit 12.
7.11	Toggle	RO	0	Toggle Bit. Transmit Code Word Bit 11.
7.10:0	Message/Unformatted Field	RW	0x001	Content of Message/Unformatted Page. Transmit Code Word Bit 10:0.

7.2.9. ANNPRR (Auto-Negotiation Next Page Receive Register, Address 0x08)

Table 26. ANNPRR (Auto-Negotiation Next Page Receive Register, Address 0x08)

Bit	Name	RW	Default	Description
8.15	Next Page	RO	0	Received Link Code Word Bit 15.
8.14	Acknowledge	RO	0	Received Link Code Word Bit 14.
8.13	Message Page	RO	0	Received Link Code Word Bit 13.
8.12	Acknowledge 2	RO	0	Received Link Code Word Bit 12.
8.11	Toggle	RO	0	Received Link Code Word Bit 11.
8.10:0	Message/Unformatted Field	RO	0x00	Received Link Code Word Bit 10:0.

Note: Register 8 is not valid until the Auto-Negotiation complete bit 1.5 indicates completed.

7.3. GBCR (1000Base-T Control Register, Address 0x09)

Table 27. GBCR (1000Base-T Control Register, Address 0x09)

Bit	Name	RW	Default	Description
9.15:13	Test Mode	RW	0	Test Mode Select. 000: Normal Mode 001: Test Mode 1 - Transmit Jitter Test 010: Test Mode 2 - Transmit Jitter Test (MASTER mode) 011: Test Mode 3 - Transmit Jitter Test (SLAVE mode) 100: Test Mode 4 - Transmit Distortion Test 101, 110, 111: Reserved
9.12	MASTER/SLAVE Manual Configuration Enable	RW	AN[3:0]	Enable Manual Master/Slave Configuration. 1: Manual MASTER/SLAVE configuration 0: Automatic MASTER/SLAVE
9.11	MASTER/SLAVE Configuration Value	RW	AN[3:0]	Advertise Master/Slave Configuration Value. 1: Manual configure as MASTER 0: Manual configure as SLAVE
9.10	Port Type	RW	AN[3:0]	Advertise Device Type Preference. 1: Prefer multi-port device (MASTER) 0: Prefer single port device (SLAVE)
9.9	1000Base-T Full Duplex	RW	AN[3:0]	Advertise 1000Base-T Full-Duplex Capability. 1: Advertise 0: Do not advertise
9.8	1000Base-T Half Duplex	RW	AN[3:0]	Advertise 1000Base-T Half-Duplex Capability. 1: Advertise 0: Do not advertise
9.7:0	RSVD	RO	0	Reserved.

Note 1: Values set in register 9.12:8 have no effect unless Auto-Negotiation is restarted (Reg0.9) or the link goes down.

Note 2: Bits 9.11 and 9.10 are ignored when bit 9.12=0.

7.3.1. GBSR (1000Base-T Status Register, Address 0x0A)

Table 28. GBSR (1000Base-T Status Register, Address 0x0A)

Bit	Name	RW	Default	Description
10.15	MASTER/SLAVE Configuration Fault	RO, RC	0	Master/Slave Manual Configuration Fault Detected. 1: MASTER/SLAVE configuration fault detected 0: No MASTER/SLAVE configuration fault detected
10.14	MASTER/SLAVE Configuration Resolution	RO	0	Master/Slave Configuration Result. 1: Local PHY configuration resolved to MASTER 0: Local PHY configuration resolved to SLAVE
10.13	Local Receiver Status	RO	0	Local Receiver Status. 1: Local Receiver OK 0: Local Receiver Not OK
10.12	Remote Receiver Status	RO	0	Remote Receiver Status. 1: Remote Receiver OK 0: Remote Receiver Not OK
10.11	Link Partner 1000Base-T Full Duplex Capability	RO	0	Link Partner 1000Base-T Full Duplex Capability. 1: Link Partner is capable of 1000Base-T full duplex 0: Link Partner is not capable of 1000Base-T full duplex
10.10	Link Partner 1000Base-T Half Duplex Capability	RO	0	Link Partner 1000Base-T Half Duplex Capability. 1: Link Partner is capable of 1000Base-T half duplex 0: Link Partner is not capable of 1000Base-T half duplex
10.9:8	RSVD	RO	00	Reserved.
10.7:0	Idle Error Count	RO, RC	0x00	MSB of Idle Error Counter. The counter stops automatically when it reaches 0xff.

Note 1: Values set in register 10.11:10 are not valid until register 6.1 is set to 1.

Note 2: Register 10 is not valid until the Auto-Negotiation complete bit 1.5 indicates completed.

7.3.2. GBESR (1000Base-T Extended Status Register, Address 0x0F)

Table 29. GBESR (1000Base-T Extended Status Register, Address 0x0F)

Bit	Name	RW	Default	Description
15.15	1000Base-X FD	RO	0	0: Not 1000Base-X full duplex capable
15.14	1000Base-X HD	RO	0	0: Not 1000Base-X half duplex capable
15.13	1000Base-T FD	RO	1	1: 1000Base-T full duplex capable
15.12	1000Base-T HD	RO	1	1: 1000Base-T half duplex capable
15.11:0	RSVD	RO	0x000	Reserved.

7.3.3. PHYCR (PHY Specific Control Register, Address 0x10)

Table 30. PHYCR (PHY Specific Control Register, Address 0x10)

Bit	Name	RW	Default	Description
16.15:12	RSVD	RW	0000	Reserved.
16.11	Assert CRS on Transmit	RW	0	1: Assert CRS on transmit 0: Never assert CRS on transmit
16.10	Force Link Good	RW	0	1: Force link good 0: Normal operation
16.9:7	RSVD	RW	011	Reserved.
16.6:5	MDI Crossover Mode	RW	11	01: Manual MDI configuration 00: Manual MDI Crossover configuration <i>Note: Before setting the register, address 0xE bit10 need set to 1. After setting the register, a PHY reset is required.</i>
16.4	Disable CLK125	RW	0	1: CLK125 remains at logic low 0: CLK125 toggling enabled
16.3:1	RSVD	RW	111	Reserved.
16.0	Disable Jabber	RW	0	1: Disable jabber function 0: Enable jabber function

7.3.4. PHYSR (PHY Specific Status Register, Address 0x11)

Table 31. PHYSR (PHY Specific Status Register, Address 0x11)

Bit	Name	RW	Default	Description
17.15:14	Speed	RO	01	Link Speed. 11: Reserved 01: 100Mbps 00: 10Mbps
17.13	Duplex	RO	0	Full/Half Duplex Mode. 1: Full duplex 0: Half duplex
17.12	Page Received	RC	0	New Page Received. 1: Page received 0: Page not received
17.11	Speed and Duplex Resolved	RO	0	Speed and Duplex Mode Resolved. 1: Resolved 0: Not resolved
17.10	Link (Real Time)	RO	0	Real Time Link Status. 1: Link OK 0: Link not OK
17.9:7	RSVD	RO	000	Reserved.
17.6	MDI Crossover Status	RO	0	MDI/MDI Crossover Status. 1: MDI Crossover 0: MDI
17.5	LED Control	RW	0	0: Low active 1: High active
17.4	LED Definition	RW	1	0: N/A 1: Link and Speed Indication by combination of LEDs
17.3	ALDPS	RW	1	0: Disable Advance link down power saving 1: Enable Advance link down power saving
17.2:1	RSVD	RW	10	Reserved.
17.0	Jabber (Real Time)	RO	0	Real Time Jabber Indication. 1: Jabber Indication 0: No jabber Indication

7.3.5. INER (Interrupt Enable Register, Address 0x12)

Table 32. INER (Interrupt Enable Register, Address 0x12)

Bit	Name	RW	Default	Description
18.15	Auto-Negotiation Error Interrupt	RW	0	1: Interrupt enable 0: Interrupt disable
18.14	Speed Change Interrupt	RW	0	1: Interrupt enable 0: Interrupt disable
18.13	Duplex Mode Change Interrupt	RW	0	1: Interrupt enable 0: Interrupt disable
18.12	Page Received Interrupt	RW	0	1: Interrupt enable 0: Interrupt disable
18.11	Auto-Negotiation Completed Interrupt	RW	0	1: Interrupt enable 0: Interrupt disable
18.10	Link Status Change Interrupt	RW	0	1: Interrupt enable 0: Interrupt disable
18.9	Symbol Error Interrupt	RW	0	1: Interrupt enable 0: Interrupt disable
18.8	False Carrier Interrupt	RW	0	1: Interrupt enable 0: Interrupt disable
18.7	RSVD	RW	0	Reserved
18.6	MDI Crossover Change Interrupt	RW	0	1: Interrupt enable 0: Interrupt disable
18.5:2	RSVD	RW	0	Reserved
18.1	Polarity Change Interrupt	RW	0	1: Interrupt enable 0: Interrupt disable
18.0	Jabber Interrupt	RW	0	1: Interrupt enable 0: Interrupt disable

7.3.6. INSR (Interrupt Status Register, Address 0x13)

Table 33. INSR (Interrupt Status Register, Address 0x13)

Bit	Name	RW	Default	Description
19.15	Auto-Negotiation Error	RC	0	1: Auto-Negotiation Error 0: No Auto-Negotiation Error
19.14	Speed Change	RC	0	1: Link speed changed 0: Link speed not changed
19.13	Duplex Mode Change	RC	0	1: Duplex mode changed 0: Duplex mode not changed
19.12	Page Received	RC	0	1: Page (a new LCW) received 0: Page not received
19.11	Auto-Negotiation Completed	RC	0	1: Auto-Negotiation completed 0: Auto-Negotiation not completed
19.10	Link Status Change	RC	0	1: Link status changed 0: Link status not changed
19.9	Symbol Error	RC	0	1: Symbol error detected 0: No symbol error detected
19.8	False Carrier	RC	0	1: False carrier 0: No false carrier detected
19.7	RSVD	RC	0	Reserved
19.6	MDI Crossover Change	RC	0	1: Crossover status changed 0: Crossover status not changed
19.5:2	RSVD	RC	0000	Reserved
19.1	Polarity Change	RC	0	1: Polarity Changed 0: Polarity not changed <i>Note: This bit is valid only when 1000Base-T is enabled.</i>
19.0	Jabber	RC	0	1: Jabber detected 0: No jabber detected

7.3.7. RXERC (Receive Error Counter, Address 0x15)

Table 34. RXERC (Receive Error Counter, Address 0x15)

Bit	Name	RW	Default	Description
21.15:0	Receive Error Count	RC	0x0000	Receive Error Count.

Note: The RXERC register is read-cleared after a read.

7.3.8. LEDCR (LED Control Register, Address 0x18)

Table 35. LEDCR (LED Control Register, Address 0x18)

Bit	Name	RW	Default	Description
24.15	RSVD	RW	0	Reserved.
24.14:12	LED Pulse Stretch Duration	RW	010	000: No pulse stretching 001: 21ms to 42ms 010: 42ms to 84ms 011: 84ms to 170ms 100: 170ms to 340ms 101: 340ms to 670ms 110: 670ms to 1.3s 111: 1.3s to 2.7s
24.11	RSVD	RW	0	Reserved.
24.10:8	RSVD	RW	111	Reserved.
24.7:4	RSVD	RW	0100	Reserved.
24.3:0	RSVD	RW	0	Reserved.

7.3.9. PAGSEL (Page Select Register, Address 0x1F)

Table 36. PAGSEL (Page Select Register, Address 0x1F)

Bit	Name	RW	Default	Description
31.15:3	RSVD	RW	0	Reserved.
31.2:0	Pagesel	RW	000	Page Select Signal. 000: Page 0 (default page) 001: Page 1 010: Page 2 011: Page 3 100: Page 4

8. Switching Regulator

The RTL8251CN-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. The switching regulator 1.05V output pin (REG_OUT; pin48) should be connected only to DVDD10 and AVDD10 (do not provide this power source to other devices).

8.1. PCB Layout

- The input 3.3V power trace connected to VDDREG should be wider than 40mils.
- The bulk de-coupling capacitors (C82 and C83) must be placed within 200mils (0.5cm) of VDDREG to prevent input voltage overshoot and reduce input noise.
- The output power trace out of REG_OUT must be wider than 60mils.
- L1 (4.7 μ H) must be kept within 200mils (0.5cm) of REG_OUT.
- C18 (X5R) and C19 must be kept within 200mils (0.5cm) of L1 to ensure stable output power and better power efficiency.
- For switching regulator stability, the capacitor C18 and C82 must be a ceramic (X5R) capacitor. C19 and C83 are recommended to be ceramic capacitors.

Note: Violation of the above rules will damage the IC.

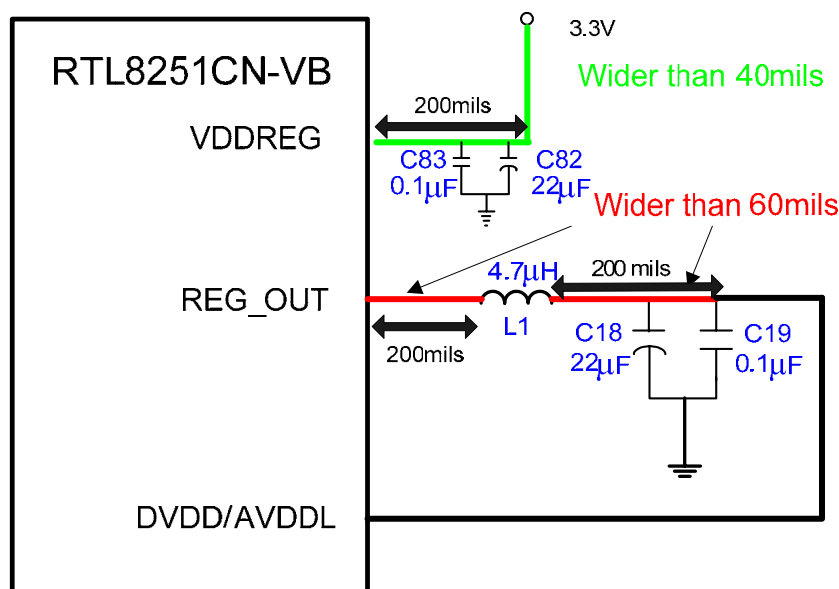


Figure 5. Switching Regulator Application

8.2. Inductor and Capacitor Parts List

Table 37. Inductor and Capacitor Parts List

Inductor Type	Inductance	ESR at 1MHz (mΩ)	Max I (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 should be able to withstand 600mA of current.

Note 3: Typically, if the power inductor's ESR at 1MHz is below 0.8 Ω, the switching regulator efficiency will be above 75%. However the actual switching regulator efficiency must be measured according to the method described in section 8.5 Efficiency Measurement, page 39.

Capacitor Type	Capacitance	ESR at 1MHz (mΩ)	Output Ripple (mV)
22μF 1210 TDK	21.5μF	24.25	9.6
22μF 1210 X5R	22.15μF	24.90	10.4

Note: C18 and C82 must be X5R ceramic. Capacitors C19 and C83 are suggested to be ceramic, as lower ESR values will yield lower output voltage ripple.

8.3. 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 VDDREG, not at the capacitor. In order to reduce the input voltage overshoot, C82 and C83 must be placed close to VDDREG. The following figures show what a good input voltage and a bad one look like.

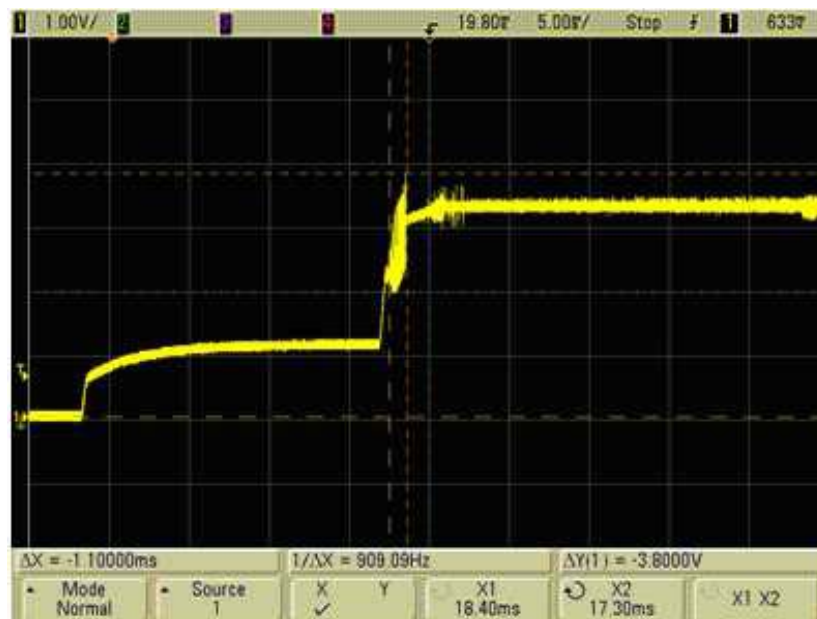


Figure 6. Input Voltage Overshoot <4V (Good)

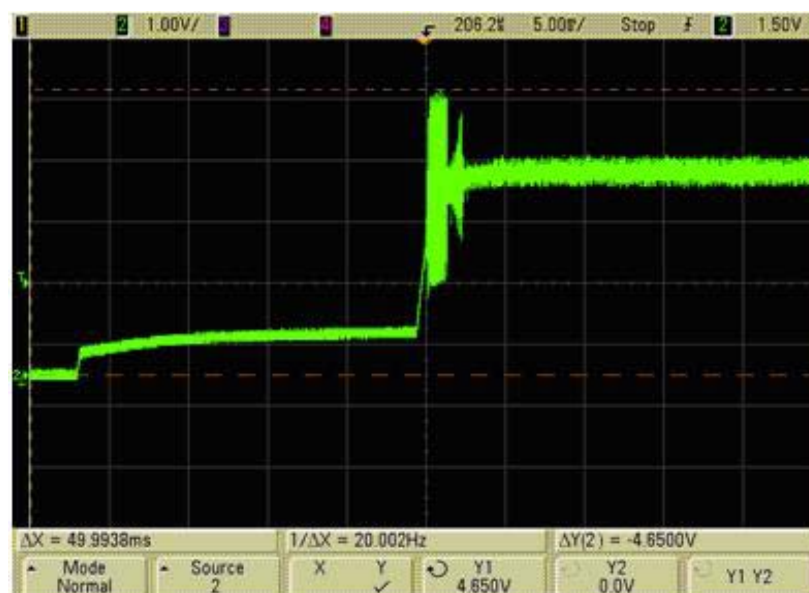


Figure 7. Input Voltage Overshoot >4V (Bad)

From the output side measured at REG_OUT, the voltage ripple must be within 100mV. Choosing different types and values of output capacitor (C18, C19) and power inductor (L1) 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 of REG_OUT before the power inductor (L1). The yellow signal (second row) is measured after the power inductor (L1), 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 8. Ceramic 22 μ F 1210(X5R) (Good)

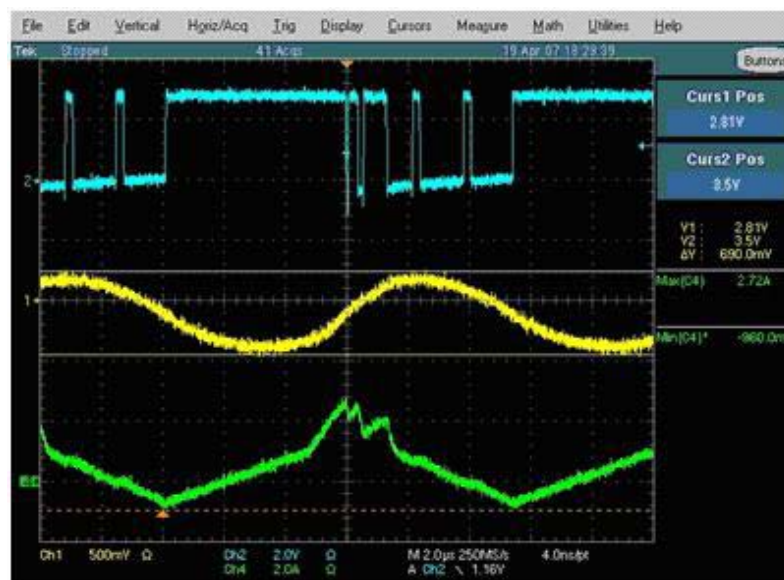


Figure 9. Ceramic 22 μ F 0805(Y5V) (Bad)

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.



Figure 10. Electrolytic 100 μ F (Ripple Too High)

The following figures show how different inductors affect the REG_OUT output waveform. The typical waveform should look like Figure 11, 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 12, 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.

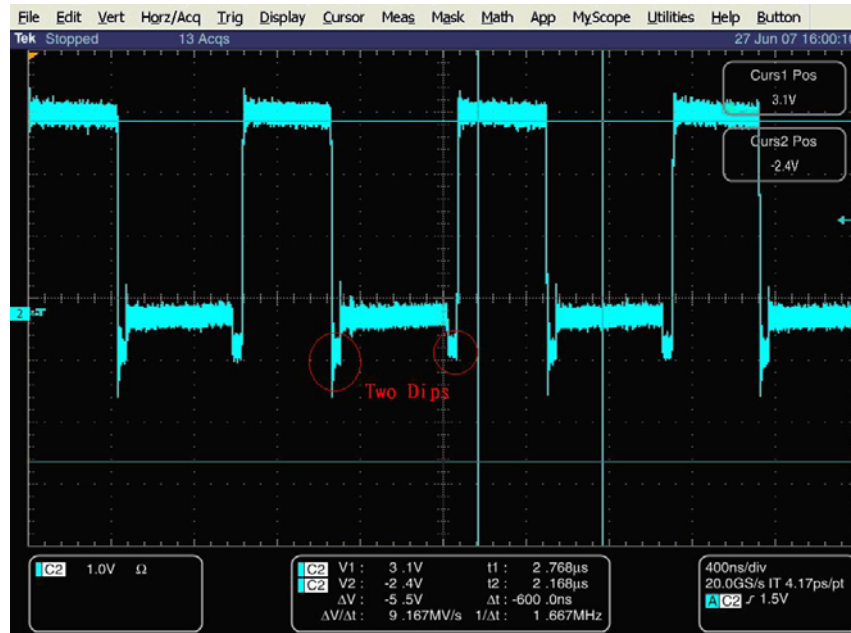


Figure 11. 4R7GTSD32 (Good)

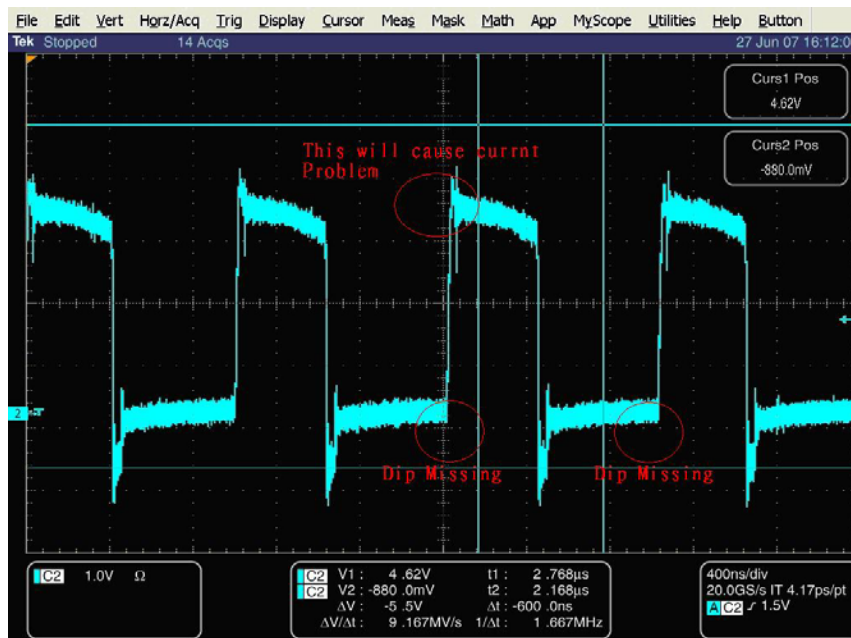


Figure 12. 1μH Bead (Bad)

8.4. Typical Switching Regulator PCB Layout

The typical layout of Figure 13 and Figure 14 are similar. The trace from RSET should pass through a via to the lower layer, and the trace should be protected by a ground trace. The width of the ground trace should be more than 5mils.

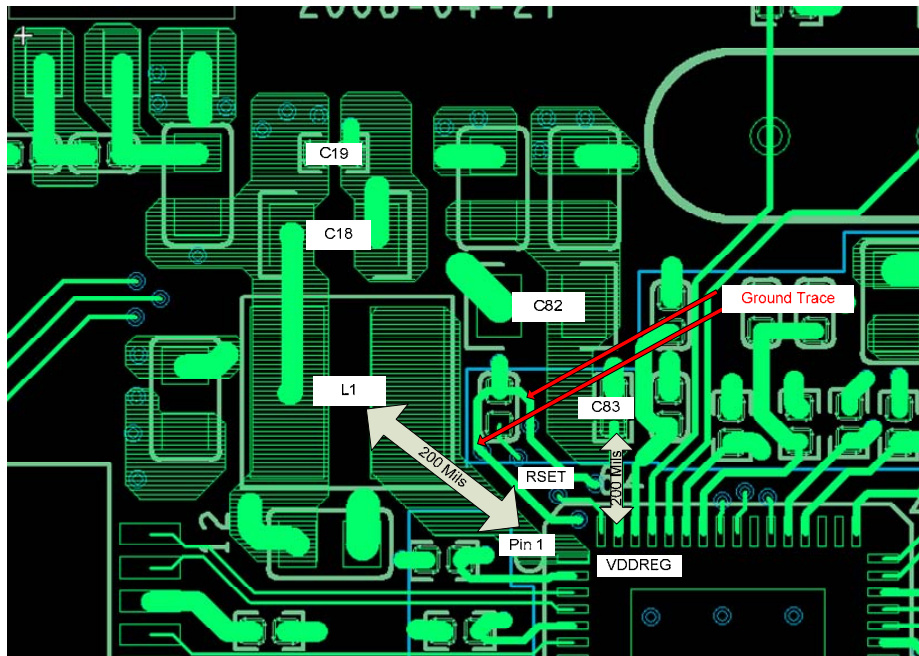


Figure 13. Typical Switching Regulator PCB Layout (Top Layer)

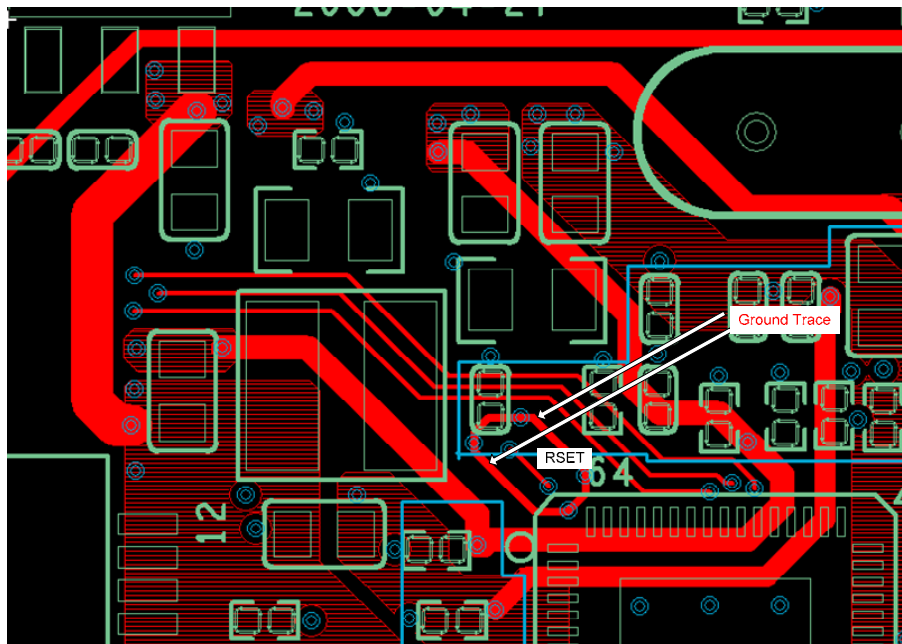


Figure 14. Typical Switching Regulator PCB Layout (Bottom Layer)

8.5. 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 15 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 160mA at CP_A
- The measured I_{cpb} is 400mA at CP_B

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

$$\text{Efficiency} = (1.05V \cdot 400mA) / (3.3V \cdot 160mA) = 0.80 = 80\%.$$

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.

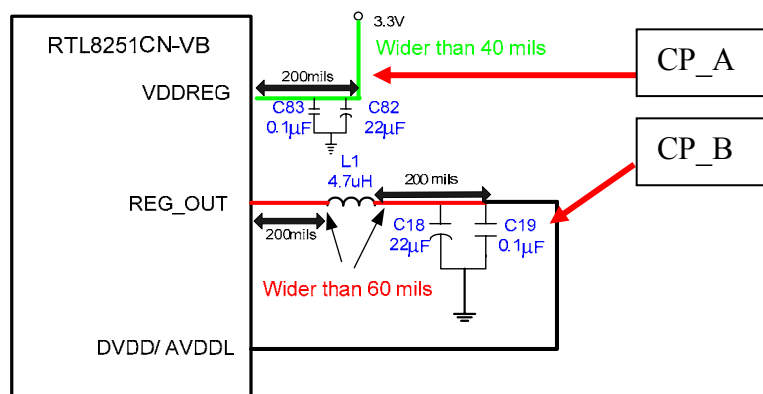


Figure 15. Switching Regulator Efficiency Measurement Checkpoint

8.6. Power Sequence

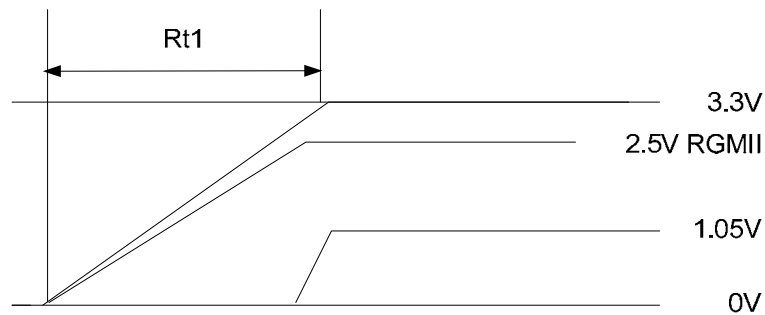


Figure 16. Power Sequence

Table 38. Power Sequence parameter

Symbol	Description	Min	Typical	Max	Units
Rt1	3.3V Rise Time	1	-	100	ms
Rt1	2.5V RGMII Rise Time	-	-	100	ms

Note: The RTL8251CN-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 VDDREG which may cause permanent damage to the switching regulator.

9. Application Diagram

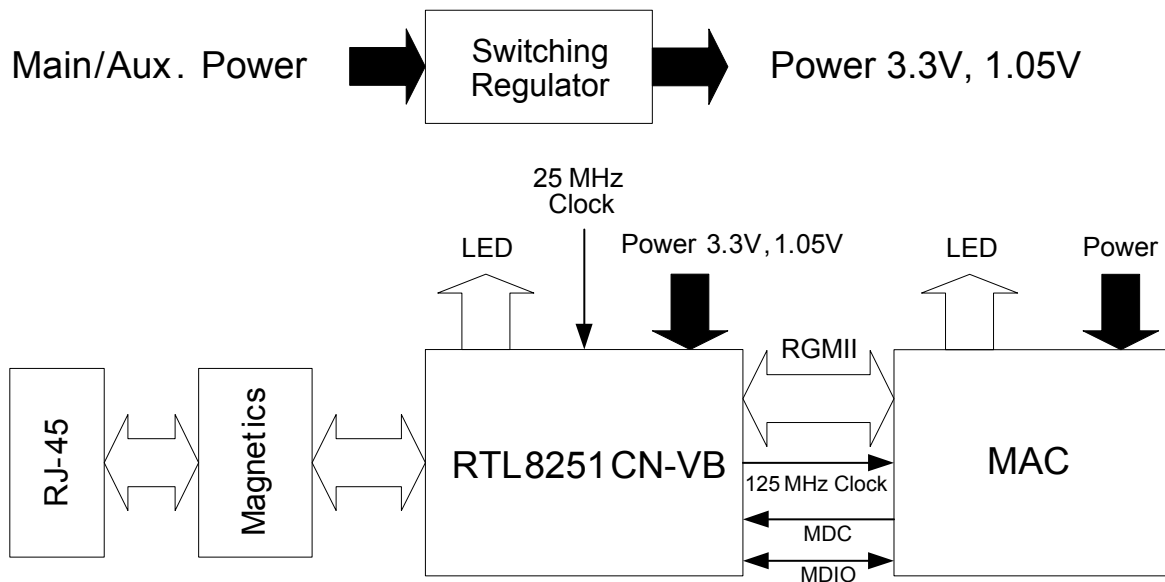


Figure 17. Application Diagram

10. Characteristics

10.1. 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 39. Absolute Maximum Ratings

Symbol	Description	Minimum	Maximum	Unit
VDD33, AVDD33	Supply Voltage 3.3V	-0.4	+0.4	V
AVDD10, DVDD10	Supply Voltage 1.05V	-0.1	+0.1	V
VDD25 (RGMII 2.5V)	Supply Voltage 2.5V	-0.2	+0.3	V
DCinput	Input Voltage	-0.5	Corresponding Supply Voltage + 0.5	V
DCoutput	Output Voltage	-0.3	Corresponding Supply Voltage + 0.5	V
NA	Storage Temperature	-55	+125	°C

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

10.2. Recommended Operating Conditions

Table 40. Recommended Operating Conditions

Description	Pins	Minimum	Typical	Maximum	Unit
Supply Voltage VDD	DVDD33, AVDD33	2.97	3.3	3.63	V
	AVDD10, DVDD10	0.95	1.05	1.09	V
	2.5V RGMII	2.4	2.5	2.62	V
Ambient Operating Temperature T _A	-	0	-	70	°C
Maximum Junction Temperature	-	-	-	125	°C

10.3. Crystal Requirements

Table 41. 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°C~70°C.	-30	-	+30	ppm
F _{ref} Tolerance	Parallel Resonant Crystal Frequency Tolerance, Fundamental Mode, AT-Cut Type. T _a =25°C.	-50	-	+50	ppm
F _{ref} Duty Cycle	Reference Clock Input Duty Cycle.	40	-	60	%
ESR	Equivalent Series Resistance.	-	-	30	Ω

Symbol	Description/Condition	Minimum	Typical	Maximum	Unit
DL	Drive Level.	-	-	0.3	mW
Jitter	Broadband Peak to Peak Jitter ^{1, 2}	-	-	200	ps

Note 1: 25KHz to 25MHz RMS < 3ps.

Note 2: Broadband RMS < 9ps.

10.4. Oscillator Requirements

Table 42. Oscillator Requirements

Parameter	Condition	Minimum	Typical	Maximum	Unit
Frequency	-	-	25	-	MHz
Frequency Stability	Ta = 0°C~+70°C	-30	-	30	ppm
Frequency Tolerance	Ta = 25°C	-50	-	50	ppm
Duty Cycle	-	40	-	60	%
Broadband Peak to Peak Jitter ^{1, 2}	-	-	-	200	ps
Vp-p	-	3.15	3.3	3.45	V
Rise Time (10%~90%)	-	-	-	10	ns
Fall Time (10%~90%)	-	-	-	10	ns
Operating Temperature Range	-	0	-	70	°C

Note 1: 25KHz to 25MHz RMS < 3ps.

Note 2: Broadband RMS < 9ps.

10.5. DC Characteristics

Table 43. DC Characteristics

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Units
VDD33, AVDD33	3.3V Supply Voltage	-	2.97	3.3	3.63	V
RGII I/O	2.5V RGII Supply Voltage	-	2.37	2.5	2.62	V
DVDD10, AVDD10	1.05V Supply Voltage	-	0.95	1.05	1.09	V
Voh (3.3V)	Minimum High Level Output Voltage	-	0.9*VDD33	-	VDD33	V
Voh (2.5V)	Minimum High Level Output Voltage	-	0.9*VDD25	-	VDD25	V
Vol (3.3V)	Maximum Low Level Output Voltage	-	0	-	0.1*VDD33	V
Vol (2.5V)	Maximum Low Level Output Voltage	-	0	-	0.1*VDD25	V
Vih	Minimum High Level Input Voltage	-	1.8	-	-	V
Vil	Maximum Low Level Input Voltage	-	-	-	0.9	V
Iin	Input Current	Vin=VDD33 or GND	0	-	0.5	μA

10.6. AC Characteristics

10.6.1. MDC/MDIO Timing

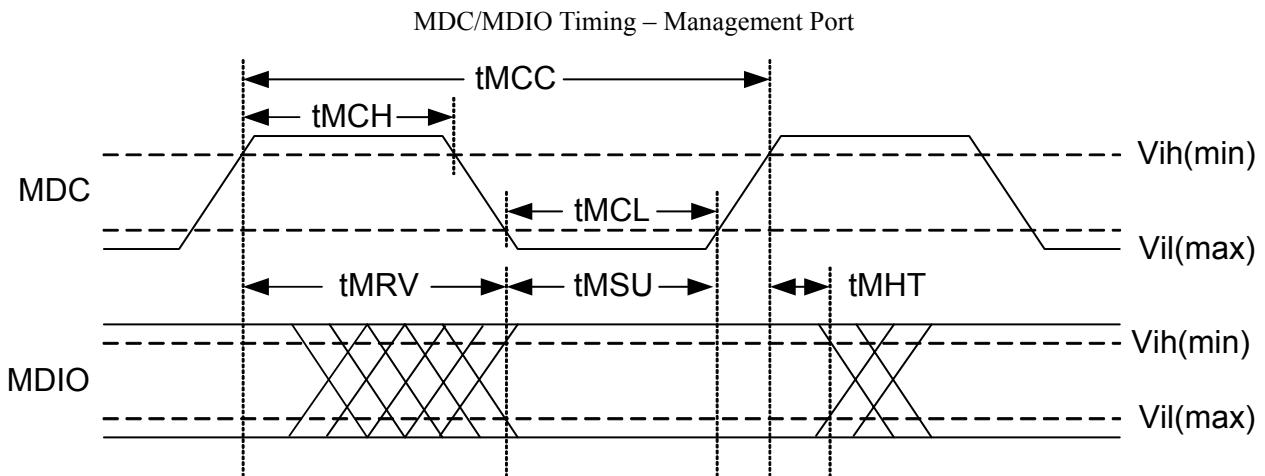


Figure 18. MDC/MDIO Management Timing Parameters

Table 44. MDC/MDIO Management Timing Parameters

Symbol	Description	Min	Max	Units
tMCC	MDC Cycle Time	80	-	ns
tMCH	MDC High Time	30	-	ns
tMCL	MDC Low Time	30	-	ns
tMSU	MDIO Setup Time	10	-	ns
tMHT	MDIO Hold Time	10	-	ns
tMRV	MDC Clock Rise to MDIO Valid	-	40	ns

10.6.2. RGMII Timing

Table 45. RGMII Timing Parameters

Symbol	Description	Min	Typical	Max	Units
tGCC	TXC, RXC Cycle Time	7.2	8	8.8	ns
tR	RXC Rise Time (20%~80%)	-	-	0.75	ns
tF	RXC Fall Time (20%~80%)	-	-	0.75	ns
TsetupT	TXDLY=1; TXD, TXCLT Setup to TXC	1	2	-	ns
TholdT	TXDLY=1; TXD, TXCLT Hold from TXC	0.8	2	-	ns
Tsetup	TXD, TXCLT Setup to TXC	-0.9	-	-	ns
Thold	TXD, TXCLT Hold from TXC	2.7	-	-	ns
Tskew	Data to Clock Output Skew	-0.5	0	0.5	ns
TsetupR	RXDLY=1; RXD, RXCLT Setup to RXC	1.2	2	-	ns
TholdR	RXDLY=1; RXD, RXCLT Hold from RXC	1	2	-	ns

10.6.3. RGMII Timing Modes

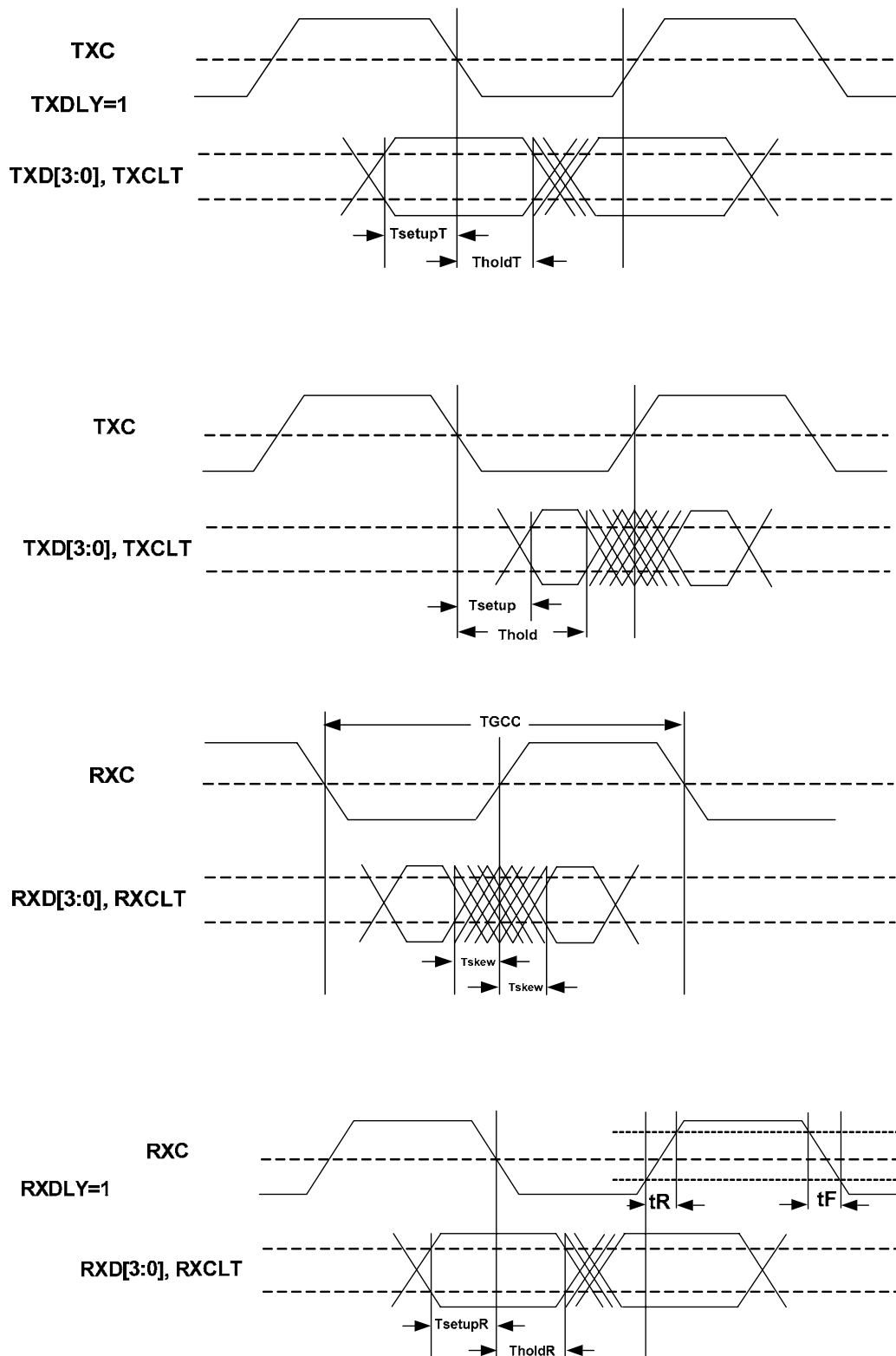
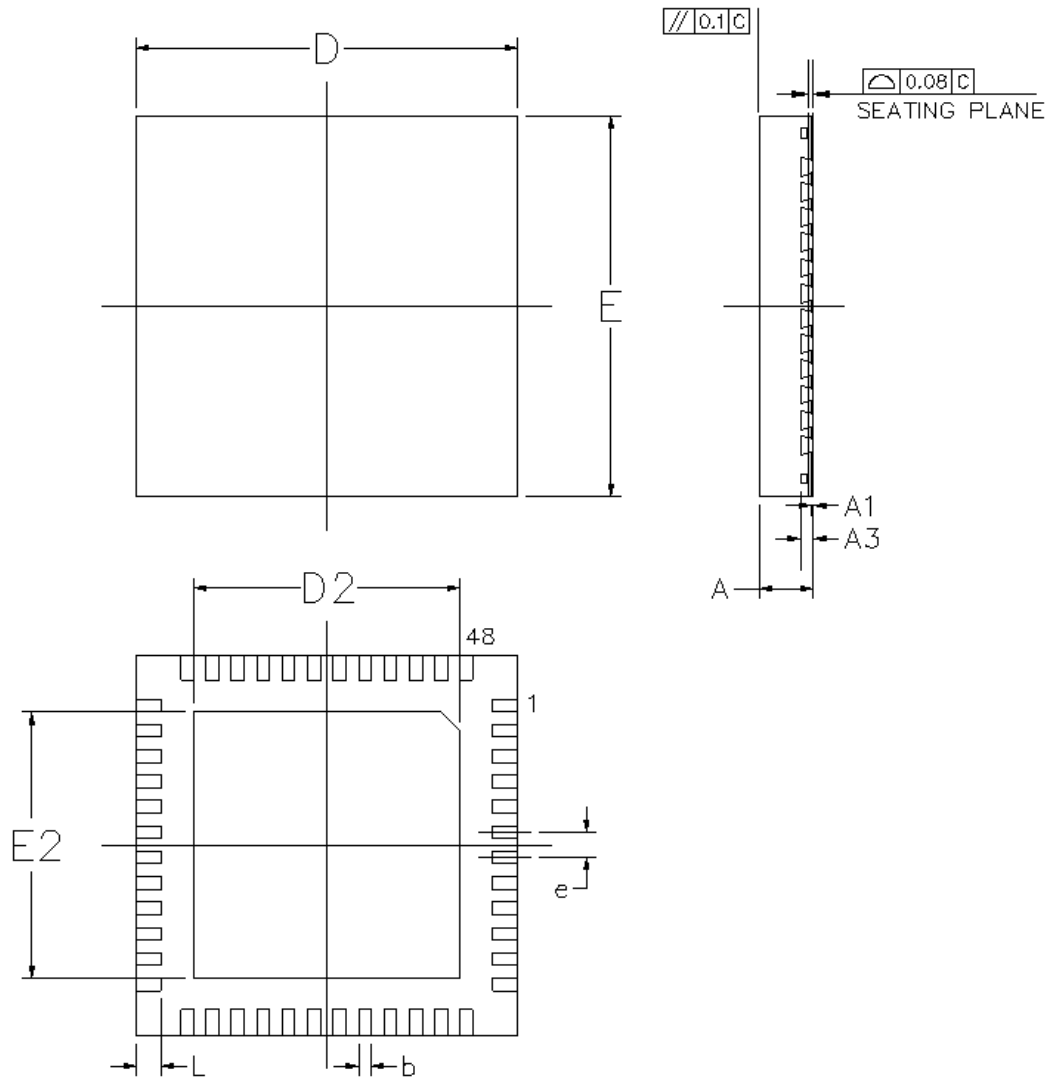


Figure 19. RGMII Timing Modes

11. Mechanical Dimensions (6mm x 6mm)



Symbol	Dimension in mm			Dimension in inch		
	Min	Nom	Max	Min	Nom	Max
A	0.75	0.85	1.00	0.030	0.034	0.039
A ₁	0.00	0.02	0.05	0.000	0.001	0.002
A ₃	0.20REF			0.008REF		
b	0.15	0.20	0.25	0.006	0.008	0.010
D/E	6.00BSC			0.236BSC		
D ₂ /E ₂	4.05	4.4	4.65	0.163	0.173	0.183
e	0.40BSC			0.016BSC		
L	0.30	0.40	0.50	0.012	0.016	0.020

Note 1: CONTROLLING DIMENSION: MILLIMETER (mm).

Note 2: REFERENCE DOCUMENT: JEDEC MO-220.

12. Ordering Information

Table 46. Ordering Information

Part Number	Package	Status
RTL8251CN-VB-GR	48-Pin QFN with 'Green' Package	Production

Note: See page 3 for package identification.

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