KSZ8061RNB/KSZ8061RND

10Base-T/100Base-TX
Physical Layer Transceiver

Revision 1.1

General Description

The KSZ8061RNB/RND is a single-chip 10Base-T/100Base-TX Ethernet physical layer transceiver for transmission and reception of data over unshielded twisted pair (UTP) cable.

The KSZ8061RNB/RND features Quiet-WIRE® internal filtering to reduce line emissions. It is ideal for applications, such as automotive or industrial networks, where stringent radiated emission limits need to be met. Quiet-WIRE can utilize low cost unshielded cable, where previously only shielded cable solutions were possible. The KSZ8061RNB/RND also features enhanced immunity to environmental EM noise.

The KSZ8061RNB/RND features a Reduced Media Independent Interface (RMII) for direct connection with RMII-compliant Ethernet MAC processors and switches.

The KSZ8061RNB generates a 50MHz RMII reference clock for use by the connected MAC device. In contrast, the KSZ8061RND receives the 50MHz RMII reference clock as an input.

The KSZ8061RNB/RND meets Automotive AEC-Q100 and EMC requirements, with an extended temperature range of –40°C to +105°C. It is supplied in 32-pin, 5mm × 5mm QFN and WQFN packages.

The KSZ8061MNX and KSZ8061MNG devices have a MII interface and are described in a separate datasheet.

Datasheets and support documentation are available on Micrel's website at: www.micrel.com.

Quiet-WIRE®

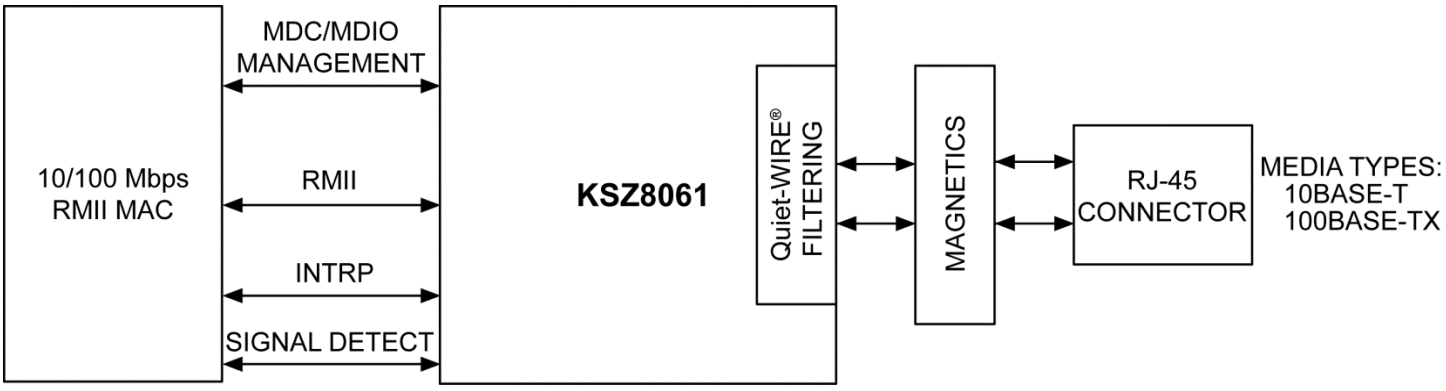
Features

- Quiet-WIRE programmable EMI filter
- RMII interface, with MDC/MDIO Management Interface for register configuration
- On-chip termination resistors for the differential pairs
- LinkMD®+ Receive Signal Quality Indicator
- Fast start-up and link
- Low Power design with IEEE 802.3az Energy Efficient Ethernet support
- Ultra Deep Sleep standby mode; CPU or Signal Detect activated.
- Loopback modes for diagnostics
- Programmable interrupt output

Applications

- Industrial control
- Vehicle on-board diagnostics (OBD)
- Automotive gateways
- Camera and sensor networking
- Infotainment

Functional Diagram



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Ordering Information

Part Number	Temperature Range	Package	Lead Finish	Description
KSZ8061RNBV[1]	–40°C to 105°C	WQFN-32LD	Pb-Free	RMII 50MHz output clock; AEC-Q100 Automotive Qualified (Extended Temperature)
KSZ8061RNBW	–40°C to 105°C	QFN-32LD	Pb-Free	RMII 50MHz output clock; Industrial Extended Temperature
KSZ8061RNDV[1]	–40°C to 105°C	WQFN-32LD	Pb-Free	RMII 50MHz input clock; AEC-Q100 Automotive Qualified (Extended Temperature)
KSZ8061RNDW	–40°C to 105°C	QFN-32LD	Pb-Free	RMII 50MHz input clock; Industrial Extended Temperature
KSZ8061RNB-EVAL[1]	0°C to 70°C	–	–	KSZ8061RNB Evaluation Board

Note:

1. Contact factory for availability.

Revision History

Date	Change Description/Edits by:	Rev.
08/27/15	Initial release of datasheet. By T. Nelson.	1.0
10/28/15	Updated footnote references in Ordering Information table	1.1

Table of Contents

List of Figures

List of Tables

Pin Configuration

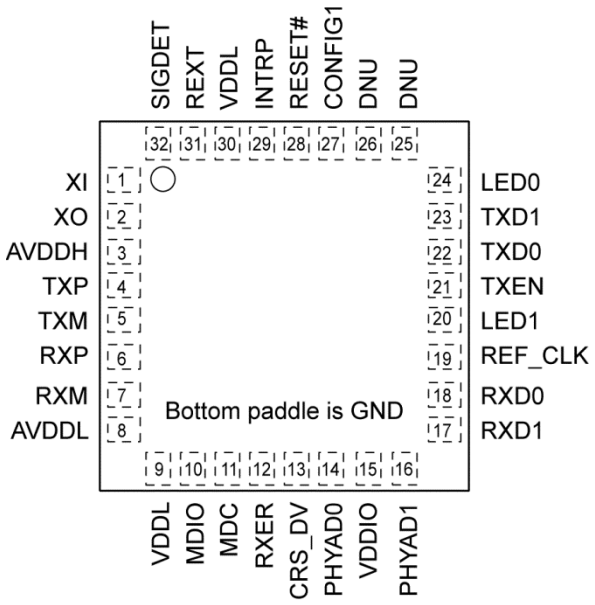


Figure 1. KSZ8061RNB/RND Pin Configuration (Top View)

Pin Description

Pin Number	Pin Name	Type[2]	Pin Function
1	XI	I	**KSZ8061RNB** 25MHz Crystal/Oscillator/External Clock Input. This input references the AVDDH power supply.
			KSZ8061RBD 50MHz RMII Reference Clock Input. This input references the AVDDH power supply.
2	XO	O	**KSZ8061RNB** Crystal feedback for 25MHz crystal This pin is a no connect if oscillator or external clock source is used.
			KSZ8061RND This pin is unused. Leave it unconnected.
3	AVDDH	Pwr	3.3V supply for analog TX drivers and XI/XO oscillator circuit.
4	TXP	I/O	Physical transmit or receive signal (+ differential) Transmit when in MDI mode; Receive when in MDI-X mode
5	TXM	I/O	Physical transmit or receive signal (– differential) Transmit when in MDI mode; Receive when in MDI-X mode
6	RXP	I/O	Physical receive or transmit signal (+ differential) Receive when in MDI mode; Transmit when in MDI-X mode
7	RXM	I/O	Physical receive or transmit signal (– differential) Receive when in MDI mode; Transmit when in MDI-X mode
8	AVDDL	Pwr	1.2V (nominal) supply for analog core
9	VDDL	Pwr	1.2V (nominal) supply for digital core
10	MDIO	Ipu/Opu	Management Interface (MIIM) Data I/O This pin has a weak pull-up, is open-drain like, and requires an external 1kΩ pull-up resistor.
11	MDC	Ipu	Management Interface (MIIM) Clock Input This clock pin is synchronous to the MDIO data pin.
12	RXER / QWF	Ipd/O	RMII Receive Error Output Config Mode: The pull-up/pull-down value is latched as QWF at the de-assertion of reset. See Strapping Options section for details.
13	CRS_DV / CONFIG2	Ipd/O	RMII Carrier Sense/Receive Data Valid Output Config Mode: The pull-up/pull-down value is latched as CONFIG2 at the de-assertion of reset. See Strapping Options section for details.
14	PHYAD0	Ipu/O	No function during normal operation Config Mode: The pull-up/pull-down value is latched as PHYADDR[0] at the de-assertion of reset. See Strapping Options section for details.

Notes:

2. Pwr = Power supply.
   Gnd = Ground.
   I = Input.
   O = Output.
   I/O = Bi-directional.
   Ipu = Input with internal pull-up (see Electrical Characteristics for value).
   Ipd = Input with internal pull-down (see Electrical Characteristics for value).
   Ipu/O = Input with internal pull-up (see Electrical Characteristics for value) during power-up/reset; output pin otherwise.
   Ipd/O = Input with internal pull-down (see Electrical Characteristics for value) during power-up/reset; output pin otherwise.
   Ipu/Opu = Input and output with internal pull-up (see Electrical Characteristics for value).

Pin Description (Continued)

Pin Number	Pin Name	Type[1]	Pin Function
15	VDDIO	Pwr	3.3V or 2.5V supply for digital I/O
16	PHYAD1	Ipd/O	No function during normal operation Config Mode: The pull-up/pull-down value is latched as PHYADDR[1] at the de-assertion of reset. See Strapping Options section for details.
17	RXD1 / PHYAD2	Ipd/O	RMII Receive Data Output[1][3] Config Mode: The pull-up/pull-down value is latched as PHYADDR[2] at the de-assertion of reset. See Strapping Options section for details.
18	RXD0 / AUTONEG	Ipu/O	RMII Receive Data Output[0][3] Config Mode: The pull-up/pull-down value is latched as AUTONEG at the de-assertion of reset. See Strapping Options section for details.
19	REF_CLK / CONFIG0	Ipd/O	**KSZ8061RNB** RMII 50MHz Reference Clock Output to the MAC Config Mode: The pull-up/pull-down value is latched as CONFIG0 at the de-assertion of reset. See Strapping Options section for details.
			KSZ8061RND This pin is unused during normal operation. Leave it unconnected except as required for Config Mode. Config Mode: The pull-up/pull-down value is latched as CONFIG0 at the de-assertion of reset. See Strapping Options section for details.
20	LED1	O	LED1 output Active low. Its function is programmable; by default it indicates link speed.
21	TXEN	I	RMII Transmit Enable Input
22	TXD0	I	RMII Transmit Data Input[0][4]
23	TXD1	I	RMII Transmit Data Input[1][4]
24	LED0	Ipd/O	LED0 Output Active low. Its function is programmable; by default it indicates link/activity.
25	DNU	I	Do Not Use. This unused input must be pulled to a logic-low level.
26	DNU	I	Do Not Use. This unused input should be pulled to a logic-low level.
27	CONFIG1	Ipd/O	No function during normal operation Config Mode: The pull-up/pull-down value is latched as CONFIG1 at the de-assertion of reset. See Strapping Options section for details.
28	RESET#	Ipu	Chip Reset (active-low)
29	INTRP / NAND_Tree#	Ipu/O	Programmable Interrupt Output (active-low [default] or active-high) This pin has a weak pull-up, is open-drain like, and requires an external 1.0kΩ pull-up resistor. Config Mode: The pull-up/pull-down value is latched as NAND_Tree# at the de-assertion of reset. See Strapping Options section for details.
30	VDDL	Pwr	1.2V (nominal) supply for digital (and analog)
31	REXT	I	Set PHY transmit output current Connect a 6.04kΩ 1% resistor from this pin to ground.
32	SIGDET	O	Signal Detect, active-high
Bottom paddle	GND	Gnd	Ground

Notes:

3. RMII Mode: The RXD[3:0] bits are synchronous with RXC. When RXDV is asserted, RXD[3:0] presents valid data to the MAC device.
4. RMII Mode: The TXD[3:0] bits are synchronous with TXC. When TXEN is asserted, TXD[3:0] accepts valid data from the MAC device.

Strapping Options

<table>
<tr><th>Pin Number</th><th>Pin Name</th><th>Type(5)</th><th>Pin Function</th></tr>
<tr><td>17
16
14</td><td>RXD1/PHYAD2
PHYAD1
PHYAD0</td><td>Ipd/O
Ipd/O
Ipu/O</td><td>The PHY Address is latched at de-assertion of reset and is configurable to any value from 0 to 7.
The default PHY Address is 00001.
PHY Address bits [4:3] are set to 00 by default.</td></tr>
<tr><td>13
27
19</td><td>CRS_DV/CONFIG2
CONFIG1
REF_CLK/CONFIG0</td><td>Ipd/O
Ipd/O
Ipd/O</td><td>The CONFIG[2:0] strap-in pins are latched at the de-assertion of reset.
<table>
<tr><th>CONFIG[2:0]</th><th colspan="2">Mode</th></tr>
<tr><td>000</td><td colspan="2">Reserved – not used</td></tr>
<tr><td>001</td><td>RMII normal mode</td><td>Auto MDI/MDI-X disabled</td></tr>
<tr><td>010 - 100</td><td colspan="2">Reserved – not used</td></tr>
<tr><td>101</td><td>RMII Back-to-Back</td><td>Auto MDI/MDI-X enabled</td></tr>
<tr><td>110</td><td colspan="2">Reserved – not used</td></tr>
<tr><td>111</td><td>RMII normal mode</td><td>Auto MDI/MDI-X enabled</td></tr>
</table></td></tr>
<tr><td>18</td><td>RXD0/AUTONEG</td><td>Ipu/O</td><td>Auto-Negotiation Disable
Pull-up (default) = Disable Auto-Negotiation
Pull-down = Enable Auto-Negotiation
At the de-assertion of reset, this pin value is latched into register 0h, bit [12].</td></tr>
<tr><td>29</td><td>INTRP/NAND_Tree#</td><td>Ipu/O</td><td>NAND Tree Mode
Pull-up (default) = Disable NAND Tree (normal operation)
Pull-down = Enable NAND Tree
At the de-assertion of reset, this pin value is latched by the chip.</td></tr>
<tr><td>12</td><td>RXER/QWF</td><td>Ipd/O</td><td>Quiet-WIRE Filtering Disable
Pull-up = Disable Quiet-WIRE Filtering
Pull-down (default) = Enable Quiet-WIRE Filtering
At the de-assertion of reset, this pin value is latched by the chip.</td></tr>
</table>

Note:

5. Ipu/O = Input with internal pull-up (see Electrical Characteristics for value) during power-up/reset; output pin otherwise.
Ipd/O = Input with internal pull-down (see Electrical Characteristics for value) during power-up/reset; output pin otherwise.

The strap-in pins are latched at the de-assertion of reset. In some systems, the MAC RMII receive input pins may drive high/low during power-up or reset, and consequently cause the PHY strap-in pins on the RMII signals to be latched to the unintended high/low states. In this case, external pull-up or pull-down resistors (4.7kΩ) should be added on these PHY strap-in pins to ensure the intended values are strapped-in correctly.

Functional Description: 10Base-T/100Base-TX Transceiver

The KSZ8061RNB/RND is an integrated Fast Ethernet transceiver that features Quiet-WIRE® internal filtering to reduce line emissions. When Quiet-WIRE filtering is disabled, it is fully compliant with the IEEE 802.3 specification. The KSZ8061RNB/RND also has high noise immunity.

On the copper media side, the KSZ8061RNB/RND supports 10Base-T and 100Base-TX for transmission and reception of data over a standard CAT-5 or similar unshielded twisted pair (UTP) cable, and HP Auto MDI/MDI-X for reliable detection of and correction for straight-through and crossover cables.

On the MAC processor side, the KSZ8061RNB/RND offers the Reduced Media Independent Interface (RMII) for direct connection with RMII-compliant Ethernet MAC processors and switches.

The RMII management bus gives the MAC processor complete access to the KSZ8061RNB/RND control and status registers. Additionally, an interrupt pin eliminates the need for the processor to poll for PHY status change.

Auto-negotiation and Auto MDI/MDI-X can be disabled at power-on to significantly reduce initial time to link up.

A signal detect pin (SIGDET) is available to indicate when the link partner in inactive. An option is available for the KSZ8061RNB/RND to automatically enter Ultra-Deep Sleep mode automatically when SIGDET is de-asserted. Ultra-Deep Sleep mode may also be entered by command of the MAC processor. Additional low power modes are available.

100Base-TX Transmit

The 100Base-TX transmit function performs parallel-to-serial conversion, 4B/5B encoding, scrambling, NRZ-to-NRZI conversion, and MLT3 encoding and transmission.

The circuitry starts with a parallel-to-serial conversion, which converts the RMII data from the MAC into a 125MHz serial bit stream. The data and control stream is then converted into 4B/5B coding and followed by a scrambler. The serialized data is further converted from NRZ-to-NRZI format, and then transmitted in MLT3 current output. The output current is set by a precision external resistor on REXT for the 1:1 transformer ratio.

The output signal has a typical rise/fall time of 4ns and complies with the ANSI TP-PMD standard regarding amplitude balance, overshoot, and timing jitter. The wave-shaped 10Base-T output is also incorporated into the 100Base-TX transmitter.

100Base-TX Receive

The 100Base-TX receiver function performs adaptive equalization, DC restoration, MLT3-to-NRZI conversion, data and clock recovery, NRZI-to-NRZ conversion, de-scrambling, 4B/5B decoding, and serial-to-parallel conversion.

The receiving side starts with the equalization filter to compensate for inter-symbol interference (ISI) over the twisted pair cable. Because the amplitude loss and phase distortion is a function of the cable length, the equalizer must adjust its characteristics to optimize performance. In this design, the variable equalizer makes an initial estimation based on comparisons of incoming signal strength against some known cable characteristics, and then tunes itself for optimization. This is an ongoing process and self-adjusts against environmental changes, such as temperature variations.

Next, the equalized signal goes through a DC restoration and data conversion block. The DC restoration circuit is used to compensate for the effect of baseline wander and to improve the dynamic range. The differential data conversion circuit converts the MLT3 format back to NRZI. The slicing threshold is also adaptive.

The clock recovery circuit extracts the 125MHz clock from the edges of the NRZI signal. This recovered clock is then used to convert the NRZI signal into the NRZ format. This signal is sent through the de-scrambler followed by the 4B/5B decoder. Finally, the NRZ serial data is converted to the RMII format and provided as the input data to the MAC.

Scrambler/De-Scrambler (100Base-TX only)

The scrambler is used to spread the power spectrum of the transmitted signal to reduce EMI and baseline wander. The de-scrambler is needed to recover the scrambled signal.

10Base-T Transmit

The 10Base-T drivers are incorporated with the 100Base-TX drivers to allow for transmission using the same magnetic. The drivers perform internal wave-shaping and pre-emphasis, then output 10Base-T signals with a typical amplitude of 2.5V peak. The 10Base-T signals have harmonic contents that are at least 27dB below the fundamental frequency when driven by an all-ones Manchester-encoded signal.

10Base-T Receive

On the receive side, input buffer and level detecting squelch circuits are employed. A differential input receiver circuit and a PLL performs the decoding function. The Manchester-encoded data stream is separated into clock signal and NRZ data. A squelch circuit rejects signals with levels less than 400mV or with short pulse widths to prevent noise at the RXP and RXM inputs from falsely trigger the decoder. When the input exceeds the squelch limit, the PLL locks onto the incoming signal and the KSZ8061RNB/RND decodes a data frame. The receive clock is kept active during idle periods in between data reception.

PLL Clock Synthesizer

The KSZ8061RNB/RND generates all internal clocks and all external clocks for system timing from the clock received at the XI pin. For the KSZ8061RNB, this is an external 25MHz crystal, oscillator, or reference clock. For the KSZ8061RND, this is the externally supplied RMII 50MHz reference clock.

Auto-Negotiation

The KSZ8061RNB/RND conforms to the auto-negotiation protocol, defined in Clause 28 of the IEEE 802.3 Specification.

Auto-negotiation allows unshielded twisted pair (UTP) link partners to select the highest common mode of operation.

During auto-negotiation, link partners advertise capabilities across the UTP link to each other, and then compare their own capabilities with those they received from their link partners. The highest speed and duplex setting that is common to the two link partners is selected as the mode of operation.

The following list shows the speed and duplex operation mode from highest to lowest priority.

- Priority 1: 100Base-TX, full-duplex
- Priority 2: 100Base-TX, half-duplex
- Priority 3: 10Base-T, full-duplex
- Priority 4: 10Base-T, half-duplex

If the KSZ8061RNB/RND is using auto-negotiation, but its link partner is not, then the KSZ8061RNB/RND sets its operating speed by observing the signal at its receiver. This is known as parallel detection, and allows the KSZ8061RNB/RND to establish link by listening for a fixed signal protocol in the absence of auto-negotiation advertisement protocol. Duplex is set by register 0h, bit [8] because the KSZ8061RNB/RND cannot determine duplex by parallel detection.

If auto-negotiation is disabled, the speed is set by register 0h, bit [13], and the duplex is set by register 0h, bit [8]. The default is 100Base-TX, full-duplex.

Auto-negotiation is enabled or disabled by hardware pin strapping (AUTONEG) and by software (register 0h, bit [12]). By default, auto-negotiation is disabled after power-up or hardware reset, but it may be enabled by pulling the RXD0 pin low at that time. Afterwards, auto-negotiation can be enabled or disabled by register 0h, bit [12].

When the link is 10Base-T or the link partner is using auto-negotiation and the Ultra-Deep Sleep mode is used, then the Signal Detect assertion timing delay bit, register 14h bit [1], must be set.

The auto-negotiation link-up process is shown in Figure 2.

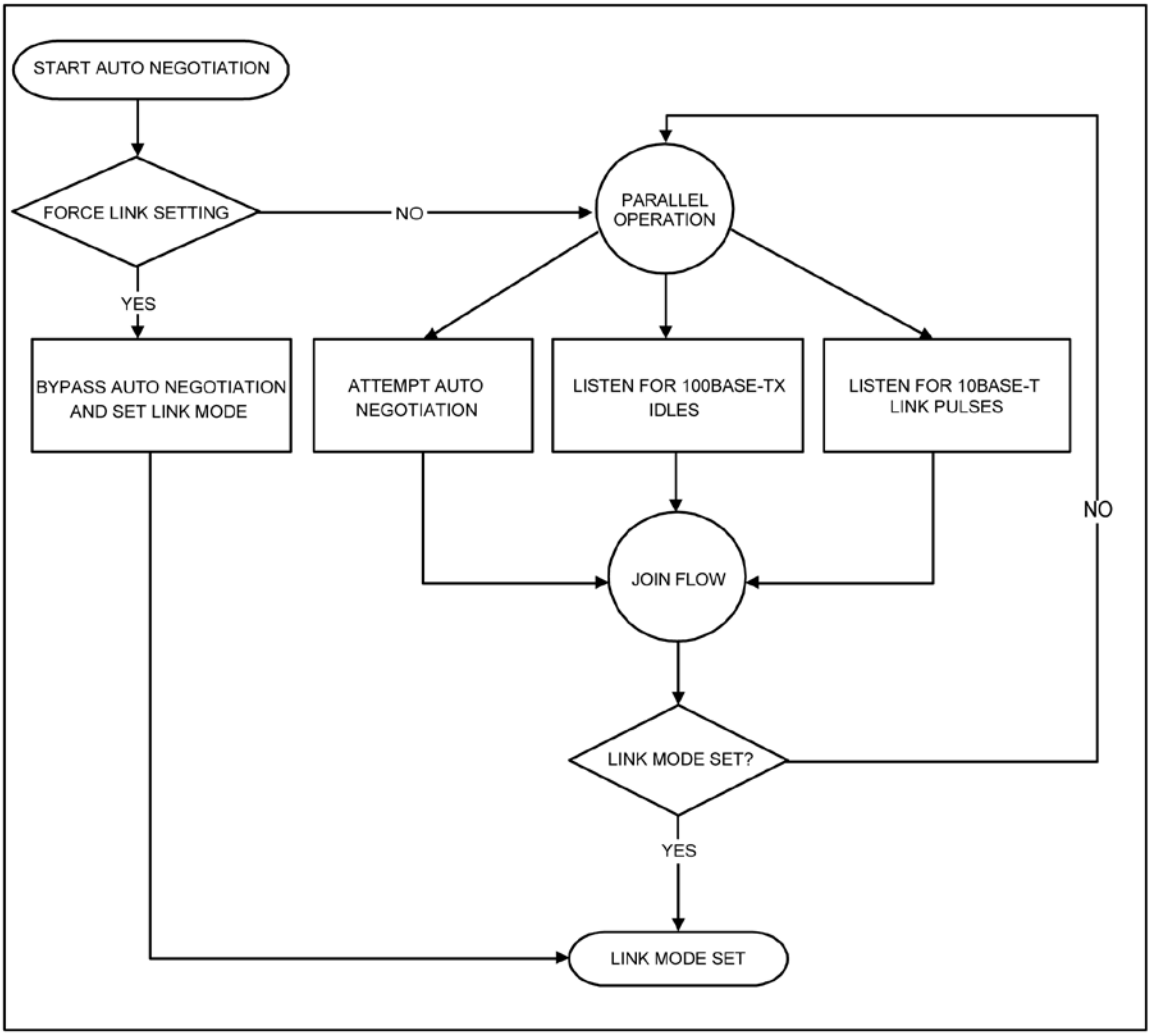


Figure 2. Auto-Negotiation Flow Chart

Quiet-WIRE® Filtering

Quiet-WIRE® is a feature to enhance 100Base-TX EMC performance by reducing both conducted and radiated emissions from the TXP/M signal pair. It can be used either to reduce absolute emissions or to enable replacement of shielded cable with unshielded cable, all while maintaining interoperability with standard 100Base-TX devices.

Quiet-WIRE filtering is implemented internally, with no additional external components required. It is enabled or disabled at power-up and reset by a strapping option on the RXER pin. Once the KSZ8061 is powered up, Quiet-WIRE can be enabled or disable by writing to register 16h, bit [12].

The default setting for Quiet-WIRE reduces emissions primarily above 60MHz, with less reduction at lower frequencies. Several dB of reduction is possible. Signal attenuation is approximately equivalent to increasing the cable length by 10 to 20 meters, thus reducing cable reach by that amount. For applications needing more modest improvement in emissions, the level of filtering can be reduced by writing a series of registers.

Fast Link-Up

Link up time is normally determined by the time it takes to complete auto-negotiation. Additional time may be added by the auto MDI/MDI-X feature. The total link up time from power-up or cable connect is typically a second or more.

Fast Link-up mode significantly reduces 100Base-TX link-up time by disabling both auto-negotiation and auto MDI/MDI-X, and fixing the TX and RX channels. This is done via the CONFIG[2:0] and AUTONEG strapping options. Because these are strapping options, fast link-up is available immediately upon power-up. Fast Link-up is available only for 100Base-TX link speed. To force the link speed to 10Base-TX requires a register write.

Fast Link-up is intended for specialized applications where both link partners are known in advance. The link must also be known so that the fixed transmit channel of one device connects to the fixed receive channel of the other device, and vice versa. [The TX and RX channel assignments are determined by the MDI/MDI-X strapping option on LED2_0.]

If a device in Fast Link-up mode is connected to a normal device (auto-negotiate and auto-MDI/MDI-X), there will be no problems linking, but the speed advantage of Fast Link-up will be realized only on one end.

Internal and External RX Termination

By default, the RX differential pair is internally terminated. This minimizes board component count by eliminating all components between the KSZ8061RNB/RND and the magnetics (transformer and common mode choke). The KSZ8061RNB/RND has the option to turn off the internal termination, to allow the use of external termination. External termination does increase the external component count, but these external components can be of tighter tolerance than the internal termination resistors. Enabling or disabling of internal RX termination is controlled by register 14h, bit [2].

External termination should consist of a 50Ω resistor between each signal (RXP and RXM) and AVDD.

RMII Interface

The Reduced Media Independent Interface (RMII) specifies a low pin count Media Independent Interface. It provides a common interface between RMII PHYs and MACs and has the following key characteristics:

- Pin count is 8 pins (3 pins for data transmission, 4 pins for data reception, and 1 pin for the 50MHz reference clock).
- 10Mbps and 100Mbps data rates are supported at both half- and full-duplex.
- Data transmission and reception are independent and belong to separate signal groups.
- Transmit data and receive data are each 2-bit wide, a dibit.

RMII Signal Definition

Table 1 describes the RMII signals. Refer to RMII Specification v1.2 for detailed information.

Table 1. RMII Signal Definition

RMII Signal Name	KSZ8061RNB/RND Signal and Direction	Direction (with respect to MAC device)	Description
REF_CLK	**KSZ8061RNB** REF_CLK, Output	Input	Synchronous 50MHz reference clock for receive, transmit and control interface
	KSZ8061RND XI, Input	Input or Output	
TX_EN	TXEN, Input	Output	Transmit Enable
TXD[1:0]	TXD[1:0], Input	Output	Transmit Data [1:0]
CRS_DV	CRS_DV , Output	Input	Carrier Sense/Receive Data Valid
RXD[1:0]	RXD[1:0], Output	Input	Receive Data [1:0]
RX_ER	RXER , Output	Input	Receive Error

Reference Clock (REF_CLK)

REF_CLK is a continuous 50MHz clock that provides the timing reference for TXEN, TXD[1:0], CRS_DV, RXD[1:0] and RXER. The KSZ8061RNB generates and outputs the 50MHz RMII REF_CLK to the MAC device at REF_CLK (pin 19). The KSZ8061RBD receives the 50MHz RMII REF_CLK from the MAC or system board at XI (pin 1), and leaves the REF_CLK (pin 19) as no connect.

Transmit Enable (TXEN)

TXEN indicates the MAC is presenting dibits on TXD[1:0] for transmission. It is asserted synchronously with the first dibit of the preamble and remains asserted while all dibits to be transmitted are presented on the RMII. It is negated prior to the first REF_CLK following the final dibit of a frame.

TXEN transitions synchronously with respect to REF_CLK.

Transmit Data [1:0] (TXD[1:0])

When TXEN is asserted, the PHY accepts TXD[1:0] for transmission. When TXEN is de-asserted, the MAC drives TXD[1:0] to either 00 for the idle state (non-EEE mode), or 01 for the LPI state (EEE mode).

TXD[1:0] transitions synchronously with respect to REF_CLK.

Carrier Sense/Receive Data Valid (CRS_DV)

The PHY asserts CRS_DV when the receive medium is non-idle. It is asserted asynchronously when a carrier is detected. This happens when squelch is passed in 10Mbps mode and when two non-contiguous 0s in 10 bits are detected in 100Mbps mode. Loss of carrier results in the de-assertion of CRS_DV.

While carrier detection criteria are met, CRS_DV remains asserted continuously from the first recovered dibit of the frame though the final recovered dibit. It is negated before the first REF_CLK that follows the final dibit. The data on RXD[1:0] is considered valid after CRS_DV is asserted. However, because the assertion of CRS_DV is asynchronous relative to REF_CLK, the data on RXD[1:0] is 00 until receive signals are properly decoded.

Receive Data[1:0] (RXD[1:0])

For each clock period in which CRS_DV is asserted, RXD[1:0] transfers a dibit of recovered data from the PHY. When CRS_DV is de-asserted, the PHY drives RXD[1:0] to either 00 for the idle state (non-EEE mode), or 01 for the LPI state (EEE mode).

RXD[1:0] transitions synchronously with respect to REF_CLK.

Receive Error (RXER)

When CRS_DV is asserted, RXER is asserted for one or more REF_CLK periods to indicate that a symbol error (for example, a coding error that a PHY can detect that may otherwise be undetectable by the MAC sub-layer) is detected somewhere in the frame that is being transferred from the PHY to the MAC.

RXER transitions synchronously with respect to REF_CLK.

RMII Signal Diagrams

The KSZ8061RNB RMII pin connections to the MAC are shown in Figure 3. The connections for the KSZ8061RND are shown in Figure 4.

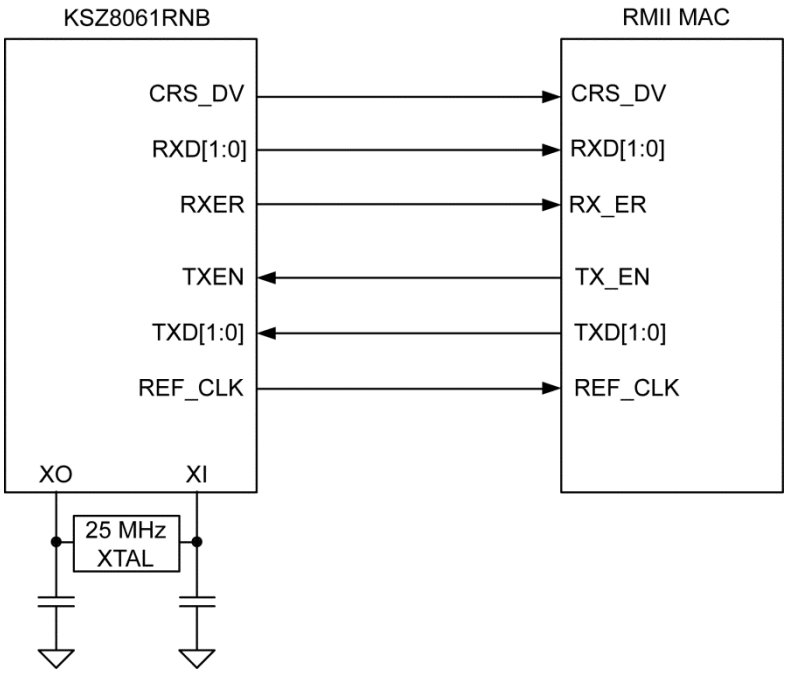


Figure 3. KSZ8061RNB RMII Interface

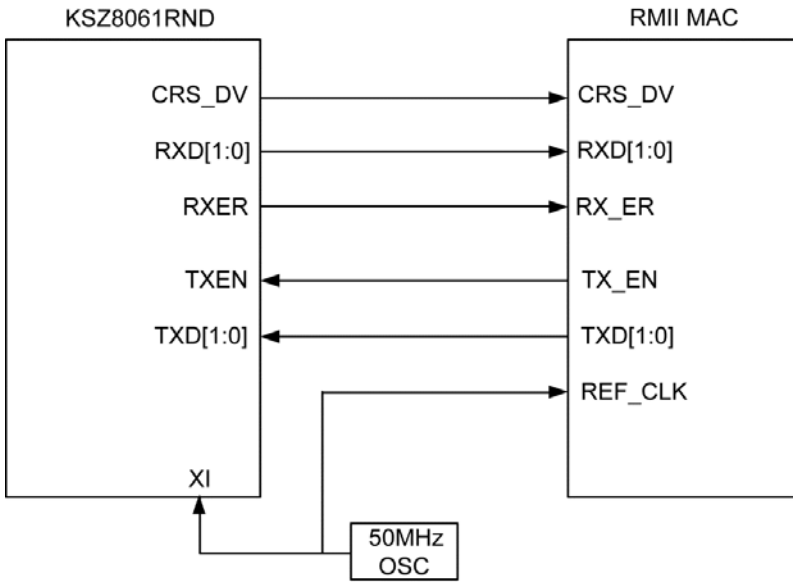


Figure 4. KSZ8061RND RMII Interface

Back-to-Back Mode – 100Mbps Repeater

Two KSZ8061RND devices can be connected back-to-back to form a 100Base-TX to 100Base-TX repeater. For testing purposes, it can also be used to loopback data on the RMII bus by physically connecting the RMII receive bus to the RMII transmit bus.

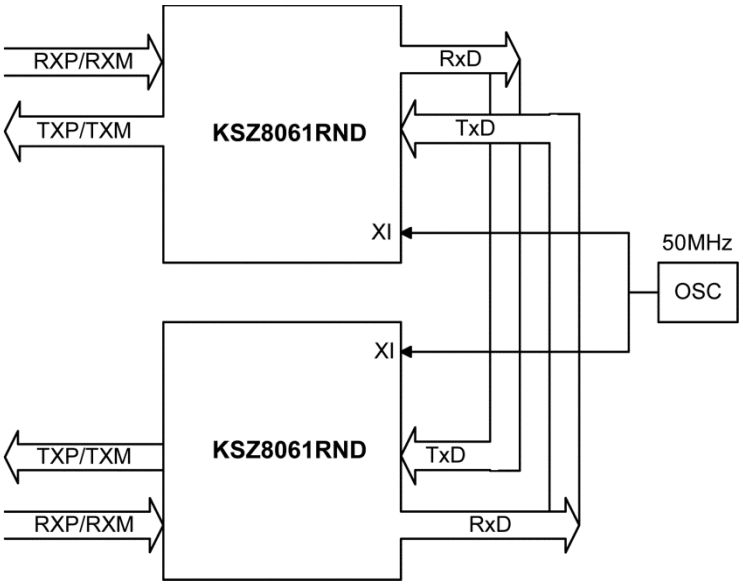


Figure 5. KSZ8061RND to KSZ8061RND Back-to-Back Repeater

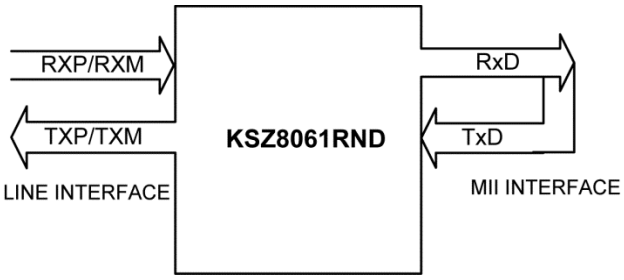


Figure 6. KSZ8061RND Back-to-Back for RMII Bus Loopback

RMII Back-to-Back Mode

In RMII back-to-back mode, a KSZ8061RND interfaces with another KSZ8061RND to provide a complete 100Mbps repeater solution.

The KSZ8061RND devices are configured to RMII Back-to-Back mode after power-up or reset with the following:

- Strapping pin CONFIG[2:0] set to ‘101’.
- A common 50MHz reference clock connected to XI of both KSZ8061RND devices.
- RMII signals connected as shown in Table 2.

Table 2. RMII Signal Connection for RMII Back-to-Back Mode

KSZ8061RND (100Base-TX) [Device 1]		KSZ8061RND (100Base-TX) [Device 1 or 2]	
Pin Name	**Pin Type**	**Pin Name**	**Pin Type**
CRS_DV	Output	TXEN	Input
RXD1	Output	TXD1	Input
RXD0	Output	TXD0	Input
TXEN	Input	CRS_DV	Output
TXD1	Input	RXD1	Output
TXD0	Input	RXD0	Output

Back-to-Back Mode and 10Base-T

If back-to-back mode is used and the line interface is operating at 10Base-T, it is necessary to also set register 18h bit [6].

MII Management (MIIM) Interface

The KSZ8061RNB/RND supports the IEEE 802.3 MII Management Interface, also known as the Management Data Input/Output (MDIO) Interface. This interface enables an upper-layer device, like a MAC processor, to monitor and control the state of the KSZ8061RNB/RND. An external device with MIIM capability is used to read the PHY status and/or configure the PHY settings. Further details on the MIIM interface can be found in Clause 22.2.4 of the IEEE 802.3 Specification.

The MIIM interface consists of the following:

- A physical connection that incorporates the clock line (MDC) and the data line (MDIO).
- A specific protocol that operates across the aforementioned physical connection that allows the external controller to communicate with one or more PHY devices.
- A set of 16-bit MDIO registers. Supported registers [0:8] are standard registers, and their functions are defined per the IEEE 802.3 Specification. The additional registers are provided for expanded functionality. See “Register Map” section for details.

The KSZ8061RNB/RND supports unique PHY addresses 1 to 7, and broadcast PHY address 0. The broadcast address is defined per the IEEE 802.3 specification, and can be used to write to multiple KSZ8061RNB/RND devices simultaneously.

The PHYAD[2:0] strapping pins are used to assign a unique PHY address between 0 and 7 to each KSZ8061RNB/RND device.

Table 3 shows the MII Management frame format.

Table 3. MII Management Frame Format

	Preamble	Start of Frame	Read/Write OP Code	PHY Address Bits [4:0]	REG Address Bits [4:0]	TA	Data Bits [15:0]	Idle
Read	32 1’s	01	10	00AAA	RRRRR	Z0	DDDDDDDD_DDDDDDDD	Z
Write	32 1’s	01	01	00AAA	RRRRR	10	DDDDDDDD_DDDDDDDD	Z

LED Output Pins

The LED0 and LED1 pins indicate link status and is intended for driving LEDs. They are active low and can sink current directly from the LEDs. By default, LED0 indicates Link/Activity and LED1 indicates Link Speed. Bits [5:4] in register 1Fh allow the definition of these pins to be changed to Link Status and Activity respectively.

- Link Status: The LED indicates that the serial link is up.
- Link/Activity: When the link is up, but there is no traffic, the LED will be on. When packets are being received or transmitted, the LED will blink.
- Activity: The LED blinks when packets are received or transmitted. It is off when there is no activity.
- Speed: When the link is up, the LED is on to indicate a 100Base-TX link and is off to indicate a 10Base-T link.

Interrupt (INTRP)

INTRP is an interrupt output signal that may be used to inform the external controller that there has been a status update to the KSZ8061RNB/RND PHY register. This eliminates the need for the processor to poll the PHY for status changes such as link up or down.

Register 1Bh, bits [15:8] are the interrupt control bits to enable and disable the conditions for asserting the INTRP signal. Register 1Bh, bits [7:0] are the interrupt status bits to indicate which interrupt conditions have occurred. The interrupt status bits are cleared after reading register 1Bh.

Register 1Fh, bit [9] sets the interrupt level to active-high or active-low. The default is active-low.

HP Auto MDI/MDI-X

HP Auto MDI/MDI-X configuration eliminates the confusion of whether to use a straight cable or a crossover cable between the KSZ8061RNB/RND and its link partner. This feature allows the KSZ8061RNB/RND to use either type of cable to connect with a link partner that is in either MDI or MDI-X mode. The auto-sense function detects transmit and receive pairs from the link partner and then assigns transmit and receive pairs of the KSZ8061RNB/RND accordingly.

Auto MDI/MDI-X is initially enabled or disabled at hardware reset by hardware pin strapping (CONFIG[2:0]). Afterwards, it can be enabled or disabled by register 1Fh, bit [13]. When Auto MDI/MDI-X is disabled, serial data is normally transmitted on the pin pair TXP/TXM, and data is received on RXP/RXM. However, this may be reversed by writing to register 1Fh, bit [14].

An isolation transformer with symmetrical transmit and receive data paths is recommended to support Auto MDI/MDI-X.

Table 4 illustrates how the IEEE 802.3 Standard defines MDI and MDI-X.

Table 4. MDI/MDI-X Pin Definition

MDI		MDI-X	
RJ-45 Pin	**Signal**	**RJ-45 Pin**	**Signal**
1	TX+	1	RX+
2	TX-	2	RX-
3	RX+	3	TX+
6	RX-	6	TX-

Straight Cable

A straight cable connects a MDI device to a MDI-X device, or a MDI-X device to a MDI device. Figure 7 depicts a typical straight cable connection between a NIC card (MDI device) and a switch, or hub (MDI-X device).

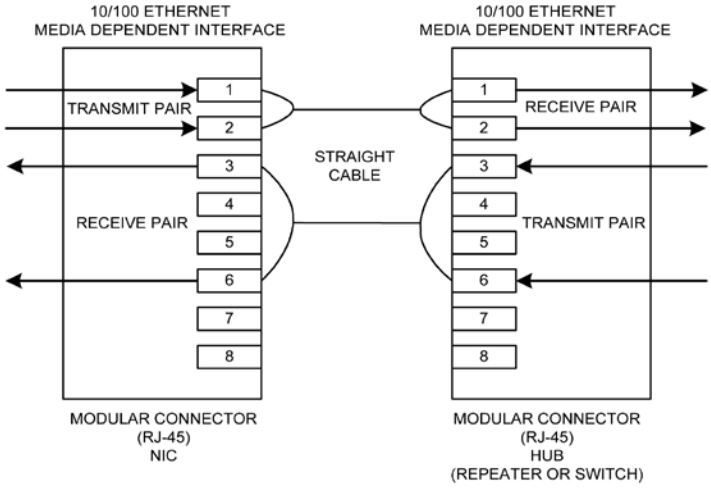


Figure 7. Typical Straight Cable Connection

Crossover Cable

A crossover cable connects a MDI device to another MDI device, or a MDI-X device to another MDI-X device. Figure 8 depicts a typical crossover cable connection between two switches or hubs (two MDI-X devices).

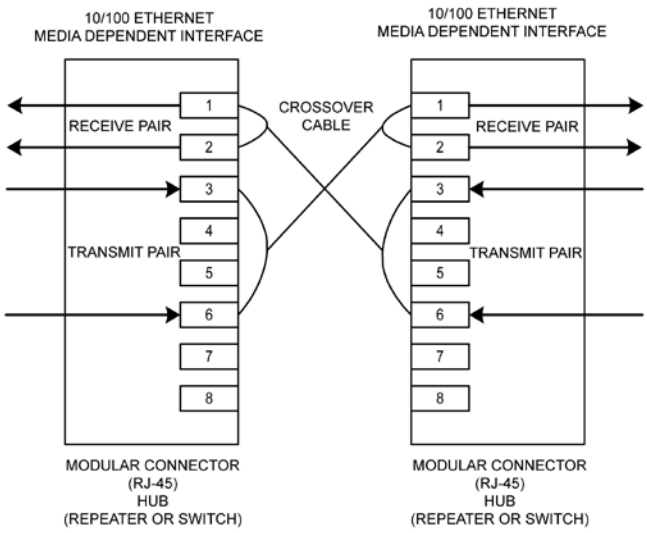


Figure 8. Typical Crossover Cable Connection

Loopback Modes

The KSZ8061RNB/RND supports the following loopback operations to verify analog and/or digital data paths.

- Local (Digital) Loopback
- Remote (Analog) Loopback

Local (Digital) Loopback Mode

This loopback mode is a diagnostic mode for checking the RMII transmit and receive data paths between KSZ8061RNB/RND and external MAC, and is supported for both speeds (10/100Mbps) at full-duplex.

The loopback data path is shown in Figure 9.

1. RMII MAC transmits frames to KSZ8061RNB/RND.
2. Frames are wrapped around inside KSZ8061RNB/RND.
3. KSZ8061RNB/RND transmits frames back to RMII MAC.

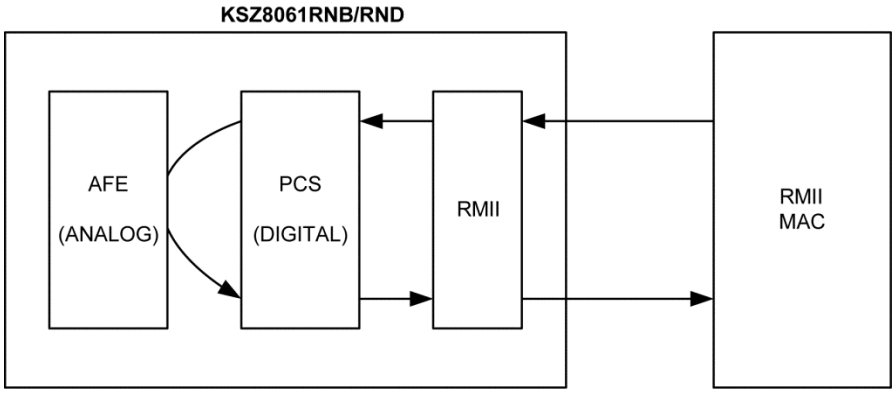


Figure 9. Local (Digital) Loopback

The following programming steps and register settings are used for Local Loopback mode.

For 10/100 Mbps loopback,

Set Register 0h,

- Bit [14] = 1 // Enable Local Loopback mode
- Bit [13] = 0 / 1 // Select 10Mbps / 100Mbps speed
- Bit [12] = 0 // Disable Auto-Negotiation
- Bit [8] = 1 // Select full-duplex mode

Set Register 1Ch,

- Bit [5] = 1

Remote (Analog) Loopback

This loopback mode checks the line (differential pairs, transformer, RJ-45 connector, Ethernet cable) transmit and receive data paths between KSZ8061RNB/RND and its link partner, and is supported for 100Base-TX full-duplex mode only.

The loopback data path is shown in the following Figure 10.

1. Fast Ethernet (100Base-TX) PHY link partner transmits frames to KSZ8061RNB/RND.
2. Frames are wrapped around inside KSZ8061RNB/RND.
3. KSZ8061RNB/RND transmits frames back to fast ethernet (100Base-TX) PHY link partner.

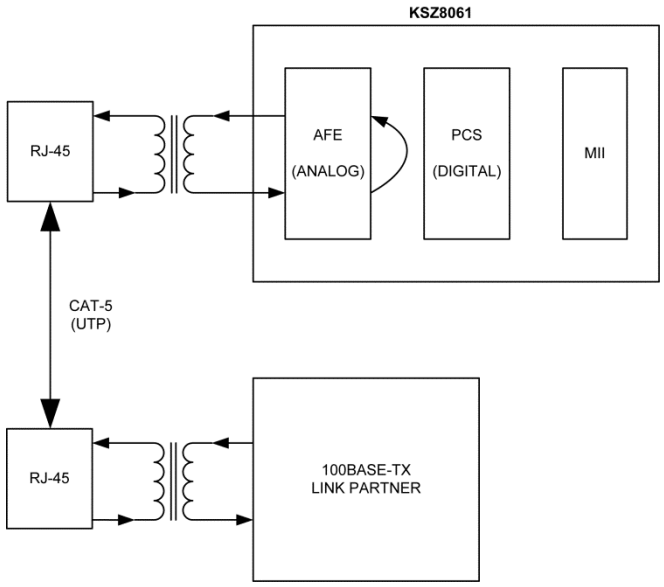


Figure 10. Remote (Analog) Loopback

The following programming steps and register settings are used for Remote Loopback mode.

Set Register 0h,

- Bit [13] = 1 // Select 100Mbps speed
- Bit [12] = 0 // Disable Auto-Negotiation
- Bit [8] = 1 // Select full-duplex mode

Or just simply auto-negotiate and link up at 100Base-TX full-duplex mode with link partner

Set Register 1Fh,

- Bit [2] = 1 // Enable Remote Loopback mode

LinkMD® Cable Diagnostics

The LinkMD® function utilizes time domain reflectometry (TDR) to analyze the cabling plant for common cabling problems, such as open circuits, short circuits and impedance mismatches.

LinkMD works by sending a pulse of known amplitude and duration down the MDI or MDI-X pair, and then analyzing the shape of the reflected signal to determine the type of fault. The time duration for the reflected signal to return provides the approximate distance to the cabling fault. The LinkMD function processes this TDR information and presents it as a numerical value that can be translated to a cable distance.

LinkMD is initiated by accessing the LinkMD Control/Status Register (register 1Dh) and the PHY Control 2 Register (register 1Fh). The latter register is used to disable auto MDI/MDI-X and to select either MDI or MDI-X as the cable differential pair for testing.

A two-step process is used to analyze the cable. The first step uses a small pulse (for short cables), while the second step uses a larger pulse (for long cables). The steps are shown here:

Step 1

- Write MMD address 1Bh, register 0, bits [7:4] = 0x2. Note that this is the power-up default value.
- Write register 13h, bit [15] = 0. Note that this is the power-up default value.
- Write register 1Fh. Disable auto MDI/MDI-X in bit [13], and select either MDI or MDI-X in bit [14] to specify the twisted pair to test.
- Write register 1Dh bit [15] to initiate the LinkMD test.
- Read register 1Dh to determine the result of the first step. Bit [15] = 0 indicates that the test is complete. After that, the result is read in bits [14:12]. Remember the result.

Step 2

- Write MMD address 1Bh, register 0, bits [7:4] = 0x7.
- Write register 13h, bit [15] = 1.
- Write register 1Dh bit [15] to initiate the LinkMD test.
- Read register 1Dh to determine the result of the first step. Bit [15] = 0 indicates that the test is complete. After that, the result is read in bits [14:12].
- If either step reveals a short, then there is a short. If either step reveals an open, then there is an open. If both tests indicate normal, then the cable is normal.

LinkMD®+ Enhanced Diagnostics: Receive Signal Quality Indicator

The KSZ8061RN provides a receive Signal Quality Indicator (SQI) feature, which indicates the relative quality of the 100Base-TX receive signal. It approximates a signal-to-noise ratio, and is affected by cable length, cable quality, and coupled of environmental noise.

The raw SQI value is available for reading at any time from indirect register: MMD 1Ch, register ACh, bits [14:8]. A lower value indicates better signal quality, while a higher value indicates worse signal quality. Even in a stable configuration in a low-noise environment, the value read from this register may vary. The value should therefore be averaged by taking multiple readings. The update interval of the SQI register is 2µs, so measurements taken more frequently than 2µs will be redundant. In a quiet environment, 6 to 10 readings are suggested for averaging. In a noisy environment, individual readings are unreliable, so a minimum of 30 readings are suggested for averaging. The SQI circuit does not include any hysteresis.

Table 5 lists typical SQI values for various CAT5 cable lengths when linked to a typical 100Base-TX device in a quiet environment. In a noisy environment or during immunity testing, the SQI value will increase.

Table 5 Typical SQI Values

CAT5 Cable Length	Typical SQI Value (MMD 1Ch, register ACh, bits [14:8])
10m	2
30m	2
50m	3
80m	3
100m	4
130m	5

NAND Tree Support

The KSZ8061RNB/RND provides parametric NAND tree support for fault detection between chip I/Os and board. The NAND tree is a chain of nested NAND gates in which each KSZ8061RNB/RND digital I/O (NAND tree input) pin is an input to one NAND gate along the chain. At the end of the chain, the CONFIG1 pin provides the output for the next NAND gates.

The NAND tree test process includes:

- Enabling NAND tree mode
- Pulling all NAND tree input pins high
- Driving low each NAND tree input pin sequentially per the NAND tree pin order
- Checking the NAND tree output to ensure there is a toggle high-to-low or low-to-high for each NAND tree input driven low

Table 6 lists the NAND tree pin order.

Table 6. KSZ8061RNB/RND NAND Tree Test Pin Order

Pin Number	Pin Name	NAND Tree Description
10	MDIO	Input
11	MDC	Input
12	RXER	Input
13	CRS_DV	Input
14	PHYAD0	Input
16	PHYAD1	Input
17	RXD1	Input
18	RXD0	Input
19	REF_CLK	Input
20	DNU	Input
21	TXEN	Input
22	TXD0	Input
23	TXD1	Input
24	LED0	Input
25	DNU	Input
26	DNU	Input
29	INTRP	Input
27	CONFIG1	Output

NAND Tree I/O Testing

The following procedure can be used to check for faults on the KSZ8061RNB/RND digital I/O pin connections to the board:

1. Enable NAND tree mode by INTRP pin strapping option.
2. Use board logic to drive all KSZ8061RNB/RND NAND tree input pins high.
3. Use board logic to drive each NAND tree input pin, per KSZ8061RNB/RND NAND Tree pin order, as follows:
   a. Toggle the first pin (MDIO) from high to low, and verify the CONFIG1 pin switch from high to low to indicate that the first pin is connected properly.
   b. Leave the first pin (MDIO) low.
   c. Toggle the second pin (MDC) from high to low, and verify the CONFIG1 pin switch from low to high to indicate that the second pin is connected properly.
   d. Leave the first pin (MDIO) and the second pin (MDC) low.
   e. Toggle the third pin (RXER) from high to low, and verify the CONFIG1 pin switch from high to low to indicate that the third pin is connected properly.
   f. Continue with this sequence until all KSZ8061RNB/RND NAND tree input pins have been toggled.

Each KSZ8061RNB/RND NAND tree input pin must cause the CONFIG1 output pin to toggle high-to-low or low-to-high to indicate a good connection. If the CONFIG1 pin fails to toggle when the KSZ8061RNB/RND input pin toggles from high to low, the input pin has a fault.

Power Management

The KSZ8061RNB/RND offers the following power management modes which are enabled and disabled by register control.

Power Saving Mode

Power Saving Mode is used to reduce the transceiver power consumption when the cable is unplugged. This mode does not interfere with normal device operation. It is enabled by writing a one to register 1Fh, bit [10], and is in effect when auto-negotiation mode is enabled and cable is disconnected (no link). In this mode, the KSZ8061RNB/RND shuts down all transceiver blocks except for the transmitter, energy detect and PLL circuits. By default, Power Saving Mode is disabled after power-up.

Energy Detect Power Down Mode

Energy Detect Power Down (EDPD) Mode is used to further reduce the transceiver power consumption when the cable is un-plugged, relative to Power Saving Mode. This mode does not interfere with normal device operation. It is enabled by writing a zero to register 18h, bit [11], and is in effect when auto-negotiation mode is enabled and cable is disconnected (no link).

EDPD Mode can be optionally enhanced with a PLL Off feature, which turns off all KSZ8061RNB/RND transceiver blocks, except for transmitter and energy detect circuits. PLL Off is set by writing a one to register 10h, bit [4].

Further power reduction is achieved by extending the time interval in between transmissions of link pulses while in this mode. The periodic transmission of link pulses is needed to ensure two link partners in the same low power state and with auto MDI/MDI-X disabled can wake up when the cable is connected between them.

By default, Energy Detect Power Down Mode is disabled after power-up.

Power Down Mode

Power Down Mode is used to power down the KSZ8061RNB/RND when it is not in use after power-up. It is enabled by writing a one to register 0h, bit [11].

In this mode, the KSZ8061RNB/RND disables all internal functions except the MII management interface. The KSZ8061RNB/RND exits (disables) Power Down Mode after register 0h, bit [11] is set back to zero.

Slow Oscillator Mode

Slow Oscillator Mode is used to disconnect the input reference crystal/clock on XI (pin 1) and select the on-chip slow oscillator when the KSZ8061RNB/RND is not in use after power-up. It is enabled by writing a one to register 11h, bit [6].

Slow Oscillator Mode works in conjunction with Power Down Mode to put the KSZ8061RNB/RND into a lower power state with all internal functions disabled, except for the MII management interface. To properly exit this mode and return to normal PHY operation, use the following programming sequence:

1. Disable Slow Oscillator Mode by writing a zero to register 11h, bit [6].
2. Disable Power Down Mode by writing a zero to register 0h, bit [11].
3. Initiate software reset by writing a one to register 0h, bit [15].

Ultra-Deep Sleep Mode

Ultra-Deep Sleep Mode is used to achieve the lowest possible power consumption while retaining the ability to detect activity on the Tx/Rx cable pairs, and is intended for achieving negligible battery drain during long periods of inactivity. It is controlled by several register bits, and Ultra-Deep Sleep Mode may be entered by writing to a register, or it may be initiated automatically when Signal Detect (SIGDET) is de-asserted. Details are given in the Signal Detect (SIGDET) and Ultra-Deep Sleep Mode section.

In Ultra-Deep Sleep Mode, the KSZ8061RNB/RND disables all internal functions and I/Os except for the ultra-low power signal detect circuit and the Signal Detect pin (SIGDET), which are powered from VDDIO. For lowest power consumption, the 1.2V supply (VDDL and AVDDL) may be turned off externally. Hardware reset is required to exit Ultra-Deep Sleep Mode.

Non-Volatile Registers

Most of the logic circuitry of the KSZ8061RNB/RND, including the status and control registers, is powered by the 1.2V supply. When the 1.2V supply is turned off in Ultra-Deep Sleep Mode, the content of the registers is lost. Because of the importance of register 14h and bit [0] of register 13h, which control the various power modes, these bits are duplicated in a logic block powered by the 3.3V supply. These register bits are therefore “non-volatile” while in Ultra-Deep Sleep Mode.

To access the non-volatile (3.3V) registers, bit [4] of register 14h must first be set. Otherwise, writes to these registers will modify only the volatile versions of these registers, and not the non-volatile versions.

Signal Detect (SIGDET) and Ultra-Deep Sleep Mode

SIGDET is an output signal which may be used for power reduction, either by directly turning off selected power or by signaling to a host controller when no signal is detected on the line interface. It is asserted when sufficient energy is detected on either of the differential pairs, and is de-asserted when cable energy is not detected. The signal detection circuit consumes almost no power from the VDDIO supply, and does not use the 1.2V supply at all.

Ultra-Deep Sleep Mode may be entered either automatically in unison with the Signal Detect signal (Automatic method), or manually by setting a register bit (CPU Control method).

The signal detect feature and Ultra-Deep Sleep Mode are controlled via multiple bits in register 14h:

- Register 14h, bit [6] Ultra Deep Sleep method: either Automatic or CPU Control.
- Register 14h, bit [5] Manually enter Ultra Deep Sleep Mode when CPU Control method is selected.
- Register 14h, bit [4] Enable R/W access to non-volatile versions of register 14h and bits [9:8] and [1:0] of register 13h. Set this bit when bit [3] is set.
- Register 14h, bit [3] Enable Ultra Deep Sleep Mode and SIGDET
- Register 14h, bit [1] Extend timing for SIGDET de-assertion and entry into Ultra Deep Sleep Mode
- Register 14h, bit [0] SIGDET output polarity

CPU Control Method (MIIM Interface)

- KSZ8061RNB/RND drives SIGDET signal to the CPU.
- SIGDET defaults to force high, in order to not interfere with PHY initialization by the CPU. At power-on, the KSZ8061RNB/RND drives SIGDET high, without consideration of cable energy level.
- During initialization, the CPU writes data 0x0058 to register 14h
  - Bit [4] enables access to the non-volatile copy of register 14h
  - Enable Ultra-Deep Sleep Mode and SIGDET by setting register 14h, bit [3].
  - Automatic Ultra-Deep Sleep functionality is disabled by setting register 14h, bit [6].
- SIGDET is now enabled and will change state as cable energy changes.
- Typically in response to the deassertion of SIGDET, the CPU puts KSZ8061RNB/RND into Ultra-Deep Sleep mode by setting register 14h, bit [5]. To further reduce power, the CPU may disable the 1.2V supply to the KSZ8061RNB/RND.
- The KSZ8061RNB/RND will assert SIGDET when energy is detected on the cable.
- To activate the KSZ8061RNB/RND, the CPU enables the 1.2V supply and asserts hardware reset (RESET#) to the KSZ8061RNB/RND. Because the KSZ8061RNB/RND has been completely reset, the registers must also be re-initialized.
- Alternately, it is possible to maintain register access during Ultra-Deep Sleep Mode by preserving the 1.2V power supply and setting register 13h, bit [0] to enable slow oscillator mode. Ultra-Deep Sleep Mode can then be exited by writing to register 14h. The 1.2V supply results in increased power consumption.

Automatic Standby Method

- The board may be designed such that the KSZ8061RNB/RND SIGDET signal enables the 1.2V power supply to KSZ8061RNB/RND.
- At power-on, the KSZ8061RNB/RND drives SIGDET high, without consideration of cable energy level.
- During initialization, CPU writes data 0x001A or 0x0018 to register 14h.
  - Bit [4] enables access to the non-volatile copy of register 14h.
  - Enable Ultra-Deep Sleep Mode and SIGDET by setting register 14h, bit [3].
  - Automatic Ultra-Deep Sleep functionality is enabled by clearing register 14h, bit [6].
  - SIGDET timing bit [1] must be set unless the link partner is not using auto-negotiation, auto-MDI/MDI-X is disabled, and link is at 100Mbps.
- When the KSZ8061RNB/RND detects signal loss, it automatically enters Ultra-Deep Sleep Mode and de-asserts SIGDET. SIGDET may be used to disable the 1.2V supply.
- When the KSZ8061RNB/RND detects a signal, it asserts SIGDET (which enables the 1.2V supply) and automatically wakes up. SIGDET may be used to wake up the CPU, which then re-initializes the KSZ8061RNB/RND.
- Alternatively, a hardware reset (RESET#) will bring the KSZ8061RNB/RND out of Ultra-Deep Sleep Mode.
- Note that the contents of register 14h and bits [9:8] and [1:0] of register 13h are preserved during Ultra-Deep Sleep Mode, but are lost during hardware reset.

Energy Efficient Ethernet (EEE)

The KSZ8061RNB/RND implements Energy Efficient Ethernet (EEE) as described in the IEEE 802.3az Standard for 100Base-TX copper signaling by the two differential pairs (analog side), and according to the multisource agreement (MSA) of collaborating Fast Ethernet chip vendors for the RMII (digital side). The MSA agreement is based on the IEEE Standard's EEE implementation for the 100Mbps Media Independent Interface (MII).

The IEEE Standard is defined around an EEE-compliant MAC on the host side and an EEE-compliant link partner on the line side that support special signaling associated with EEE. EEE saves power by keeping the voltage for the AC signal on the Ethernet cable at approximately 0V peak-to-peak for as often as possible during periods of no traffic activity, while maintaining the link-up status. This is referred to as the Low Power Idle (LPI) state.

During LPI mode, the copper link responds automatically when it receives traffic and resumes normal PHY operation immediately, without blockage of traffic or loss of packet. This involves exiting LPI mode and returning to normal 100Mbps operating mode. Wake-up time is <30µs for 100Base-TX.

The LPI state is controlled independently for transmit and receive paths, allowing the LPI state to be active (enabled) for:

- Transmit cable path only
- Receive cable path only
- Both transmit and receive cable paths

Upon power-up or reset, the EEE function is off. To enable the EEE function for 100Mbps mode, use the following programming sequence:

1. Enable 100Mbps EEE mode advertisement by writing a '1' to MMD address 7h, register 3Ch, bit [1].
2. Restart auto-negotiation by writing a '1' to standard register 0h, bit [9].

In 100Base-TX EEE operation, refresh transmissions are used to maintain link, and the quiet periods are when the power savings takes place. Approximately every 20ms – 22ms, a Refresh transmission of 200µs - 220µs is sent to the link partner. The refresh transmissions and quiet periods are shown in Figure 11.

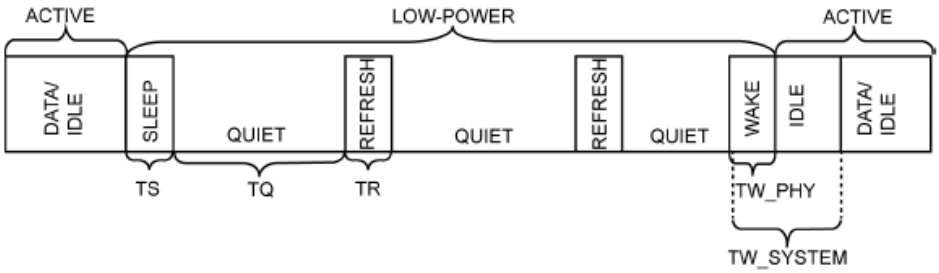


Figure 11. LPI Mode (Refresh Transmissions and Quiet Periods)

Transmit Direction Control (MAC-to-PHY)

The KSZ8061RNB/RND enters the LPI state for the transmit direction when the attached EEE-compliant RMII MAC de-asserts TXEN and drives TXD[1:0] to 01. It remains in the LPI transmit state while the RMII MAC maintains the state of these signals.

When the RMII MAC changes any of the TXEN or TXD[1:0] signals from the set LPI state value, the KSZ8061RNB/RND exits the LPI transmit state. Figure 12 shows the LPI transition for RMII (100Mbps) transmit.

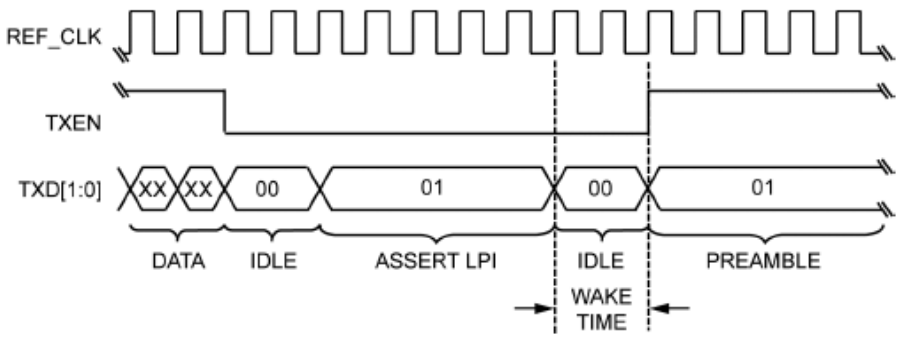


Figure 12. LPI Transition - RMII (100Mbps) Transmit

Receive Direction Control (PHY-to-MAC)

The KSZ8061RNB/RND enters the LPI state for the receive direction when it receives the /P/ code bit pattern (Sleep/Refresh) from its EEE-compliant link partner. It then de-asserts CRS_DV and drives RXD[1:0] to 01. The KSZ8061RNB/RND remains in the LPI receive state while it continues to receive the refresh from the link partner, so it will continue to maintain and drive the LSPI output state for the RMII receive signals to inform the attached EEE-compliant RMII MAC that it is in the LPI receive state.

When the KSZ8061RNB/RND receives a non /P/ code bit pattern (non-refresh), it exits the LPI state and sets the CSR_DV and RXD[1:0] signals accordingly for a normal frame or normal idle. Figure 13 shows the LPI transition for RMII (100Mbps) receive.

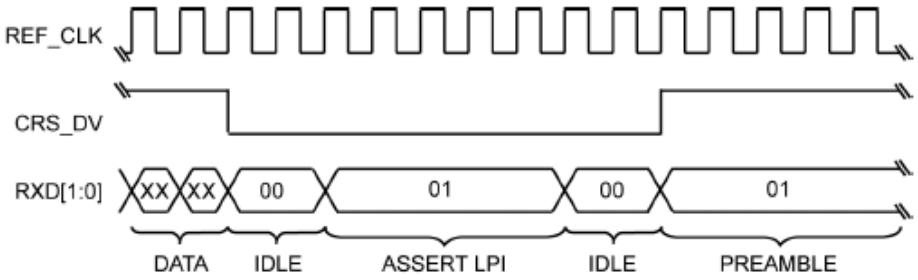


Figure 13. LPI Transition - RMII (100Mbps) Receive

Reference Circuit for Power and Ground Connections

The KSZ8061RNB and KSZ8061RND require a minimum of two supply voltages. 1.2V is required for VDDL and AVDDL. 3.3V is required for VDDIO and AVDDH. Optionally, VDDIO may be operated at 2.5V.

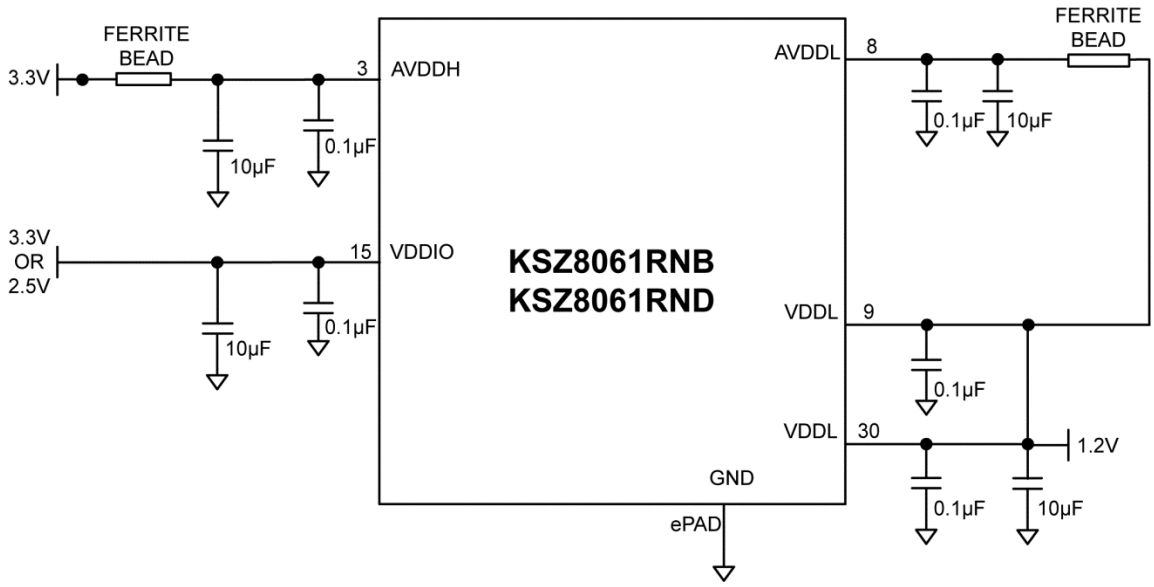


Figure 14. KSZ8061RNB/RND Power and Ground Connections

Register Map

The register space within the KSZ8061RNB/RND consists of two distinct areas.

- Standard registers // Direct register access
- MDIO Manageable device (MMD) registers // Indirect register access

Table 7. Standard Registers

Register Number (hex)	Description
IEEE-Defined Registers	
0h	Basic Control
1h	Basic Status
2h	PHY Identifier 1
3h	PHY Identifier 2
4h	Auto-Negotiation Advertisement
5h	Auto-Negotiation Link Partner Ability
6h	Auto-Negotiation Expansion
7h	Auto-Negotiation Next Page
8h	Auto-Negotiation Link Partner Next Page Ability
9h – Ch	Reserved
Dh	MMD Access Control Register
Eh	MMD Access Address Data Register
Fh	Reserved
Vendor-Specific Registers	
10h	Digital Control
11h	AFE Control 0
12h	Reserved
13h	AFE Control 2
14h	AFE Control 3
15h	RXER Counter
16h	Operation Mode
17h	Operation Mode Strap Status
18h	Expanded Control
19h – 1Ah	Reserved
1Bh	Interrupt Control/Status
1Ch	Function Control
1Dh	LinkMD® Control/Status
1Eh	PHY Control 1
1Fh	PHY Control 2

The KSZ8061RNB/RND supports the following MMD device addresses and their associated register addresses, which make up the indirect MMD registers.

Table 8. MMD Registers

Device Address (Hex)	Register Address (Hex)	Description
7h	3Ch	EEE Advertisement
	3Dh	Link Partner EEE Advertisement
1Bh	0h	AFED Control
1Ch	ACh	Signal Quality

Standard Registers

Standard registers provide direct read/write access to a 32-register address space, as defined in Clause 22 of the IEEE 802.3 standard. Within this address space, the first 16 registers (0h to Fh) are defined according to the IEEEE specification, while the remaining 16 registers (10h to 1Fh) are defined specific to the PHY vendor.

Standard Register Description

Address	Name	Description	Mode[6]	Default
Register 0h – Basic Control				
0.15	Reset	1 = Software reset 0 = Normal operation This bit is self-cleared after a '1' is written to it.	RW/SC	0
0.14	Loopback	1 = Loop-back mode (RMII TX to RMII RX. Line side is disconnected.) 0 = Normal operation Loopback must be enabled both here and in register 1Ch.	RW	0
0.13	Speed Select	1 = 100Mbps 0 = 10Mbps This bit is ignored if auto-negotiation is enabled (register 0.12 = 1).	RW	1
0.12	Auto-Negotiation Enable	1 = Enable auto-negotiation process 0 = Disable auto-negotiation process If enabled, auto-negotiation result overrides settings in register 0.13 and 0.8.	RW	Set by AUTONEG strapping pin. See Strapping Options section for details.
0.11	Power Down	1 = Power down mode 0 = Normal operation If software reset (register 0.15) is used to exit Power Down mode (register 0.11 = 1), two software reset writes (register 0.15 = 1) are required. First write clears Power Down mode; second write resets chip and re-latches the pin strapping pin values.	RW	0
0.10	Isolate	1 = Electrical isolation of PHY from RMII 0 = Normal operation	RW	0
0.9	Restart Auto-Negotiation	1 = Restart auto-negotiation process 0 = Normal operation. This bit is self-cleared after a '1' is written to it.	RW/SC	0
0.8	Duplex Mode	1 = Full-duplex 0 = Half-duplex	RW	1
0.7	Collision Test	1 = Enable COL test 0 = Disable COL test	RW	0
0.6:0	Reserved		RO	000_0000

Note:

6. RW = Read/Write.
RO = Read only.
SC = Self-cleared.
LH = Latch high.
LL = Latch low.

Standard Register Description (Continued)

Address	Name	Description	Mode[6]	Default
Register 1h – Basic Status				
1.15	100Base-T4	1 = T4 capable 0 = Not T4 capable	RO	0
1.14	100Base-TX Full-Duplex	1 = Capable of 100Mbps full-duplex 0 = Not capable of 100Mbps full-duplex	RO	1
1.13	100Base-TX Half-Duplex	1 = Capable of 100Mbps half-duplex 0 = Not capable of 100Mbps half-duplex	RO	1
1.12	10Base-T Full-Duplex	1 = Capable of 10Mbps full-duplex 0 = Not capable of 10Mbps full-duplex	RO	1
1.11	10Base-T Half-Duplex	1 = Capable of 10Mbps half-duplex 0 = Not capable of 10Mbps half-duplex	RO	1
1.10:7	Reserved		RO	000_0
1.6	No Preamble	1 = Preamble suppression acceptable 0 = Normal preamble required	RW	1
1.5	Auto-Negotiation Complete	1 = Auto-negotiation process completed 0 = Auto-negotiation process not completed	RO	0
1.4	Remote Fault	1 = Remote fault 0 = No remote fault	RO/LH	0
1.3	Auto-Negotiation Ability	1 = Capable to perform auto-negotiation 0 = Not capable to perform auto-negotiation	RO	1
1.2	Link Status	1 = Link is up 0 = Link is down	RO/LL	0
1.1	Jabber Detect	1 = Jabber detected 0 = Jabber not detected (default is low)	RO/LH	0
1.0	Extended Capability	1 = Supports extended capabilities registers	RO	1
Register 2h – PHY Identifier 1				
2.15:0	PHY ID Number	Assigned to the 3rd through 18th bits of the Organizationally Unique Identifier (OUI). Kendin Communication's OUI is 0010A1 (hex)	RO	0022h
Register 3h – PHY Identifier 2				
3.15:10	PHY ID Number	Assigned to the 19th through 24th bits of the Organizationally Unique Identifier (OUI). Kendin Communication's OUI is 0010A1 (hex)	RO	0001_01
3.9:4	Model Number	Six bit manufacturer's model number	RO	01_0111
3.3:0	Revision Number	Four bit manufacturer's revision number	RO	Indicates silicon revision

Standard Register Description (Continued)

Address	Name	Description	Mode[6]	Default
Register 4h – Auto-Negotiation Advertisement				
4.15	Next Page	1 = Next page capable 0 = No next page capability	RW	1
4.14	Reserved		RO	0
4.13	Remote Fault	1 = Remote fault supported 0 = No remote fault	RW	0
4.12	Reserved		RO	0
4.11:10	Pause	[00] = No PAUSE [10] = Asymmetric PAUSE [01] = Symmetric PAUSE [11] = Asymmetric & Symmetric PAUSE	RW	00
4.9	100Base-T4	1 = T4 capable 0 = No T4 capability	RO	0
4.8	100Base-TX Full-Duplex	1 = 100Mbps full-duplex capable 0 = No 100Mbps full-duplex capability	RW	1
4.7	100Base-TX Half-Duplex	1 = 100Mbps half-duplex capable 0 = No 100Mbps half-duplex capability	RW	1
4.6	10Base-T Full-Duplex	1 = 10Mbps full-duplex capable 0 = No 10Mbps full-duplex capability	RW	1
4.5	10Base-T Half-Duplex	1 = 10Mbps half-duplex capable 0 = No 10Mbps half-duplex capability	RW	1
4.4:0	Selector Field	[00001] = IEEE 802.3	RW	0_0001
Register 5h – Auto-Negotiation Link Partner Ability				
5.15	Next Page	1 = Next page capable 0 = No next page capability	RO	0
5.14	Acknowledge	1 = Link code word received from partner 0 = Link code word not yet received	RO	0
5.13	Remote Fault	1 = Remote fault detected 0 = No remote fault	RO	0
5.12	Reserved		RO	0
5.11:10	Pause	[00] = No PAUSE [10] = Asymmetric PAUSE [01] = Symmetric PAUSE [11] = Asymmetric & Symmetric PAUSE	RO	00
5.9	100Base-T4	1 = T4 capable 0 = No T4 capability	RO	0
5.8	100Base-TX Full-Duplex	1 = 100Mbps full-duplex capable 0 = No 100Mbps full-duplex capability	RO	0
5.7	100Base-TX Half-Duplex	1 = 100Mbps half-duplex capable 0 = No 100Mbps half-duplex capability	RO	0
5.6	10Base-T Full-Duplex	1 = 10Mbps full-duplex capable 0 = No 10Mbps full-duplex capability	RO	0
5.5	10Base-T Half-Duplex	1 = 10Mbps half-duplex capable 0 = No 10Mbps half-duplex capability	RO	0
5.4:0	Selector Field	[00001] = IEEE 802.3	RO	0_0001

Standard Register Description (Continued)

Address	Name	Description	Mode[6]	Default
Register 6h – Auto-Negotiation Expansion				
6.15:5	Reserved		RO	0000_0000_000
6.4	Parallel Detection Fault	1 = Fault detected by parallel detection 0 = No fault detected by parallel detection	RO/LH	0
6.3	Link Partner Next Page Able	1 = Link partner has next page capability 0 = Link partner does not have next page capability	RO	0
6.2	Next Page Able	1 = Local device has next page capability 0 = Local device does not have next page capability	RO	1
6.1	Page Received	1 = New page received 0 = New page not received yet	RO/LH	0
6.0	Link Partner Auto-Negotiation Able	1 = Link partner has auto-negotiation capability 0 = Link partner does not have auto-negotiation capability	RO	0
Register 7h – Auto-Negotiation Next Page				
7.15	Next Page	1 = Additional next page(s) will follow 0 = Last page	RW	0
7.14	Reserved		RO	0
7.13	Message Page	1 = Message page 0 = Unformatted page	RW	1
7.12	Acknowledge2	1 = Will comply with message 0 = Cannot comply with message	RW	0
7.11	Toggle	1 = Previous value of the transmitted link code word equaled logic one 0 = Logic zero	RO	0
7.10:0	Message Field	11-bit wide field to encode 2048 messages	RW	000_0000_0001

Standard Register Description (Continued)

Address	Name	Description	Mode[6]	Default
Register 8h – Link Partner Next Page Ability				
8.15	Next Page	1 = Additional Next Page(s) will follow 0 = Last page	RO	0
8.14	Acknowledge	1 = Successful receipt of link word 0 = No successful receipt of link word	RO	0
8.13	Message Page	1 = Message page 0 = Unformatted page	RO	0
8.12	Acknowledge2	1 = Able to act on the information 0 = Not able to act on the information	RO	0
8.11	Toggle	1 = Previous value of transmitted link code word equal to logic zero 0 = Previous value of transmitted link code word equal to logic one	RO	0
8.10:0	Message Field		RO	000_0000_0000
Register Dh – MMD Access Control Register				
D.15:14	Function	00 = address 01 = data, no post increment 10 = data, post increment on reads and writes 11 = data, post increment on writes only	RW	00
D.13:5	Reserved	Write as 0, ignore on read	RW	00_0000_000
D.4:0	DEVAD	Device address	RW	0_0000
Register Eh – MMD Access Address Data Register				
E.15:0	Address Data	If D.15:14 = 00, this is MMD DEVAD's address register. Otherwise, this is MMD DEVAD's data register as indicated by the contents of its address register.	RW	0000_0000_0000_0000
Register 10h – Digital Control Register				
10.15:5	Reserved		RW	0000_0000_000
10.4	PLL off in EDPD Mode	This mode may optionally be combined with EDPD mode for additional power reduction. 1 = PLL is off in EDPD mode 0 = PLL is on in EDPD mode	RW	0
10.3:0	Reserved		RW	0000
Register 11h – AFE Control 0 Register				
11.15:7	Reserved		RW	0000_0000_0
11.6	Slow Oscillator Mode	This mode substitutes the 25MHz clock with a slow oscillator clock, to save oscillator power during power down. 1 = Slow Oscillator mode enabled 0 = Slow Oscillator mode disabled	RW	0
11.5:0	Reserved		RW	00_0000

Standard Register Description (Continued)

Address	Name	Description	Mode[6]	Default
Register 13h – AFE Control 2 Register				
13.15	LinkMD Detector Threshold	Sets the threshold for the LinkMD pulse detector. Use high threshold with the large LinkMD pulse, and the low threshold with the small LinkMD pulse. Also see MMD address 1Bh, register 0h bits [7:4]. 1 = Enable high threshold comparator 0 = Disable high threshold comparator	RW	0
13.14:1	Reserved		RW	000_0000_0000_000
13.0	Slow Oscillator Mode for Ultra Deep Sleep Mode	This mode substitutes the 25MHz clock with a slow oscillator clock, to save oscillator power if register access is required during Ultra Deep Sleep Mode. Note that the 1.2V supply is required if this mode is used. 1 = Slow Oscillator mode enabled 0 = Slow Oscillator mode disabled	RW	0

Standard Register Description (Continued)

Address	Name	Description	Mode[6]	Default
Register 14h – AFE Control Register 3				
14.15:7	Reserved		RW	0000_0000_0
14.6	Ultra Deep Sleep method	1 = CPU Control method. Entry into Ultra Deep Sleep Mode determined by value of register bit 14.5 0 = Automatic method. Enter into Ultra Deep Sleep Mode automatically when no cable energy is detected	RW	0
14.5	Manual Ultra Deep Sleep Mode	1 = Enter into Standby Mode 0 = Normal Mode This bit is used to enter Ultra Deep Sleep Mode when the CPU Control method is selected in bit 14.6. To exit Ultra Deep Sleep Mode, a hardware reset is required.	RW	0
14.4	NV Register Access	1 = Enable the non-volatile copy of register 14h and bits [9:8] and [1:0] of 13h. 0 = Disable access to non-volatile registers When Ultra Deep Sleep Mode is enabled, this bit must be set to 1.	RW	0
14.3	Ultra Deep Sleep Mode and SIGDET Enable	1 = Ultra Deep Sleep Mode is enabled (but not necessarily entered), and SIGDET indicates cable energy detected 0 = Ultra Deep Sleep Mode is disabled, and SIGDET output signal is forced true.	RW	0
14.2	Disable RX internal termination	1 = Disable RX internal termination 0 = Enable RX internal termination [Has no effect on TX internal termination.]	RW	0
14.1	Signal Detect de-assertion timing delay	When Ultra Deep Sleep Mode is enabled, this bit determines the delay from loss of cable energy to de-assertion of SIGDET. When automatic method is selected for Ultra Deep Sleep Mode, this delay also applies to powering down. 1 = Increased delay. This setting is required to allow automatic exiting of Ultra Deep Sleep Mode (automatic method) if the link partner auto-negotiation is enabled, if auto-MDI/MDI-X is enabled, or if linking at 10Base-T. 0 = Minimum delay. When using the Automatic method for Ultra Deep Sleep Mode, use this setting only if the link partner's auto-negotiation is disabled, auto-MDI/MDI-X is disabled, and linking is at 100Base-TX. This setting may also be used for CPU Control method.	RW	0
14.0	Signal Detect polarity	1 = SIGDET is active low (low = signal detected) 0 = SIGDET is active high (high = signal detected)	RW	0

Standard Register Description (Continued)

Address	Name	Description	Mode[6]	Default
Register 15h – RXER Counter				
15.15:0	RXER Counter	Receive error counter for symbol error frames	RO/SC	0000h
Register 16h – Operation Mode				
16.15:13	Reserved		RW	000
16.12	QWF disable	1 = Disable Quiet-WIRE Filtering 0 = Enable Quiet-WIRE Filtering	RW	Strapping input at RXER pin
16.11:0	Reserved		RW	0000_0000_0000
Register 17h – Operation Mode Strap Status				
17.15:13	PHYAD[2:0] strap-in status	[000] = Strap to PHY Address 0 [001] = Strap to PHY Address 1 [010] = Strap to PHY Address 2 [011] = Strap to PHY Address 3 [100] = Strap to PHY Address 4 [101] = Strap to PHY Address 5 [110] = Strap to PHY Address 6 [111] = Strap to PHY Address 7	RO	
17.12:9	Reserved		RO	
17.8	QWF strap-in status	1 = Strap to enable Quiet-WIRE Filtering	RO	
17.7	Reserved		RO	0
17.6	RMII B-to-B strap-in status	1 = Strap to RMII Back-to-Back mode	RO	
17.5	NAND Tree strap-in status	1 = Strap to NAND Tree mode	RO	
17.4:2	Reserved		RO	0
17.1	RMII strap-in status	1 = Strap to RMII normal mode	RO	
17.0	Reserved		RO	0
Register 18h – Expanded Control				
18.15:12	Reserved		RW	0000
18.11	Energy Detect Power Down Mode disable	1 = Disable Energy Detect Power Down (EDPD) Mode 0 = Enable EDPD Mode	RW	1
18.10	RX PHY Latency	1 = Variable RX PHY latency with no preamble suppression 0 = Fixed RX PHY latency with possible suppression of one preamble octet	RW	0
18.9:7	Reserved		RW	00_0
18.6	Enable 10BT Preamble	When in Back-to-Back Mode and in 10Base-T, this bit must be set.	RW	0
18.5:0	Reserved		RW	00_0001

Standard Register Description (Continued)

Address	Name	Description	Mode[6]	Default
Register 1Bh – Interrupt Control/Status				
1B.15	Jabber Interrupt Enable	1 = Enable Jabber Interrupt 0 = Disable Jabber Interrupt	RW	0
1B.14	Receive Error Interrupt Enable	1 = Enable Receive Error Interrupt 0 = Disable Receive Error Interrupt	RW	0
1B.13	Page Received Interrupt Enable	1 = Enable Page Received Interrupt 0 = Disable Page Received Interrupt	RW	0
1B.12	Parallel Detect Fault Interrupt Enable	1 = Enable Parallel Detect Fault Interrupt 0 = Disable Parallel Detect Fault Interrupt	RW	0
1B.11	Link Partner Acknowledge Interrupt Enable	1 = Enable Link Partner Acknowledge Interrupt 0 = Disable Link Partner Acknowledge Interrupt	RW	0
1B.10	Link Down Interrupt Enable	1= Enable Link Down Interrupt 0 = Disable Link Down Interrupt	RW	0
1B.9	Remote Fault Interrupt Enable	1 = Enable Remote Fault Interrupt 0 = Disable Remote Fault Interrupt	RW	0
1B.8	Link Up Interrupt Enable	1 = Enable Link Up Interrupt 0 = Disable Link Up Interrupt	RW	0
1B.7	Jabber Interrupt	1 = Jabber occurred 0 = Jabber did not occurred	RO/SC	0
1B.6	Receive Error Interrupt	1 = Receive Error occurred 0 = Receive Error did not occurred	RO/SC	0
1B.5	Page Receive Interrupt	1 = Page Receive occurred 0 = Page Receive did not occur	RO/SC	0
1B.4	Parallel Detect Fault Interrupt	1 = Parallel Detect Fault occurred 0 = Parallel Detect Fault did not occur	RO/SC	0
1B.3	Link Partner Acknowledge Interrupt	1 = Link Partner Acknowledge occurred 0 = Link Partner Acknowledge did not occur	RO/SC	0
1B.2	Link Down Interrupt	1 = Link Down occurred 0 = Link Down did not occur	RO/SC	0
1B.1	Remote Fault Interrupt	1 = Remote Fault occurred 0 = Remote Fault did not occur	RO/SC	0
1B.0	Link Up Interrupt	1 = Link Up occurred 0 = Link Up did not occur	RO/SC	0
Register 1Ch – Function Control				
1C.15:6	Reserved		RW	0000_0000_00
1C.5	Local Loopback Option	1 = Enable local loopback 0 = Disable local loopback Local loopback must be enabled both here and in register 0h.	RW	0
1C.4:0	Reserved		RW	1_0000

Standard Register Description (Continued)

Address	Name	Description	Mode[6]	Default
Register 1Dh – LinkMD® Control/Status				
1D.15	Cable Diagnostic Test Enable	1 = Enable cable diagnostic test. After test has completed, this bit is self-cleared. 0 = Indicates cable diagnostic test (if enabled) has completed and the status information is valid for read.	RW/SC	0
1D.14:13	Cable Diagnostic Test Result	[00] = normal condition [01] = open condition has been detected in cable [10] = short condition has been detected in cable [11] = cable diagnostic test has failed	RO	00
1D.12	Short Cable Indicator	1 = Short cable (<10 meter) has been detected by LinkMD®.	RO	0
1D.11:9	Reserved		RW	000
1D.8:0	Cable Fault Counter	Distance to fault	RO	0_0000_0000
Register 1Eh – PHY Control 1				
1E.15:10	Reserved		RO	0000_00
1E.9	Enable Pause (Flow Control)	1 = Flow control capable 0 = No flow control capability	RO	0
1E.8	Link Status	1 = Link is up 0 = Link is down	RO	
1E.7	Polarity Status	1 = Polarity is reversed 0 = Polarity is not reversed	RO	
1E.6	Reserved		RO	0
1E.5	MDI/MDI-X State	1 = MDI-X 0 = MDI	RO	
1E.4	Energy Detect	1 = Presence of signal on receive differential pair 0 = No signal detected on receive differential pair	RO	
1E.3	PHY Isolate	1 = PHY in isolate mode 0 = PHY in normal operation [Same as register bit 0.10]	RW	0
1E.2:0	Operation Mode Indication	[000] = still in auto-negotiation [001] = 10Base-T half-duplex [010] = 100Base-TX half-duplex [011] = reserved [100] = reserved [101] = 10Base-T full-duplex [110] = 100Base-TX full-duplex [111] = reserved	RO	

Standard Register Description (Continued)

Address	Name	Description	Mode[6]	Default
Register 1Fh – PHY Control 2				
1F.15	HP_MDIX	1 = HP Auto MDI/MDI-X mode 0 = Micrel Auto MDI/MDI-X mode	RW	1
1F.14	MDI/MDI-X Select	When Auto MDI/MDI-X is disabled, 1 = MDI-X Mode Transmit on RXP,RXM and Receive on TXP,TXM 0 = MDI Mode Transmit on TXP,TXM and Receive on RXP,RXM	RW	0
1F.13	Pair Swap Disable	1 = Disable auto MDI/MDI-X 0 = Enable auto MDI/MDI-X	RW	Value determined by pin strapping option
1F.12	Reserved		RW	0
1F.11	Force Link	1 = Force link pass 0 = Normal link operation This bit bypasses the control logic and allow transmitter to send pattern even if there is no link.	RW	0
1F.10	Power Saving	1 = Enable power saving 0 = Disable power saving	RW	0
1F.9	Interrupt Level	1 = Interrupt pin active high 0 = Interrupt pin active low	RW	0
1F.8	Enable Jabber	1 = Enable jabber counter 0 = Disable jabber counter	RW	1
1F.7:6	Reserved		RW	00
1F.5:4	LED Mode	[00] = LED1: Speed, LED0: Link / Activity [01] = LED1: Activity, LED0: Link [10] = reserved [11] = reserved	RW	00
1F.3	Disable Transmitter	1 = Disable transmitter 0 = Enable transmitter	RW	0
1F.2	Remote Loopback	1 = Remote (analog) loopback is enabled 0 = Normal mode	RW	0
1F.1	Enable SQE Test	1 = Enable SQE test 0 = Disable SQE test	RW	0
1F.0	Disable Data Scrambling	1 = Disable scrambler 0 = Enable scrambler	RW	0

MMD Registers

MMD registers provide indirect read/write access to up to 32 MMD Device Addresses with each device supporting up to 65,536 16-bit registers, as defined in clause 22 of the IEEE 802.3 specification. The KSZ8061RNB/RND, however, uses only a small fraction of the available registers. See the Register Map section for a list of supported MMD device addresses and their associated register addresses.

The following two standard registers serve as the portal registers to access the indirect MMD registers.

- Standard register Dh – MMD Access – Control
- Standard register Eh – MMD Access – Register/Data

Address	Name	Description	Mode[6]	Default
Register Dh – MMD Access Control Register				
D.15:14	Function	00 = address 01 = data, no post increment 10 = data, post increment on reads and writes 11 = data, post increment on writes only	RW	00
D.13:5	Reserved	Write as 0, ignore on read	RW	00_0000_000
D.4:0	DEVAD	These five bits set the MMD device address	RW	0_0000
Register Eh – MMD Access Address Data Register				
E.15:0	Address/Data	When register Dh, bits [15:14] = 00, this register contains the MMD DEVAD's address register. Otherwise, this register contains the MMD DEVAD's data register as indicated by the contents of its address register.	RW	0000_0000_0

Examples:

MMD Register Write

Write MMD – Device Address 7h, Register 3Ch = 0002h to enable EEE advertisement.

1. Write Register Dh with 0007h // Set up register address for MMD – Device Address 7h.
2. Write Register Eh with 003Ch // Select register 3Ch of MMD – Device Address 7h.
3. Write Register Dh with 4007h // Select register data for MMD – Device Address 7h, Register 3Ch.
4. Write Register Eh with 0002h // Write value 0002h to MMD – Device Address 7h, Register 3Ch.

MMD Register Read

Read MMD – Device Address 1Fh, Register 19h – 1Bh

1. Write Register Dh with 001Fh // Set up register address for MMD – Device Address 1Fh.
2. Write Register Eh with 0019h // Select register 19h of MMD – Device Address 1Fh.
3. Write Register Dh with 801Fh // Select register data for MMD – Device Address 1Fh, Register 19h
   // with post increments.
4. Read Register Eh // Read data in MMD – Device Address 1Fh, Register 19h.
5. Read Register Eh // Read data in MMD – Device Address 1Fh, Register 1Ah.
6. Read Register Eh // Read data in MMD – Device Address 1Fh, Register 1Bh.

MMD Registers

Address	Name	Description	Mode[6]	Default
MMD Address 7h, Register 3Ch – EEE Advertisement				
7.3C.15:8	Reserved	Reserved	RO	0000_0000
7.3C.7:3	Reserved	Reserved	RW	0000
7.3C.2	1000Base-T EEE Capable	0 = 1000Mbps EEE is not supported	RW	0
7.3C.1	100Base-TX EEE Capable	1 = 100Mbps EEE capable 0 = No 100Mbps EEE capability This bit is set to '0' as the default after power-up or reset. Set this bit to '1' to enable 100Mbps EEE mode.	RW	0
7.3C.0	Reserved	Reserved	RW	0
MMD Address 7h, Register 3Dh – Link Partner EEE Advertisement				
7.3D.15:3	Reserved	Reserved	RO	0000_0000_0000_0
7.3D.2	Link Partner 1000Base-T EEE Capable	1 = Link partner is 1000Mbps EEE capable 0 = Link partner is not 1000Mbps EEE capable	RO	0
7.3D.1	Link Partner 100Base-TX EEE Capable	1 = Link partner is 100Mbps EEE capable 0 = Link partner is not 100Mbps EEE capable	RO	0
7.3D.0	Reserved	Reserved	RO	0
MMD Address 1Bh, Register 0h – AFED Control Register				
1B.0.15:8	Reserved	Reserved	RW	0000_0000
1B.0.7:4	LinkMD Pulse Amplitude	Sets the amplitude of the LinkMD pulse. Default value (0x2) is a small pulse. Set to 0x7 for a large pulse. Also see register 13h bit [15].	RW	0010
1B.0.3:0	Reserved	Reserved	RW	0000
MMD Address 1Ch, Register ACh – Signal Quality Register				
1C.AC.15	Reserved	Reserved	RO	0
1C.AC.14:8	Signal Quality Indicator	SQI indicates relative quality of the signal. A lower value indicates better signal quality.	RO	xxx_xxxx
1C.AC.7:0	Reserved	Reserved	RO	0000_0000

Absolute Maximum Ratings[7]

Supply Voltage
- (VDDIO, AVDDH) ..... –0.5V to +5.0V
- (VDDL, AVDDL) ..... –0.5V to +1.8V

Input Voltage (all inputs) ..... –0.5V to +5.0V
Output Voltage (all outputs) ..... –0.5V to +5.0V
Lead Temperature (soldering, 10sec.) ..... 260°C
Storage Temperature (T_s) ..... –55°C to +150°C
HBM ESD Rating 5kV

Operating Ratings[8]

Supply Voltage
- (AVDDH @ 3.3V) ..... +3.135V to +3.465V
- (VDDIO @ 3.3V) ..... +3.135V to +3.465V
- (VDDIO @ 2.5V) ..... +2.375V to +2.625V
- (VDDL, AVDDL) ..... +1.14V to +1.26V

Ambient Temperature
- (T_A, Extended) ..... –40°C to +105°C

Maximum Junction Temperature (T_J max.) ..... 125°C
Thermal Resistance (θ_{JA}, 32-QFN, 32-WQFN) ..... 34°C/W
Thermal Resistance (θ_{JC}, 32-QFN, 32-WQFN) ..... 6°C/W

Electrical Characteristics[9]

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
Supply Current for VDDL, AVDDL						
I_{CORE}	1.2V Current for VDDL + AVDDL	No link, attempting to auto-negotiate		59		mA
		100BASE-TX full-duplex at 100% utilization		45		mA
		100BASE-TX link up, no traffic		45		mA
		10BASE-T full-duplex at 100% utilization		17		mA
		10BASE-T link up, no traffic		17		mA
		Energy Efficient Ethernet (EEE), both TX and RX in LPI state		14		mA
		Energy Detect Power Down (EDPD) mode, no link partner (reg. 18h.11 = 0)		16		mA
		EDPD mode with PLL off, no link partner (reg. 18h.11 = 0; reg. 10h.4 = 1)		0.7		mA
		Power Down mode (reg. 0h.11 = 1)		0.5		mA
		Power Down mode, MII isolate, slow oscillator mode (reg. 0h.11 = 1; reg. 0h.10 = 1; reg. 11h.6 = 1)		0.05		mA
		Ultra Deep Sleep mode with 1.2V (reg. 14h = 0x0078)		46		µA
		Ultra Deep Sleep mode, VDDL and AVDDL = 0V (reg. 14h = 0x0078)		0		µA

Notes:

7. Exceeding the absolute maximum rating may damage the device. Stresses greater than the absolute maximum rating may cause permanent damage to the device. Operation of the device at these or any other conditions above those specified in the operating sections of this specification is not implied. Maximum conditions for extended periods may affect reliability.
8. The device is not guaranteed to function outside its operating ratings.
9. T_A = 25°C. Specification is for packaged product only.

Electrical Characteristics[9] (Continued)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
Supply Current for VDDIO						
$I_{VDDIO\_2.5}$	2.5V Current for Digital I/Os	No link, attempting to auto-negotiate		3.3		mA
		100BASE-TX full-duplex at 100% utilization		5.9		mA
		100BASE-TX link up, no traffic		3.3		mA
		10BASE-T full-duplex at 100% utilization		1.0		mA
		10BASE-T link up, no traffic		0.6		mA
		Energy Efficient Ethernet (EEE), both TX and RX in LPI state		1.9		mA
		Energy Detect Power Down (EDPD) mode, no link partner (reg. 18h.11 = 0)		3.9		mA
		EDPD mode with PLL off, no link partner (reg. 18h.11 = 0; reg. 10h.4 = 1)		0.23		mA
		Power Down mode (reg. 0h.11 = 1)		0.23		mA
		Power Down mode, MII isolate, slow oscillator mode (reg. 0h.11 = 1; reg. 0h.10 = 1; reg. 11h.6 = 1)		0.10		mA
		Ultra Deep Sleep mode with 1.2V (reg. 14h = 0x0078)		100		µA
		Ultra Deep Sleep mode, VDDL and AVDDL = 0V (reg. 14h = 0x0078)		0.01		µA
$I_{VDDIO\_3.3}$	3.3V Current for Digital I/Os	No link, attempting to auto-negotiate		6.5		mA
		100BASE-TX full-duplex at 100% utilization		11		mA
		100BASE-TX link up, no traffic		6.5		mA
		10BASE-T full-duplex at 100% utilization		1.7		mA
		10BASE-T link up, no traffic		1.1		mA
		Energy Efficient Ethernet (EEE), both TX and RX in LPI state		3.6		mA
		Energy Detect Power Down (EDPD) mode, no link partner (reg. 18h.11 = 0)		6.6		mA
		EDPD mode with PLL off, no link partner (reg. 18h.11 = 0; reg. 10h.4 = 1)		0.56		mA
		Power Down mode (reg. 0h.11 = 1)		0.51		mA
		Power Down mode, MII isolate, slow oscillator mode (reg. 0h.11 = 1; reg. 0h.10 = 1; reg. 11h.6 = 1)		0.18		mA
		Ultra Deep Sleep mode with 1.2V (reg. 14h = 0x0078)		180		µA
		Ultra Deep Sleep mode, VDDL and AVDDL = 0V (reg. 14h = 0x0078)		0.01		µA

Electrical Characteristics[9] (Continued)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
Supply Current for AVDDH						
$I_{AVDDH\_3.3}$	3.3V Current for Transceiver	No link, attempting to auto-negotiate		19		mA
		100BASE-TX full-duplex at 100% utilization		24		mA
		100BASE-TX link up, no traffic		24		mA
		10BASE-T full-duplex at 100% utilization		28		mA
		10BASE-T link up, no traffic		16		mA
		Energy Efficient Ethernet (EEE), both TX and RX in LPI state		10		mA
		Energy Detect Power Down (EDPD) mode, no link partner (reg. 18h.11 = 0)		4.3		mA
		EDPD mode with PLL off, no link partner (reg. 18h.11 = 0; reg. 10h.4 = 1)		2.2		mA
		Power Down mode (reg. 0h.11 = 1)		1.0		mA
		Power Down mode, MII isolate, slow oscillator mode (reg. 0h.11 = 1; reg. 0h.10 = 1; reg. 11h.6 = 1)		0.18		mA
		Ultra Deep Sleep mode with 1.2V (reg. 14h = 0x0078)		0.5		µA
		Ultra Deep Sleep mode, VDDL and AVDDL = 0V (reg. 14h = 0x0078)		0.4		µA

Electrical Characteristics[9] (Continued)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
CMOS Inputs (MDC, RESET, TXD, TXEN)						
V_{IH}	Input High Voltage	VDDIO = 3.3V	2.0			V
		VDDIO = 2.5V	1.5			
V_{IL}	Input Low Voltage	VDDIO = 3.3V			1.3	V
		VDDIO = 2.5V			1.0	
$\|I_{IN}\|$	Input Current	V_{IN} = GND ~ VDDIO			10	µA
CMOS Outputs (CRS_DV, LED, REF_CLK, RXD, RXER, SIGDET)						
V_{OH}	Output High Voltage	VDDIO = 3.3V, I_{OH} = 12 mA	2.4			V
		VDDIO = 2.5V, I_{OH} = 6 mA	2.0			
V_{OL}	Output Low Voltage	VDDIO = 3.3V, I_{OL} = 6 mA			0.4	V
		VDDIO = 2.5V, I_{OL} = 5 mA			0.4	
$\|I_{oz}\|$	Output Tri-State Leakage	V_{OUT} = GND ~ VDDIO			10	µA
All Pull-Up/Pull-Down Pins (including Strapping Pins)						
pu	Internal Pull-Up Resistance	VDDIO = 3.3V, external 4.7kΩ pull-down		33		kΩ
		VDDIO = 2.5V, external 4.7kΩ pull-down		47		kΩ
pd	Internal Pull-Down Resistance	VDDIO = 3.3V, external 4.7kΩ pull-up		36		kΩ
		VDDIO = 2.5V, external 4.7kΩ pull-up		48		kΩ
100Base-TX Transmit (measured differentially after 1:1 transformer)						
V_O	Peak Differential Output Voltage	100Ω termination across differential output	0.95		1.05	V
V_{IMB}	Output Voltage Imbalance	100Ω termination across differential output			2	%
t_r, t_f	Rise/Fall Time		3		5	ns
	Rise/Fall Time Imbalance		0		0.5	ns
	Duty Cycle Distortion				± 0.25	ns
	Overshoot				5	%
	Output Jitter	Peak-to-peak		0.7		ns
10Base-T Transmit (measured differentially after 1:1 transformer)						
V_P	Peak Differential Output Voltage	100Ω termination across differential output	2.2		2.8	V
	Jitter Added	Peak-to-peak			3.5	ns
t_r, t_f	Rise/Fall Time			25		ns
10Base-T Receive						
V_{SQ}	Squelch Threshold	5MHz square wave		400		mV
100Mbps Mode – Industrial Applications Parameters						
t_{llr}	Link Loss Reaction (Indication) Time	Link loss detected at receive differential inputs to PHY signal indication time for each of the following: 1. For LED0 Mode “01”, Link LED output change from low (link-up) to high (link-down). 2. INTRP pin assertion for link-down status change.		4.8		µs

Timing Diagrams

RMII Transmit Timing

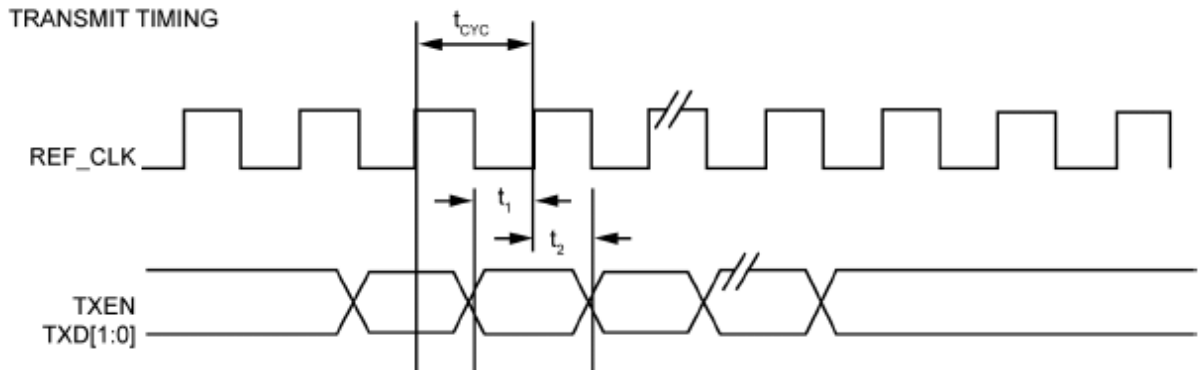


Figure 15. RMII Transmit Timing

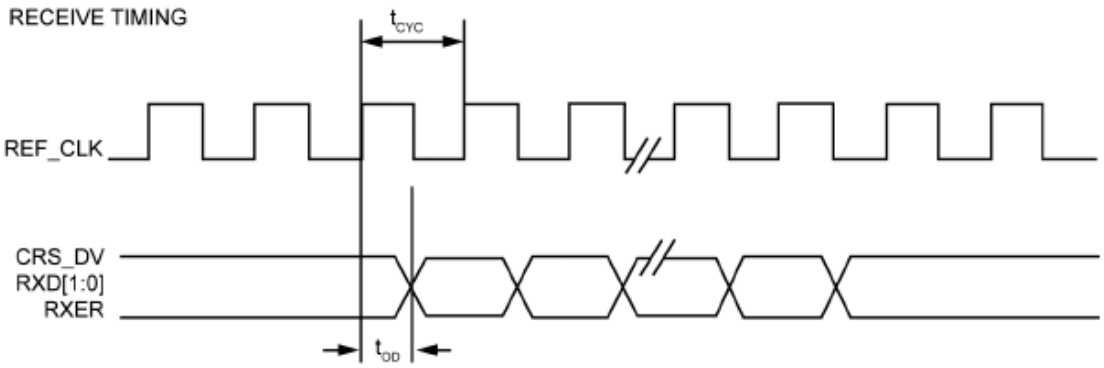


Figure 16. RMII Receive Timing

Table 9. RMII Timing Parameters

Timing Parameter	Description	Min.	Typ.	Max.	Units
t_{CYC}	Clock period		20		ns
t_1	Setup time	4			ns
t_2	Hold time	2			ns
t_{OD}	Output delay	7	10	13	ns

Auto-Negotiation Timing

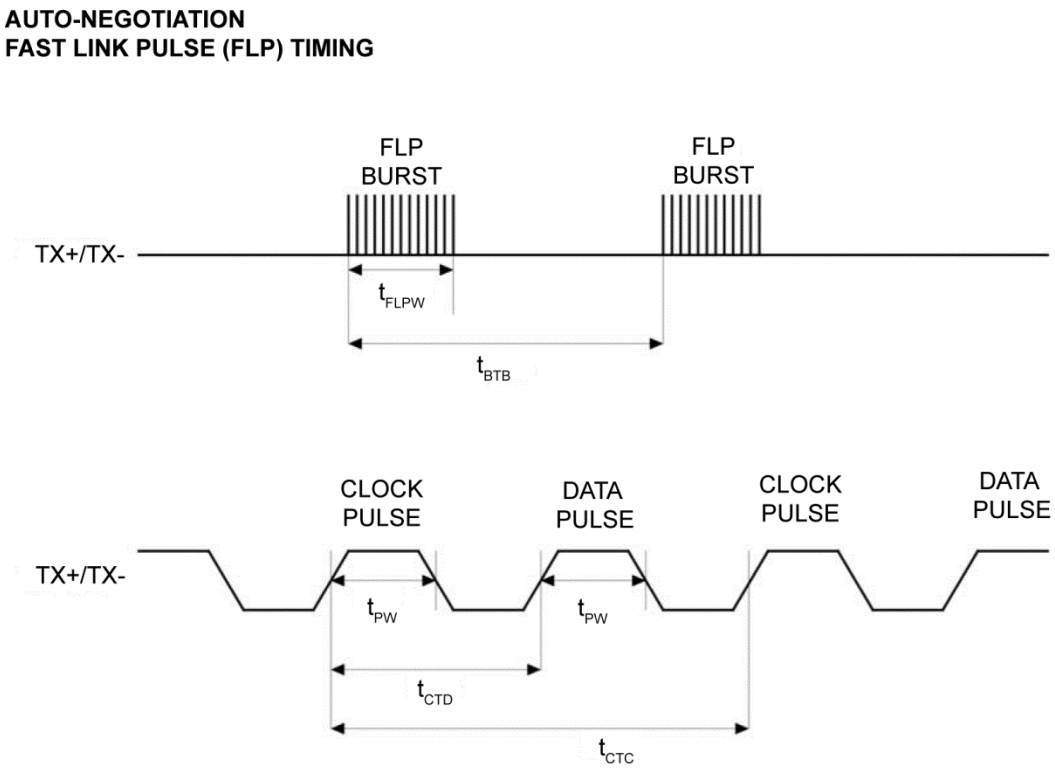


Figure 17. Auto-Negotiation Fast Link Pulse (FLP) Timing

Table 10. Auto-Negotiation Fast Link Pulse (FLP) Timing Parameters

Timing Parameter	Description	Min.	Typ.	Max.	Units
t_{BTB}	FLP Burst to FLP Burst	8	16	24	ms
t_{FLPW}	FLP Burst width		2		ms
t_{PW}	Clock/Data Pulse width		100		ns
t_{CTD}	Clock Pulse to Data Pulse	55.5	64	69.5	µs
t_{CTC}	Clock Pulse to Clock Pulse	111	128	139	µs
	Number of Clock/Data Pulse per FLP Burst	17		33	

MDC/MDIO Timing

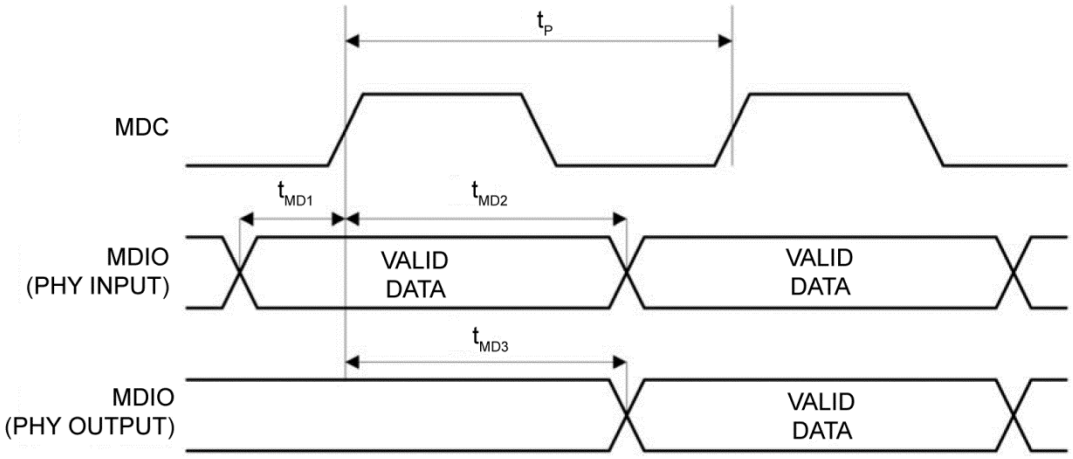


Figure 18. MDC/MDIO Timing

Table 11. MDC/MDIO Timing Parameters

Timing Parameter	Description	Min.	Typ.	Max.	Units
t_P	MDC period	400			ns
t_{MD1}	MDIO (PHY input) setup to rising edge of MDC	10			ns
t_{MD2}	MDIO (PHY input) hold from rising edge of MDC	4			ns
t_{MD3}	MDIO (PHY output) delay from rising edge of MDC	5			ns

Power-up/Reset Timing

The KSZ8061RNB/RND reset timing requirement is summarized in Figure 19 and Table 12.

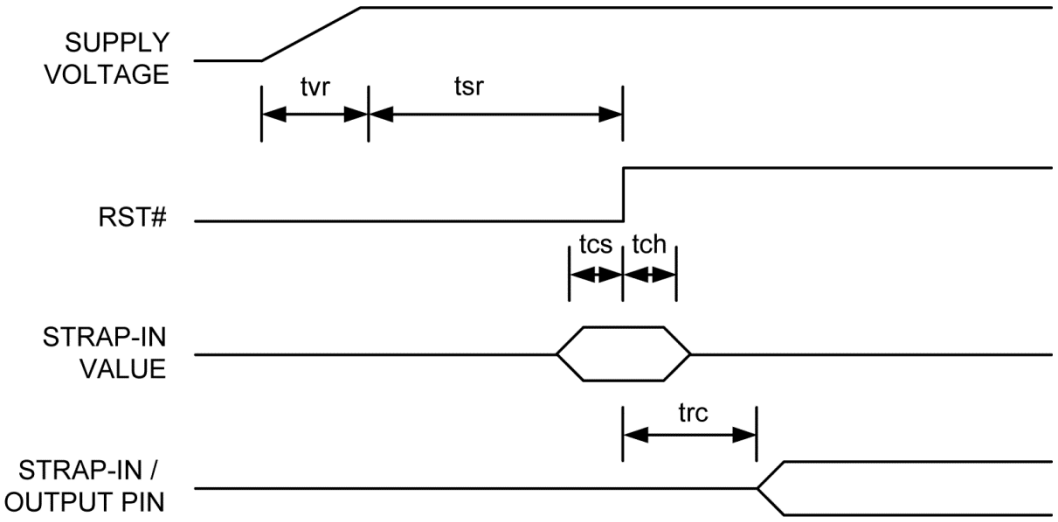


Figure 19. Power-up/Reset Timing

Table 12. Power-up/Reset Timing Parameters

Parameter	Description	Min.	Max.	Units
t_{vr}	Supply voltage (VDDIO, AVDD, VDDL, AVDDL) rise time	300		µs
t_{sr}	Stable supply voltage (VDDIO, AVDD, VDDL, AVDDL) to reset high	10		ms
t_{cs}	Configuration setup time	5		ns
t_{ch}	Configuration hold time	5		ns
t_{rc}	Reset to strap-in pin output	6		ns

The supply voltage (VDDIO, AVDD, VDDL, AVDDL) power-up waveforms should be monotonic, and the 300µs minimum rise time is from 10% to 90%.

For warm reset, the reset (RESET#) pin should be asserted low for a minimum of 500µs. The strap-in pin values are read and updated at the de-assertion of reset.

After the de-assertion of reset, it is recommended to wait a minimum of 100µs before starting programming on the MIIM (MDC/MDIO) Interface.

Reset Circuit

Figure 20 shows a reset circuit recommended for powering up the KSZ8061RNB/RND if reset is triggered by the power supply.

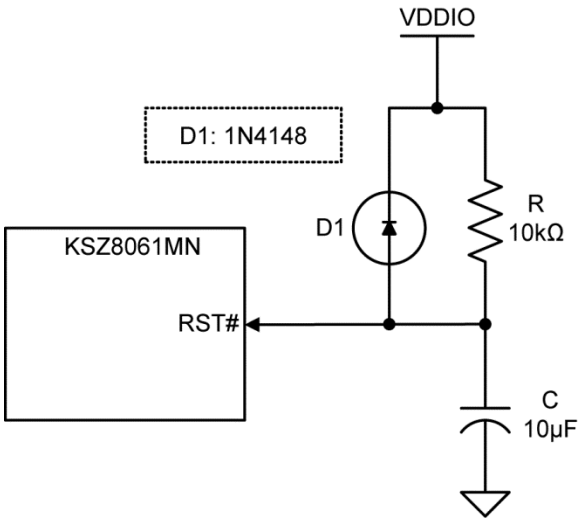


Figure 20. Recommended Reset Circuit

Figure 21 represents a reset circuit recommended for applications where reset is driven by another device (e.g., CPU or FPGA). At power-on-reset, R, C and D1 provide the necessary ramp rise time to reset the KSZ8061RNB/RND. The RST_OUT_n from CPU/FPGA provides the warm reset after power up.

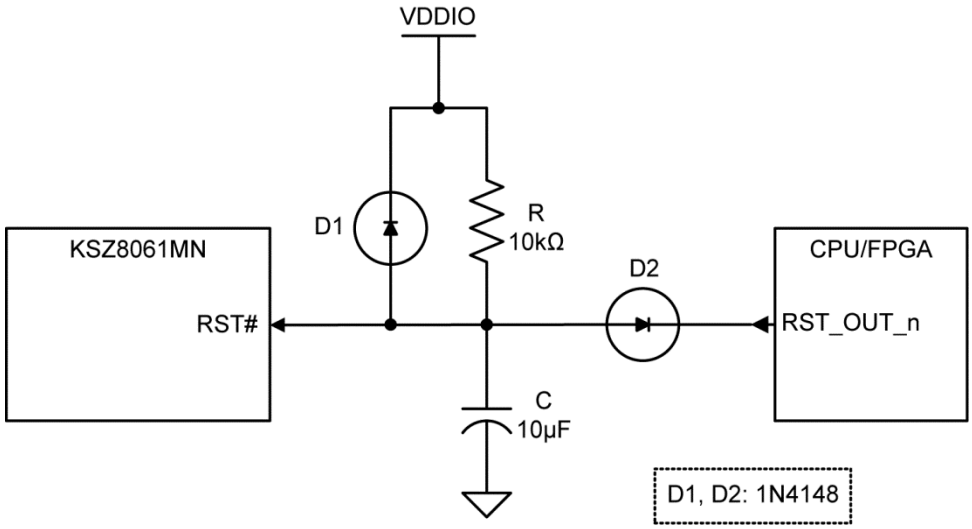


Figure 21. Recommended Reset Circuit for interfacing with CPU/FPGA Reset Output

Reference Clock Connection and Selection – KSZ8061RNB

A crystal or external clock source, such as an oscillator, is used to provide the reference clock for the KSZ8061RNB. For the KSZ8061RNB in all operating modes, the reference clock is 25MHz. The reference clock connections to XI (pin 1) and XO (pin 2), and the reference clock selection criteria are provided in Figure 22 and Table 13.

The KSZ8061RNB outputs a 50MHz RMII reference clock on the REF_CLK pin.

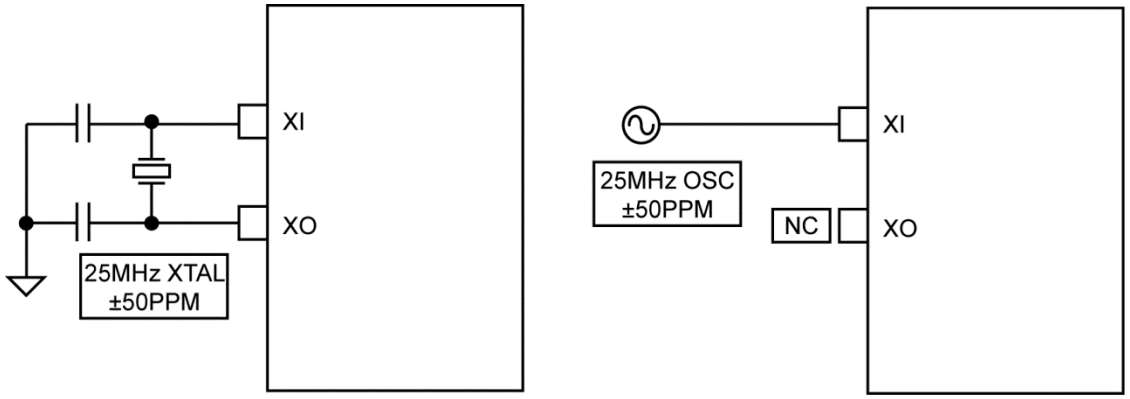


Figure 22. KSZ8061RNB 25MHz Crystal/Oscillator Reference Clock Connection

Table 13 25MHz Crystal/Reference Clock Selection Criteria

Characteristics	Value	Units
Frequency	25	MHz
Frequency tolerance (max)	±50	ppm

Table 14. Recommended Crystals

Manufacturer	Part Number
NDK[10]	NX2016SA
Murata[11]	XRCGB25M000F3A00R0

Notes:

10. NDK: www.ndk.com.
11. Murata: www.murata.com.

Reference Clock Connection – KSZ8061RND

The KSZ8061RND uses a 50MHz RMII reference clock input for all of its timing. The 50MHz clock connects to the XI pin as shown in Figure 23. Note that XI is powered from the AVDDH power rail, not VDDIO. The XO and REF_CLK pins are unconnected.

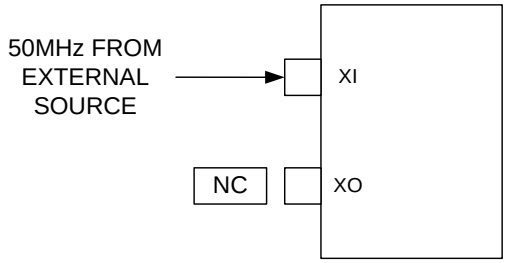
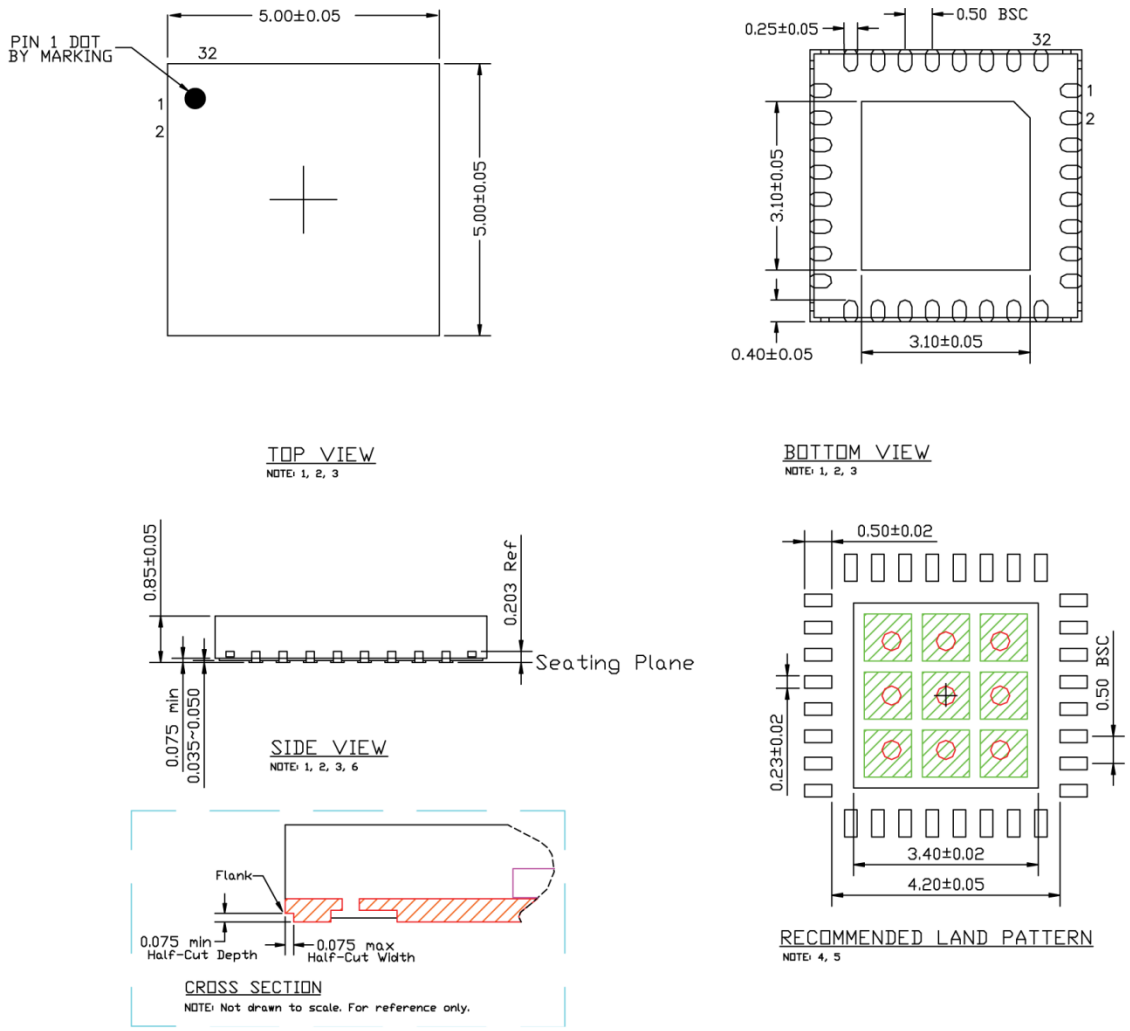


Figure 23. KSZ8061RND 50MHz Clock Connection

Package Information and Recommended Land Pattern[12]



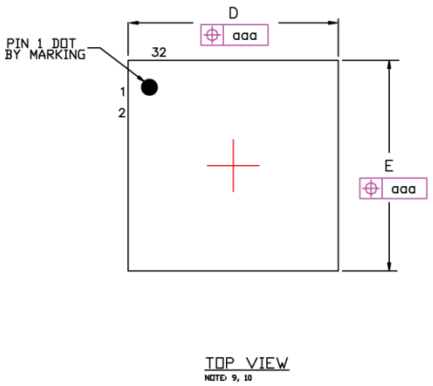
NOTE:
1. MAX PACKAGE WARPAGE IS 0.05mm.
2. MAX ALLOWABLE BURR IS 0.076mm IN ALL DIRECTIONS.
3. PIN #1 IS ON TOP WILL BE LASER MARKED.
4. RED CIRCLES IN LAND PATTERN INDICATES THERMAL VIA. SIZE SHOULD BE 0.30-0.35mm IN DIAMETER, 1.00mm PITCH & SHOULD BE CONNECTED TO GND FOR MAX THERMAL PERFORMANCE.
5. GREEN RECTANGLES (SHADED AREA) REPRESENT SOLDER STENCIL OPENING ON EXPOSED PAD AREA. RECOMMENDED SIZE IS 0.87x0.87mm, 1.07mm PITCH.
6. "W" IN WQFN IS WETTABLE FLANK PACKAGE.

32-Pin 5mm × 5mm WQFN

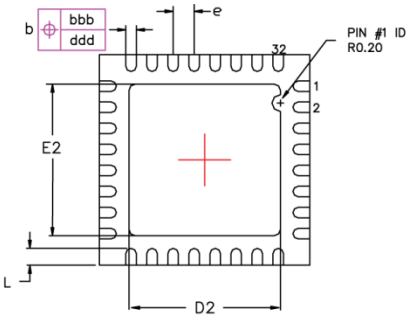
Note:

12. Package information is correct as of the publication date. For updates and most current information, go to www.micrel.com.

Package Information and Recommended Land Pattern[12] (Continued)



TOP VIEW
NOTE: 9, 10

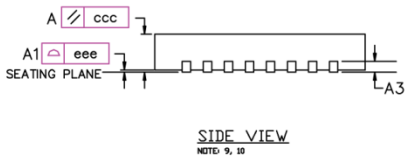


BOTTOM VIEW
NOTE: 9, 10

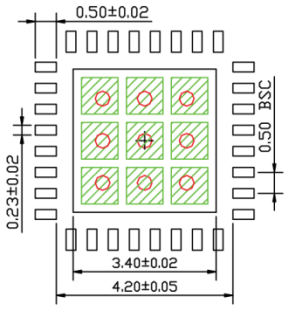
	DIMENSION IN mm		
SYMBOL	MIN	NOM	MAX
A	0.80	0.85	1.00
A1	0.00	0.02	0.05
A3		0.20 (REF)	
D		5.00 BSC	
D2	3.00	3.10	3.20
E		5.00 BSC	
E2	3.00	3.10	3.20
L	0.35	0.40	0.45

	b (mm)			e (mm)		
N	MIN	NOM	MAX	MIN	NOM	MAX
32	0.18	0.25	0.30		0.50 BSC	

TOLERANCE OF FORM AND POSITION	
aaa	0.15
bbb	0.10
ccc	0.10
ddd	0.05
eee	0.08



SIDE VIEW
NOTE: 9, 10



RECOMMENDED LAND PATTERN
NOTE: 11, 12

NOTE:
1. REFER TO JEDEC STANDARD MO-220 VHHD-2.
2. DIMENSION "b" APPLIES TO METALIZED TERMINAL AND IS MEASURED BETWEEN 0.15mm TO 0.30mm FROM THE TERMINAL TIP.
3. "aaa" THE BILATERAL PROFILE TOLERANCE THAT CONTROLS THE POSITION OF THE PLASTIC BODY SIDES. THE CENTERS OF THE PROFILE ZONES ARE DEFINED BY THE BASIC DIMENSIONS "D" AND "E".
4. "bbb" THE TOLERANCE THAT CONTROLS THE POSITION OF THE ENTIRE TERMINAL PATTERN WITH RESPECT TO DATUM'S A AND B. THE CENTER OF THE TOLERANCE ZONE OF EACH TERMINAL IS DEFINED BY THE BASIC DIMENSION "e" AS RELATED TO DATUM A AND B.
5. "ccc" THE TOLERANCE LOCATED PARALLEL TO THE SEATING PLANE IN WHICH THE TOP SURFACE OF THE PACKAGE MUST BE LOCATED.
6. "ddd" THE TOLERANCE THAT CONTROLS THE POSITION OF THE TERMINALS TO EACH OTHER. THE CENTERS OF THE PROFILE ZONES ARE DEFINED BY BASIC DIMENSION "e".
7. "eee" THE UNILATERAL TOLERANCE LOCATED ABOVE THE SEATING PLANE WHEREIN THE BOTTOM SURFACE OF THE TERMINALS MUST BE LOCATED.
8. THE TOLERANCE THAT CONTROLS THE POSITION OF THE EXPOSED METAL HEAT FEATURE. THE CENTER OF THE TOLERANCE ZONE WILL BE THE DATUM'S DEFINED BY THE CENTERLINES OF THE PACKAGE BODY.
9. MAX PACKAGE WARPAGE IS 0.05 MM.
10. PIN #1 IS ON TOP WILL BE LASER MARKED.
11. RED CIRCLE IN LAND PATTERN INDICATE THERMAL VIA. SIZE SHOULD BE 0.30-0.35M IN DIAMETER AND SHOULD BE CONNECTED TO GND FOR MAX THERMAL PERFORMANCE.
12. GREEN RECTANGLES (SHADED AREA) indicate SOLDER STENCIL OPENING ON EXPOSED PAD AREA. SIZE SHOULD BE 0.87x0.87 MM IN SIZE, 1.07 MM PITCH.
13. THIS DOCUMENT IS FOR AUTOMOTIVE PRODUCT USE ONLY.

32-Pin 5mm × 5mm QFN

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