VSC8531 Datasheet
Single Port Gigabit Ethernet Copper PHY with RGMII/RMII Interfaces

Microsemi
Power Matters.™

Microsemi Corporate Headquarters
One Enterprise, Aliso Viejo,
CA 92656 USA
Within the USA: +1 (800) 713-4113
Outside the USA: +1 (949) 380-6100
Fax: +1 (949) 215-4996
Email: sales.support@microsemi.com
www.microsemi.com

About Microsemi

Microsemi Corporation (Nasdaq: MSCC) offers a comprehensive portfolio of semiconductor and system solutions for aerospace & defense, communications, data center and industrial markets. Products include high-performance and radiation-hardened analog mixed-signal integrated circuits, FPGAs, SoCs and ASICs; power management products; timing and synchronization devices and precise time solutions, setting the world's standard for time; voice processing devices; RF solutions; discrete components; enterprise storage and communication solutions, security technologies and scalable anti-tamper products; Ethernet solutions; Power-over-Ethernet ICs and midspans; as well as custom design capabilities and services. Microsemi is headquartered in Aliso Viejo, California, and has approximately 4,800 employees globally. Learn more at www.microsemi.com.

VMDS-10482. 4.0 9/16

Contents

1 Revision History 1
1.1 Revision 4.0 1
1.2 Revision 2.0 1

2 Overview 2
2.1 Key Features 2
2.1.1 Superior PHY and Interface Technology 2
2.1.2 Fast Link Up/Link Drop Modes 2
2.1.3 Best-in-Class Power Consumption 2
2.1.4 Key Specifications 3
2.2 Block Diagram 3

3 Functional Descriptions 4
3.1 Operating Modes 4
3.2 MAC Interface 4
3.2.1 RGMII MAC Interface Mode 4
3.2.2 RMII Mode 5
3.2.3 MAC Interface Edge Rate Control 7
3.3 Hardware Mode Strapping and PHY Addressing 8
3.3.1 CLKOUT Signal Configuration 8
3.3.2 Managed Mode 8
3.3.3 Unmanaged Mode 9
3.4 Cat5 Twisted Pair Media Interface 9
3.4.1 Voltage Mode Line Driver 9
3.4.2 Cat5 Auto-Negotiation and Parallel Detection 10
3.4.3 Automatic Crossover and Polarity Detection 10
3.4.4 Manual MDI/MDIX Setting 11
3.4.5 Link Speed Downshift 11
3.4.6 Energy-Efficient Ethernet 11
3.4.7 Ring Resiliency 12
3.5 Reference Clock 12
3.6 Ethernet Inline-Powered Devices 13
3.7 IEEE 802.3af Power-over-Ethernet Support 15
3.8 ActiPHY Power Management 15
3.8.1 Low Power State 16
3.8.2 Link Partner Wake-Up State 16
3.8.3 Normal Operating State 16
3.9 Serial Management Interface 16
3.9.1 SMI Frames 16
3.9.2 SMI Interrupt 17
3.10 LED Interface 18
3.10.1 LED Modes 18
3.10.2 Basic Serial LED Mode 19
3.10.3 Extended LED Modes 20
3.10.4 LED Behavior 20
3.11 Wake-On-LAN and SecureOn 21
3.12 Fast Link Failure Indication 21
3.13 Fast Link Failure 2™ (FLF2™) Indication 22
3.14 Testing Features 22
3.14.1 Ethernet Packet Generator 22

3.14.2 Far-End Loopback . . . 22
3.14.3 Near-End Loopback . . . 23
3.14.4 Connector Loopback . . . 23
3.15 Configuration . . . 23

4 Registers . . . 25
4.1 Register and Bit Conventions . . . 25
4.2 IEEE 802.3 and Main Registers . . . 26
4.2.1 Mode Control . . . 27
4.2.2 Mode Status . . . 28
4.2.3 Device Identification . . . 28
4.2.4 Auto-Negotiation Advertisement . . . 29
4.2.5 Link Partner Auto-Negotiation Capability . . . 29
4.2.6 Auto-Negotiation Expansion . . . 30
4.2.7 Transmit Auto-Negotiation Next Page . . . 30
4.2.8 Auto-Negotiation Link Partner Next Page Receive . . . 30
4.2.9 1000BASE-T Control . . . 31
4.2.10 1000BASE-T Status . . . 31
4.2.11 MMD Access Control Register . . . 32
4.2.12 MMD Address or Data Register . . . 32
4.2.13 1000BASE-T Status Extension 1 . . . 32
4.2.14 100BASE-TX Status Extension . . . 32
4.2.15 1000BASE-T Status Extension 2 . . . 33
4.2.16 Bypass Control . . . 34
4.2.17 Error Counter 1 . . . 34
4.2.18 Error Counter 2 . . . 35
4.2.19 Error Counter 3 . . . 35
4.2.20 Extended Control and Status . . . 35
4.2.21 Extended PHY Control 1 . . . 36
4.2.22 Extended PHY Control 2 . . . 37
4.2.23 Interrupt Mask . . . 37
4.2.24 Interrupt Status . . . 38
4.2.25 Device Auxiliary Control and Status . . . 39
4.2.26 LED Mode Select . . . 39
4.2.27 LED Behavior . . . 40
4.2.28 Extended Page Access . . . 40
4.3 Extended Page 1 Registers . . . 41
4.3.1 Cu Media CRC Good Counter . . . 41
4.3.2 Extended Mode Control . . . 42
4.3.3 ActiPHY Control . . . 42
4.3.4 PoE and Miscellaneous Functionality . . . 43
4.3.5 VeriPHY Control 1 . . . 44
4.3.6 VeriPHY Control 2 . . . 44
4.3.7 VeriPHY Control 3 . . . 44
4.3.8 Ethernet Packet Generator (EPG) Control 1 . . . 45
4.3.9 Ethernet Packet Generator Control 2 . . . 46
4.4 Extended Page 2 Registers . . . 46
4.4.1 Cu PMD Transmit Control . . . 47
4.4.2 EEE Control . . . 48
4.4.3 RGMII Control . . . 49
4.4.4 Wake-on-LAN MAC Address [15:0] . . . 50
4.4.5 Wake-on-LAN MAC Address [31:16] . . . 51
4.4.6 Wake-on-LAN MAC Address [47:32] . . . 51
4.4.7 Secure-On Password [15:0] . . . 51
4.4.8 Secure-On Password [31:16] . . . 51
4.4.9 Secure-On Password [47:32] . . . 51
4.4.10 Wake-on-LAN and MAC Interface Control . . . 52
4.4.11 Extended Interrupt Mask . . . 53

4.4.12 Extended Interrupt Status . . . 53
4.4.13 Ring Resiliency Control . . . 53
4.5 General Purpose Registers . . . 54
4.5.1 Reserved General Purpose Address Space . . . 54
4.5.2 CLKOUT Control . . . 54
4.5.3 GPIO Control 2 . . . 54
4.5.4 Enhanced LED Control . . . 55
4.6 Clause 45 Registers to Support Energy-Efficient Ethernet and 802.3bf . . . 55
4.6.1 PMA/PMD Status 1 . . . 56
4.6.2 PCS Status 1 . . . 56
4.6.3 EEE Capability . . . 56
4.6.4 EEE Wake Error Counter . . . 56
4.6.5 EEE Advertisement . . . 57
4.6.6 EEE Link Partner Advertisement . . . 57

5 Electrical Specifications . . . 59
5.1 DC Characteristics . . . 59
5.1.1 VDDMAC, VDDIO, and VDDMDIO (2.5 V) . . . 59
5.1.2 VDDMAC, VDDIO, and VDDMDIO (3.3 V) . . . 59
5.1.3 VDDMAC and VDDMDIO (1.5 V) . . . 60
5.1.4 VDDMAC and VDDMDIO (1.8 V) . . . 60
5.1.5 VDDMDIO (1.2 V) . . . 60
5.1.6 XTAL1 . . . 61
5.1.7 LED . . . 61
5.1.8 Internal Pull-Up or Pull-Down Resistors . . . 61
5.1.9 Current Consumption . . . 61
5.2 AC Characteristics . . . 62
5.2.1 Reference Clock . . . 62
5.2.2 CLKOUT . . . 63
5.2.3 RMII_CLKOUT . . . 64
5.2.4 Basic Serial LEDs . . . 64
5.2.5 Uncompensated RGMII . . . 65
5.2.6 Compensated RGMII . . . 66
5.2.7 Serial Management Interface . . . 67
5.2.8 Reset Timing . . . 68
5.2.9 PHY Latency Specifications . . . 68
5.3 Operating Conditions . . . 69
5.4 Stress Ratings . . . 69

6 Pin Descriptions . . . 71
6.1 Pin Identifications . . . 71
6.2 Pin Diagram . . . 71
6.3 Pins by Function . . . 72

7 Package Information . . . 76
7.1 Package Drawing . . . 76
7.2 Thermal Specifications . . . 77
7.3 Moisture Sensitivity . . . 78

8 Design Considerations . . . 79
8.1 Transmitter test mode selection does not work as intended . . . 79
8.2 CLKOUT duty cycle in 50 MHz mode exceeds datasheet specification limits . . . 79
8.3 Excessive jitter on CLKOUT signal when PHY link is established . . . 79
8.4 CLKOUT frequency is fixed to 25 MHz and cannot be changed . . . 79
8.5 MDINT may not trigger properly . . . 79

8.6 100/1000 receive error counter counts good packets 80
8.7 LED drive pins cannot tri-state 80
8.8 LED pulse stretch enable turns off LED pins 80
8.9 FLF/FLF2 indication delay when using interrupts 80
8.10 Extended interrupt mask bit cannot be set 80
9 Ordering Information 81

Figures

Figure 1 Application Diagram . . . 2
Figure 2 Block Diagram . . . 3
Figure 3 RGMII MAC Interface . . . 5
Figure 4 RMII MAC Interface . . . 5
Figure 5 Mode 1 . . . 6
Figure 6 Mode 2 . . . 7
Figure 7 Cat5 Media Interface . . . 10
Figure 8 Low Power Idle Operation . . . 11
Figure 9 XTAL Reference Clock . . . 12
Figure 10 External 3.3 V Reference Clock . . . 13
Figure 11 Inline-Powered Ethernet Switch Diagram . . . 14
Figure 12 ActiPHY State Diagram . . . 15
Figure 13 SMI Read Frame . . . 17
Figure 14 SMI Write Frame . . . 17
Figure 15 MDINT Configured as an Open-Drain (Active-Low) Pin . . . 18
Figure 16 Wake-on-LAN Functionality . . . 21
Figure 17 Far-End Loopback Diagram . . . 23
Figure 18 Near-End Loopback Diagram . . . 23
Figure 19 Connector Loopback Diagram . . . 23
Figure 20 Register Space Diagram . . . 25
Figure 21 Test Circuit for Clock Output Signal . . . 63
Figure 22 Basic Serial LED Timing . . . 65
Figure 23 Uncompensated RGMII Timing . . . 66
Figure 24 Compensated Input RGMII Timing . . . 67
Figure 25 Compensated Output RGMII Timing . . . 67
Figure 26 Serial Management Interface Timing . . . 68
Figure 27 Pin Diagram . . . 72
Figure 28 Package Drawing . . . 76

Tables

Table 1 Operating Modes . . . 4
Table 2 Recommended Values for R_S (± 5%) . . . 4
Table 3 RMII Pin Allocation . . . 5
Table 4 Recommended Edge Rate Settings . . . 7
Table 5 MAC Interface Edge Rate Control . . . 7
Table 6 Hardware Mode Strapping and PHY Addressing . . . 8
Table 7 Managed Mode . . . 8
Table 8 Signals A and B . . . 9
Table 9 Signals C and D . . . 9
Table 10 Supported MDI Pair Combinations . . . 11
Table 11 REFCLK Frequency Selection . . . 12
Table 12 LED Drive State . . . 18
Table 13 LED Mode and Function Summary . . . 18
Table 14 LED Serial Bitstream Order . . . 19
Table 15 Extended LED Mode and Function Summary . . . 20
Table 16 IEEE 802.3 Registers . . . 26
Table 17 Main Registers . . . 26
Table 18 Mode Control, Address 0 (0x00) . . . 27
Table 19 Mode Status, Address 1 (0x01) . . . 28
Table 20 Identifier 1, Address 2 (0x02) . . . 28
Table 21 Identifier 2, Address 3 (0x03) . . . 28
Table 22 Device Auto-Negotiation Advertisement, Address 4 (0x04) . . . 29
Table 23 Auto-Negotiation Link Partner Ability, Address 5 (0x05) . . . 29
Table 24 Auto-Negotiation Expansion, Address 6 (0x06) . . . 30
Table 25 Auto-Negotiation Next Page Transmit, Address 7 (0x07) . . . 30
Table 26 Auto-Negotiation LP Next Page Receive, Address 8 (0x08) . . . 30
Table 27 1000BASE-T Control, Address 9 (0x09) . . . 31
Table 28 1000BASE-T Status, Address 10 (0x0A) . . . 31
Table 29 MMD EEE Access, Address 13 (0x0D) . . . 32
Table 30 MMD Address or Data Register, Address 14 (0x0E) . . . 32
Table 31 1000BASE-T Status Extension 1, Address 15 (0x0F) . . . 32
Table 32 100BASE-TX Status Extension, Address 16 (0x10) . . . 32
Table 33 1000BASE-T Status Extension 2, Address 17 (0x11) . . . 33
Table 34 Bypass Control, Address 18 (0x12) . . . 34
Table 35 Extended Control and Status, Address 19 (0x13) . . . 34
Table 36 Extended Control and Status, Address 20 (0x14) . . . 35
Table 37 Extended Control and Status, Address 21 (0x15) . . . 35
Table 38 Extended Control and Status, Address 22 (0x16) . . . 35
Table 39 Extended PHY Control 1, Address 23 (0x17) . . . 36
Table 40 Extended PHY Control 2, Address 24 (0x18) . . . 37
Table 41 Interrupt Mask, Address 25 (0x19) . . . 37
Table 42 Interrupt Status, Address 26 (0x1A) . . . 38
Table 43 Auxiliary Control and Status, Address 28 (0x1C) . . . 39
Table 44 LED Mode Select, Address 29 (0x1D) . . . 40
Table 45 LED Behavior, Address 30 (0x1E) . . . 40
Table 46 Extended/GPIO Register Page Access, Address 31 (0x1F) . . . 41
Table 47 Extended Registers Page 1 Space . . . 41
Table 48 Cu Media CRC Good Counter, Address 18E1 (0x12) . . . 41
Table 49 Extended Mode Control, Address 19E1 (0x13) . . . 42
Table 50 Extended PHY Control 3, Address 20E1 (0x14) . . . 42
Table 51 Extended PHY Control 4, Address 23E1 (0x17) . . . 43
Table 52 VeriPHY Control Register 1, Address 24E1 (0x18) . . . 44
Table 53 VeriPHY Control Register 2, Address 25E1 (0x19) . . . 44
Table 54 VeriPHY Control Register 3, Address 26E1 (0x1A) . . . 44

Table 55 VeriPHY Control Register 3 Fault Codes . . . 45
Table 56 EPG Control Register 1, Address 29E1 (0x1D) . . . 45
Table 57 EPG Control Register 2, Address 30E1 (0x1E) . . . 46
Table 58 Extended Registers Page 2 Space . . . 46
Table 59 Cu PMD Transmit Control, Address 16E2 (0x10) . . . 47
Table 60 EEE Control, Address 17E2 (0x11) . . . 48
Table 61 RGMII Control, Address 20E2 (0x14) . . . 49
Table 62 Wake-on-LAN MAC Address, 21E2 (0x15) . . . 50
Table 63 Wake-on-LAN MAC Address, 22E2 (0x16) . . . 51
Table 64 Wake-on-LAN MAC Address, 23E2 (0x17) . . . 51
Table 65 Secure-On Password, 24E2 (0x18) . . . 51
Table 66 Secure-On Password, 25E2 (0x19) . . . 51
Table 67 Secure-On Password, 26E2 (0x1A) . . . 51
Table 68 WoL and MAC Interface Control, Address 27E2 (0x1B) . . . 52
Table 69 Extended Interrupt Mask, Address 28E2 (0x1C) . . . 53
Table 70 Extended Interrupt Status, Address 29E2 (0x1D) . . . 53
Table 71 Ring Resiliency, Address 30E2 (0x1E) . . . 53
Table 72 CLKOUT Control, Address 13G (0x0D) . . . 54
Table 73 GPIO Control 2, Address 14G (0x0E) . . . 54
Table 74 Enhanced LED Control, Address 25G (0x19) . . . 55
Table 75 Clause 45 Registers Page Space . . . 55
Table 76 PMA/PMD Status 1 . . . 56
Table 77 PCS Status 1, Address 3.1 . . . 56
Table 78 EEE Capability, Address 3.20 . . . 56
Table 79 EEE Wake Error Counter, Address 3.22 . . . 57
Table 80 EEE Advertisement, Address 7.60 . . . 57
Table 81 EEE Advertisement, Address 7.61 . . . 57
Table 82 802.3bf Registers . . . 57
Table 83 VDDMAC, VDDIO, and VDDMDIO (2.5 V) DC Characteristics . . . 59
Table 84 VDDMAC, VDDIO, and VDDMDIO (3.3 V) DC Characteristics . . . 59
Table 85 VDDMAC and VDDMDIO DC Characteristics (1.5 V) . . . 60
Table 86 VDDMAC and VDDMDIO DC Characteristics (1.8 V) . . . 60
Table 87 VDDMDIO DC Characteristics . . . 60
Table 88 XTAL1 DC Characteristics . . . 61
Table 89 LED DC Characteristics . . . 61
Table 90 Internal Pull-Up or Pull-Down Resistors (RGMII/RMII Interface) . . . 61
Table 91 Internal Pull-Up or Pull-Down Resistors (Other I/Os) . . . 61
Table 92 Current Consumption . . . 62
Table 93 Current Consumption (VDDMAC) . . . 62
Table 94 RefClk . . . 62
Table 95 XTAL RefClk . . . 63
Table 96 CLKOUT AC Characteristics . . . 64
Table 97 RMII_CLKOUT AC Characteristics . . . 64
Table 98 Basic Serial LEDs AC Characteristics . . . 64
Table 99 Uncompensated RGMII AC Characteristics . . . 65
Table 100 PHY Input (GTX_CLK Delay When Register 20E2.[2:0]=011’b) . . . 66
Table 101 PHY Output (RX_CLK Delay When Register 20E2.[6:4]=100’b) . . . 67
Table 102 Serial Management Interface AC Characteristics . . . 67
Table 103 Reset Timing AC Characteristics . . . 68
Table 104 PHY Latency in RGMII Mode . . . 68
Table 105 PHY Latency in RMII Mode . . . 69
Table 106 Recommended Operating Conditions . . . 69
Table 107 Stress Ratings . . . 69
Table 108 Pin Type Symbol Definitions . . . 71
Table 109 Thermal Resistances . . . 78
Table 110 Ordering Information . . . 81

1 Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

1.1 Revision 4.0

The following is a summary of the changes in revision 4.0 of this document.

- Recommended Values for R_S were updated. For more information, see Table 2, page 4.
- RMII MAC Interface block diagram was added. For more information, see Figure 4, page 5.
- RMII Clocking Mode illustrations were corrected. For more information, see Figure 5, page 6 and Figure 6, page 7.
- MAC Interface Edge Rate Control values were added. For more information, see Table 5, page 7.
- Fast Link Failure and Fast Link Failure 2™ information was updated. For more information, see Fast Link Failure Indication, page 21 and Fast Link Failure 2™ (FLF2™) Indication, page 22.
- Extended PHY Control 1, Extended PHY Control 2, ActiPHY Control, Cu PMD Transmit Control, and Wake-on-LAN and MAC Interface Control registers were updated. For more information, see Table 39, page 36, Table 40, page 37, Table 50, page 42, Table 59, page 47, and Table 68, page 52.
- XTAL1 DC specifications were added. For more information, see Table 88, page 61.
- Current Consumption tables were updated. For more information, see Table 92, page 62 and Table 93, page 62.
- Uncompensated and Compensated RGMII values and timing diagrams were updated. For more information, see Uncompensated RGMII, page 65 and Compensated RGMII, page 66.
- PHY latency values were added. For more information, see PHY Latency Specifications, page 68.
- Pins were updated to include I/O supply domain information and remove unsupported voltage levels from VDDIO. For more information, see Pins by Function, page 72.
- Design considerations were added to the datasheet. For more information, see Design Considerations, page 79.
- ESD (electrostatic discharge) was added. For human body model (HBM), it is ±2000 V. For charged device model (CDM), it is ±1000 V.
- Moisture sensitivity level (MSL) is level 3.

1.2 Revision 2.0

- Revision 2.0 was the first publication of this document.

2 Overview

The VSC8531 device is designed for space-constrained 10/100/1000BASE-T applications. It features integrated, line-side termination to conserve board space, lower EMI, and improve system performance. Additionally, integrated RGMII timing compensation eliminates the need for on-board delay lines.

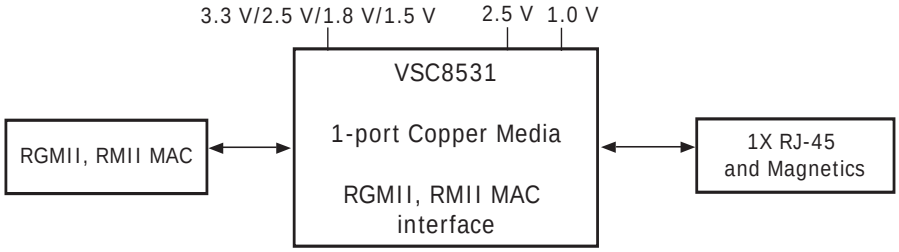
Microsemi's EcoEthernet™ v2.0 technology supports IEEE 802.3az Energy-Efficient Ethernet (EEE) and power-saving features to reduce power based on link state and cable reach. VSC8531 optimizes power consumption in all link operating speeds and features a Wake-on-LAN (WoL) power management mechanism for bringing the PHY out of a low-power state using designated magic packets.

Fast link failure (FLF) indication for high availability networks identifies the onset of a link failure in less than 1 ms typical to go beyond the IEEE 802.3 standard requirement of 750 ms ±10 ms (link master). Potential link failure events can be more flexibly monitored using an enhanced FLF2 state machine, which goes beyond FLF indication by enabling signaling of the link potentially going down within 10 µS.

The device includes recovered clock output for Synchronous Ethernet applications. Programmable clock squelch control is included to inhibit undesirable clocks from propagating and to help prevent timing loops. Ring Resiliency allows a PHY port to switch between master and slave timing references with no link drop in 1000BASE-T mode.

The following illustration shows a high-level, general view of a typical VSC8531 application.

Figure 1 • **Application Diagram**



2.1 Key Features

This section lists the main features and benefits of the VSC8531 device.

2.1.1 Superior PHY and Interface Technology

- Integrated 10/100/1000BASE-T Ethernet copper transceiver (IEEE 802.3ab compliant) with the industry's only non-TDR-based VeriPHY™ cable diagnostics algorithm
- Patented line driver with low EMI voltage mode architecture and integrated line-side termination resistors
- Wake-on-LAN using magic packets
- HP Auto-MDIX and manual MDI/MDIX support
- RGMII/RMII MAC interface
- Jumbo frame support up to 16 kilobytes with programmable synchronization FIFOs

2.1.2 Fast Link Up/Link Drop Modes

- Fast link failure indication (<1 ms typical, programmable down to <10 µS)
- Supports 1000Base-T forced mode for both master and slave end point configurations with constant link self-monitoring and link auto-reset should the link come down

2.1.3 Best-in-Class Power Consumption

- EcoEthernet™ v2.0 green energy efficiency with ActiPHY™, PerfectReach™, and IEEE 802.3az Energy-Efficient Ethernet
- Fully optimized power consumption for all link speeds
- Clause 45 registers to support Energy-Efficient Ethernet

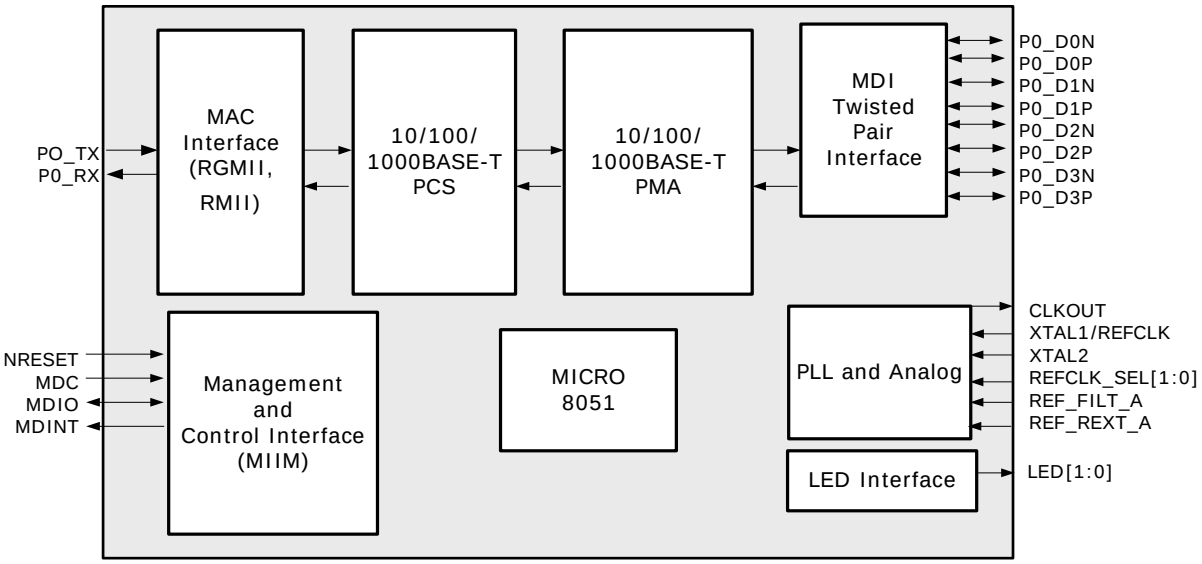
2.1.4 Key Specifications

- Compliant with IEEE 802.3 (10BASE-T, 100BASE-TX, and 1000BASE-T) specifications
- Supports RGMII, RMII
- Supports 1.5 V, 1.8 V, 2.5 V, and 3.3 V CMOS for RGMII versions 1.3 and 2.0 (without HSTL support), as well as RMII version 1.2
- Supports a variety of clock sources: 25 MHz Xtal, 25 MHz OSC, 50 MHz OSC, 125 MHz OSC
- Supports programmable output frequencies of 25 MHz, 50 MHz, or 125 MHz, regardless of chosen Xtal or OSC frequencies
- Supports a wide array of stand-alone hardware configuration options
- Supports all 5 bits of MDIO/MDC addressing possible for managed mode designs using pull-up/pull-down resistors
- Devices support operating temperatures of –40 °C ambient to 125 °C junction or 0 °C ambient to 125 °C junction
- Optionally reports if a link partner is requesting inline Power-over-Ethernet (PoE and PoE+)
- Available in 6 mm x 6 mm, 48-pin QFN package

2.2 Block Diagram

The following illustration shows the primary functional blocks of the VSC8531 device.

Figure 2 • **Block Diagram**



3 Functional Descriptions

This section describes the functional aspects of the VSC8531 device, including available configurations, operational features, and testing functionality. It also defines the device setup parameters that configure the device for a particular application.

3.1 Operating Modes

The following table lists the operating modes of the VSC8531 device.

Table 1 • **Operating Modes**

Operating Mode	Supported Media
RGMII-Cat5	10/100/1000BASE-T
RMII-Cat5	10/100BASE-T

3.2 MAC Interface

The VSC8531 device supports RMII version 1.2 and RGMII versions 1.3 and 2.0, and MAC interfaces at 1.5 V, 1.8 V, 2.5 V, and 3.3 V operating voltages. In order to help reduce EMI, the VSC8531 device also includes edge rate programmability for the MAC interface signals through register 27E2.7:5.

The recommended values for R_S (as shown in Figure 3, page 5, Figure 5, page 6, and Figure 6, page 7) are listed in the following table.

Table 2 • **Recommended Values for R_S (± 5%)**

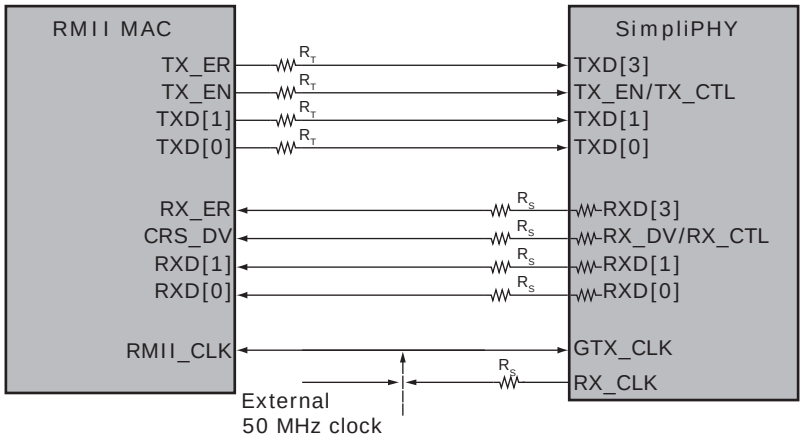
VDDMAC Value	R_S Value
1.5 V	27 Ω
1.8 V	33 Ω
2.5 V	39 Ω
3.3 V	39 Ω

Refer to the MAC datasheet for the value to use for R_T.

3.2.1 RGMII MAC Interface Mode

The VSC8531 device supports RGMII versions 1.3 and 2.0 (without HSTL modes). The RGMII interface supports all three speeds (10 Mbps,100 Mbps, and 1000 Mbps) and is used as an interface to a RGMII-compatible MAC. The device is compliant with the RGMII interface specification when VDDMAC is operating at 2.5 V. While the RGMII specification only specifies operation at 2.5 V, the device can also support the RGMII interface at 1.5 V, 1.8 V, and 3.3 V.

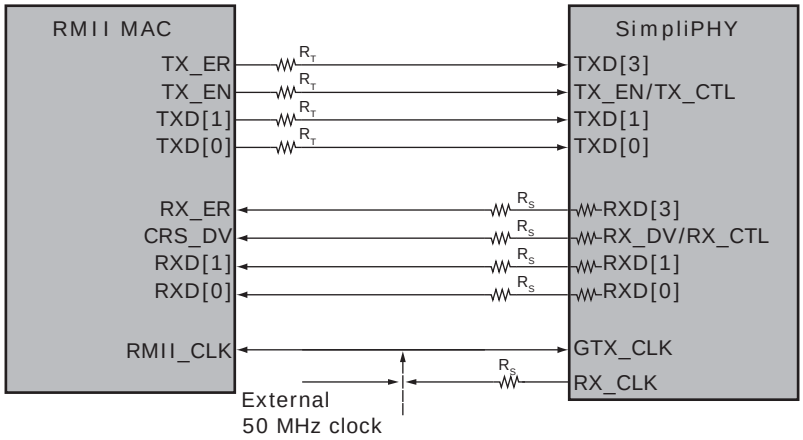
Figure 3 • **RGMII MAC Interface**



3.2.2 RMII Mode

The RMII interface supports 10 Mbps and 100 Mbps speeds, and is used as an interface to a RMII-compatible MAC. The device is compliant with the RMII interface specification when VDDMAC is operating at 3.3 V. While the RMII specification only specifies operation at 3.3 V, the device can also support the RMII interface at 1.5 V, 1.8 V, and 2.5 V.

Figure 4 • **RMII MAC Interface**



3.2.2.1 RMII Pin Allocation

The following table lists the chip pins used for RMII signaling in RMII mode.

Table 3 • **RMII Pin Allocation**

Chip Pin	RMII Signal
TX_CLK	RMII_CLKIN
RX_CLK	RMII_CLKOUT
TXD3	TX_ER (to support 802.3az)
TXD1	TXD1
TXD0	TXD0
TX_CTL	TX_EN
RXD1	RXD1
RXD0	RXD0

Table 3 • **RMII Pin Allocation *(continued)***

Chip Pin	RMII Signal
RXD3	RX_ER
RX_CTL	CRS_DV

Even though the RMII specification does not call for the use of TX_ER signal, it is required in order to support Energy-Efficient Ethernet (802.3az).

3.2.2.2 RMII Clocking Overview

When the device is in RMII mode, the clock inputs to the device need to support the various modes in which RMII devices can operate. There are two basic modes of operation in RMII mode:

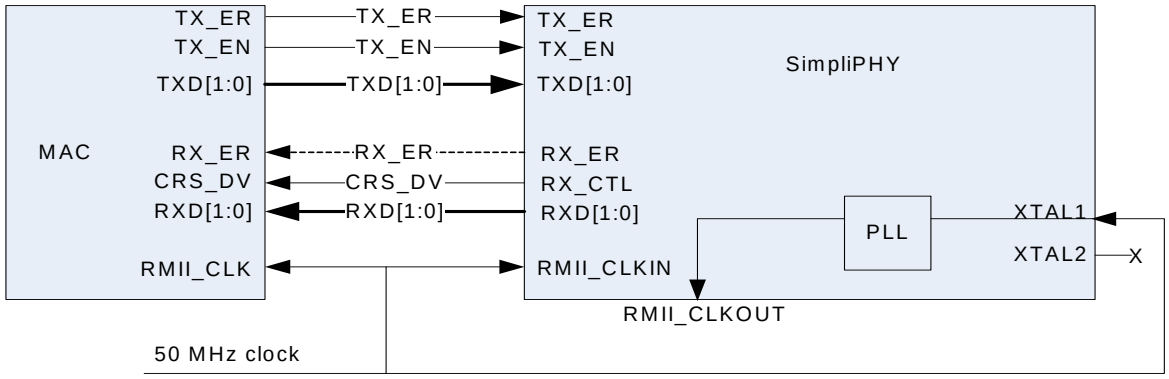
- Mode 1—system provides a 50 MHz clock that is used to clock the RMII interface and must be used as the chip reference clock.
- Mode 2—PHY operates from a 25 MHz or 125 MHz reference clock, and sources the 50 MHz clock used for the RMII interface.

These two modes of operation and the clocking schemes are described in the following sections.

3.2.2.2.1 Mode 1

In this mode of operation, an external source is used to provide a 50 MHz clock through the RMII_CLKIN and the XTAL1 pin. This 50 MHz clock is used as the main clock for the RMII interface, and must be used as the reference clock for the PHY connected to the XTAL1 pin. In this mode, the RMII_CLKOUT signal from the PHY is not used. The RMII_CLKOUT is enabled by default and that clock output should be disabled through register 27E2.4. The following figure illustrates RMII signal connections at the system level.

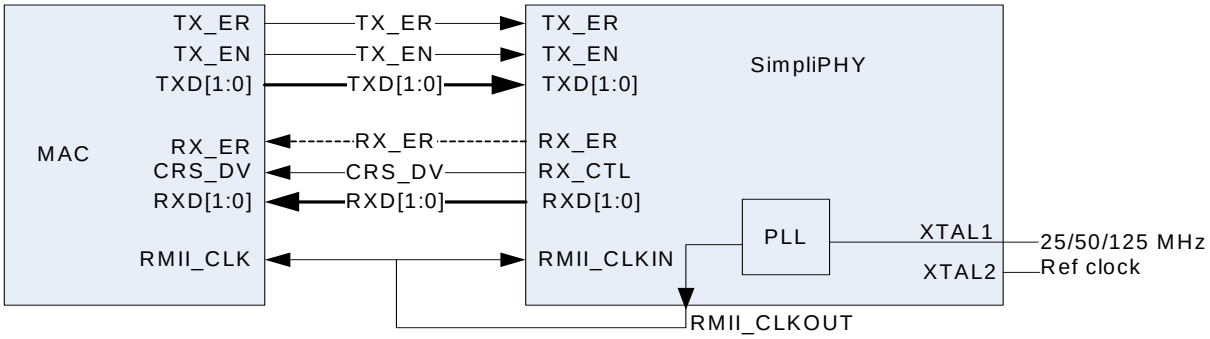
Figure 5 • **Mode 1**



3.2.2.2.2 Mode 2

In this mode of operation, the PHY operates from a 25 MHz crystal (XTAL1 and XTAL2) or 25 MHz/125 MHz single-ended external clock (XTAL1), and sources the 50 MHz clock required for the RMII interface. This 50 MHz clock is output from the PHY on the RMII_CLKOUT pin and then connected to the MAC and PHY RMII_CLKIN signals. In this mode, the PHY generates a 50 MHz clock for the system and that clock output is enabled. The following figure illustrates RMII signal connections at the system level.

Figure 6 • **Mode 2**



3.2.3 MAC Interface Edge Rate Control

The VSC8531 device includes programmable control of the rise/fall times for the MAC interface signals. The default setting will select the fastest rise/fall times. However, the fast edge rate will result in higher power consumption on the MAC interface and may result in higher EMI.

It is recommended that the user select the appropriate edge rate setting based on the VDDMAC supply voltage, as shown in the following table.

Table 4 • **Recommended Edge Rate Settings**

VDDMAC Voltage	Edge Rate Setting
3.3 V	100
2.5 V	100
1.8 V	111
1.5 V	111

In order to further reduce power consumption and EMI, the user may elect to choose a slower edge rate than recommended if the end application supports it.

The MAC interface signal rise/fall times can be changed by writing to register bits 27E2.7:5. The typical change in edge rate for each setting at various VDDMAC voltages is shown in the following table.

Table 5 • **MAC Interface Edge Rate Control**

	Edge Rate Change (VDDMAC)			
Register Setting	**3.3 V**	**2.5 V**	**1.8 V**	**1.5 V**
111 (fastest)	Default	Default	Default (recommended)	Default (recommended)
110	–2%	–3%	–5%	–6%
101	–4%	–6%	–9%	–14%
100	–7% (recommended)	–10% (recommended)	–16%	–21%
011	–10%	–14%	–23%	–29%
010	–17%	–23%	–35%	–42%
001	–29%	–37%	–52%	–58%
000 (slowest)	–53%	–63%	–76%	–77%

These values are based on measurements performed on typical silicon at nominal supply and room temperature settings.

3.3 Hardware Mode Strapping and PHY Addressing

The VSC8531 device provides hardware-configured modes of operation that are achieved by sampling output pins on the rising edge of reset and externally pulling the pin to a logic HIGH or LOW (based on the desired configuration). These output pins are required by the device as inputs while NRESET is asserted and the logic state of the pin is latched in the device upon de-assertion of NRESET. To ensure correct operation of the hardware strapping function, any other device connected to these pins must not actively drive a signal onto them.

The following table describes the pins used for this purpose and their respective modes.

Table 6 • **Hardware Mode Strapping and PHY Addressing**

Pin(s)	Operation Mode
CLKOUT	Enable/disable CLKOUT signal
RX_CLK	Managed or unmanaged mode
RXD0	Signal A
RXD1	Signal B
RXD2	Signal C
RXD3	Signal D
RX_CTL	Signal E

3.3.1 CLKOUT Signal Configuration

When the CLKOUT signal is pulled LOW and the state of that signal is latched to logic 0 on the rising edge of reset, the CLKOUT output is disabled and the device will drive a logic low level on that pin after reset de-assertion. When the CLKOUT signal is pulled HIGH externally and the state of that signal is latched to logic 1, the CLKOUT output is enabled. This behavior can also be controlled through register 13G.15.

The CLKOUT signal is frequency-locked to the reference clock signal input through XTAL1/XTAL2 pins. The frequency of CLKOUT can be programed to the following values through register 13G.14:13:

- 25 MHz
- 50 MHz
- 125 MHz

3.3.2 Managed Mode

When RX_CLK pin is pulled LOW and the state of that signal is latched to logic 0 on the rising edge of reset, the device operates in a managed mode. In managed mode, the remaining 5 signals (A–E) are used to set the PHY address, allowing up to 32 devices to reside on the shared MDIO bus. In this mode, the device can be configured using register access and no additional hardware configurability is provided. The following table lists the assigned PHY address values in managed mode.

Table 7 • **Managed Mode**

Signal	PHY Address Values
Signal A	PHY address bit 0
Signal B	PHY address bit 1
Signal C	PHY address bit 2
Signal D	PHY address bit 3
Signal E	PHY address bit 4

3.3.3 Unmanaged Mode

When RX_CLK is pulled HIGH externally and the state of that signal is latched to logic 1 on the rising edge of reset, the device operates in an unmanaged mode. In unmanaged mode, the PHY address of the device is fixed to 5'b00000. The signals A–E are used to set default chip configurations, as described in the following sections.

3.3.3.1 Signals A and B

Signals A and B are used to set the RGMII RX_CLK and TX_CLK delay settings (as defined in register 20E2), as per the following table.

Table 8 • **Signals A and B**

Signals A, B	RX_CLK and TX_CLK Delay Setting
0, 0	000 - 0.2 ns
0, 1	010 - 1.1 ns
1, 0	100 - 2.0 ns
1, 1	110 - 2.6 ns

3.3.3.2 Signals C and D

Signals C and D are used to select the link advertisement settings, as defined in the following table.

Table 9 • **Signals C and D**

Signals C, D	Link Advertisement
0, 0	Default mode of operation, 10/100/1000 FDX/HDX, autoneg ON
0, 1	10/100 FDX/HDX, autoneg ON (disable 1000BT advertisements)
1, 0	100BTX, HDX forced mode, autoneg OFF
1, 1	10BT, HDX forced mode, autoneg OFF

3.3.3.3 Signal E

Signal E is used to select between RMII and RGMII MAC interface modes. When the state of Signal E is latched to logic 0 on the rising edge of reset, the device operates in RGMII mode. When the state of Signal E is latched to logic 1 on the rising edge of reset, the device operates in RMII mode.

Note: RMII only supports 10/100 Mbps speeds. When RMII mode is selected, the link advertisement selection must also be changed to either 01, 10, or 11 settings, as defined in Table 9, page 9.

Note: Correct configuration of the device is an end user responsibility, and no attempt is made in the device to disallow incorrect configurations.

Additionally, in unmanaged mode, the following settings are changed from their default values:

- Enable link speed downshift (register 20E1.4 set to 1)
- Enable ActiPHY (register 28.6 set to 1)

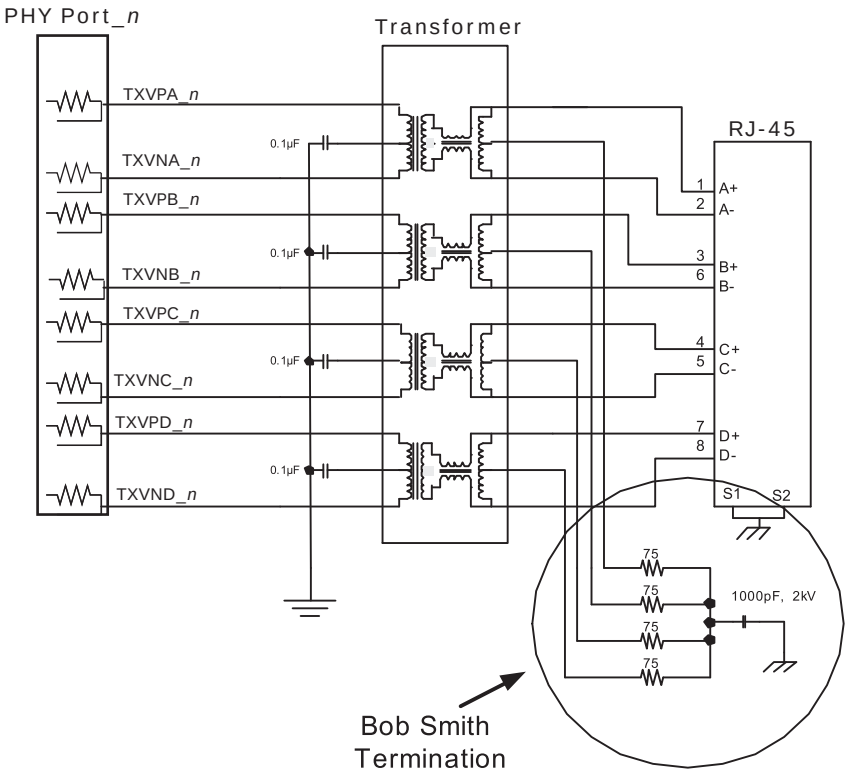
3.4 Cat5 Twisted Pair Media Interface

The twisted pair interface is compliant with IEEE 802.3-2008 and the IEEE 802.3az-2010 standard for Energy-Efficient Ethernet.

3.4.1 Voltage Mode Line Driver

The VSC8531 device uses a patented voltage mode line driver that allows it to fully integrate the series termination resistors that are required to connect the PHY's Cat5 interface to an external 1:1 transformer. The interface does not require the user to place an external voltage on the center tap of the magnetic. The following figure illustrates the connections.

Figure 7 • **Cat5 Media Interface**



3.4.2 Cat5 Auto-Negotiation and Parallel Detection

The VSC8531 device supports twisted pair auto-negotiation, as defined by IEEE 802.3-2008 Clause 28 and IEEE 802.3az-2010. The auto-negotiation process evaluates the advertised capabilities of the local PHY and its link partner to determine the best possible operating mode. In particular, auto-negotiation can determine speed, duplex configuration, and master or slave operating modes for 1000BASE-TX. Auto-negotiation also enables a connected MAC to communicate with its link partner MAC through the VSC8531 device using optional next pages to set attributes that may not otherwise be defined by the IEEE standard.

If the Category 5 (Cat5) link partner does not support auto-negotiation, the VSC8531 device automatically uses parallel detection to select the appropriate link speed.

Auto-negotiation is disabled by clearing register 0, bit 12. When auto-negotiation is disabled, the state of register bits 0.6, 0.13, and 0.8 determine the device operating speed and duplex mode.

Note: While 10BASE-T and 100BASE-TX do not require auto-negotiation, IEEE 802.3-2008 Clause 40 has defined 1000BASE-T to require auto-negotiation.

3.4.3 Automatic Crossover and Polarity Detection

For trouble-free configuration and management of Ethernet links, the VSC8531 device includes a robust automatic crossover detection feature for all three speeds on the twisted pair interface (10BASE-T, 100BASE-T, and 1000BASE-T). Known as HP Auto-MDIX, the function is fully compliant with Clause 40 of IEEE 802.3-2008.

Additionally, the device detects and corrects polarity errors on all MDI pairs—a useful capability that exceeds the requirements of the standard.

Both HP Auto-MDIX detection and polarity correction are enabled in the device by default. Default settings can be changed using device register bits 18.5:4. Status bits for each of these functions are located in register 28.

Note: The VSC8531 device can be configured to perform HP Auto-MDIX, even when auto-negotiation is disabled and the link is forced into 10/100 speeds. To enable this feature, set register 18.7 to 0. To use the feature, also set register 0.12 to 0.

The HP Auto-MDIX algorithm successfully detects, corrects, and operates with any of the MDI wiring pair combinations listed in the following table, which shows that twisted pair A (of four twisted pairs A, B, C, and D) is connected to the RJ45 connector 1, 2 in normal MDI mode.

Table 10 • **Supported MDI Pair Combinations**

RJ45 Connections				
1, 2	**3, 6**	**4, 5**	**7, 8**	**Mode**
A	B	C	D	Normal MDI
B	A	D	C	Normal MDI-X
A	B	D	C	Normal MDI with pair swap on C and D pair
B	A	C	D	Normal MDI-X with pair swap on C and D pair

3.4.4 Manual MDI/MDIX Setting

As an alternative to HP Auto-MDIX detection, the PHY can be forced to be MDI or MDI-X using register 19E1, bits 3:2. Setting these bits to 10 forces MDI and setting 11 forces MDI-X. Leaving the bits 00 enables the HP Auto-MDIX setting to be based on register 18, bits 7 and 5.

3.4.5 Link Speed Downshift

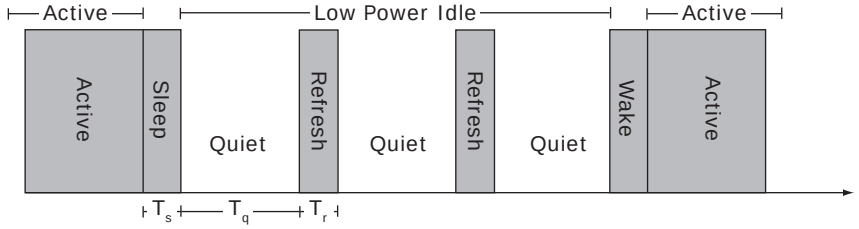
For operation in cabling environments that are incompatible with 1000BASE-T, the VSC8531 device provides an automatic link speed downshift option. When enabled, the device automatically changes its 1000BASE-T auto-negotiation advertisement to the next slower speed after a set number of failed attempts at 1000BASE-T. No reset is required to get out of this state when a subsequent link partner with 1000BASE-T support is connected. This feature is useful in setting up in networks using older cable installations that include only pairs A and B, and not pairs C and D.

To configure and monitor link speed downshifting, set register 20E1, bits 4:1.

3.4.6 Energy-Efficient Ethernet

The VSC8531 device supports the IEEE 802.3az-2010 Energy-Efficient Ethernet standard to provide a method for reducing power consumption on an Ethernet link during times of low utilization. It uses low power idles (LPI) to achieve this objective.

Figure 8 • **Low Power Idle Operation**



Using LPI, the usage model for the link is to transmit data as fast as possible and then return to a low power idle state. Energy is saved on the link by cycling between active and low power idle states. During LPI, power is reduced by turning off unused circuits and using this method, energy use scales with bandwidth utilization. The VSC8531 device uses LPI to optimize power dissipation in 100BASE-TX and 1000BASE-T modes of operation.

In addition, the IEEE 802.3az-2010 standard defines a 10BASE-Te mode that reduces transmit signal amplitude from 5 V peak-to-peak to approximately 3.3 V peak-to-peak. This mode reduces power consumption in 10 Mbps link speed and fully interoperates with legacy 10BASE-T-compliant PHYs over 100 m Cat5 cable or better.

To configure the VSC8531 device in 10BASE-Te mode, set register 17E2.15 to 1 for each port. Additional energy-efficient Ethernet features are controlled through Clause 45 registers. For more information, see Clause 45 Registers to Support Energy-Efficient Ethernet and 802.3bf, page 55.

3.4.7 Ring Resiliency

Ring resiliency changes the timing reference between the master and slave PHYs without altering the master/slave configuration in 1000BASE-T mode. The master PHY transmitter sends data based on the local clock and initiates timing recovery in the receiver. The slave PHY instructs nodes to switch the local timing reference to the recovered clock from other PHYs in the box, freezes timing recovery, and locks clock frequency for the transmitter. The master PHY makes a smooth transition to transmission from local clock to recovered clock after timing lock is achieved.

Ring resiliency can be used in synchronous Ethernet systems because the local clocks in each node are synchronized to a grandmaster clock.

Note: For ring resiliency to successfully exchange master/slave timing over 1000BASE-T, the link partner must also support ring resiliency.

3.5 Reference Clock

The VSC8531 device supports multiple reference clock input options to allow maximum system level flexibility. There are two REFCLK_SEL signals available to allow an end user to select between the various options. The following table shows the functionality and associated reference clock frequency.

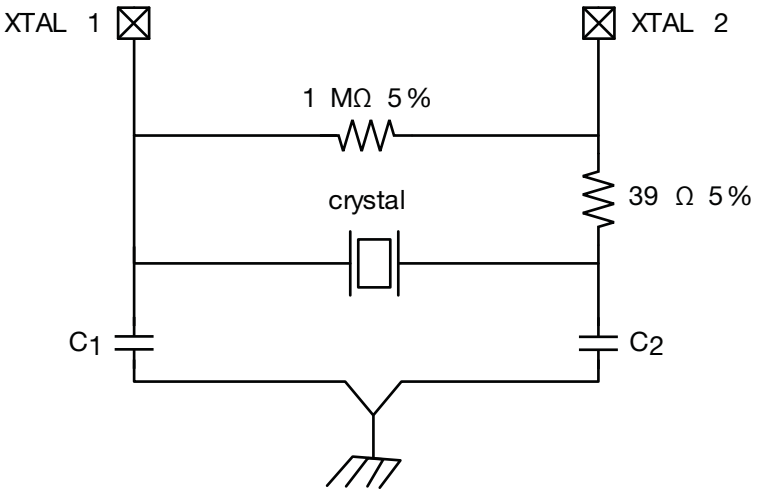
Table 11 • **REFCLK Frequency Selection**

REFCLK_SEL [1:0]	Reference Clock Mode
00	25 MHz, on-chip oscillator ON (XTAL1/2 pins)
01	25 MHz, on-chip oscillator OFF (XTAL1 pin)
10	50 MHz, on-chip oscillator OFF (XTAL1 pin)
11	125 MHz, on-chip oscillator OFF (XTAL1 pin)

The following figure shows a reference tank circuit for a fundamental mode crystal.

Note: For best performance, traces on PCB should be of similar length and Kelvin-connected to ground.

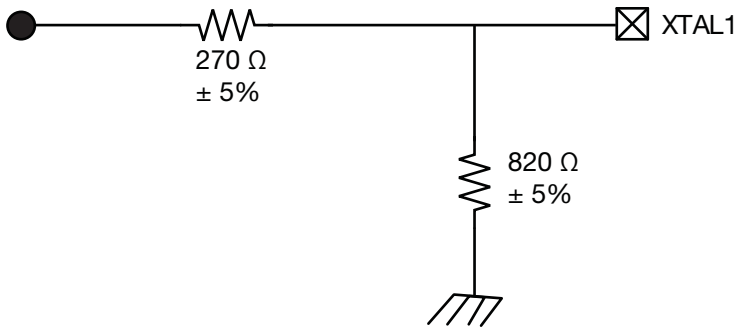
Figure 9 • **XTAL Reference Clock**



with REFCLK_SEL [1:0] = 00

The following figure shows an external 3.3 V reference clock.

Figure 10 • **External 3.3 V Reference Clock**



Note: Reference clock source less than λ/10 from XTAL1, and routing capacitance less than 1 pF.

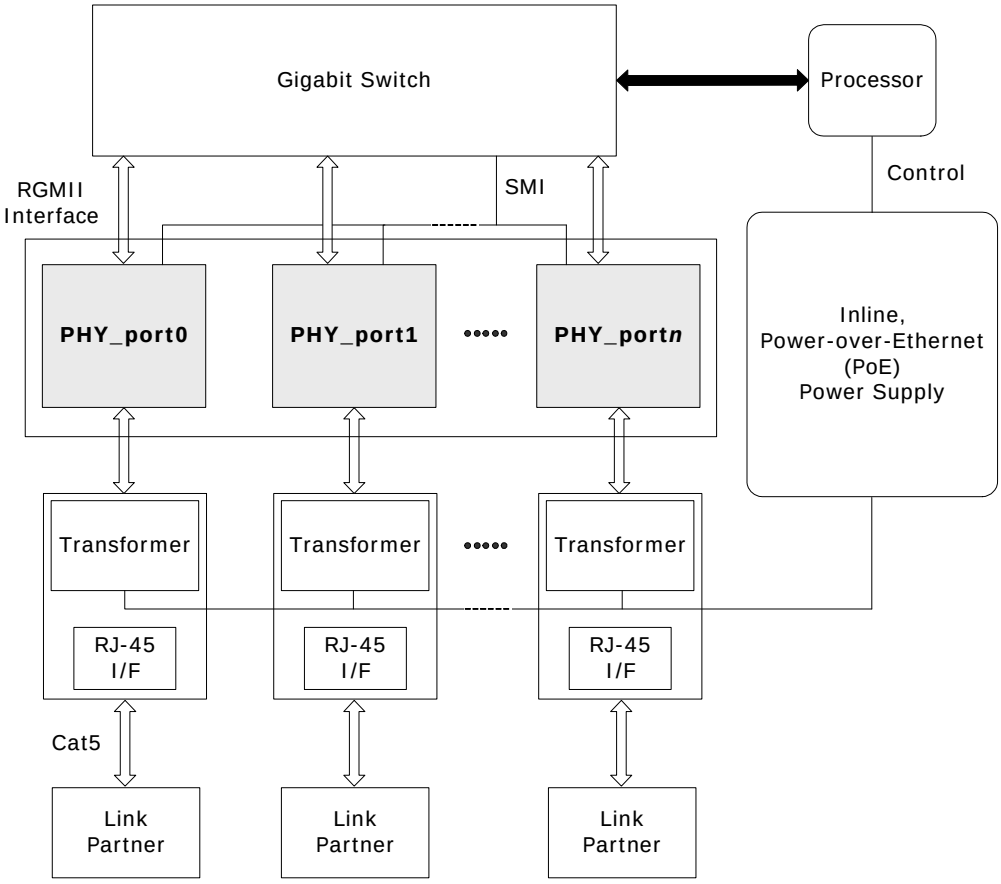
Note: No voltage scaling is required for a 2.5 V external reference.

3.6 Ethernet Inline-Powered Devices

The VSC8531 device can detect legacy inline-powered devices in Ethernet network applications. Inline-powered detection capability is useful in systems that enable IP phones and other devices (such as wireless access points) to receive power directly from their Ethernet cable, similar to office digital phones receiving power from a private branch exchange (PBX) office switch over telephone cabling. This type of setup eliminates the need for an external power supply and enables the inline-powered device to remain active during a power outage, assuming that the Ethernet switch is connected to an uninterrupted power supply, battery, back-up power generator, or other uninterruptable power source.

For more information about legacy inline-powered device detection, visit the Cisco website at www.cisco.com. The following illustration shows an example of an inline-powered Ethernet switch application.

Figure 11 • **Inline-Powered Ethernet Switch Diagram**



The following procedure describes the steps that an Ethernet switch must perform to process inline-power requests made by a link partner that is, in turn, capable of receiving inline-power:

1. Enable the inline-powered device detection mode on each VSC8531 PHY using its serial management interface. Set register bit 23E1.10 to 1.
2. Ensure that the auto-negotiation enable bit (register 0.12) is also set to 1. In the application, the device sends a special fast link pulse signal to the link partner. Reading register bit 23E1.9:8 returns 00 during the search for devices that require Power-over-Ethernet (PoE).
3. The VSC8531 PHY monitors its inputs for the fast link pulse signal looped back by the link partner. A link partner capable of receiving PoE loops back the fast link pulses when the link partner is in a powered down state. This is reported when register bit 23E1.9:8 reads back 01. It can also be verified as an inline-power detection interrupt by reading register bit 26.9, which should be a 1, and which is subsequently cleared and the interrupt de-asserted after the read. When a link partner device does not loop back the fast link pulse after a specific time, register bit 23E1.9:8 automatically resets to 10.
4. If the VSC8531 PHY reports that the link partner requires PoE, the Ethernet switch must enable inline-power on this port, independent of the PHY.
5. The PHY automatically disables inline-powered device detection when the register bits 23E1.9:8 automatically reset to 10, and then automatically changes to its normal auto-negotiation process. A link is then autonegotiated and established when the link status bit is set (register bit 1.2 is set to 1).
6. In the event of a link failure (indicated when register bit 1.2 reads 0), it is recommended that the inline-power be disabled to the inline-powered device independent of the PHY. The VSC8531 PHY disables its normal auto-negotiation process and re-enables its inline-powered device detection mode.

3.7 IEEE 802.3af Power-over-Ethernet Support

The VSC8531 device is compatible with designs intended for use in systems that supply power to data terminal equipment (DTE) by means of the MDI or twisted pair cable, as described in IEEE 802.3af Clause 33.

3.8 ActiPHY Power Management

In addition to the IEEE-specified power down control bit (device register bit 0.11), the VSC8531 device also includes an ActiPHY power management mode for each PHY. This mode enables support for power-sensitive applications. It utilizes a signal-detect function that monitors the media interface for the presence of a link to determine when to automatically power down the PHY. The PHY wakes up at a programmable interval and attempts to wake up the link partner PHY by sending a burst of fast link pulse over copper media.

The ActiPHY power management mode is enabled on a per-port basis during normal operation at any time by setting register bit 28.6 to 1.

The following operating states are possible when ActiPHY mode is enabled:

- Low power state
- Link partner wake-up state
- Normal operating state (link-up state)

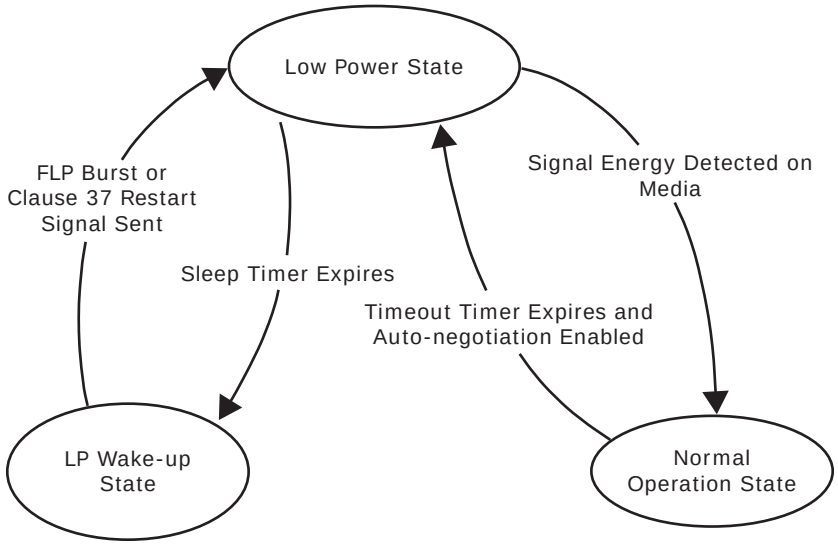
The VSC8531 device switches between the low power state and link partner wake-up state at a programmable rate (the default is two seconds) until signal energy has been detected on the media interface pins. When signal energy is detected, the PHY enters the normal operating state. If the PHY is in its normal operating state and the link fails, the PHY returns to the low power state after the expiration of the link status time-out timer. After reset, the PHY enters the low power state.

When auto-negotiation is enabled in the PHY, the ActiPHY state machine operates as described.

When auto-negotiation is disabled and the link is forced to use 10BASE-T or 100BASE-TX modes while the PHY is in its low power state, the PHY continues to transition between the low power and link partner wake-up states until signal energy is detected on the media pins. At that time, the PHY transitions to the normal operating state and stays in that state even when the link is dropped. When auto-negotiation is disabled while the PHY is in the normal operation state, the PHY stays in that state when the link is dropped and does not transition back to the low power state.

The following illustration shows the relationship between ActiPHY states and timers.

Figure 12 • **ActiPHY State Diagram**



3.8.1 Low Power State

In the low power state, all major digital blocks are powered down. However, the SMI interface (MDC, MDIO, and MDINT) functionality is provided.

In this state, the PHY monitors the media interface pins for signal energy. The PHY comes out of low power state and transitions to the normal operating state when signal energy is detected on the media. This happens when the PHY is connected to an auto-negotiation-capable link partner or another PHY in enhanced ActiPHY link partner wake-up state

In the absence of signal energy on the media pins, the PHY periodically transitions from low-power state to link partner wake-up state, based on the programmable sleep timer (register bits 20E1.14:13). The actual sleep time duration is randomized from –80 ms to 60 ms to avoid two linked PHYs in ActiPHY mode entering a lock-up state during operation.

3.8.2 Link Partner Wake-Up State

In the link partner wake-up state, the PHY attempts to wake up the link partner. Up to three complete fast link pulse bursts are sent on alternating pairs A and B of the Cat5 media for a duration based on the wake-up timer, which is set using register bits 20E1.12:11.

In this state, SMI interface (MDC, MDIO, and MDINT) functionality is provided.

After sending signal energy on the relevant media, the PHY returns to the low power state.

3.8.3 Normal Operating State

In the normal operating state, the PHY establishes a link with a link partner. When the media is unplugged or the link partner is powered down, the PHY waits for the duration of the programmable link status time-out timer, which is set using register bit 28.7 and bit 28.2. It then enters the low power state.

3.9 Serial Management Interface

The VSC8531 device includes an IEEE 802.3-compliant Serial Management Interface (SMI) that is affected by use of its MDC and MDIO pins. The SMI provides access to device control and status registers. The register set that controls the SMI consists of 32 16-bit registers, including all required IEEE-specified registers. Additional pages of registers are accessible using device register 31.

Energy-efficient Ethernet control registers are available through the SMI using Clause 45 registers and Clause 22 register access in registers 13 through 14.

The SMI is a synchronous serial interface with input data to the VSC8531 device on the MDIO pin that is clocked on the rising edge of the MDC pin. The output data is sent on the MDIO pin on the rising edge of the MDC signal. The interface can be clocked at a rate from 0 MHz to 12.5 MHz, depending on the total load on MDIO. An external 2 kΩ pull-up resistor is required on the MDIO pin.

3.9.1 SMI Frames

Data is transferred over the SMI using 32-bit frames with an optional, arbitrary-length preamble. Before the first frame can be sent, at least two clock pulses on MDC must be provided with the MDIO signal at logic one to initialize the SMI state machine. The following illustrations show the SMI frame format for read and write operations.

Figure 13 • **SMI Read Frame**

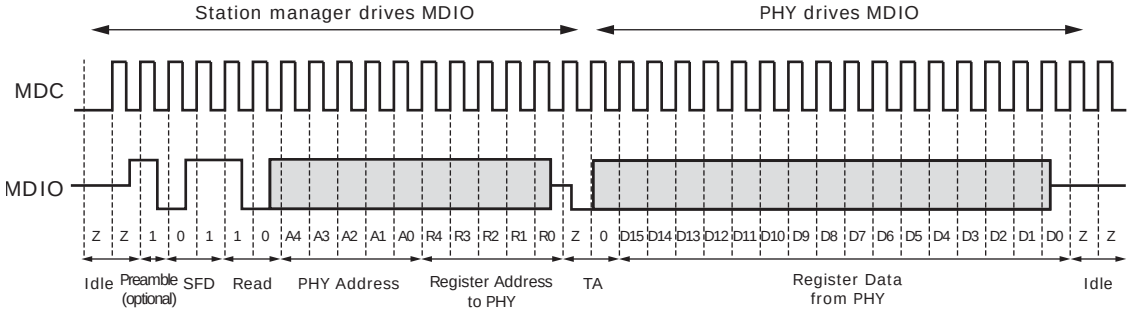
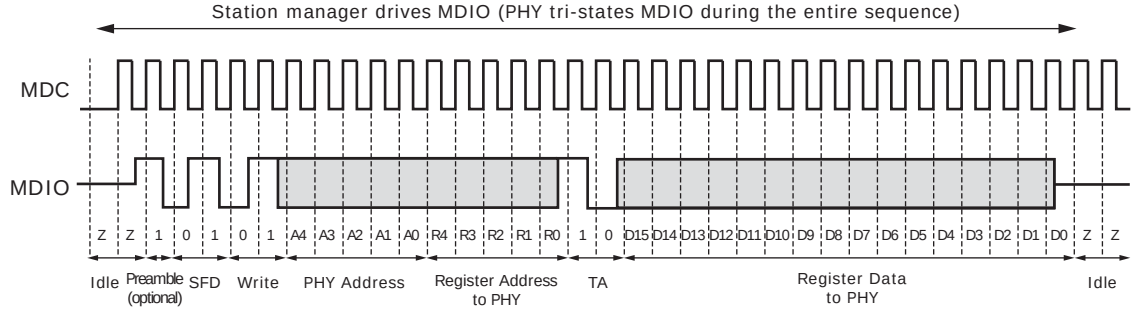


Figure 14 • **SMI Write Frame**



The following list defines the terms used in the SMI read and write timing diagrams.

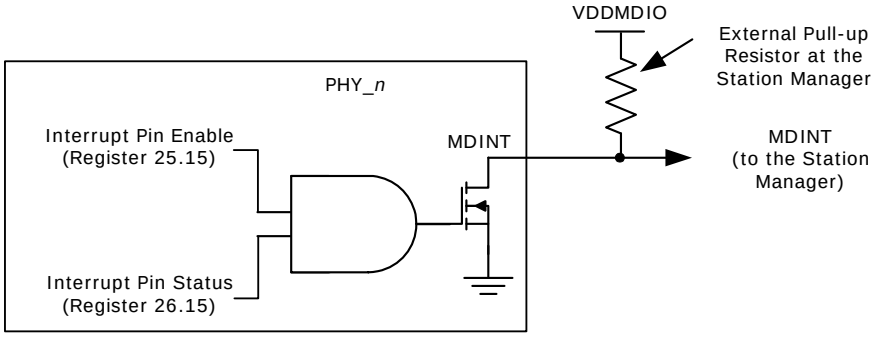
- **Idle**—During idle, the MDIO node goes to a high-impedance state. This allows an external pull-up resistor to pull the MDIO node up to a logical 1 state. Because the idle mode does not contain any transitions on MDIO, the number of bits is undefined during idle.
- **Preamble**—By default, preambles are not expected or required. The preamble is a string of ones. If it exists, the preamble must be at least 1 bit; otherwise, it can be of an arbitrary length.
- **Start of Frame Delimiter (SFD**—A pattern of 01 indicates the start of frame. If the pattern is not 01, all following bits are ignored until the next preamble pattern is detected.
- **Read or Write Opcode**—A pattern of 10 indicates a read. A 01 pattern indicates a write. If the bits are not either 01 or 10, all following bits are ignored until the next preamble pattern is detected.
- **PHY Address**—The particular VSC8531 device responds to a message frame only when the received PHY address matches its physical address. The physical address is 5 bits long (4:0).
- **Register Address**—The next five bits are the register address.
- **Turnaround**—The two bits used to avoid signal contention when a read operation is performed on the MDIO are called the turnaround (TA) bits. During read operations, the VSC8531 device drives the second TA bit, a logical 0.
- **Data**—The 16-bits read from or written to the device are considered the data or data stream. When data is read from a PHY, it is valid at the output from one rising edge of MDC to the next rising edge of MDC. When data is written to the PHY, it must be valid around the rising edge of MDC.
- **Idle**—The sequence is repeated.

3.9.2 SMI Interrupt

The SMI includes an interrupt signal, MDINT, for signaling the station manager when certain events occur in the VSC8531 device.

When a PHY generates an interrupt, the MDINT pin is asserted by driving low if the interrupt pin enable bit (register 25.15) is set. The MDINT pin is configured for open-drain (active-low) operation. Tie the pin to a pull-up resistor to VDDMDIO. The following illustration shows the configuration.

Figure 15 • **MDINT Configured as an Open-Drain (Active-Low) Pin**



3.10 LED Interface

The LED interface supports direct drive and basic serial LED mode configuration. The polarity of the LED outputs is programmable and can be changed using register 17E2, bits 13:10. The default polarity is active low.

Direct drive mode provides two LED signals, LED0 and LED1. The mode and function of each LED signal can be configured independently.

In basic serial LED mode, all signals that can be displayed on LEDs are sent as LED_Data and LED_CLK for external processing.

The following table shows the bit 9 settings for register 14G that are used to control the LED behavior for all the LEDs in the VSC8531 device.

Table 12 • **LED Drive State**

Setting	Active	Not Active
14G.9 = 1 (default)	Ground	Tristate
14G.9 = 0 (alternate setting)	Ground	V_{DD}

3.10.1 LED Modes

Each LED pin can be configured to display different status information that can be selected by setting the LED mode in register 29. The default LED state is active low and can be changed by modifying the value in register 17E2, bits 13:10. The blink/pulse stretch is dependent on the LED behavior setting in register 30.

The following table provides a summary of the LED modes and functions. The modes listed are equivalent to the setting used in register 29 to configure each LED pin.

Table 13 • **LED Mode and Function Summary**

Mode	Function Name	LED State and Description
0	Link/Activity	1: No link in any speed on any media interface. 0: Valid link at any speed on any media interface. Blink or pulse-stretch = Valid link at any speed on any media interface with activity present.
1	Link1000/Activity	1: No link in 1000BASE-T. 0: Valid 1000BASE-T. Blink or pulse-stretch = Valid 1000BASE-T link with activity present.
2	Link100/Activity	1: No link in 100BASE-TX. 0: Valid 100BASE-TX. Blink or pulse-stretch = Valid 100BASE-TX link with activity present.

Table 13 • **LED Mode and Function Summary *(continued)***

Mode	Function Name	LED State and Description
3	Link10/Activity	1: No link in 10BASE-T. 0: Valid 10BASE-T link. Blink or pulse-stretch = Valid 10BASE-T link with activity present.
4	Link100/1000/Activity	1: No link in 100BASE-TX or 1000BASE-T. 0: Valid 100BASE-TX or 1000BASE-T link. Blink or pulse-stretch = Valid 100BASE-TX or 1000BASE-T link with activity present.
5	Link10/1000/Activity	1: No link in 10BASE-T or 1000BASE-T. 0: Valid 10BASE-T or 1000BASE-T link. Blink or pulse-stretch = Valid 10BASE-T or 1000BASE-T link with activity present.
6	Link10/100/Activity	1: No link in 10BASE-T or 100BASE-TX. 0: Valid 10BASE-T or 100BASE-TX link. Blink or pulse-stretch = Valid 10BASE-T or 100BASE-TX link with activity present.
7	Reserved	Reserved.
8	Duplex/Collision	1: Link established in half-duplex mode, or no link established. 0: Link established in full-duplex mode. Blink or pulse-stretch = Link established in half-duplex mode but collisions are present.
9	Collision	1: No collision detected. Blink or pulse-stretch = Collision detected.
10	Activity	1: No activity present. Blink or pulse-stretch = Activity present (becomes TX activity present when register bit 30.14 is set to 1).
11	Reserved	Reserved.
12	Autonegotiation Fault	1: No auto-negotiation fault present. 0: Auto-negotiation fault occurred.
13	Serial Mode	Serial stream. See Basic Serial LED Mode, page 19. Only relevant on PHY port 0. Reserved in others.
14	Force LED Off	1: De-asserts the LED[1].
15	Force LED On	0: Asserts the LED[1].

1. Setting this mode suppresses LED blinking after reset.

3.10.2 Basic Serial LED Mode

The VSC8531 device can be configured so that access to all its LED signals is available through two pins. This option is enabled by setting LED0 to serial LED mode in register 29, bits 3:0 to 0xD. When serial LED mode is enabled, the LED0 pin becomes the serial data pin, and the LED1 pin becomes the serial clock pin. The serial LED mode clocks the LED status bits on the rising edge of the serial clock.

The LED behavior settings can also be used in serial LED mode. The LED combine and LED blink or pulse-stretch setting of LED0 is used to control the behavior of each bit of the serial LED stream. To configure LED behavior, set device register 30.

The following table shows the serial output bitstream of each LED signal.

Table 14 • **LED Serial Bitstream Order**

Output	
Link/activity	1
Link1000/activity	2

Table 14 • **LED Serial Bitstream Order *(continued)***

Output	
Link100/activity	3
Link10/activity	4
Reserved	5
Duplex/collision	6
Collision	7
Activity	8
Reserved	9
Tx activity	10
Rx activity	11
Autonegotiation fault	12

3.10.3 Extended LED Modes

In addition to the LED modes in register 29, there are also additional LED modes that are enabled on the LED pin whenever the corresponding register 19E1, bits 13 to 12 are set to 1. Each of these bits enable an extended mode shown in the following table. For example, LED0 = mode 22 means that register 19E1 bit 12 = 1 and register 29 bits 3 to 0 = 0110.

The following table provides a summary of the extended LED modes and functions.

Table 15 • **Extended LED Mode and Function Summary**

Mode	Function Name	LED State and Description
16-19	Reserved	Reserved.
20	Force LED Off	1: De-asserts the LED.
21	Force LED On	0: Asserts the LED. LED pulsing is disabled in this mode.
22	Fast Link Fail	Enable fast link fail on the LED pin.
23	WoL interrupt	Enable WoL interrupt indication on the LED pin.

3.10.4 LED Behavior

Several LED behaviors can be programmed into the VSC8531 device. Use the settings in register 30 and 19E1 to program LED behavior, as described in the following sections.

3.10.4.1 LED Combine

Enables an LED to display the status for a combination of primary and secondary modes. This can be enabled or disabled for each LED pin. For example, a copper link running in 1000BASE-T mode and activity present can be displayed with one LED by configuring an LED pin to Link1000/Activity mode. The LED asserts when linked to a 1000BASE-T partner and also blinks or performs pulse-stretch when activity is either transmitted by the PHY or received by the link partner. When disabled, the combine feature only provides the status of the selected primary function. In this example, only Link1000 asserts the LED, and the secondary mode, Activity, does not display when the combine feature is disabled.

3.10.4.2 LED Blink or Pulse-Stretch

This behavior is used for activity and collision indication. This can be uniquely configured for each LED pin. Activity and collision events can occur randomly and intermittently throughout the link-up period. Blink is a 50% duty cycle oscillation of asserting and de-asserting an LED pin. Pulse-stretch ensures that an LED is asserted and de-asserted for a specific period of time when activity is either present or not present. These rates can also be configured using a register setting.

3.10.4.3 Rate of LED Blink or Pulse-Stretch

This behavior controls the LED blink rate or pulse-stretch length when blink/pulse-stretch is enabled on a LED pin. The blink rate, which alternates between a high and low voltage level at a 50% duty cycle, can be set to 2.5 Hz, 5 Hz, 10 Hz, or 20 Hz. For pulse-stretch, the rate can be set to 50 ms, 100 ms, 200 ms, or 400 ms.

3.10.4.4 LED Pulsing Enable

To provide additional power savings, the LEDs (when asserted) can be pulsed at 5 kHz programmable duty cycle. The pulsing enable is controlled through register 30, bit 12 and the duty cycle through register 25G, bits 15:8.

3.10.4.5 LED Blink After Reset

The LEDs will blink for one second after a software reset is applied. This feature can be enabled by setting register 19E1, bit 11 = 1.

3.10.4.6 Pulse Programmable Control

These bits add the ability to width and frequency of LED pulses. This feature facilitates power reduction options.

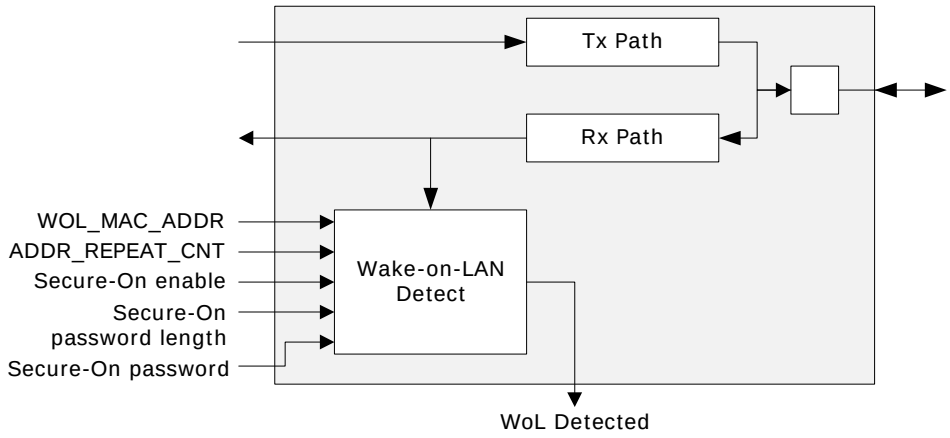
3.10.4.7 Fast Link Failure

For more information about this feature, see Fast Link Failure Indication, page 21.

3.11 Wake-On-LAN and SecureOn

The VSC8531 device supports Wake-on-LAN, an Ethernet networking standard to awaken hosts by using a “magic packet” that is decoded to ascertain the source, and then assert an interrupt pin or a LED. The VSC8531 device also supports SecureOn to secure Wake-on-LAN against unauthorized access. The following illustration shows an overview of the Wake-on-LAN functionality.

Figure 16 • **Wake-on-LAN Functionality**



Wake-on-LAN detection is available in 10BASE-T, 100BASE-TX, and 1000BASE-T modes. It is enabled by setting the interrupt mask register (25.6) and its status is read in the interrupt status register (26.6). Wake-on-LAN and SecureOn are configured using register 27E2. The MAC address is saved in its local register space (21E2, 22E2, and 23E2).

3.12 Fast Link Failure Indication

The VSC8531 device can indicate the onset of a link failure in less than 1 ms (<3 ms, worst case). In comparison, the IEEE 802.3 standard establishes a delay of up to 750 ms before indicating that a 1000BASE-T link is no longer present. Fast link failure is supported through the MDINT (active low) pin only in 1000BASE-T and 100BASE-TX modes.

Note: For all links except 1000BASE-T, the fast link failure indication matches the link status register (address 1, bit 2). For 1000BASE-T links, the link failure is based on a circuit that analyzes the integrity of the link, and will assert at the indication of failure. The MDINT pin is not reset until register 26 is cleared.

Note: A system can later confirm the fast link down indication for system management purposes by actively polling the link status bit to determine if a link has failed.

3.13 Fast Link Failure 2™ (FLF2™) Indication

In order to enable specific industrial applications in which the system must be warned as quickly as possible that a link might be going down, the VSC8531 device features the FLF2 indicator function. This new feature enables the PHY to indicate the onset of a potential link failure in less than 10 µs for 1000BASE-T operation and 150 µs for 100BASE-TX operation. FLF2 is supported through the MDINT (active low) pin.

This new functionality goes beyond the normal FLF indicator function, which must be enabled concurrently with FLF2, and is enabled by writing a 1 to bit 15 of register 20E2. The MDINT pin is not reset until register 26 is cleared.

A system can later confirm the fast link down indication for system management purposes by actively polling the link status bit to determine if a link has failed.

Note: For 10/100 links, the notification timing performance is only guaranteed for link loss due to failure of the PHY MDI pair operating as the ingress (receive) pair to the PHY.

3.14 Testing Features

The VSC8531 device includes several testing features designed to facilitate performing system-level debugging and in-system production testing. This section describes the available features.

3.14.1 Ethernet Packet Generator

The Ethernet Packet Generator (EPG) can be used at each of the 10/100/1000BASE-T speed settings for copper Cat5 media to isolate problems between the MAC and the VSC8531 device, or between a locally connected PHY and its remote link partner. Enabling the EPG feature disables all MAC interface transmit pins and selects the EPG as the source for all data transmitted onto the twisted pair interface.

Note: The EPG is intended for use with laboratory or in-system testing equipment only. Do not use the EPG testing feature when the VSC8531 device is connected to a live network.

To enable the EPG feature, set the device register bit 29E1.15 to 1.

When the EPG is enabled, packet loss occurs during transmission of packets from the MAC to the PHY. However, the PHY receive output pins to the MAC are still active when the EPG is enabled. When it is necessary to disable the MAC receive pins as well, set the register bit 0.10 to 1.

When the device register bit 29E1.14 is set to 1, the PHY begins transmitting Ethernet packets based on the settings in registers 29E1 and 30E1. These registers set:

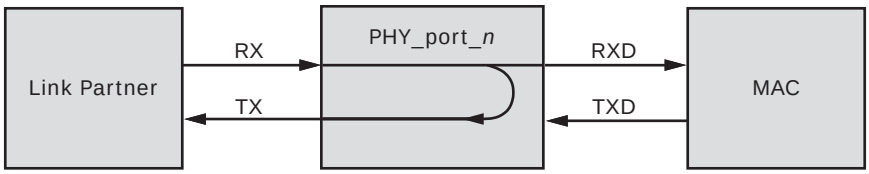
- Source and destination addresses for each packet
- Packet size
- Interpacket gap
- FCS state
- Transmit duration
- Payload pattern

When register bit 29E1.13 is set to 0, register bit 29E1.14 is cleared automatically after 30,000,000 packets are transmitted.

3.14.2 Far-End Loopback

The far-end loopback testing feature is enabled by setting register bit 23.3 to 1. When enabled, it forces incoming data from a link partner on the current media interface into the MAC interface of the PHY where it is retransmitted back to the link partner on the media interface, as shown in the following illustration. In addition, the incoming data also appears on the receive data pins of the MAC interface. Data present on the transmit data pins of the MAC interface is ignored when using this testing feature.

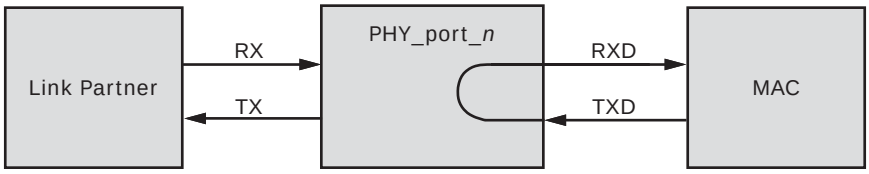
Figure 17 • **Far-End Loopback Diagram**



3.14.3 Near-End Loopback

When the near-end loopback testing feature is enabled, transmitted data (TXD) is looped back in the PCS block onto the receive data signals (RXD), as shown in the following illustration. When using this testing feature, no data is transmitted over the network. To enable near-end loopback, set the device register bit 0.14 to 1.

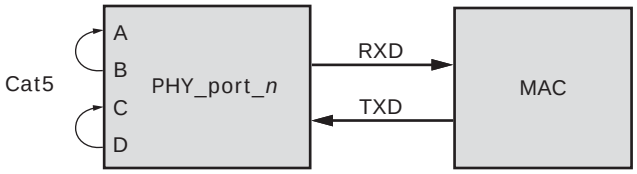
Figure 18 • **Near-End Loopback Diagram**



3.14.4 Connector Loopback

The connector loopback testing feature allows the twisted pair interface to be looped back externally. When using this feature, the PHY must be connected to a loopback connector or a loopback cable. Connect pair A to pair B, and pair C to pair D, as shown in the following illustration. The connector loopback feature functions at all available interface speeds.

Figure 19 • **Connector Loopback Diagram**



When using the connector loopback testing feature, the device auto-negotiation, speed, and duplex configuration is set using device registers 0,4, and 9.

For 1000BASE-T connector loopback, additional writes are required in the following order:

1. Enable the 1000BASE-T connector loopback. Set register bit 24.0 to 1.
2. Disable pair swap correction. Set register bit 18.5 to 1.

3.15 Configuration

The VSC8531 device can be configured by setting internal memory registers using the management interface. To configure the device, perform the following steps:

1. Apply power.
2. Apply RefClk.
3. Release reset, drive high. Power and clock must be high before releasing reset.
4. Wait 15 ms minimum.
5. Apply patch from PHY_API if available (required for production release, optional for board testing).
6. Configure register 23 for MAC interface mode.
   - Read register 23 (to access register 23, register 31 must be 0).
   - Set bits 12:11, MAC configuration, as follows:
     10: RGMII
     01: RMII
   - Write new register 23.
7. Software reset.

- Read register 0 (to access register 0, register 31 must be 0).
- Set bit 15 to 1.
- Write new register 0.

8. Read register 0 until bit 15 equals to 0.
9. For RGMII mode: Configure register 20E2 (to access register 20E2, register 31 must be set to 2). Set bit 11 to 0 and set RX_CLK delay and TX_CLK delay accordingly through bit [6:4] and/or bit [2:0] respectively.

4 Registers

This section provides information about how to configure the VSC8531 device using its internal memory registers and the management interface. The registers marked reserved and factory test should not be read or written to, because doing so may produce undesired effects.

The default value documented for registers is based on the value at reset; in some cases, that value may change immediately after reset.

The access type for each register is shown using the following abbreviations:

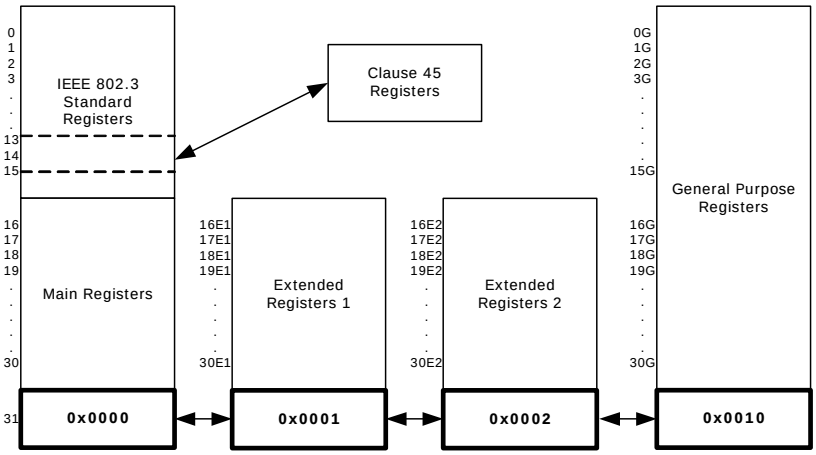
- RO: Read Only
- ROCR: Read Only, Clear on Read
- RO/LH: Read Only, Latch High
- RO/LL: Read Only, Latch Low
- R/W: Read and Write
- RWSC: Read and Write, Self-Clearing

The VSC8531 device uses several different types of registers:

- IEEE Clause 22 device registers with addresses from 0 to 31
- Two pages of extended registers with addresses from 17E1–30E1 and 16E2–30E2
- General-purpose registers with addresses from 0G to 30G
- IEEE Clause 45 devices registers accessible through the Clause 22 registers 13 and 14 to support IEEE 802.3az-2010 Energy-Efficient Ethernet registers and IEEE 802.3bf-2011 registers

The following illustration shows the relationship between the device registers and their address spaces.

Figure 20 • **Register Space Diagram**



Reserved Registers

For main registers 16–31, extended registers 17E1–30E1, 16E2–30E2, and general purpose registers 0G–30G, any bits marked as Reserved should be processed as read-only and their states as undefined.

Reserved Bits

In writing to registers with reserved bits, use a read-modify-then-write technique, where the entire register is read but only the intended bits to be changed are modified. Reserved bits cannot be changed and their read state cannot be considered static or unchanging.

4.1 Register and Bit Conventions

This document refers to registers by their address and bit number in decimal notation. A range of bits is indicated with a colon. For example, a reference to address 26, bits 15 through 14 is shown as 26.15:14.

A register with an E and a number attached (such as 27E1) means it is a register contained within extended register page number 1. A register with a G attached (such as 13G) means it is a GPIO page register.

Bit numbering follows the IEEE standard with bit 15 being the most significant bit and bit 0 being the least significant bit.

4.2 IEEE 802.3 and Main Registers

In the VSC8531 device, the page space of the standard registers consists of the IEEE 802.3 standard registers and the Microsemi standard registers. The following table lists the names of the registers associated with the addresses as specified by IEEE 802.3.

Table 16 • **IEEE 802.3 Registers**

Address	Name
0	Mode Control
1	Mode Status
2	PHY Identifier 1
3	PHY Identifier 2
4	Auto-negotiation Advertisement
5	Auto-negotiation Link Partner Ability
6	Auto-negotiation Expansion
7	Auto-negotiation Next-Page Transmit
8	Auto-negotiation Link Partner Next-Page Receive
9	1000BASE-T Control
10	1000BASE-T Status
11–12	Reserved
13	Clause 45 Access Registers from IEEE 802.3 Table 22-6 and 22.24.3.11-12 and Annex 22D
14	Clause 45 Access Registers from IEEE 802.3 Table 22-6 and 22.24.3.11-12 and Annex 22D
15	1000BASE-T Status Extension 1

The following table lists the names of the registers in the main page space of the device. These registers are accessible only when register address 31 is set to 0x0000.

Table 17 • **Main Registers**

Address	Name
16	100BASE-TX status extension
17	1000BASE-T status extension 2
18	Bypass control
19	Error Counter 1
20	Error Counter 2
21	Error Counter 3
22	Extended control and status
23	Extended PHY control 1

Table 17 • **Main Registers *(continued)***

Address	Name
24	Extended PHY control 2
25	Interrupt mask
26	Interrupt status
27	Reserved
28	Auxiliary control and status
29	LED mode select
30	LED behavior
31	Extended register page access

4.2.1 Mode Control

The device register at memory address 0 controls several aspects of the VSC8531 device functionality. The following table shows the available bit settings in this register and what they control.

Table 18 • **Mode Control, Address 0 (0x00)**

Bit	Name	Access	Description	Default
15	Software reset	R/W	Self-clearing. Restores all serial management interface (SMI) registers to default state, except for sticky and super-sticky bits. 1: Reset asserted. 0: Reset de-asserted. Wait 1 µs after setting this bit to initiate another SMI register access.	0
14	Loopback	R/W	1: Loopback enabled. 0: Loopback disabled. When loopback is enabled, the device functions at the current speed setting and with the current duplex mode setting (bits 6, 8, and 13 of this register).	0
13	Forced speed selection LSB	R/W	Least significant bit. MSB is bit 6. 00: 10 Mbps 01: 100 Mbps 10: 1000 Mbps 11: Reserved	0
12	Autonegotiation enable	R/W	1: Autonegotiation enabled. 0: Autonegotiation disabled.	1
11	Power-down	R/W	1: Power down enabled.	0
10	Isolate	R/W	1: Disable MAC interface outputs and ignore MAC interface inputs.	0
9	Restart autonegotiation	R/W	Self-clearing bit. 1: Restart autonegotiation on media interface.	0
8	Duplex	R/W	1: Full-duplex. 0: Half-duplex.	0
7	Collision test enable	R/W	1: Collision test enabled.	0
6	Forced speed selection MSB	R/W	Most significant bit. LSB is bit 13.[1] 00: 10 Mbps 01: 100 Mbps 10: 1000 Mbps 11: Reserved	1

Table 18 • **Mode Control, Address 0 (0x00) *(continued)***

Bit	Name	Access	Description	Default
5:0	Reserved		Reserved.	00000

1. Before selecting the 1000 Mbps forced speed mode, manually configure the PHY as master or slave by setting bit 11 in register 9 (1000BASE-T Control) and MDI or MDIX by setting bits 3:2 in register 19E1 (Extended Mode Control).

4.2.2 Mode Status

The register at address 1 in the device main registers space enables reading the currently enabled mode setting. The following table shows possible readouts of this register.

Table 19 • **Mode Status, Address 1 (0x01)**

Bit	Name	Access	Description	Default
15	100BASE-T4 capability	RO	1: 100BASE-T4 capable.	0
14	100BASE-TX FDX capability	RO	1: 100BASE-TX FDX capable.	1
13	100BASE-TX HDX capability	RO	1: 100BASE-TX HDX capable.	1
12	10BASE-T FDX capability	RO	1: 10BASE-T FDX capable.	1
11	10BASE-T HDX capability	RO	1: 10BASE-T HDX capable.	1
10	100BASE-T2 FDX capability	RO	1: 100BASE-T2 FDX capable.	0
9	100BASE-T2 HDX capability	RO	1: 100BASE-T2 HDX capable.	0
8	Extended status enable	RO	1: Extended status information present in register 15.	1
7	Reserved	RO	Reserved.	
6	Preamble suppression capability	RO	1: MF preamble can be suppressed. 0: MF required.	1
5	Autonegotiation complete	RO	1: Auto-negotiation complete.	0
4	Remote fault	RO	Latches high. 1: Far-end fault detected.	0
3	Autonegotiation capability	RO	1: Auto-negotiation capable.	1
2	Link status	RO	Latches low. 1: Link is up.	0
1	Jabber detect	RO	Latches high. 1: Jabber condition detected.	0
0	Extended capability	RO	1: Extended register capable.	1

4.2.3 Device Identification

All 16 bits in both register 2 and register 3 in the VSC8531 device are used to provide information associated with aspects of the device identification. The following tables list the expected readouts.

Table 20 • **Identifier 1, Address 2 (0x02)**

Bit	Name	Access	Description	Default
15:0	Organizationally unique identifier (OUI)	RO	OUI most significant bits (3:18)	0×0007

Table 21 • **Identifier 2, Address 3 (0x03)**

Bit	Name	Access	Description	Default
15:10	OUI	RO	OUI least significant bits (19:24)	000001

Table 21 • **Identifier 2, Address 3 (0x03) *(continued)***

Bit	Name	Access	Description	Default
9:4	Microsemi model number	RO	VSC8531	010111
3:0	Device revision number	RO	Revision A	0000

4.2.4 Auto-Negotiation Advertisement

The bits in address 4 in the main registers space control the ability to notify other devices of the status of its auto-negotiation feature. The following table shows the available settings and readouts.

Table 22 • **Device Auto-Negotiation Advertisement, Address 4 (0x04)**

Bit	Name	Access	Description	Default
15	Next page transmission request	R/W	1: Request enabled	0
14	Reserved	RO	Reserved	
13	Transmit remote fault	R/W	1: Enabled	0
12	Reserved	R/W	Reserved	0
11	Advertise asymmetric pause	R/W	1: Advertises asymmetric pause	0
10	Advertise symmetric pause	R/W	1: Advertises symmetric pause	0
9	Advertise100BASE-T4	R/W	1: Advertises 100BASE-T4	0
8	Advertise100BASE-TX FDX	R/W	1: Advertise 100BASE-TX FDX	1
7	Advertise100BASE-TX HDX	R/W	1: Advertises 100BASE-TX HDX	1
6	Advertise10BASE-T FDX	R/W	1: Advertises 10BASE-T FDX	1
5	Advertise10BASE-T HDX	R/W	1: Advertises 10BASE-T HDX	1
4:0	Advertise selector	R/W		00001

4.2.5 Link Partner Auto-Negotiation Capability

The bits in main register 5 can be used to determine if the Cat5 link partner (LP) used with the VSC8531 device is compatible with the auto-negotiation functionality.

Table 23 • **Auto-Negotiation Link Partner Ability, Address 5 (0x05)**

Bit	Name	Access	Description	Default
15	LP next page transmission request	RO	1: Requested	0
14	LP acknowledge	RO	1: Acknowledge	0
13	LP remote fault	RO	1: Remote fault	0
12	Reserved	RO	Reserved	
11	LP advertise asymmetric pause	RO	1: Capable of asymmetric pause	0
10	LP advertise symmetric pause	RO	1: Capable of symmetric pause	0
9	LP advertise 100BASE-T4	RO	1: Capable of 100BASE-T4	0
8	LP advertise 100BASE-TX FDX	RO	1: Capable of 100BASE-TX FDX	0
7	LP advertise 100BASE-TX HDX	RO	1: Capable of 100BASE-TX HDX	0
6	LP advertise 10BASE-T FDX	RO	1: Capable of 10BASE-T FDX	0
5	LP advertise 10BASE-T HDX	RO	1: Capable of 10BASE-T HDX	0
4:0	LP advertise selector	RO		00000

4.2.6 Auto-Negotiation Expansion

The bits in main register 6 work together with those in register 5 to indicate the status of the LP auto-negotiation functioning. The following table shows the available settings and readouts.

Table 24 • **Auto-Negotiation Expansion, Address 6 (0x06)**

Bit	Name	Access	Description	Default
15:5	Reserved	RO	Reserved.	
4	Parallel detection fault	RO	This bit latches high. 1: Parallel detection fault.	0
3	LP next page capable	RO	1: LP is next page capable.	0
2	Local PHY next page capable	RO	1: Local PHY is next page capable.	1
1	Page received	RO	This bit latches high. 1: New page is received.	0
0	LP is autonegotiation capable	RO	1: LP is capable of auto-negotiation.	0

4.2.7 Transmit Auto-Negotiation Next Page

The settings in register 7 in the main registers space provide information about the number of pages in an auto-negotiation sequence. The following table shows the settings available.

Table 25 • **Auto-Negotiation Next Page Transmit, Address 7 (0x07)**

Bit	Name	Access	Description	Default
15	Next page	R/W	1: More pages follow.	0
14	Reserved	RO	Reserved.	
13	Message page	R/W	1: Message page. 0: Unformatted page.	1
12	Acknowledge 2	R/W	1: Complies with request. 0: Cannot comply with request.	0
11	Toggle	RO	1: Previous transmitted LCW = 0. 0: Previous transmitted LCW = 1.	0
10:0	Message/unformatted code	R/W		00000000001

4.2.8 Auto-Negotiation Link Partner Next Page Receive

The bits in register 8 of the main register space work together with register 7 to determine certain aspects of the LP auto-negotiation. The following table shows the possible readouts.

Table 26 • **Auto-Negotiation LP Next Page Receive, Address 8 (0x08)**

Bit	Name	Access	Description	Default
15	LP next page	RO	1: More pages follow.	0
14	Acknowledge	RO	1: LP acknowledge.	0
13	LP message page	RO	1: Message page. 0: Unformatted page.	0
12	LP acknowledge 2	RO	1: LP complies with request.	0
11	LP toggle	RO	1: Previous transmitted LCW = 0. 0: Previous transmitted LCW = 1.	0
10:0	LP message/unformatted code	RO		All zeros

4.2.9 1000BASE-T Control

The 1000BASE-T functionality is controlled by the bits in register 9 of the main register space. The following table shows the settings and readouts available.

Table 27 • **1000BASE-T Control, Address 9 (0x09)**

Bit	Name	Access	Description	Default
15:13	Transmitter test mode	R/W	000: Normal. 001: Mode 1: Transmit waveform test. 010: Mode 2: Transmit jitter test as master. 011: Mode 3: Transmit jitter test as slave. 100: Mode 4: Transmitter distortion test. 101–111: Reserved.	000
12	Master/slave manual configuration	R/W	1: Master/slave manual configuration enabled.	0
11	Master/slave value	R/W	This register is only valid when bit 9.12 is set to 1. 1: Configure PHY as master during negotiation. 0: Configure PHY as slave during negotiation.	0
10	Port type	R/W	1: Multi-port device. 0: Single-port device.	0
9	1000BASE-T FDX capability	R/W	1: PHY is 1000BASE-T FDX capable.	1
8	1000BASE-T HDX capability	R/W	1: PHY is 1000BASE-T HDX capable.	1
7:0	Reserved	RO	Reserved.	

Note: Transmitter test mode (bits 15:13) operates in the manner described in IEEE 802.3 section 40.6.1.1.2.

4.2.10 1000BASE-T Status

The bits in register 10 of the main register space can be read to obtain the status of the 1000BASE-T communications enabled in the device. The following table shows the readouts.

Table 28 • **1000BASE-T Status, Address 10 (0x0A)**

Bit	Name	Access	Description	Default
15	Master/slave configuration fault	RO	This bit latches high; self-clearing. 1: Master/slave configuration fault detected. 0: No master/slave configuration fault detected.	0
14	Master/slave configuration resolution	RO	1: Local PHY configuration resolved to master. 0: Local PHY configuration resolved to slave.	1
13	Local receiver status	RO	1: Local receiver is operating normally.	0
12	Remote receiver status	RO	1: Remote receiver OK.	0
11	LP 1000BASE-T FDX capability	RO	1: LP 1000BASE-T FDX capable.	0
10	LP 1000BASE-T HDX capability	RO	1: LP 1000BASE-T HDX capable.	0
9:8	Reserved	RO	Reserved.	
7:0	Idle error count	RO	Self-clearing register.	0x00

4.2.11 MMD Access Control Register

The bits in register 13 of the main register space are a window to the EEE registers as defined in IEEE 802.3az-2010 Clause 45.

Table 29 • **MMD EEE Access, Address 13 (0x0D)**

Bit	Name	Access	Description
15:14	Function	R/W	00: Address. 01: Data, no post increment. 10: Data, post increment for read and write. 11: Data, post increment for write only.
13:5	Reserved	RO	Reserved.
4:0	DVAD	R/W	Device address as defined in IEEE 802.3az-2010 table 45–1.

4.2.12 MMD Address or Data Register

The bits in register 14 of the main register space are a window to the EEE registers as defined in IEEE 802.3az-2010 Clause 45.

Table 30 • **MMD Address or Data Register, Address 14 (0x0E)**

Bit	Name	Access	Description
15:0	Register Address/Data	R/W	When register 13.15:14 = 2'b00, address of register of the device that is specified by 13.4:0. Otherwise, the data to be written to or read from the register.

4.2.13 1000BASE-T Status Extension 1

Register 15 provides additional information about the operation of the device 1000BASE-T communications. The following table shows the readouts available.

Table 31 • **1000BASE-T Status Extension 1, Address 15 (0x0F)**

Bit	Name	Access	Description	Default
15	Reserved	RO	Reserved	
14	1000BASE-X HDX capability	RO	1: PHY is 1000BASE-X HDX capable	0
13	1000BASE-T FDX capability	RO	1: PHY is 1000BASE-T FDX capable	1
12	1000BASE-T HDX capability	RO	1: PHY is 1000BASE-T HDX capable	1
11:0	Reserved	RO	Reserved	

4.2.14 100BASE-TX Status Extension

Register 16 in the main registers page space provides additional information about the status of the 100BASE-TX operation.

Table 32 • **100BASE-TX Status Extension, Address 16 (0x10)**

Bit	Name	Access	Description	Default
15	100BASE-TX Descrambler	RO	1: Descrambler locked.	0
14	100BASE-TX lock error	RO	Self-clearing bit. 1: Lock error detected.	0
13	100BASE-TX disconnect state	RO	Self-clearing bit. 1: PHY 100BASE-TX link disconnect detected.	0

Table 32 • **100BASE-TX Status Extension, Address 16 (0x10) *(continued)***

Bit	Name	Access	Description	Default
12	100BASE-TX current link status	RO	1: PHY 100BASE-TX link active.	0
11	100BASE-TX receive error	RO	Self-clearing bit. 1: Receive error detected.	0
10	100BASE-TX transmit error	RO	Self-clearing bit. 1: Transmit error detected.	0
9	100BASE-TX SSD error	RO	Self-clearing bit. 1: Start-of-stream delimiter error detected.	0
8	100BASE-TX ESD error	RO	Self-clearing bit. 1: End-of-stream delimiter error detected.	0
7:0	Reserved	RO	Reserved.	

4.2.15 1000BASE-T Status Extension 2

The second status extension register is at address 17 in the device main registers space. It provides information about another set of parameters associated with 1000BASE-T communications. For information about the first status extension register, see Table 31, page 32.

Table 33 • **1000BASE-T Status Extension 2, Address 17 (0x11)**

Bit	Name	Access	Description	Default
15	1000BASE-T descrambler	RO	1: Descrambler locked.	0
14	1000BASE-T lock error	RO	Self-clearing bit. 1: Lock error detected.	0
13	1000BASE-T disconnect state	RO	Self-clearing bit. 1: PHY 1000BASE-T link disconnect detected.	0
12	1000BASE-T current link status	RO	1: PHY 1000BASE-T link active.	0
11	1000BASE-T receive error	RO	Self-clearing bit. 1: Receive error detected.	0
10	1000BASE-T transmit error	RO	Self-clearing bit. 1: Transmit error detected.	0
9	1000BASE-T SSD error	RO	Self-clearing bit. 1: Start-of-stream delimiter error detected.	0
8	1000BASE-T ESD error	RO	Self-clearing bit. 1: End-of-stream delimiter error detected.	0
7	1000BASE-T carrier extension error	RO	Self-clearing bit. 1: Carrier extension error detected.	0
6	Non-compliant BCM5400 detected	RO	1: Non-compliant BCM5400 link partner detected.	0
5	MDI crossover error	RO	1: MDI crossover error was detected.	0
4:0	Reserved	RO	Reserved.	

4.2.16 Bypass Control

The bits in this register control aspects of functionality in effect when the device is disabled for the purpose of traffic bypass. The following table shows the settings available.

Table 34 • **Bypass Control, Address 18 (0x12)**

Bit	Name	Access	Description	Default
15	Transmit disable	R/W	1: PHY transmitter disabled.	0
14	4B5B encoder/decoder	R/W	1: Bypass 4B/5B encoder/decoder.	0
13	Scrambler	R/W	1: Bypass scrambler.	0
12	Descrambler	R/W	1: Bypass descrambler.	0
11	PCS receive	R/W	1: Bypass PCS receiver.	0
10	PCS transmit	R/W	1: Bypass PCS transmit.	0
9	LFI timer	R/W	1: Bypass Link Fail Inhibit (LFI) timer.	0
8	Reserved	RO	Reserved.	
7	HP Auto-MDIX at forced 10/100	R/W	Sticky bit. 1: Disable HP Auto-MDIX at forced 10/100 speeds.	1
6	Non-compliant BCM5400 detect disable	R/W	Sticky bit. 1: Disable non-compliant BCM5400 detection.	0
5	Disable pair swap correction (HP Auto-MDIX when autonegotiation enabled)	R/W	Sticky bit. 1: Disable the automatic pair swap correction.	0
4	Disable polarity correction	R/W	Sticky bit. 1: Disable polarity inversion correction on each subchannel.	0
3	Parallel detect control	R/W	Sticky bit. 1: Do not ignore advertised ability. 0: Ignore advertised ability.	1
2	Pulse shaping filter	R/W	1: Disable pulse shaping filter.	0
1	Disable automatic 1000BASE-T next page exchange	R/W	Sticky bit. 1: Disable automatic 1000BASE T next page exchanges.	0
0	Reserved	RO	Reserved.	

Note: If bit 18.1 is set to 1 in this register, automatic exchange of next pages is disabled, and control is returned to the user through the SMI after the base page is exchanged. The user then must send the correct sequence of next pages to the link partner, determine the common capabilities, and force the device into the correct configuration following the successful exchange of pages.

4.2.17 Error Counter 1

The bits in register 19 provide an error counter. The following table shows the settings available.

Table 35 • **Extended Control and Status, Address 19 (0x13)**

Bit	Name	Access	Description	Default
15:8	Reserved	RO	Reserved.	
7:0	100/1000 receive error counter	RO	8-bit counter that saturates when it reaches 255. These bits are self-clearing when read.	0x00

4.2.18 Error Counter 2

The bits in register 20 provide an error counter. The following table shows the settings available.

Table 36 • **Extended Control and Status, Address 20 (0x14)**

Bit	Name	Access	Description	Default
15:8	Reserved	RO	Reserved.	
7:0	100/1000 false carrier counter	RO	8-bit counter that saturates when it reaches 255. These bits are self-clearing when read.	0x00

4.2.19 Error Counter 3

The bits in register 21 provide an error counter. The following table shows the settings available.

Table 37 • **Extended Control and Status, Address 21 (0x15)**

Bit	Name	Access	Description	Default
15:8	Reserved	RO	Reserved.	
7:0	Copper media link disconnect counter	RO	8-bit counter that saturates when it reaches 255. These bits are self-clearing when read.	0x00

4.2.20 Extended Control and Status

The bits in register 22 provide additional device control and readouts. The following table shows the settings available.

Table 38 • **Extended Control and Status, Address 22 (0x16)**

Bit	Name	Access	Description	Default
15	Force 10BASE-T link high	R/W	Sticky bit. 1: Bypass link integrity test. 0: Enable link integrity test.	0
14	Jabber detect disable	R/W	Sticky bit. 1: Disable jabber detect.	0
13	Disable 10BASE-T echo	R/W	Sticky bit. 1: Disable 10BASE-T echo.	1
12	Disable SQE mode	R/W	Sticky bit. 1: Disable SQE mode.	1
11:10	10BASE-T squelch control	R/W	Sticky bit. 00: Normal squelch. 01: Low squelch. 10: High squelch. 11: Reserved.	00
9	Sticky reset enable	R/W	Super-sticky bit. 1: Enabled.	1
8	EOF Error	RO	This bit is self-clearing. 1: EOF error detected.	0
7	10BASE-T disconnect state	RO	This bit is self-clearing. 1: 10BASE-T link disconnect detected.	0
6	10BASE-T link status	RO	1: 10BASE-T link active.	0
5:1	Reserved	RO	Reserved.	

Table 38 • **Extended Control and Status, Address 22 (0x16) *(continued)***

Bit	Name	Access	Description	Default
0	SMI broadcast write	R/W	Sticky bit. 1: Enabled.	0

The following information applies to the extended control and status bits:

- When bit 22.15 is set, the link integrity state machine is bypassed and the PHY is forced into a link pass status.
- When bits 22.11:10 are set to 00, the squelch threshold levels are based on the IEEE standard for 10BASE-T. When set to 01, the squelch level is decreased, which can improve the bit error rate performance on long loops. When set to 10, the squelch level is increased and can improve the bit error rate in high-noise environments.
- When bit 22.9 is set, all sticky register bits retain their values during a software reset. Clearing this bit causes all sticky register bits to change to their default values upon software reset. Super-sticky bits retain their values upon software reset regardless of the setting of bit 22.9.
- When bit 22.0 is set, if a write to any PHY register (registers 0–31, including extended registers), the same write is broadcast to all PHYs. For example, if bit 22.0 is set to 1 and a write to PHY0 is executed (register 0 is set to 0x1040), all PHYs' register 0s are set to 0x1040. Disabling this bit restores normal PHY write operation. Reads are still possible when this bit is set, but the value that is read corresponds only to the particular PHY being addressed.

4.2.21 Extended PHY Control 1

The following table shows the settings available.

Table 39 • **Extended PHY Control 1, Address 23 (0x17)**

Bit	Name	Access	Description	Default
15:13	Reserved	RO	Reserved.	
12:11	MAC interface selection	R/W	MAC interface mode. 00: Reserved. 10: Reserved. 01: RMII. 11: RGMII. **Note:** These bits may be changed or written prior to a soft-reset, after which it takes effect.	11
10:4	Reserved	RO	Reserved.	
3	Far-end loopback mode	R/W	1: Enabled.	0
2:0	Reserved	RO	Reserved.	

Note: After configuring bits 12:11 of the extended PHY control register set 1, a software reset (register 0, bit 15) must be written to change the device operating mode. On read, these bits only indicate the actual operating mode and not the pending operating mode setting before a software reset has taken place.

4.2.22 Extended PHY Control 2

The second set of extended controls is located in register 24 in the main register space for the device. The following table shows the settings and readouts available.

Table 40 • **Extended PHY Control 2, Address 24 (0x18)**

Bit	Name	Access	Description	Default
15:13	100BASE-TX edge rate control	R/W	Sticky bit. 011: +7 edge rate (slowest). 010: +6 edge rate. 001: +5 edge rate. 000: +4 edge rate. 111: +3 edge rate. 110: +2 edge rate. 101: +1 edge rate. 100: Fastest edge rate.	000
12	PICMG 2.16 reduced power mode	R/W	Sticky bit. 1: Enabled.	0
11:6	Reserved	RO	Reserved.	
5:4	Jumbo packet mode	R/W	Sticky bit. 00: Normal IEEE 1.5 kB packet length. 01: 9 kB jumbo packet length (12 kB with 60 ppm or better reference clock). 10: 12 kB jumbo packet length (16 kB with 70 ppm or better reference clock). 11: Reserved.	00
3:1	Reserved	RO	Reserved.	
0	1000BASE-T connector loopback	R/W	1: Enabled.	0

Note: When bits 5:4 are set to jumbo packet mode, the default maximum packet values are based on 100 ppm driven reference clock to the device. Controlling the ppm offset between the MAC and the PHY as specified in the bit description results in a higher jumbo packet length.

4.2.23 Interrupt Mask

These bits control the device interrupt mask. The following table shows the settings available.

Table 41 • **Interrupt Mask, Address 25 (0x19)**

Bit	Name	Access	Description	Default
15	MDINT interrupt status enable	R/W	Sticky bit. 1: Enabled.	0
14	Speed state change mask	R/W	Sticky bit. 1: Enabled.	0
13	Link state change mask	R/W	Sticky bit. 1: Enabled.	0
12	FDX state change mask	R/W	Sticky bit. 1: Enabled.	0
11	Autonegotiation error mask	R/W	Sticky bit. 1: Enabled.	0
10	Autonegotiation complete mask	R/W	Sticky bit. 1: Enabled.	0
9	Inline-powered device (PoE) detect mask	R/W	Sticky bit. 1: Enabled.	0
8	Symbol error interrupt mask	R/W	Sticky bit. 1: Enabled.	0
7	Fast link failure interrupt mask	R/W	Sticky bit. 1: Enabled.	0
6	Wake-on-LAN event interrupt mask	R/W	Sticky bit. 1: Enabled.	0
5	Extended interrupt mask	R/W	Sticky bit. 1: Enabled.	0

Table 41 • **Interrupt Mask, Address 25 (0x19) *(continued)***

Bit	Name	Access	Description	Default
4	Reserved	R/W	Reserved.	0
3	False carrier interrupt mask	R/W	Sticky bit. 1: Enabled.	0
2	Link speed downshift detect mask	R/W	Sticky bit. 1: Enabled.	0
1	Master/Slave resolution error mask	R/W	Sticky bit. 1: Enabled.	0
0	RX_ER interrupt mask	R/W	Sticky bit. 1: Enabled.	0

Note: When bit 25.15 is set, the MDINT pin is enabled. When enabled, the state of this pin reflects the state of bit 26.15. Clearing this bit only inhibits the MDINT pin from being asserted. Also, before enabling this bit, read register 26 to clear any previously inactive interrupts pending that will cause bit 25.15 to be set.

4.2.24 Interrupt Status

The status of interrupts already written to the device is available for reading from register 26 in the main registers space. The following table shows the expected readouts.

Table 42 • **Interrupt Status, Address 26 (0x1A)**

Bit	Name	Access	Description	Default
15	Interrupt status	RO	Self-clearing bit. 1: Interrupt pending.	0
14	Speed state change status	RO	Self-clearing bit. 1: Interrupt pending.	0
13	Link state change status	RO	Self-clearing bit. 1: Interrupt pending.	0
12	FDX state change status	RO	Self-clearing bit. 1: Interrupt pending.	0
11	Autonegotiation error status	RO	Self-clearing bit. 1: Interrupt pending.	0
10	Autonegotiation complete status	RO	Self-clearing bit. 1: Interrupt pending.	0
9	Inline powered device detect status	RO	Self-clearing bit. 1: Interrupt pending.	0
8	Symbol error status	RO	Self-clearing bit. 1: Interrupt pending.	0
7	Fast link failure detect status	RO	Self-clearing bit. 1: Interrupt pending.	0
6	Wake-on-LAN event status	RO	Self-clearing bit. 1: Interrupt pending.	0
5	Extended interrupt status	RO	Self-clearing bit. 1: Interrupt pending.	0
4	Reserved	RO	Reserved.	
3	False carrier interrupt status	RO	Self-clearing bit. 1: Interrupt pending.	0
2	Link speed downshift detect status	RO	Self-clearing bit. 1: Interrupt pending.	0
1	Master/Slave resolution error status	RO	Self-clearing bit. 1: Interrupt pending.	0
0	RX_ER interrupt status	RO	Self-clearing bit. 1: Interrupt pending.	0

The following information applies to the interrupt status bits:

- All set bits in this register are cleared after being read (self-clearing). If bit 26.15 is set, the cause of the interrupt can be read by reading bits 26.14:0.
- For bits 26.14 and 26.12, bit 0.12 must be set for this interrupt to assert.
- For bit 26.2, bits 4.8:5 must be set for this interrupt to assert.
- For bit 26.0, this interrupt will not occur when RX_ER is used for carrier-extension decoding of a link partner's data transmission.
- If bit 5 is set, register 29E2 must be read to determine the source of the interrupt.

4.2.25 Device Auxiliary Control and Status

Register 28 provides control and status information for several device functions not controlled or monitored by other device registers. The following table shows the settings available and the expected readouts.

Table 43 • **Auxiliary Control and Status, Address 28 (0x1C)**

Bit	Name	Access	Description	Default
15	Autonegotiation complete	RO	Duplicate of bit 1.5 when auto-negotiation is enabled, otherwise this is the current link status.	0
14	Autonegotiation disabled	RO	Inverted duplicate of bit 0.12.	0
13	HP Auto-MDIX crossover indication	RO	1: HP Auto-MDIX crossover performed internally.	0
12	CD pair swap	RO	1: CD pairs are swapped.	0
11	A polarity inversion	RO	1: Polarity swap on pair A.	0
10	B polarity inversion	RO	1: Polarity swap on pair B.	0
9	C polarity inversion	RO	1: Polarity swap on pair C.	0
8	D polarity inversion	RO	1: Polarity swap on pair D.	0
7	ActiPHY link status time-out control [1]	R/W	Sticky bit. Bits 7 and 2 are part of the ActiPHY Link Status time-out control. Bit 7 is the MSB. 00: 2.3 seconds. 01: 3.3 seconds. 10: 4.3 seconds. 11: 5.3 seconds.	0
6	ActiPHY mode enable	R/W	Sticky bit. 1: Enabled.	0
5	FDX status	RO	1: Full-duplex. 0: Half-duplex.	0
4:3	Speed status	RO	00: Speed is 10BASE-T. 01: Speed is 100BASE-TX. 10: Speed is 1000BASE-T. 11: Reserved.	00
2	ActiPHY link status time-out control [0]	R/W	Sticky bit. Bits 7 and 2 are part of the ActiPHY Link Status time-out control. Bit 7 is the MSB. 00: 2.3 seconds. 01: 3.3 seconds. 10: 4.3 seconds. 11: 5.3 seconds.	1
1:0	Media mode status	RO	00: No media selected. 01: Copper media selected. 10: Reserved. 11: Reserved.	00

4.2.26 LED Mode Select

The device LED outputs are controlled using the bits in register 29 of the main register space. The following table shows the information needed to access the functionality of each of the outputs. For more

information about LED modes, see Table 13, page 18. For information about enabling the extended LED mode bits in Register 19E1 bits 13 to 12, see Table 15, page 20.

Table 44 • **LED Mode Select, Address 29 (0x1D)**

Bit	Name	Access	Description	Default
15	Reserved	RO	Reserved.	1
14:8	Reserved	R/W	Reserved.	0000
7:4	LED1 mode select	R/W	Sticky bit. Select from LED modes 0–15.	0010
3:0	LED0 mode select	R/W	Sticky bit. Select from LED modes 0–15.	0001

4.2.27 LED Behavior

The bits in register 30 control and enable you to read the status of the pulse or blink rate of the device LEDs. The following table shows the settings you can write to the register or read from the register.

Table 45 • **LED Behavior, Address 30 (0x1E)**

Bit	Name	Access	Description	Default
15:13	Reserved	RO	Reserved.	
12	LED pulsing enable	R/W	Sticky bit. 0: Normal operation. 1: LEDs pulse with a 5 kHz, programmable duty cycle when active.	0
11:10	LED blink/pulse-stretch rate	R/W	Sticky bit. 00: 2.5 Hz blink rate/400 ms pulse-stretch. 01: 5 Hz blink rate/200 ms pulse-stretch. 10: 10 Hz blink rate/100 ms pulse-stretch. 11: 20 Hz blink rate/50 ms pulse-stretch. The blink rate selection sets the rate used for all LED pins.	01
9:7	Reserved	RO	Reserved.	
6	LED1 pulse-stretch/blink select	R/W	Sticky bit. 1: Pulse-stretch. 0: Blink.	0
5	LED0 pulse-stretch/blink select	R/W	Sticky bit. 1: Pulse-stretch. 0: Blink.	0
4:2	Reserved	RO	Reserved.	
1	LED1 combine feature disable	R/W	Sticky bit. 0: Combine enabled (link/activity, duplex/collision). 1: Disable combination (link only, duplex only).	0
0	LED0 combine feature disable	R/W	Sticky bit. 0: Combine enabled (link/activity, duplex/collision). 1: Disable combination (link only, duplex only).	0

Note: Bits 30.11:10 are active only in port 0 and affect the behavior of LEDs for all the ports.

4.2.28 Extended Page Access

To provide functionality beyond the IEEE 802.3-specified registers and main device registers, an extended set of registers provide an additional 15 register spaces.

The register at address 31 controls access to the extended registers. Accessing the GPIO page register space is similar to accessing the extended page registers. The following table shows the settings available.

Table 46 • **Extended/GPIO Register Page Access, Address 31 (0x1F)**

Bit	Name	Access	Description	Default
15:0	Extended/GPIO page register access	R/W	0x0000: Register 16–30 accesses main register space. Writing 0x0000 to register 31 restores the main register access. 0x0001: Registers 16–30 access extended register space 1. 0x0002: Registers 16–30 access extended register space 2. 0x0010: Registers 0–30 access GPIO register space.	0x0000

4.3 Extended Page 1 Registers

To access the extended page 1 registers (17E1–30E1), enable extended register access by writing 0x0001 to register 31. Writing 0x0000 to register 31 restores the main register access.

When extended page 1 register access is enabled, reads and writes to registers 16–30 affect the extended registers 17E1–30E1 instead of those same registers in the IEEE-specified register space. Registers 0–15 are not affected by the state of the extended page register access.

Table 47 • **Extended Registers Page 1 Space**

Address	Name
16E1	Reserved
17E1	Reserved
18E1	Cu Media CRC good counter
19E1	Extended mode control
20E1	Extended PHY control 3 (ActiPHY)
21E1–22E1	Reserved
23E1	Extended PHY control 4 (PoE and CRC error counter)
24E1	VeriPHY 1
25E1	VeriPHY 2
26E1	VeriPHY 3
27E1–28E1	Reserved
29E1	Ethernet packet generator (EPG) 1
30E1	EPG 2

4.3.1 Cu Media CRC Good Counter

Register 18E1 makes it possible to read the contents of the CRC good counter for packets that are received on the Cu media interface: the number of CRC routines that have executed successfully. The following table shows the expected readouts.

Table 48 • **Cu Media CRC Good Counter, Address 18E1 (0x12)**

Bit	Name	Access	Description	Default
15	Packet since last read	RO	Self-clearing bit. 1: Packet received since last read.	0
14	Reserved	RO	Reserved.	

Table 48 • **Cu Media CRC Good Counter, Address 18E1 (0x12) *(continued)***

Bit	Name	Access	Description	Default
13:0	Cu Media CRC good counter contents	RO	Self-clearing bit. Counter containing the number of packets with valid CRCs modulo 10,000; this counter does not saturate and will roll over to zero on the next good packet received after 9,999.	0x000

4.3.2 Extended Mode Control

Register 19E1 controls the extended LED and other chip modes. The following table shows the settings available.

Table 49 • **Extended Mode Control, Address 19E1 (0x13)**

Bit	Name	Access	Description	Default
15:14	Reserved	R/W	Reserved.	0
13	LED1 Extended Mode	R/W	1: See Basic Serial LED Mode, page 19.	0
12	LED0 Extended Mode	R/W	1: See Basic Serial LED Mode, page 19.	0
11	LED Reset Blink Suppress	R/W	1: Blink LEDs after Software reset is de-asserted. 0: Suppress LED blink after Software reset is de-asserted.	0
10:4	Reserved	RO	Reserved.	
3:2	Force MDI crossover	R/W	00: Normal HP Auto-MDIX operation. 01: Reserved. 10: Copper media forced to MDI. 11: Copper media forced MDI-X.	00
1	Reserved	RO	Reserved.	
0	Reserved	R/W	Reserved.	0

4.3.3 ActiPHY Control

Register 20E1 controls the device ActiPHY sleep timer, its wake-up timer, and its link speed downshifting feature. The following table shows the settings available.

Table 50 • **Extended PHY Control 3, Address 20E1 (0x14)**

Bit	Name	Access	Description	Default
15	Disable carrier extension	R/W	1: Disable carrier extension in 1000BASE-T copper links.	1
14:13	ActiPHY sleep timer	R/W	Sticky bit. 00: 1 second. 01: 2 seconds. 10: 3 seconds. 11: 4 seconds.	01
12:11	ActiPHY wake-up timer	R/W	Sticky bit. 00: 160 ms. 01: 400 ms. 10: 800 ms. 11: 2 seconds.	00

Table 50 • **Extended PHY Control 3, Address 20E1 (0x14) *(continued)***

Bit	Name	Access	Description	Default
10	Slow MDC	R/W	Sticky bit. 1: Indicates that MDC runs at less than 1 MHz (use of this bit is optional and indicated when MDC runs at less than 1 MHz).	0
9:8	Reserved	RO	Reserved.	
7:6	Media mode status	RO	00: No media selected. 01: Copper media selected. 10: Reserved. 11: Reserved.	00
5	Enable 10BASE-T no preamble mode	R/W	Sticky bit. 1: 10BASE-T will assert RX_DV indication when data is presented to the receiver even without a preamble preceding it.	0
4	Enable link speed autodownshift feature	R/W	Sticky bit. 1: Enable auto link speed downshift from 1000BASE-T.	0
3:2	Link speed auto downshift control	R/W	Sticky bit. 00: Downshift after 2 failed 1000BASE-T auto-negotiation attempts. 01: Downshift after 3 failed 1000BASE-T auto-negotiation attempts. 10: Downshift after 4 failed 1000BASE-T auto-negotiation attempts. 11: Downshift after 5 failed 1000BASE-T auto-negotiation attempts.	01
1	Link speed auto downshift status	R/W	0: No downshift. 1: Downshift is required or has occurred.	1
0	Reserved	RO	Reserved.	

4.3.4 PoE and Miscellaneous Functionality

The register at address 23E1 controls various aspects of inline-powering and the CRC error counter in the VSC8531 device.

Table 51 • **Extended PHY Control 4, Address 23E1 (0x17)**

Bit	Name	Access	Description	Default
15:11	PHY address	RO	Internal PHY address: 0–31.	
10	Inline powered device detection	R/W	Sticky bit. 1: Enabled.	0
9:8	Inline powered device detection status	RO	Only valid when bit 10 is set. 00: Searching for devices. 01: Device found; requires inline-power. 10: Device found; does not require inline-power. 11: Reserved.	00
7:0	Cu Media CRC error counter	RO	Self-clearing bit.	

4.3.5 VeriPHY Control 1

Register 24E1 in the extended register space provides control over the device VeriPHY diagnostics features. There are three separate VeriPHY control registers. The following table shows the settings available and describes the expected readouts.

Table 52 • **VeriPHY Control Register 1, Address 24E1 (0x18)**

Bit	Name	Access	Description	Default
15	VeriPHY trigger	R/W	Self-clearing bit. 1: Triggers the VeriPHY algorithm and clears when VeriPHY has completed. Settings in registers 24E–26E become valid after this bit clears.	0
14	VeriPHY valid	RO	1: VeriPHY results in registers 24E–26E are valid.	0
13:8	Pair A (1, 2) distance	RO	Loop length or distance to anomaly for pair A (1, 2).	0x00
7:6	Reserved	RO	Reserved.	
5:0	Pair B (3, 6) distance	RO	Loop length or distance to anomaly for pair B (3, 6).	0x00

Note: The resolution of the 6-bit length field is 3 meters.

4.3.6 VeriPHY Control 2

The register at address 25E1 consists of the second of the three device registers that provide control over VeriPHY diagnostics features. The following table shows the expected readouts.

Table 53 • **VeriPHY Control Register 2, Address 25E1 (0x19)**

Bit	Name	Access	Description	Default
15:14	Reserved	RO	Reserved	
13:8	Pair C (4, 5) distance	RO	Loop length or distance to anomaly for pair C (4, 5)	0x00
7:6	Reserved	RO	Reserved	
5:0	Pair D (7, 8) distance	RO	Loop length or distance to anomaly for pair D (7, 8)	0x00

Note: The resolution of the 6-bit length field is 3 meters.

4.3.7 VeriPHY Control 3

The register at address 26E1 consists of the third of the three device registers that provide control over VeriPHY diagnostics features. Specifically, this register provides information about the termination status (fault condition) for all link partner pairs. The following table shows the expected readouts.

Table 54 • **VeriPHY Control Register 3, Address 26E1 (0x1A)**

Bit	Name	Access	Description	Default
15:12	Pair A (1, 2) termination status	RO	Termination fault for pair A (1, 2)	0x00
11:8	Pair B (3, 6) termination status	RO	Termination fault for pair B (3, 4)	0x00
7:4	Pair C (4, 5) termination status	RO	Termination fault for pair C (4, 5)	0x00
3:0	Pair D (7, 8) termination status	RO	Termination fault for pair D (7, 8)	0x00

The following table shows the meanings for the various fault codes.

Table 55 • **VeriPHY Control Register 3 Fault Codes**

Code	Denotes
0000	Correctly terminated pair
0001	Open pair
0010	Shorted pair
0100	Abnormal termination
1000	Cross-pair short to pair A
1001	Cross-pair short to pair B
1010	Cross-pair short to pair C
1011	Cross-pair short to pair D
1100	Abnormal cross-pair coupling with pair A
1101	Abnormal cross-pair coupling with pair B
1110	Abnormal cross-pair coupling with pair C
1111	Abnormal cross-pair coupling with pair D

4.3.8 Ethernet Packet Generator (EPG) Control 1

The EPG control register provides access to and control of various aspects of the EPG testing feature. There are two separate EPG control registers. The following table shows the settings available in the first register.

Table 56 • **EPG Control Register 1, Address 29E1 (0x1D)**

Bit	Name	Access	Description	Default
15	EPG enable[1]	R/W	1: Enable EPG.	0
14	EPG run or stop	R/W	1: Run EPG.	0
13	Transmission duration	R/W	1: Continuous (sends in 10,000-packet increments). 0: Send 30,000,000 packets and stop.	0
12:11	Packet length	R/W	00: 125 bytes. 01: 64 bytes. 10: 1518 bytes. 11: 10,000 bytes (jumbo packet).	0
10	Interpacket gap	R/W	1: 8,192 ns. 0: 96 ns.	0
9:6	Destination address	R/W	Lowest nibble of the 6-byte destination address.	0001
5:2	Source address	R/W	Lowest nibble of the 6-byte destination address.	0000
1	Payload type	R/W	1: Randomly generated payload pattern. 0: Fixed based on payload pattern.	0
0	Bad frame check sequence (FCS) generation	R/W	1: Generate packets with bad FCS. 0: Generate packets with good FCS.	0

1. To end forced transmission of EEE LPIs from the PHY, clear the force EEE LPI bit (17E2.4) first before clearing the EPG enable bit (29E1.15).

The following information applies to the EPG control number 1:

- Do not run the EPG when the VSC8531 device is connected to a live network.

- Bit 29E1.13 (continuous EPG mode control): when enabled, this mode causes the device to send continuous packets. When disabled, the device continues to send packets only until it reaches the next 10,000-packet increment mark. It then ceases to send packets.
- The 6-byte destination address in bits 9:6 is assigned one of 16 addresses in the range of 0xFF FF FF FF FF F0 through 0xFF FF FF FF FF FF.
- The 6-byte source address in bits 5:2 is assigned one of 16 addresses in the range of 0xFF FF FF FF FF F0 through 0xFF FF FF FF FF FF.
- If any of bits 13:0 are changed while the EPG is running (bit 14 is set to 1), bit 14 must be cleared and then set back to 1 for the change to take effect and to restart the EPG.

4.3.9 Ethernet Packet Generator Control 2

Register 30E1 consists of the second set of bits that provide access to and control over the various aspects of the EPG testing feature. The following table shows the settings available.

Table 57 • **EPG Control Register 2, Address 30E1 (0x1E)**

Bit	Name	Access	Description	Default
15:0	EPG packet payload	R/W	Data pattern repeated in the payload of packets generated by the EPG	0x00

Note: If any of bits 15:0 in this register are changed while the EPG is running (bit 14 of register 29E1 is set to 1), that bit (29E1.14) must first be cleared and then set back to 1 for the change to take effect and to restart the EPG.

4.4 Extended Page 2 Registers

To access the extended page 2 registers (16E2–30E2), enable extended register access by writing 0x0002 to register 31. For more information, see Table 46, page 41.

When extended page 2 register access is enabled, reads and writes to registers 16–30 affect the extended registers 16E2–30E2 instead of those same registers in the IEEE-specified register space. Registers 0–15 are not affected by the state of the extended page register access.

Writing 0x0000 to register 31 restores the main register access.

The following table lists the addresses and register names in the extended register page 2 space. These registers are accessible only when the device register 31 is set to 0x0002.

Table 58 • **Extended Registers Page 2 Space**

Address	Name
16E2	Cu PMD Transmit Control
17E2	EEE Control
18E2	Reserved
19E2	Reserved
20E2	RGMII Control
21E2	Wake-on-LAN MAC Address [15:0]
22E2	Wake-on-LAN MAC Address [31:16]
23E2	Wake-on-LAN MAC Address [47:32]
24E2	Secure-On Password [15:0]
25E2	Secure-On Password [31:16]
26E2	Secure-On Password [47:32]
27E2	Wake-on-LAN and MDINT Control
28E2	Extended Interrupt Mask

Table 58 • **Extended Registers Page 2 Space *(continued)***

Address	Name
29E2	Extended Interrupt Status
30E2	Ring Resiliency Control

4.4.1 Cu PMD Transmit Control

The register at address 16E2 consists of the bits that provide control over the amplitude settings for the transmit side Cu PMD interface. These bits provide the ability to make small adjustments in the signal amplitude to compensate for minor variations in the magnetics from different vendors. Extreme caution must be exercised when changing these settings from the default values as they have a direct impact on the signal quality. Changing these settings also affects the linearity and harmonic distortion of the transmitted signals. For help with changing these values, contact your Microsemi representative.

Table 59 • **Cu PMD Transmit Control, Address 16E2 (0x10)**

Bit	Name	Access	Description	Default
15:12	1000BASE-T signal amplitude trim[1]	R/W	Sticky bit. 1000BASE-T signal amplitude 0000: 1.8% 0001: 2.7% 0010: 3.6% 0011: 4.5% 0100: 5.4% 0101: 6.3% 0110: 7.2% 0111: 8.1% 1000: -8% 1001: –6.2% 1010: –4.4% 1011: –2.7% 1100: –1.8% 1101: –0.9% 1110: 0% 1111: 0.9%	0000
11:8	100BASE-TX signal amplitude trim[2]	R/W	Sticky bit. 100BASE-TX signal amplitude 0000: 1.8% 0001: 2.7% 0010: 3.6% 0011: 4.5% 0100: 5.4% 0101: 6.3% 0110: 7.2% 0111 8.1% 1000: –8% 1001: –6.2% 1010: –4.4% 1011: –2.7% 1100: -1.8% 1101: –0.9% 1110: 0% 1111: 0.9%	0010

Table 59 • **Cu PMD Transmit Control, Address 16E2 (0x10) *(continued)***

Bit	Name	Access	Description	Default
7:4	10BASE-T signal amplitude trim[3]	R/W	Sticky bit. 10BASE-T signal amplitude 0000: 0% 0001: 0.9% 0010: 1.8% 0011: 2.7% 0100: 3.6% 0101: 4.5% 0110: 5.4% 0111: 6.1% 1000: –7.2% 1001: –6.3% 1010: –5.4% 1011: –4.5% 1100: –3.6% 1101: –2.7% 1110: –1.8% 1111: –0.9%	1000
3:0	10BASE-Te signal amplitude trim	R/W	Sticky bit. 10BASE-Te signal amplitude 0000: 0% 0001: 0.65% 0010: 1.3% 0011: 1.95% 0100: 2.6% 0101: 3.25% 0110: 3.9% 0111: 4.55% 1000: –5.2% 1001: –4.55% 1010: –3.9% 1011: –3.25% 1100: –2.6% 1101: –1.95% 1110: –1.3% 1111: –0.65%	1110

1. Changes to 1000BASE-T amplitude may result in unpredictable side effects.
2. Adjust 100BASE-TX to specific magnetics.
3. Amplitude is limited by V_{CC} (2.5 V).

4.4.2 EEE Control

The register at address 17E2 consists of the bits that provide additional control over the chip behavior in energy-efficient Ethernet (IEEE 802.3az-2010) mode for debug and to allow interoperation with legacy MACs that do not support IEEE 802.3az-2010.

Table 60 • **EEE Control, Address 17E2 (0x11)**

Bit	Name	Access	Description	Default
15	Enable 10BASE-Te	R/W	Sticky bit. Enable energy efficient (IEEE 802.3az-2010) 10BASE-Te operating mode.	0
14:12	Reserved	RO	Reserved.	

Table 60 • **EEE Control, Address 17E2 (0x11) *(continued)***

Bit	Name	Access	Description	Default
11:10	Invert LED polarity	R/W	Sticky bit. Invert polarity of LED signals. Default is to drive an active low signal on the LED pins. For more information, see Extended LED Modes, page 20.	00
9	Reserved	RO	Reserved.	
8	Link status	RO	1: Link is up.	0
7	1000BASE-T EEE enable	RO	1: EEE is enabled for 1000BASE-T.	0
6	100BASE-TX EEE enable	RO	1: EEE is enabled for 100BASE-TX.	0
5	Enable 1000BASE-T force mode	R/W	Sticky bit. 1: Enable 1000BASE-T force mode to allow PHY to link-up in 1000BASE-T mode without forcing master/slave when register 0, bits 6 and 13 are set to 2'b10.	0
4	Force transmit LPI[1]	R/W	Sticky bit. 1: Enable the EPG to transmit LPI on the MDI instead of normal idles when receiving normal idles from the MAC. 0: Transmit idles being received from the MAC.	0
3	Inhibit 100BASE-TX transmit EEE LPI	R/W	Sticky bit. 1: Disable transmission of EEE LPI on transmit path MDI in 100BASE-TX mode when receiving LPI from MAC.	0
2	Inhibit 100BASE-TX receive EEE LPI	R/W	Sticky bit. 1: Disable transmission of EEE LPI on receive path MAC interface in 100BASE-TX mode when receiving LPI from the MDI.	0
1	Inhibit 1000BASE-T transmit EEE LPI	R/W	Sticky bit. 1: Disable transmission of EEE LPI on transmit path MDI in 1000BASE-T mode when receiving LPI from MAC.	0
0	Inhibit 1000BASE-T receive EEE LPI	R/W	Sticky bit. 1: Disable transmission of EEE LPI on receive path MAC interface in 1000BASE-T mode when receiving LPI from the MDI.	0

1. To end forced transmission of EEE LPIs from the PHY, clear this bit first before clearing the EPG enable bit (29E1.15).

4.4.3 RGMII Control

The following table shows the register settings for the RGMII controls at address 20E2.

Table 61 • **RGMII Control, Address 20E2 (0x14)**

Bit	Name	Access	Description	Default
15	FLF2 enable	R/W	Fast Link Failure 2 indication enable. 0: Disabled. 1: Enabled.	0

Table 61 • **RGMII Control, Address 20E2 (0x14) *(continued)***

Bit	Name	Access	Description	Default
14:12	Reserved	RO	Reserved.	
11	RX_CLK output disable[1]	R/W	0: Normal RX_CLK behavior. 1: RXCLK driven low.	0
10:8	Reserved	RO	Reserved.	
7	RGMII RXD bit reversal	R/W	Sticky bit. When set to 1, makes the following reversed mapping internally: **RGMII Mode** RXD3 maps to RXD0 RXD2 maps to RXD1 RXD1 maps to RXD2 RXD0 maps to RXD3	0
6:4	RX_CLK delay	R/W	Sticky bit. 000: 0.2 ns delay. 001: 0.8 ns delay. 010: 1.1 ns delay. 011: 1.7 ns delay. 100: 2.0 ns delay. 101: 2.3 ns delay. 110: 2.6 ns delay. 111: 3.4 ns delay.	000
3	RGMII TXD bit reversal	R/W	Sticky bit. When set to 1, makes the following reversed mapping internally: **RGMII Mode** TXD3 maps to TXD0 TXD2 maps to TXD1 TXD1 maps to TXD2 TXD0 maps to TXD3	0
2:0	TX_CLK delay	R/W	Sticky bit. 000: 0.2 ns delay. 001: 0.8 ns delay. 010: 1.1 ns delay. 011: 1.7 ns delay. 100: 2.0 ns delay. 101: 2.3 ns delay. 110: 2.6 ns delay. 111: 3.4 ns delay.	000

1. After port power down is performed (by setting register 0, bit 11), the RX_CLK output may be disabled in order to further reduce power dissipation.

4.4.4 Wake-on-LAN MAC Address [15:0]

The following table shows the register settings for the Wake-on-LAN MAC address at 21E2.

Table 62 • **Wake-on-LAN MAC Address, 21E2 (0x15)**

Bit	Name	Access	Description	Default
15:0	WoL MAC address [15:0]	R/W	Sticky bit. WoL MAC address lower two bytes.	00

4.4.5 Wake-on-LAN MAC Address [31:16]

The following table shows the register settings for the Wake-on-LAN MAC address at 22E2.

Table 63 • **Wake-on-LAN MAC Address, 22E2 (0x16)**

Bit	Name	Access	Description	Default
15:0	WoL MAC address [31:16]	R/W	Sticky bit. WoL MAC address middle two bytes.	00

4.4.6 Wake-on-LAN MAC Address [47:32]

The following table shows the register settings for the Wake-on-LAN MAC address at 23E2.

Table 64 • **Wake-on-LAN MAC Address, 23E2 (0x17)**

Bit	Name	Access	Description	Default
15:0	WoL MAC address [47:32]	R/W	Sticky bit. WoL MAC address upper two bytes.	00

4.4.7 Secure-On Password [15:0]

The following table shows the register settings for the Secure-On password used for WoL at 24E2.

Table 65 • **Secure-On Password, 24E2 (0x18)**

Bit	Name	Access	Description	Default
15:0	Secure-On password [15:0]	R/W	Sticky bit. Secure-On password for WoL lower two bytes.	00

4.4.8 Secure-On Password [31:16]

The following table shows the register settings for the Secure-On password used for WoL at 25E2.

Table 66 • **Secure-On Password, 25E2 (0x19)**

Bit	Name	Access	Description	Default
15:0	Secure-On password [31:16]	R/W	Sticky bit. Secure-On password for WoL middle two bytes.	00

4.4.9 Secure-On Password [47:32]

The following table shows the register settings for the Secure-On password used for WoL at 26E2.

Table 67 • **Secure-On Password, 26E2 (0x1A)**

Bit	Name	Access	Description	Default
15:0	Secure-On password [47:32]	R/W	Sticky bit. Secure-On password for WoL upper two bytes.	00

4.4.10 Wake-on-LAN and MAC Interface Control

The following table shows the register settings for the Wake-on-LAN and MAC interface control at address 27E2.

Table 68 • **WoL and MAC Interface Control, Address 27E2 (0x1B)**

Bit	Name	Access	Description	Default
15	Secure-On enable	R/W	Sticky bit. 0: Disabled. 1: Enabled.	0
14	Secure-On password length	R/W	Sticky bit. 0: 6 byte password. 1: 4 byte password.	0
13:12	Reserved	RO	Reserved.	
11:8	Address repetition count in Magic packet	R/W	Sticky bit. Count value: 0000: 1 0001: 2 0010: 3 0011: 4 0100: 5 0101: 6 0110: 7 0111: 8 1000: 9 1001: 10 1010: 11 1011: 12 1100: 13 1101: 14 1110: 15 1111: 16	1111
7:5	Pad edge rate control	R/W	Sticky bit. MAC interface edge rate control. 000: Slowest edge rate 001: +1 pad edge rate 010: +2 pad edge rate 011: +3 pad edge rate 100: +4 pad edge rate 101: +5 pad edge rate 110: +6 pad edge rate 111: +7 pad edge rate (fastest)	111
4	RMII CLKOUT enable	R/W	0: RMII CLKOUT disabled. 1: RMII CLKOUT enabled.	1
3:1	Reserved	RO	Reserved.	
0	MDINT CMOS drive	R/W	0: Disabled. 1: Enabled.	0

4.4.11 Extended Interrupt Mask

The following table shows the register settings for the extended interrupt mask at address 28E2.

Table 69 • **Extended Interrupt Mask, Address 28E2 (0x1C)**

Bit	Name	Access	Description	Default
15:14	Reserved interrupt mask	R/W	Reserved.	0
13	Rx FIFO overflow/underflow interrupt mask	R/W	Sticky bit. 1: Enabled.	0
12	Tx FIFO overflow/underflow interrupt mask	R/W	Sticky bit. 1: Enabled.	0
11:5	Reserved interrupt mask	R/W	Reserved.	0
4	RR switchover complete interrupt mask	R/W	Sticky bit. 1: Enabled.	0
3	EEE link fail interrupt mask	R/W	Sticky bit. 1: Enabled.	0
2	EEE Rx TQ timer interrupt mask	R/W	Sticky bit. 1: Enabled.	0
1	EEE wait quiet/Rx TS timer interrupt mask	R/W	Sticky bit. 1: Enabled.	0
0	EEE wake error interrupt mask	R/W	Sticky bit. 1: Enabled.	0

4.4.12 Extended Interrupt Status

The following table shows the register settings for the extended interrupt status at address 29E2.

Table 70 • **Extended Interrupt Status, Address 29E2 (0x1D)**

Bit	Name	Access	Description	Default
15:14	Reserved	RO	Reserved.	
13	Rx FIFO overflow/underflow interrupt status	RO	Self-clearing bit. 1: Interrupt pending.	0
12	Tx FIFO overflow/underflow interrupt status	RO	Self-clearing bit. 1: Interrupt pending.	0
11:5	Reserved	RO	Reserved.	
4	RR switchover complete interrupt status	RO	Self-clearing bit. 1: Interrupt pending.	0
3	EEE link fail interrupt status	RO	Self-clearing bit. 1: Interrupt pending.	0
2	EEE Rx TQ timer interrupt status	RO	Self-clearing bit. 1: Interrupt pending.	0
1	EEE wait quiet/Rx TS timer interrupt status	RO	Self-clearing bit. 1: Interrupt pending.	0
0	EEE wake error interrupt mask	RO	Self-clearing bit. 1: Interrupt pending.	0

4.4.13 Ring Resiliency Control

The following table shows the register settings for the ring resiliency controls at address 30E2.

Table 71 • **Ring Resiliency, Address 30E2 (0x1E)**

Bit	Name	Access	Description	Default
15	Ring resiliency startup enable (master TR enable)	R/W	Sticky.	0

Table 71 • **Ring Resiliency, Address 30E2 (0x1E) *(continued)***

Bit	Name	Access	Description	Default
14	Advertise ring resiliency	R/W	Sticky.	0
13	LP ring resiliency advertisement	RO		0
12	Force ring resiliency enable (override autoneg)	R/W	Sticky.	0
11:6	Reserved	RO	Reserved.	
5:4	Ring resiliency status	RO	Ring resiliency status. 00: Timing slave[1] 10: Timing slave becoming master 11: Timing master[1] 01: Timing master becoming slave	00
3:1	Reserved	RO	Reserved.	
0	Start switchover (only when not in progress)	R/W	Self clearing. 1: Initiate timing Master/Slave switchover.	0

1. Reflects autoneg master/slave at initial link-up.

4.5 General Purpose Registers

Accessing the general purpose register space is similar to accessing the extended page registers. Set register 31 to 0x0010. This sets all 32 registers to the general purpose register space.

To restore main register page access, write 0x0000 to register 31. All general purpose register bits are super-sticky

4.5.1 Reserved General Purpose Address Space

The bits in registers 0G to 12G, 15G to 18G, and 30G of the general purpose register space are reserved.

4.5.2 CLKOUT Control

The CLKOUT control register configures the functionality of the CLKOUT output pin.

Table 72 • **CLKOUT Control, Address 13G (0x0D)**

Bit	Name	Access	Description	Default
15	CLKOUT enable	R/W	1: CLKOUT enabled. 0: CLKOUT disabled.	0
14:13	CLKOUT frequency select	R/W	00: 25 MHz. 01: 50 MHz. 10: 125 MHz. 11: Reserved.	00
12:0	Reserved	R/W	Reserved.	00

4.5.3 GPIO Control 2

The GPIO control 2 register configures the functionality of the COMA_MODE and LED pins.

Table 73 • **GPIO Control 2, Address 14G (0x0E)**

Bit	Name	Access	Description	Default
15:10	Reserved	R/W	Reserved.	00

Table 73 • **GPIO Control 2, Address 14G (0x0E) *(continued)***

Bit	Name	Access	Description	Default
9	Tri-state enable for LEDs	R/W	1: Tri-state LED output signals instead of driving them high. This allows the signals to be pulled above V_{DDIO} using an external pull-up resistor. 0: Drive LED bus output signals to high and low values.	1
8:0	Reserved	RO	Reserved.	

4.5.4 Enhanced LED Control

Register 25G in the extended register space controls the advanced functionality of the parallel LED signals.

Table 74 • **Enhanced LED Control, Address 25G (0x19)**

Bit	Name	Access	Description	Default
15:8	LED pulsing duty cycle control	R/W	Programmable control for LED pulsing duty cycle when bit 30.12 is set to 1. Valid settings are between 0 and 198. A setting of 0 corresponds to a 0.5% duty cycle and 198 corresponds to a 99.5% duty cycle. Intermediate values change the duty cycle in 0.5% increments.	00
7:0	Reserved	RO	Reserved.	

4.6 Clause 45 Registers to Support Energy-Efficient Ethernet and 802.3bf

This section describes the Clause 45 registers that are required to support energy-efficient Ethernet. Access to these registers is through the IEEE standard registers 13 and 14 (MMD access control and MMD data or address registers).

The following table lists the addresses and register names in the Clause 45 register page space. When the link is down, 0 is the value returned for the x.180x addresses.

Table 75 • **Clause 45 Registers Page Space**

Address	Name
1.1	PMA/PMD status 1
3.1	PCS status 1
3.20	EEE capability
3.22	EEE wake error counter
4.1800	TimeSync PHY XS capability
4.1801	Tx maximum delay through xMII, including FIFO variations
4.1803	Tx minimum delay through xMII, including FIFO variations
4.1805	Rx maximum delay through xMII, including FIFO variations
4.1807	Rx minimum delay through xMII, including FIFO variations
7.60	EEE advertisement
7.61	EEE link partner advertisement

4.6.1 PMA/PMD Status 1

The following table shows the bit descriptions for the PMA/PMD Status 1 register.

Table 76 • **PMA/PMD Status 1**

Bit	Name	Access	Description
15:3	Reserved	RO	Reserved.
2	PMD/PMA receive link status	RO/LL	1: PMA/PMD receive link up. 0: PMA/PMD receive link down.
1:0	Reserved	RO	Reserved.

4.6.2 PCS Status 1

The bits in the PCS Status 1 register provide a status of the EEE operation from the PCS for the link that is currently active.

Table 77 • **PCS Status 1, Address 3.1**

Bit	Name	Access	Description
15:12	Reserved	RO	Reserved.
11	Tx LPI received	RO/LH	1: Tx PCS has received LPI. 0: LPI not received.
10	Rx LPI received	RO/LH	1: Rx PCS has received LPI. 0: LPI not received.
9	Tx LPI indication	RO	1: Tx PCS is currently receiving LPI. 0: PCS is not currently receiving LPI.
8	Rx LPI indication	RO	1: Rx PCS is currently receiving LPI. 0: PCS is not currently receiving LPI.
7:3	Reserved	RO	Reserved.
2	PCS receive link status	RO/LL	1: PCS receive link up. 0: PCS receive link down.
1:0	Reserved	RO	Reserved.

4.6.3 EEE Capability

This register is used to indicate the capability of the PCS to support EEE functions for each PHY type. The following table shows the bit assignments for the EEE capability register.

Table 78 • **EEE Capability, Address 3.20**

Bit	Name	Access	Description
15:3	Reserved	RO	Reserved.
2	1000BASE-T EEE	RO	1: EEE is supported for 1000BASE-T. 0: EEE is not supported for 1000BASE-T.
1	100BASE-TX EEE	RO	1: EEE is supported for 100BASE-TX. 0: EEE is not supported for 100BASE-TX.
0	Reserved	RO	Reserved.

4.6.4 EEE Wake Error Counter

This register is used by PHY types that support EEE to count wake time faults where the PHY fails to complete its normal wake sequence within the time required for the specific PHY type. The definition of

the fault event to be counted is defined for each PHY and can occur during a refresh or a wakeup as defined by the PHY. This 16-bit counter is reset to all zeros when the EEE wake error counter is read or when the PHY undergoes hardware or software reset.

Table 79 • **EEE Wake Error Counter, Address 3.22**

Bit	Name	Access	Description
15:0	Wake error counter	RO	Count of wake time faults for a PHY

4.6.5 EEE Advertisement

This register defines the EEE advertisement that is sent in the unformatted next page following a EEE technology message code. The following table shows the bit assignments for the EEE advertisement register.

Table 80 • **EEE Advertisement, Address 7.60**

Bit	Name	Access	Description	Default
15:3	Reserved	RO	Reserved.	
2	1000BASE-T EEE	R/W	1: Advertise that the 1000BASE-T has EEE capability. 0: Do not advertise that the 1000BASE-T has EEE capability.	0
1	100BASE-TX EEE	R/W	1: Advertise that the 100BASE-TX has EEE capability. 0: Do not advertise that the 100BASE-TX has EEE capability.	0
0	Reserved	RO	Reserved.	

4.6.6 EEE Link Partner Advertisement

All the bits in the EEE LP advertisement register are read only. A write to the EEE LP advertisement register has no effect. When the AN process has been completed, this register will reflect the contents of the link partner's EEE advertisement register. The following table shows the bit assignments for the EEE advertisement register.

Table 81 • **EEE Advertisement, Address 7.61**

Bit	Name	Access	Description
15:3	Reserved	RO	Reserved.
2	1000BASE-T EEE	RO	1: Link partner is advertising EEE capability for 1000BASE-T. 0: Link partner is not advertising EEE capability for 1000BASE-T.
1	100BASE-TX EEE	RO	1: Link partner is advertising EEE capability for 100BASE-TX. 0: Link partner is not advertising EEE capability for 100BASE-TX.
0	Reserved	RO	Reserved.

The following table shows the bit assignments for the 802.3bf registers. When the link is down, 0 is the value returned. cl45reg1_1801 would be device address of 1 and register address of 1801.

Table 82 • **802.3bf Registers**

Register	Name	Function
1.1800	PMA/PMD Time Sync capable	1: PMA/PMD Time Sync Tx capable. 0: PMA/PMD Time Sync Rx capable.
1.1801	cl45reg1_1801_val[15:0]	Tx maximum delay through PHY (PMA/PMD/PCS).
1.1803	cl45reg1_1803_val[15:0]	Tx minimum delay through PHY (PMA/PMD/PCS).

Table 82 • **802.3bf Registers *(continued)***

Register	Name	Function
1.1805	cl45reg1_1805_val[15:0]	Rx maximum delay through PHY (PMA/PMD/PCS).
1.1807	cl45reg1_1807_val[15:0]	Rx minimum delay through PHY (PMA/PMD/PCS).

For information about PHY latency specifications between the media interface and the MAC interface, see PHY Latency Specifications, page 68.

5 Electrical Specifications

This section provides the DC characteristics, AC characteristics, recommended operating conditions, and stress ratings for the VSC8531 device.

5.1 DC Characteristics

This section contains the DC specifications for the VSC8531 device.

5.1.1 VDDMAC, VDDIO, and VDDMDIO (2.5 V)

The following table shows the DC specifications for the pins referenced to VDDMAC, VDDIO, and VDDMDIO when it is set to 2.5 V. The specifications listed in the following table are valid only when VDD1 = 1.0 V, VDD1A = 1.0 V, and VDD25A = 2.5 V.

Table 83 • **VDDMAC, VDDIO, and VDDMDIO (2.5 V) DC Characteristics**

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
Output high voltage	V_{OH}	2.0			V	I_{OH} = –1.0 mA
Output low voltage	V_{OL}			0.4	V	I_{OL} = 1.0 mA
Input high voltage	V_{IH}	1.85		3.6	V	
Input high voltage	V_{IH}	1.85		3.1	V	SMI pins (MDC, MDIO)
Input high voltage	V_{IH}	1.85		2.75	V	VDDMAC-referenced pins
Input low voltage	V_{IL}	–0.3		0.7	V	
Input leakage current	I_{ILEAK}	–85		85	µA	Internal resistor included
Output leakage current	I_{OLEAK}	–85		85	µA	Internal resistor included

5.1.2 VDDMAC, VDDIO, and VDDMDIO (3.3 V)

The following table shows the DC specifications for the pins referenced to VDDMAC, VDDIO, and VDDMDIO when it is set to 3.3 V. The specifications listed in the following table are valid only when VDD1 = 1.0 V, VDD1A = 1.0 V, and VDD25A = 2.5 V.

Table 84 • **VDDMAC, VDDIO, and VDDMDIO (3.3 V) DC Characteristics**

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
Output high voltage	V_{OH}	2.6			V	I_{OH} = –1.0 mA
Output low voltage	V_{OL}			0.4	V	I_{OL} = 1.0 mA
Input high voltage	V_{IH}	2.25		3.6	V	
Input low voltage	V_{IL}	–0.3		0.8	V	
Input leakage current	I_{ILEAK}	–135		135	µA	Internal resistor included
Output leakage current	I_{OLEAK}	–135		135	µA	Internal resistor included

5.1.3 VDDMAC and VDDMDIO (1.5 V)

The following table shows the DC specifications for the pins referenced to VDDMAC and VDDMDIO when it is set to 1.5 V. The specifications listed in the following table are valid only when VDD1 = 1.0 V, VDD1A = 1.0 V, VDD25A = 2.5 V, and VDDIO = 2.5 V or 3.3 V.

Table 85 • **VDDMAC and VDDMDIO DC Characteristics (1.5 V)**

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
Output high voltage	V_{OH}	1.2			V	I_{OH} = –1 mA
Output low voltage	V_{OL}			0.25	V	I_{OL} = 1 mA
Input high voltage	V_{IH}	1.13		1.87	V	
Input high voltage	V_{IH}	1.13		1.65	V	VDDMAC-referenced pins
Input low voltage	V_{IL}	–0.375		0.45	V	
Input leakage current	I_{ILEAK}	–40		40	µA	Internal resistor included
Output leakage current	I_{OLEAK}	–40		40	µA	Internal resistor included

5.1.4 VDDMAC and VDDMDIO (1.8 V)

The following table shows the DC specifications for the pins references to VDDMAC and VDDMDIO when it is set to 1.8 V. The specifications listed in the following table are valid only when VDD1 = 1.0 V, VDD1A = 1.0 V, VDD25A = 2.5 V, and VDDIO = 2.5 V or 3.3 V.

Table 86 • **VDDMAC and VDDMDIO DC Characteristics (1.8 V)**

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
Output high voltage	V_{OH}	1.43			V	I_{OH} = –1 mA
Output low voltage	V_{OL}			0.3	V	I_{OL} = 1 mA
Input high voltage	V_{IH}	1.35		2.25	V	
Input high voltage	V_{IH}	1.35		1.98	V	VDDMAC-referenced pins
Input low voltage	V_{IL}	–0.45		0.54	V	
Input leakage current	I_{ILEAK}	–48		48	µA	Internal resistor included
Output leakage current	I_{OLEAK}	–48		48	µA	Internal resistor included

5.1.5 VDDMDIO (1.2 V)

The following table shows the DC specifications for the pins referenced to VDDMDIO when it is set to 1.2 V. The specifications listed in the following table are valid only when VDD1 = 1.0 V, VDD1A = 1.0 V, and VDD25A = 2.5 V.

Table 87 • **VDDMDIO DC Characteristics**

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
Output high voltage	V_{OH}	0.95			V	I_{OH} = –1 mA
Output low voltage	V_{OL}			0.2	V	I_{OL} = 1 mA
Input high voltage	V_{IH}	0.9		1.5	V	
Input low voltage	V_{IL}	–0.3		0.36	V	
Input leakage current	I_{ILEAK}	–32		32	µA	Internal resistor included
Output leakage current	I_{OLEAK}	–32		32	µA	Internal resistor included

5.1.6 XTAL1

The following table shows the DC specifications for the XTAL1 pin referenced to VDD25A. The specifications listed in the following table are valid only when VDD1 = 1.0 V, VDD1A = 1.0 V, and the on-chip oscillator is turned off.

Table 88 • **XTAL1 DC Characteristics**

Parameter	Symbol	Minimum	Typical	Maximum	Unit
Input high voltage	V_{IH}	1.85		2.75	V
Input low voltage	V_{IL}	–0.3		0.7	V
Input leakage current	I_{ILEAK}	–85		85	µA
Output leakage current	I_{OLEAK}	–85		85	µA

5.1.7 LED

The following table shows the DC specifications for the LED pins.

Table 89 • **LED DC Characteristics**

Parameter	Symbol	Minimum	Typical	Maximum	Unit
Output high current drive strength	I_{OH}			–24	mA
Output low current drive strength	I_{OL}	24			mA

5.1.8 Internal Pull-Up or Pull-Down Resistors

Internal pull-up or pull-down resistors are specified in the following table. All internal pull-up resistors are connected to their respective I/O supply.

Table 90 • **Internal Pull-Up or Pull-Down Resistors (RGMII/RMII Interface)**

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
Internal pull-down resistor	R_{PD}	31	46	72	kΩ	3.3 V
Internal pull-down resistor	R_{PD}	38	59	96	kΩ	2.5 V
Internal pull-down resistor	R_{PD}	57	91	155	kΩ	1.8 V
Internal pull-down resistor	R_{PD}	78	125	220	kΩ	1.5 V

Table 91 • **Internal Pull-Up or Pull-Down Resistors (Other I/Os)**

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
Internal pull-up resistor	R_{PU}	26	39	64	kΩ	3.3 V
Internal pull-down resistor	R_{PD}	26	45	79	kΩ	3.3 V
Internal pull-up resistor	R_{PU}	33	53	93	kΩ	2.5 V
Internal pull-down resistor	R_{PD}	34	58	108	kΩ	2.5 V

5.1.9 Current Consumption

The following table shows the measured current consumption values for each mode of operation. Add values from table for VDDMAC current consumption to calculate total typical and maximum current for each power supply. Add significant margin above the values for sizing power supplies.

Note: VDDMAC currents at 1.5 V and 1.8 V are measured with an edge rate setting of 111. Currents at 2.5 V and 3.3 V are measured with an edge rate setting of 100.

Table 92 • **Current Consumption**

	Typical (mA)				Maximum (mA)			
Mode	**VDD1**	**VDD1A**	**VDD25A**	**VDDIO/ VDDMDIO**	**VDD1**	**VDD1A**	**VDD25A**	**VDDIO/ VDDMDIO**
Reset	2	2	1	2	73	14	1	3
Powerdown	8	15	11	2	80	29	12	3
ActiPHY	8	15	17	2	80	29	18	3
No Link	16	17	52	2	90	31	56	3
1000BASE-T	72	21	141	2	160	38	150	3
100BASE-TX	22	17	91	2	97	33	98	3
10BASE-T	10	16	57	2	80	32	60	3
1000BASE-T EEE	14	17	57	2	87	31	66	3
100BASE-TX EEE	10	17	57	2	82	31	64	3
10BASE-Te	10	16	51	2	80	32	53	3

Table 93 • **Current Consumption (VDDMAC)**

	Typical (mA)				Maximum (mA)			
Mode	**1.5 V**	**1.8 V**	**2.5 V**	**3.3 V**	**1.5 V**	**1.8 V**	**2.5 V**	**3.3 V**
Reset	0	0	0	0	0	0	0	0
Powerdown (RMII)	0	0	0	0	0	0	0	0
Powerdown (RGMII)	6	8	12	18	7	9	13	19
ActiPHY	6	8	12	12	7	9	13	13
No Link (RMII)	1	1	1	1	2	2	2	2
No Link (RGMII)	6	8	12	18	7	9	13	19
RGMII (1000BASE-T)	24	31	43	58	26	34	45	63
RGMII (100BASE-TX)	5	7	8	13	5	8	9	15
RGMII (10BASE-T/Te)	1	2	3	4	1	2	3	4
RMII (100BASE-TX)	9	11	14	20	10	12	15	21
RMII (10BASE-T/Te)	5	7	9	13	6	7	10	14

5.2 AC Characteristics

This section provides the AC specifications for the VSC8531 device.

5.2.1 Reference Clock

The following table lists the AC specifications for the REFCLK reference clock.

Table 94 • **RefClk**

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
REFCLK frequency, REFCLK_SEL[1:0]= 11	*f*	–100 ppm	125	100 ppm	MHz	

Table 94 • **RefClk *(continued)***

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
REFCLK frequency, REFCLK_SEL[1:0]= 10	*f*	–100 ppm	50	100 ppm	MHz	
REFCLK frequency, REFCLK_SEL[1:0]= 01	*f*	–100 ppm	25	100 ppm	MHz	
Rise time and fall time	t_R, t_F			1.5	ns	20% to 80%, 5.1 pF load
Duty cycle		45		55	%	
Phase jitter—Gaussian				4	ps_{RMS}	Bandwidth from 10 kHz to 10 MHz
Total jitter, peak-to-peak				200	ps_{PP}	10 k samples.

5.2.1.1 XTAL Reference Clock

When using the 25 MHz crystal clock input option (REFCLK_SEL[1:0] = 00), the additional specifications listed in the following table are required.

Table 95 • **XTAL RefClk**

Parameter	Symbol	Minimum	Typical	Maximum	Unit
CL[1]		8			pF
Crystal ESR				60	Ω

1. $$CL = \frac{C1_{EXT} \times C2_{EXT}}{C1_{EXT} + C2_{EXT}}$$

where

$C1_{EXT} = C1 + CIN_{EXT}$

$C2_{EXT} = C2 + COUT_{EXT}$

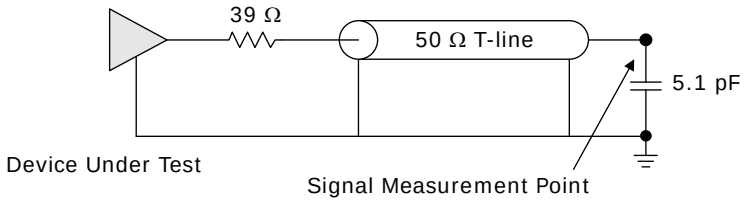
CIN_{EXT} represents input (XTAL1) I/O, bond pad, package pin, and routing parasitic capacitance

and $COUT_{EXT}$ represents output (XTAL2) I/O, bond pad, package pin, and routing parasitic capacitance.

For a reference tank circuit, see Figure 9, page 12.

The following illustration shows the test circuit for the CLKOUT, RCVRD_CLK, and RMII_CLKOUT outputs.

Figure 21 • **Test Circuit for Clock Output Signal**



5.2.2 CLKOUT

This section provides the AC characteristics for the CLKOUT signal.

The following table shows the AC specifications for the CLKOUT output.

Table 96 • **CLKOUT AC Characteristics**

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
CLKOUT frequency	*f*		125		MHz	
CLKOUT frequency	*f*		50		MHz	
CLKOUT frequency	*f*		25		MHz	
CLKOUT cycle time	t_{COCYC}		8		ns	
CLKOUT cycle time	t_{COCYC}		20		ns	
CLKOUT cycle time	t_{COCYC}		40		ns	
Frequency stability	$f_{STABILITY}$			5	ppm	Relative to device REFCLK frequency
Duty cycle	DC	40	50	60	%	
Clock rise time and fall time	t_R, t_F			1.5	ns	20% to 80%
Peak-to-peak jitter	JPP_{CLKOUT}			1000	ps	10 k samples

5.2.3 RMII_CLKOUT

This section provides the AC characteristics for the RMII_CLKOUT signal.

Note: The RMII_CLKOUT signal is provided on the RX_CLK pin (see Table 3, page 5) when the device is operating in RMII mode.

The following table shows the AC specifications for RMII_CLKOUT.

Table 97 • **RMII_CLKOUT AC Characteristics**

Parameter	Symbol	Minimum	Typical	Maximum	Unit
RMII_CLKOUT frequency	*f*		50		MHz
RMII_CLKOUT duty cycle	DC	35		65	%
RMII_CLKOUT rise time	t_R			1	ns
RMII_CLKOUT fall time	t_F			1	ns

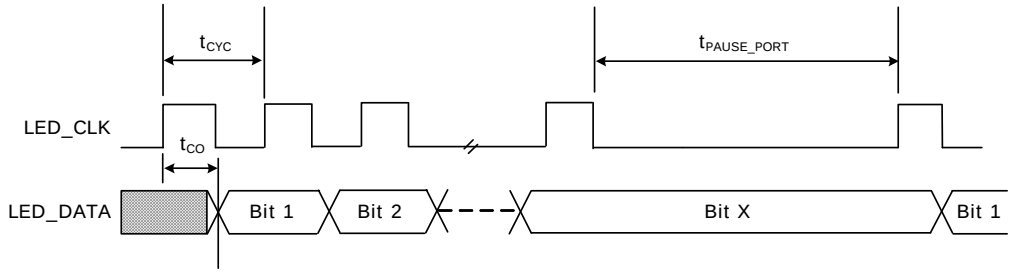
5.2.4 Basic Serial LEDs

This section contains the AC specifications for the basic serial LEDs.

Table 98 • **Basic Serial LEDs AC Characteristics**

Parameter	Symbol	Typical	Unit
LED_CLK cycle time	t_{CYC}	1024	ns
Pause between LED port sequences	t_{PAUSE_PORT}	3072	ns
Pause between LED bit sequences	t_{PAUSE_BIT}	25.541632	ms
LED_CLK to LED_DATA	t_{CO}	1	ns

Figure 22 • **Basic Serial LED Timing**



5.2.5 Uncompensated RGMII

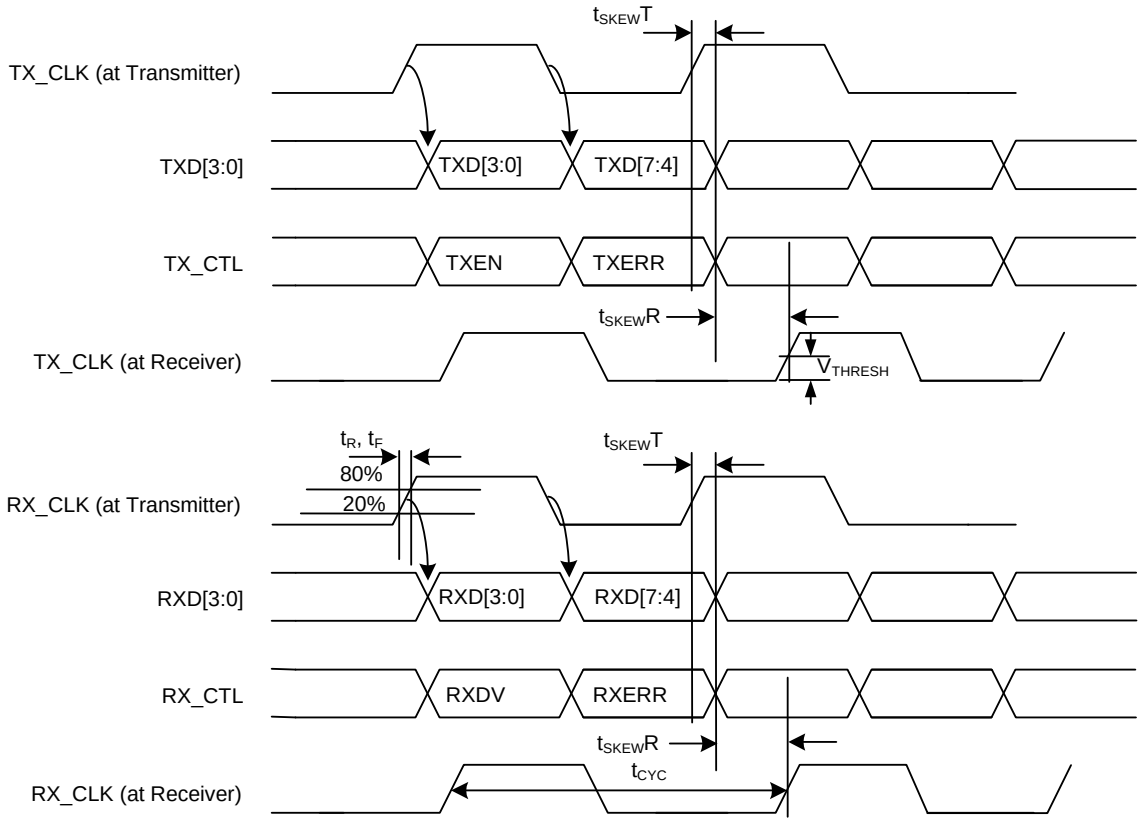
The following table lists the characteristics when using the device in RGMII uncompensated mode. For more information about the RGMII uncompensated timing, see Figure 23, page 66.

Table 99 • **Uncompensated RGMII AC Characteristics**

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
Clock frequency	f_{CLK}		125 25 2.5		MHz	1000BASE-T operation 100BASE-TX operation 10BASE-T operation
1000BASE-T duty cycle	$t_{DUTY1000}$	40	50	60	%	Register 20E.6:4 = 000
10/100BASE-T duty cycle	$t_{DUTY10/100}$	35 40	38 50	65 60	%	10BASE-T 100BASE-TX
Data to clock output skew (at Transmitter)[1]	$t_{SKEW}T$	–500		500	ps	
Data to clock output skew (at Receiver)[1]	$t_{SKEW}R$	1	1.8	2.6	ns	
TX_CLK switching threshold	V_{THRESH}		0.75 0.90 1.25 1.65		V	VDDMAC = 1.5 V VDDMAC = 1.8 V VDDMAC = 2.5 V VDDMAC = 3.3 V
Clock/data output rise and fall times	t_R, t_F			0.75	ns	VDDMAC = 1.5 V, 27E2.7:5 = 111
						VDDMAC = 1.8 V, 27E2.7:5 = 111
						VDDMAC = 2.5 V, 27E2.7:5 = 100
						VDDMAC = 3.3 V, 27E2.7:5 = 100

1. When operating in uncompensated mode, the PC board design requires a clock to be routed such that an additional trace delay of greater than 1.5 ns is added to the associated clock signal.

Figure 23 • **Uncompensated RGMII Timing**



5.2.6 Compensated RGMII

The following table lists the characteristics when using the device in RGMII compensated mode.

Table 100 • **PHY Input (GTX_CLK Delay When Register 20E2.[2:0]=011'b)**

Parameter	Symbol	Minimum	Typical	Maximum	Unit
Data to clock setup (TX_CLK delay = 011'b)	t_{SETUP_T}	–1.0			ns
Clock to data hold (TX_CLK delay = 011'b)	t_{HOLD_T}	2.8			ns

Figure 24 • **Compensated Input RGMII Timing**

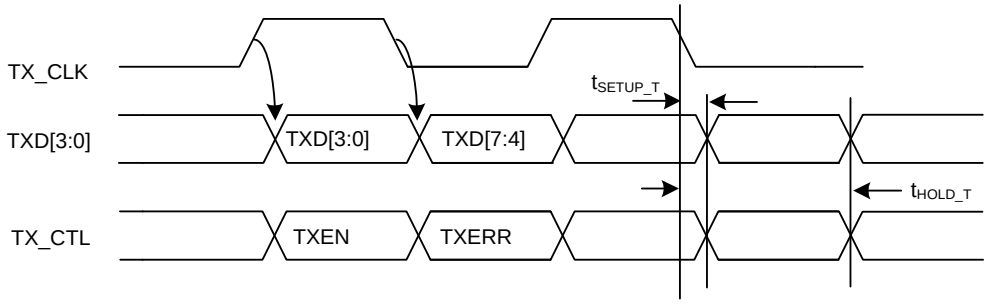
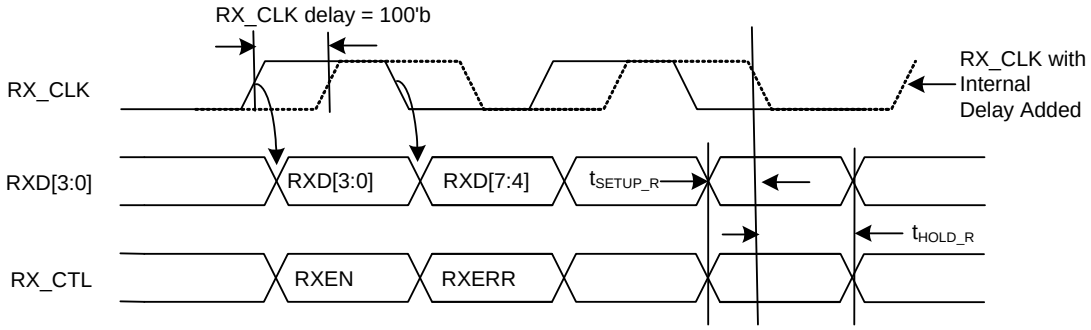


Table 101 • **PHY Output (RX_CLK Delay When Register 20E2.[6:4]=100'b)**

Parameter	Symbol	Minimum	Typical	Maximum	Unit
Data to clock setup (RX_CLK delay = 100'b)	t_{SETUP_R}	1.4	2.0		ns
Clock to data hold (RX_CLK delay = 100'b)	t_{HOLD_R}	1.5	2.0		ns

Figure 25 • **Compensated Output RGMII Timing**



5.2.7 Serial Management Interface

This section contains the AC specifications for the serial management interface (SMI).

Table 102 • **Serial Management Interface AC Characteristics**

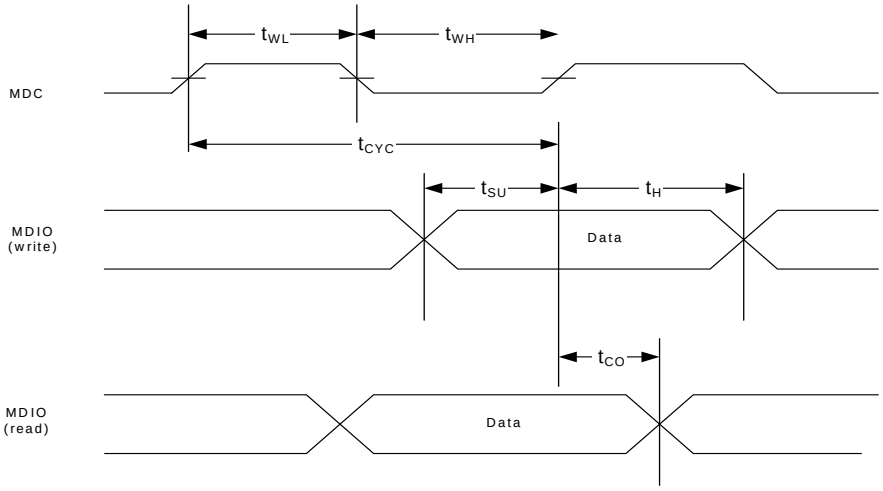
Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
MDC frequency[1]	f_{CLK}		2.5	12.5	MHz	
MDC cycle time	t_{CYC}	80	400		ns	
MDC time high	t_{WH}	20	50		ns	
MDC time low	t_{WL}	20	50		ns	
Setup to MDC rising	t_{SU}	10			ns	
Hold from MDC rising	t_H	14			ns	
MDC rise time	t_R			100 t_{CYC} × 10%[1]	ns	MDC = 0: 1 MHz MDC = 1: MHz – f_{CLK} maximum
MDC fall time	t_F			100 t_{CYC} × 10%[1]		

Table 102 • **Serial Management Interface AC Characteristics *(continued)***

Parameter	Symbol	Minimum	Typical	Maximum	Unit	Condition
MDC to MDIO valid	t_{CO}		10	300	ns	Time-dependent on the value of the external pull-up resistor on the MDIO pin

1. For f_{CLK} above 1 MHz, the minimum rise time and fall time is in relation to the frequency of the MDC clock period. For example, if f_{CLK} is 2 MHz, the minimum clock rise time and fall time is 50 ns.

Figure 26 • **Serial Management Interface Timing**



5.2.8 Reset Timing

This section contains the AC specifications that apply to device reset functionality. The signal applied to the NRESET input must comply with the specifications listed in the following table.

Table 103 • **Reset Timing AC Characteristics**

Parameter	Symbol	Minimum	Typical	Maximum	Unit
NRESET assertion time after power supplies and clock stabilize	t_W	2			ms
Recovery time from reset inactive to device fully active	t_{REC}			15	ms
NRESET pulse width	$t_{W(RL)}$	100			ns
Wait time between NRESET de-assert and access of the SMI interface	t_{WAIT}	15			ms

5.2.9 PHY Latency Specifications

The following table shows the PHY latency, measured between the media interface and RGMII MAC interface pins.

Table 104 • **PHY Latency in RGMII Mode**

Mode	Transmit (egress)			Receive (ingress)			
	Minimum	Typical	Maximum	Minimum	Typical	Maximum	Unit
1000BASE-T	92 - 8	92	92 + 8	220 - 16	220	220 + 16	ns
100BASE-TX	378 - 24	378	378 + 24	280 - 24	280	280 + 24	ns
10BASE-T	3520 - 200	3520	3520 + 200	3740 - 200	3740	3740 + 200	ns

The following table shows the PHY latency, measured between the media interface and RMII MAC interface pins.

Table 105 • **PHY Latency in RMII Mode**

Mode	Transmit (egress)			Receive (ingress)			
	Minimum	Typical	Maximum	Minimum	Typical	Maximum	Unit
100BASE-TX	208 - 4	208	208 + 4	160 - 40	160	160 + 40	ns
10BASE-T	1870 - 100	1870	1870 + 100	775 - 128	775	775 + 128	ns

5.3 Operating Conditions

The following table shows the recommended operating conditions for the VSC8531 device.

Table 106 • **Recommended Operating Conditions**

Parameter	Symbol	Minimum	Typical	Maximum	Unit
Power supply voltage for core supply	V_{DD1}	0.95	1.00	1.05	V
Power supply voltage for analog circuits	V_{DD1A}	0.95	1.00	1.05	V
2.5 V power supply voltage for analog circuits	V_{DD25A}	2.38	2.5	2.62	V
2.5 V power supply voltage for VDDMAC, VDDIO, and VDDMDIO	V_{25}	2.38	2.5	2.62	V
3.3 V power supply voltage for VDDMAC, VDDIO, and VDDMDIO	V_{33}	3.135	3.3	3.465	V
1.8 V power supply voltage for VDDMAC and VDDMDIO	V_{18}	1.71	1.8	1.89	V
1.5 V power supply voltage for VDDMAC and VDDMDIO	V_{15}	1.425	1.5	1.575	V
1.2 V power supply voltage for VDDMDIO	V_{12}	1.14	1.2	1.26	V
VSC8531 operating temperature[1]	T	0		125	°C
VSC8531-03 operating temperature[1]	T	–40		125	°C

1. Minimum specification is ambient temperature, and the maximum is junction temperature.

5.4 Stress Ratings

This section contains the stress ratings for the VSC8531 device.

Warning Stresses listed in the following table may be applied to devices one at a time without causing permanent damage. Functionality at or exceeding the values listed is not implied. Exposure to these values for extended periods may affect device reliability.

Table 107 • **Stress Ratings**

Parameter	Symbol	Minimum	Maximum	Unit
Power supply voltage for core supply	V_{DD1}	–0.3	1.10	V
Power supply voltage for analog circuits	V_{DD1A}	–0.3	1.10	V
Power supply voltage for analog circuits	V_{DD25A}	–0.3	2.75	V
Power supply voltage for digital I/O	V_{DDMAC}, V_{DDIO}, V_{DDMDIO}	–0.3	3.6	V
Input voltage for digital I/O (3.3 V)			3.6	V
Input voltage for digital I/O (2.5 V)			3.3	V

Table 107 • **Stress Ratings *(continued)***

Parameter	Symbol	Minimum	Maximum	Unit
Storage temperature	T_S	–55	125	°C
Electrostatic discharge voltage, charged device model	V_{ESD_CDM}	–1000	1000	V
Electrostatic discharge voltage, human body model	V_{ESD_HBM}	See note[1]		V

1. This device has completed all required testing as specified in the JEDEC standard JESD22-A114, *Electrostatic Discharge (ESD) Sensitivity Testing Human Body Model (HBM)*, and complies with a Class 2 rating. The definition of Class 2 is any part that passes an ESD pulse of 2000 V, but fails an ESD pulse of 4000 V.

Warning This device can be damaged by electrostatic discharge (ESD) voltage. Microsemi recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures may adversely affect reliability of the device.

6 Pin Descriptions

The VSC8531 device has 48 pins, which are described in this section.

The pin information is also provided as an attached Microsoft Excel file so that you can copy it electronically. In Acrobat, double-click the attachment icon.

6.1 Pin Identifications

This section contains the pin descriptions for the VSC8531 device. The following table provides notations for definitions of the various pin types.

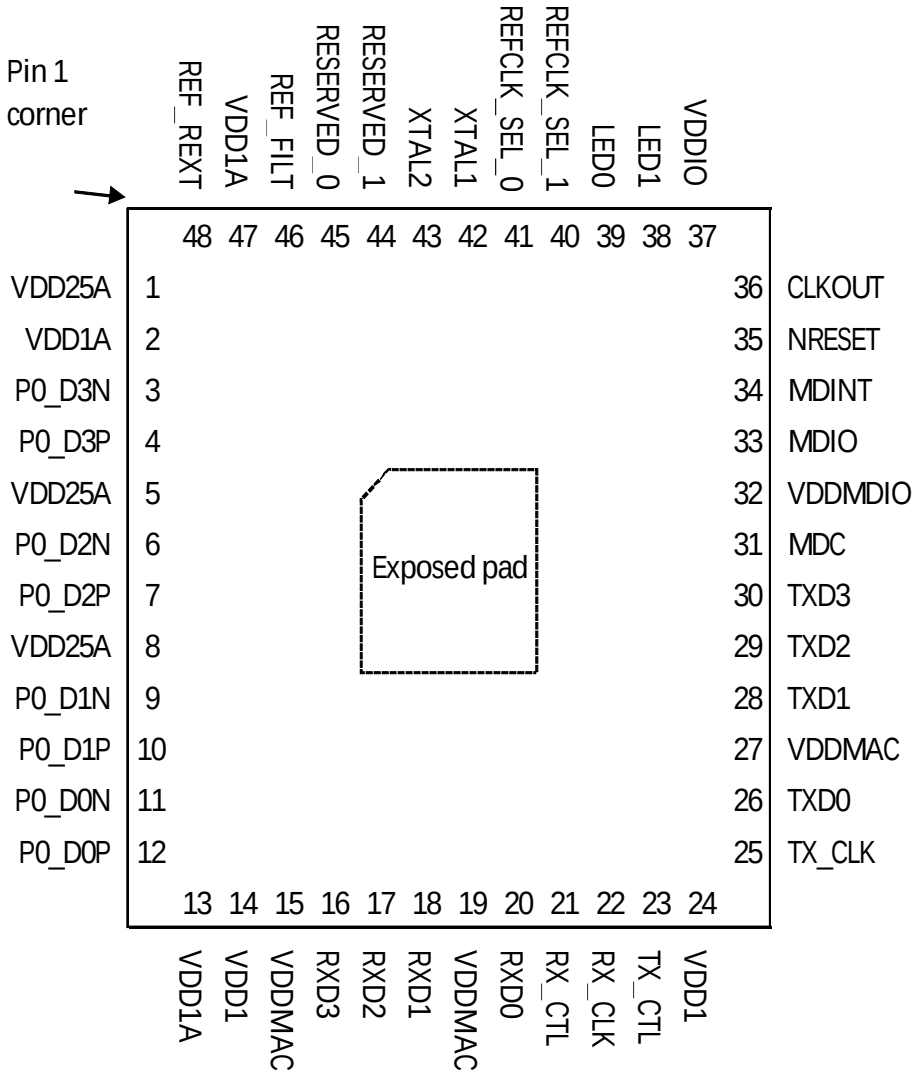
Table 108 • **Pin Type Symbol Definitions**

Symbol	Pin Type	Description
A	Analog	Analog.
ADIFF	Analog differential	Analog differential signal pair.
I	Input	Input without on-chip pull-up or pull-down resistor.
I/O	Bidirectional	Bidirectional input or output signal.
O	Output	Output signal.
P	Power	Power.
PD	Pull-down	On-chip pull-down resistor present.
PU	Pull-up	On-chip pull-up resistor present.

6.2 Pin Diagram

The following illustration shows the pin diagram for the VSC8531 device, as seen looking through the package from the top of it. Note that the exposed pad connects to the package ground.

Figure 27 • **Pin Diagram**



6.3 Pins by Function

This section contains the functional pin descriptions for the VSC8531 device. All power supply pins must be connected to their respective voltage input, even if certain functions are not used for a specific application. No power supply sequencing is required. However, clock and power must be stable before releasing Reset. The SMI pins are referenced to VDD25 and can be set to a 2.5 V power supply.

Functional Group	Name	Number	Type	I/O Domain	Description
Cu PHY Media	P0_D0N	11	ADIFF	VDD25A	Tx/Rx channel A negative signal
Cu PHY Media	P0_D0P	12	ADIFF	VDD25A	Tx/Rx channel A positive signal
Cu PHY Media	P0_D1N	9	ADIFF	VDD25A	Tx/Rx channel B negative signal
Cu PHY Media	P0_D1P	10	ADIFF	VDD25A	Tx/Rx channel B positive signal
Cu PHY Media	P0_D2N	6	ADIFF	VDD25A	Tx/Rx channel C negative signal
Cu PHY Media	P0_D2P	7	ADIFF	VDD25A	Tx/Rx channel C positive signal

Cu PHY Media	P0_D3N	3	ADIFF	VDD25A	Tx/Rx channel D negative signal
Cu PHY Media	P0_D3P	4	ADIFF	VDD25A	Tx/Rx channel D positive signal
Miscellaneous	REF_FILT	46	A	VDD25A	Reference filter connects to an external 0.01 uF (20%) capacitor to analog ground
Miscellaneous	REF_REXT	48	A	VDD25A	Reference connects to an external 2k Ω (1%) resistor to analog ground
Miscellaneous	RESERVED_0	45		VDD25A	Reserved signal, leave unconnected
Miscellaneous	RESERVED_1	44		VDD25A	Reserved signal, leave unconnected
PHY Configuration	CLKOUT	36	I/O, PD	VDDIO	Clock output, can be enabled or disabled. Output a clock based on the local reference clock with programmable frequency. This pin is not active when NRESET is asserted and is disabled by default. When disabled, the pin is held low. The logic state on this pin is latched on the rising edge of NRESET to configure CLKOUT output. See "Hardware Mode Strapping and PHY Addressing" for details.
PHY Configuration	LED0	39	O	VDDIO	LED direct drive outputs. All LED pins are active low. LED_DATA output in serial LED mode.
PHY Configuration	LED1	38	O	VDDIO	LED direct drive outputs. All LED pins are active low. LED_CLK output in serial LED mode.
PHY Configuration	NRESET	35	I, PD	VDDIO	Device reset. Active low input that powers down the device and sets all register bits to their default state.
PHY Configuration	REFCLK_SEL_0	41	I, PU	VDDIO	Reference clock mode/frequency select signal
PHY Configuration	REFCLK_SEL_1	40	I, PU	VDDIO	Reference clock mode/frequency select signal
PHY Configuration	XTAL1	42	I	VDD25A	Crystal/single ended reference clock input
PHY Configuration	XTAL2	43	O	VDD25A	Crystal output, leave unconnected when using single ended reference clock
Power	VDD1	14	P		1.0 V digital core power
Power	VDD1	24	P		1.0 V digital core power
Power	VDD1A	2	P		1.0 V analog power requiring additional PCB power supply filtering
Power	VDD1A	13	P		1.0 V analog power requiring additional PCB power supply filtering
Power	VDD1A	47	P		1.0 V analog power requiring additional PCB power supply filtering
Power	VDD25A	1	P		2.5 V analog power requiring additional PCB power supply filtering
Power	VDD25A	5	P		2.5 V analog power requiring additional PCB power supply filtering
Power	VDD25A	8	P		2.5 V analog power requiring additional PCB power supply filtering
Power	VDDIO	37	P		2.5 V or 3.3 V general I/O power

Power	VDDMAC	15	P		1.5 V, 1.8 V, 2.5 V, or 3.3 V RGMII/RMII MAC power
Power	VDDMAC	19	P		1.5 V, 1.8 V, 2.5 V, or 3.3 V RGMII/RMII MAC power
Power	VDDMAC	27	P		1.5 V, 1.8 V, 2.5 V, or 3.3 V RGMII/RMII MAC power
Power	VDDMDIO	32	P		1.2 V, 1.5 V, 1.8 V, 2.5 V or 3.3 V power for SMI pins
RGMII/RMII	RX_CLK	22	I/O, PD	VDDMAC	RGMII receive clock output. The logic state on this pin is latched on the rising edge of NRESET to configure the device. See "Hardware Mode Strapping and PHY Addressing" for details.
RGMII/RMII	RX_CTL	21	I/O, PD	VDDMAC	RGMII receive control output. The logic state on this pin is latched on the rising edge of NRESET to configure the device. See "Hardware Mode Strapping and PHY Addressing" for details.
RGMII/RMII	RXD0	20	I/O, PD	VDDMAC	RGMII data output. The logic state on this pin is latched on the rising edge of NRESET to configure the device. See "Hardware Mode Strapping and PHY Addressing" for details.
RGMII/RMII	RXD1	18	I/O, PD	VDDMAC	RGMII data output. The logic state on this pin is latched on the rising edge of NRESET to configure the device. See "Hardware Mode Strapping and PHY Addressing" for details.
RGMII/RMII	RXD2	17	I/O, PD	VDDMAC	RGMII data output. The logic state on this pin is latched on the rising edge of NRESET to configure the device. See "Hardware Mode Strapping and PHY Addressing" for details.
RGMII/RMII	RXD3	16	I/O, PD	VDDMAC	RGMII data output. The logic state on this pin is latched on the rising edge of NRESET to configure the device. See "Hardware Mode Strapping and PHY Addressing" for details.
RGMII/RMII	TX_CLK	25	I, PD	VDDMAC	RGMII transmit clock input
RGMII/RMII	TX_CTL	23	I, PD	VDDMAC	RGMII transmit data control input
RGMII/RMII	TXD0	26	I, PD	VDDMAC	RGMII data input
RGMII/RMII	TXD1	28	I, PD	VDDMAC	RGMII data input
RGMII/RMII	TXD2	29	I, PD	VDDMAC	RGMII data input
RGMII/RMII	TXD3	30	I, PD	VDDMAC	RGMII data input
SMI	MDC	31	I	VDDMDIO	Management data clock. A 0 MHz to 12.5 MHz reference input is used to clock serial MDIO data into and out of the PHY.
SMI	MDINT	34	O, OD	VDDMDIO	Management interrupt signal. These pins can be tied together in a wired-OR configuration with only a single pull-up resistor.

SMI	MDIO	33	I/O	VDDMDIO	Management data input/output pin. Serial data is written or read form this pin bi-directionally between the PHY and station manager synchronously on the positive edge of MDC. One external pull-up resistor is required at the station manager.

7 Package Information

The VSC8531XMW package is a lead-free (Pb-free), 48-pin, plastic quad flat no-lead (QFN) package with an exposed pad, 6 mm × 6 mm body size, 0.4 mm pin pitch, and 0.9 mm maximum height.

Lead-free products from Microsemi comply with the temperatures and profiles defined in the joint IPC and JEDEC standard IPC/JEDEC J-STD-020. For more information, see the IPC and JEDEC standard.

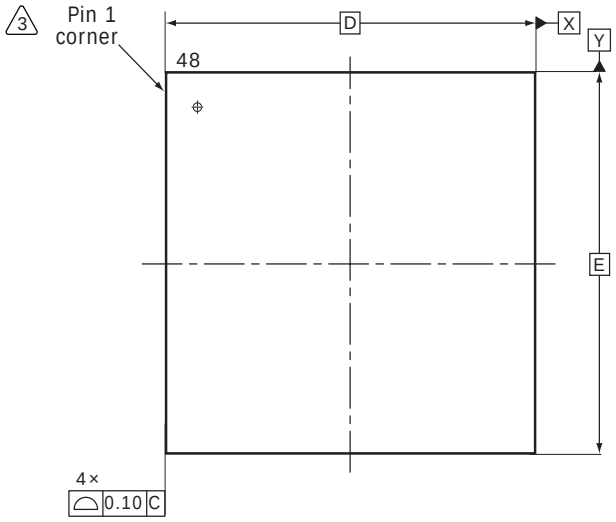
This section provides the package drawing, thermal specifications, and moisture sensitivity rating for the VSC8531 device.

7.1 Package Drawing

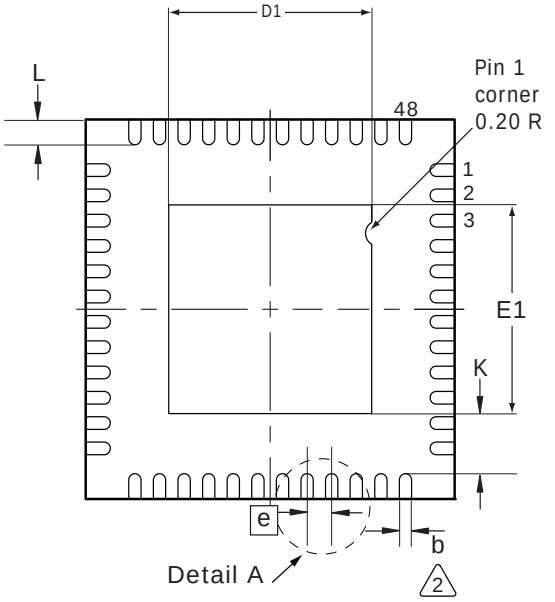
The following illustration shows the package drawing for the VSC8531 device. The drawing contains the top view, bottom view, side view, dimensions, tolerances, and notes.

Figure 28 • **Package Drawing**

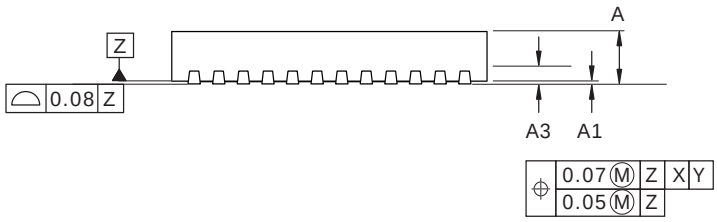
Top View



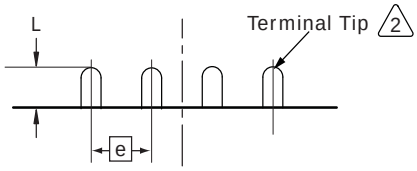
Bottom View



Side View



Detail A



Notes

1. All dimensions and tolerances are in millimeters (mm).
2. Dimension b applies to the metallized terminal and is measured between 0.15 mm and 0.30 mm from the terminal tip.
3. Maximum package warpage is 0.08 mm.

Dimensions and Tolerances

Reference	Minimum	Nominal	Maximum
A	0.80	0.85	0.90
A1	0.00	0.02	0.05
A3		0.203 Ref	
D		6.00 BSC	
D1	3.20	3.30	3.40
E		6.00 BSC	
E1	3.20	3.30	3.40
K		0.95 Ref	
e		0.40 BSC	
L	0.30	0.40	0.50
b	0.15	0.20	0.25

7.2 Thermal Specifications

Thermal specifications for this device are based on the JEDEC JESD51 family of documents. These documents are available on the JEDEC website at www.jedec.org. The thermal specifications are modeled using a four-layer test board with two signal layers, a power plane, and a ground plane (2s2p

PCB). For more information about the thermal measurement method used for this device, see the JESD51-1 standard.

Table 109 • **Thermal Resistances**

Symbol	°C/W	Parameter
θ_{JCtop}	31.62	Die junction to package case top
θ_{JB}	9.34	Die junction to printed circuit board
θ_{JA}	31.73	Die junction to ambient
θ_{JMA} at 1 m/s	25.0	Die junction to moving air measured at an air speed of 1 m/s
θ_{JMA} at 2 m/s	23.75	Die junction to moving air measured at an air speed of 2 m/s

To achieve results similar to the modeled thermal measurements, the guidelines for board design described in the JESD51 family of publications must be applied. For information about applications using QFN packages, see the following:

- JESD51-2A, *Integrated Circuits Thermal Test Method Environmental Conditions, Natural Convection (Still Air)*
- JESD51-6, *Integrated Circuit Thermal Test Method Environmental Conditions, Forced Convection (Moving Air)*
- JESD51-8, *Integrated Circuit Thermal Test Method Environmental Conditions, Junction-to-Board*
- JESD51-7, *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-5, *Extension of Thermal Test Board Standards for Packages with Direct Thermal Attachment Mechanisms*

7.3 Moisture Sensitivity

This device is rated moisture sensitivity level 3 or better as specified in the joint IPC and JEDEC standard IPC/JEDEC J-STD-020. For more information, see the IPC and JEDEC standard.

8 Design Considerations

This section provides information about design considerations for the VSC8531 device.

8.1 Transmitter test mode selection does not work as intended

When any of the transmitter test modes are selected by writing to register 9, bits 15:13, the device is not configured continuously in the intended test mode. Instead, the device alternates between test mode and normal mode, and any transmitter testing performed while in this state will produce erroneous results.

In addition, when exiting test mode by writing value 0 to register 9, bits 15:13, the device continues transmitting the alternating test mode signal. A software reset must be performed to bring the device out of this state and into normal operation.

As a workaround for this issue, execute the following register writes before setting transmitter test modes:

1. Write 0x0010 to register address 31.
2. Read register address 0.
3. Modify read back value and set bit 15 to 0. Write updated value to register address 0.
4. Write 0x0000 to register address 31.

When exiting transmitter test mode, execute the following register writes to restore normal device operation:

1. Write 0x0010 to register address 31.
2. Read register address 0.
3. Modify read back value and set bit 15 to 1. Write updated value to register address 0.
4. Write 0x0000 to register address 31.

8.2 CLKOUT duty cycle in 50 MHz mode exceeds datasheet specification limits

When a CLKOUT frequency of 50 MHz is selected, the device puts out a clock with a duty cycle that exceeds the datasheet limit of 55%. The output clock has a duty cycle close to 70% in this mode.

8.3 Excessive jitter on CLKOUT signal when PHY link is established

The CLKOUT signal exhibits excessive jitter in all frequency output modes when a PHY link is established. This jitter can be as high as 1 ns in some link speeds.

8.4 CLKOUT frequency is fixed to 25 MHz and cannot be changed

When CLKOUT is enabled, the frequency is fixed to 25 MHz and cannot be changed either through hardware strapping or by writing to register 13G, bits 14:13.

8.5 MDINT may not trigger properly

Not all interrupts described in Interrupt Status, page 38 may trigger as specified. As a workaround for this issue, execute the following register writes:

1. Write 0x0010 to register address 31.
2. Read register address 0.
3. Modify read back value and set bit 15 to 1. Write updated value to register address 0.
4. Write 0x0000 to register address 31.

8.6 100/1000 receive error counter counts good packets

The 100/1000 receive error counter of register 19 (Error Counter 1, page 34) does not function correctly in speeds other than 1000 Mbps. It should not be used for counting symbol errors at other speeds. The packet error counters in registers 19E1 and 23E1 can be used instead to identify packet errors at all speeds.

8.7 LED drive pins cannot tri-state

The inactive states described in Table 12, page 18 will always be VDDIO, regardless of register 14G.9 settings. The signals connected to the LED0 and LED1 pins should not be connected to a voltage reference higher than VDDIO.

8.8 LED pulse stretch enable turns off LED pins

Enabling the pulse stretch function for LED0 or LED1 by setting register 30, bits 5:6 shuts off those LED pins.

Use the default blink function setting of LED0 and LED1 rather than pulse stretching. For more information, see LED Behavior, page 40.

8.9 FLF/FLF2 indication delay when using interrupts

Whenever the Fast Link Failure interrupt mask is enabled (see register 25 bit 7, Table 41, page 37), MDINT will assert at the onset of a link failure in less than 6 ms typical (8 ms, worst-case).

8.10 Extended interrupt mask bit cannot be set

In order for the interrupt status to correctly clear when the interrupt bit (reg 26.15) asserts, the extended interrupt mask bit (reg 25.5) must never be set. The user application should poll Extended Interrupts (Extended Interrupt Status, page 53) to use extended interrupts in the device.

Contact your Microsemi representative for software workaround support.

9 Ordering Information

The VSC8531 device is offered with two operating temperature ranges. The range for VSC8531XMW is 0 °C ambient to 125 °C junction. The range for VSC8531XMW-03 is –40 °C ambient to 125 °C junction.

The VSC8531XMW package is a lead-free (Pb-free), 48-pin, plastic quad flat no-lead (QFN) package with an exposed pad, 6 mm × 6 mm body size, 0.4 mm pin pitch, and 0.9 mm maximum height.

Lead-free products from Microsemi comply with the temperatures and profiles defined in the joint IPC and JEDEC standard IPC/JEDEC J-STD-020. For more information, see the IPC and JEDEC standard.

The following table lists the ordering information for the VSC8531 device.

Table 110 • **Ordering Information**

Part Order Number	Description
VSC8531XMW	Lead-free, 48-pin, plastic QFN package with an exposed pad, 6 mm × 6 mm body size, 0.4 mm pin pitch, and 0.9 mm maximum height. The operating temperature is 0 °C ambient to 125 °C junction.
VSC8531XMW-03	Lead-free, 48-pin, plastic QFN package with an exposed pad, 6 mm × 6 mm body size, 0.4 mm pin pitch, and 0.9 mm maximum height. The operating temperature is –40 °C ambient to 125 °C junction.