

DS90UB953-Q1 适用于 2.3MP/60fps 摄像头、雷达和其他传感器并具有 CSI-2 接口的 FPD-Link III 4.16Gbps 串行器

1 特性

- 符合面向汽车应用的 AEC-Q100 标准：
 - 器件温度等级 2：环境工作温度范围为 -40°C 至 $+105^{\circ}\text{C}$
- 符合 ISO 10605 和 IEC 61000-4-2 ESD 标准
- 同轴电缆供电 (PoC) 兼容收发器
- 4.16Gbps 级串行器支持高速传感器包括全高清 1080p 2MP 60fps 和 4MP 30fps 成像器
- 符合 D-PHY v1.2 和 CSI-2 v1.3 标准的系统接口
 - 多达 4 条数据通道，每通道速率为 832Mbps
 - 支持多达四个虚拟通道
- 精密多传感器时钟和同步
- 灵活的可编程输出时钟发生器
- 高级数据保护和诊断，包括 CRC 数据保护、传感器数据完整性检查、I2C 写保护、电压和温度测量、可编程警报器以及线路故障检测
- 支持单端同轴或屏蔽双绞线 (STP) 电缆
- 超低延迟双向 I2C 和 GPIO 控制通道支持从 ECU 侧进行 ISP 控制，
- 1.8V 单电源
- 低功耗 (0.25W 典型值)
- 兼容 DS90UB954-Q1、DS90UB960-Q1、DS90UB934-Q1、DS90UB914A-Q1 解串器
- 宽温度范围： -40°C 至 105°C
- 小型 5mm x 5mm VQFN 封装和 PoC 解决方案尺寸，适合紧凑型摄像头模块设计

2 应用

- 汽车驾驶员辅助系统 (ADAS)
 - 环视系统 (SVS)
 - 摄像头监控系统 (CMS)
 - 前视摄像头 (FC)
 - 驾驶员监控系统 (DMS)
 - 后视摄像头 (RVC)
 - 汽车卫星雷达和激光雷达模块
 - 飞行时间 (ToF) 传感器
- 安防和监控摄像头
- 工业和医疗成像

3 说明

DS90UB953-Q1 串行器是 TI FPD-Link III 器件系列的一部分，旨在支持高速原始数据传感器，包括 60fps 的 2MP 成像器以及 4MP 30fps 摄像头、卫星雷达、激光雷达和飞行时间 (ToF) 传感器。该芯片提供 4.16Gbps 正向通道和超低延迟的 50Mbps 双向控制通道，并支持单根同轴 (PoC) 或 STP 电缆进行供电。DS90UB953-Q1 具有高级数据保护和诊断特性，可支持 ADAS 和自动驾驶。DS90UB953-Q1 与配套的解串器一起提供精确的多摄像头传感器时钟和传感器同步。

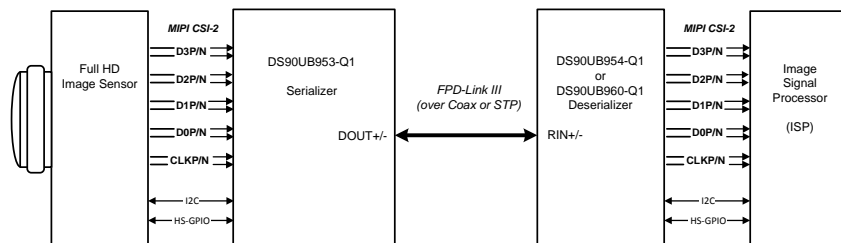
DS90UB953-Q1 完全符合 AEC-Q100 标准，具有 -40°C 至 105°C 的宽温度范围。该串行器采用 5mm x 5mm 的小型 VQFN 封装，非常适合空间受限型传感器应用。

器件信息(1)

| 器件型号 | 封装 | 封装尺寸 (标称值) |
|--------------|-----------|-----------------|
| DS90UB953-Q1 | VQFN (32) | 5.00mm x 5.00mm |

(1) 要了解所有可用封装，请见产品说明书末尾的可订购产品附录。

典型应用



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4 修订历史记录

| Changes from Revision A (February 2018) to Revision B | Page |
|--|-------------|
| • Updated GPIO pin descriptions. | 6 |
| • Replace CLK_IN with clock throughout document. | 6 |
| • Changed Supply voltage from 2.5V to 2.16V | 7 |
| • Changed asynchronous to non-synchronous | 8 |
| • Deleted "for synchronous mode" | 8 |
| • Added internal reference frequency in EC table..... | 10 |
| • Added Internal AON Clock to Block Diagram..... | 15 |
| • 已更改 mode to modes. | 18 |
| • Changed 130ns to 225ns. | 22 |
| • Changed latency to 1.5us and jitter to 0.7us. | 22 |
| • Changed CLK_IN Mode to Modes. | 22 |
| • Added DVP Mode | 22 |
| • Changed table formatting. | 23 |
| • 已更改 REFLCK to Back Channel | 23 |
| • 已添加 Frequency for Synchronous Mode | 23 |
| • 已更改 naming convention from "asynchronous CLK_IN" to "Non-Synchronous external CLK_IN" mode column dor CLKIN_DIV = 2..... | 23 |
| • 已更改 from CLK_IN to Back Channel (Half Rate)..... | 23 |
| • 已添加 Non-Synchronous Internal Clock Mode | 23 |
| • 已更改 the value from 24.2 - 25.5 MHz to 48.4 - 51 MHz | 23 |
| • 已更改 the value from 25 - 52 MHz to 24.2 to 25.5 MHz | 23 |
| • Added DVP External Clock..... | 23 |
| • 已添加 text "Deserializer Mode" to clarify mode RAW10 | 23 |
| • 已添加 additional information to note. | 23 |

修订历史记录 (接下页)

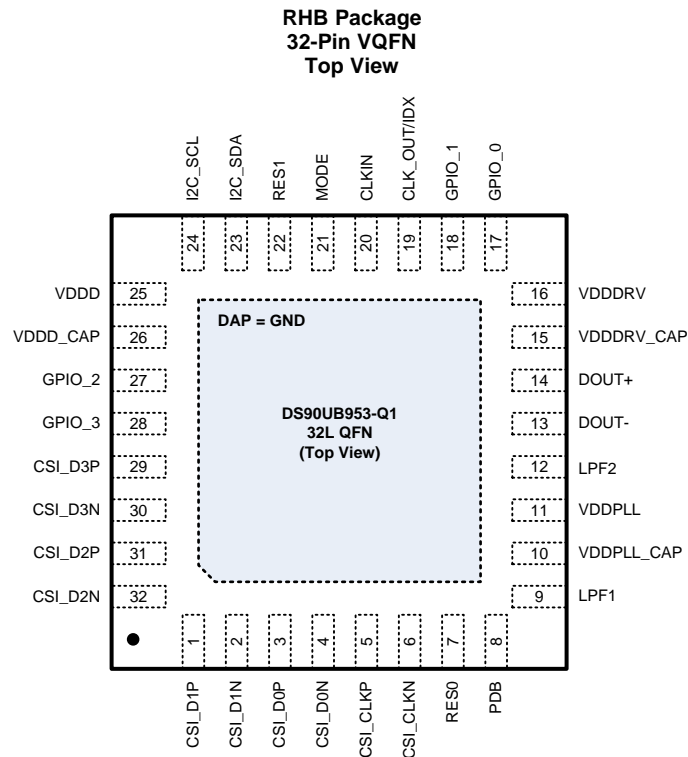
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|---|----|
| • 已添加 text "Deserializer Mode" to clarify mode RAW12 HF | 23 |
| • 已更改 CLK_IN to Clock. | 23 |
| • Added Non-Synchronous Internal Clocking Mode section. | 24 |
| • 已更改 the internal clock 25 MHz to 24.2 MHz | 24 |
| • 已更改 forward channel rate to 1.936 Gbps instead of 2 Gbps | 24 |
| • 已更改 the average CSI-2 throughput value to 3.1 Gbps instead of 1.6 Gbps | 24 |
| • Added DVP Backwards Compatibility Mode section. | 24 |
| • 已更改 "asynchronous CLK_IN" to "Non-Synchronous external CLK_IN" | 24 |
| • Added sentence "CLK_OUT functionality is not..." | 24 |
| • 已添加 Non-Synchronous Internal Clock Mode | 26 |
| • Deleted "with accuracy of 25 MHz ±10%." | 28 |
| • Changed clock to from 25 MHz ±10% to 26.25 MHz. | 28 |
| • Changed clock to from 25 MHz ±10% to 26.25 MHz. | 28 |
| • Updated registers map | 32 |
| • Added information for DVP mode to register 0x04. | 33 |
| • Added "operating with Non-Synchronous internal clock or" | 34 |
| • Changed the frequency value from 26 MHz to range value (24.2 MHz to 25.5 MHz) | 34 |
| • Added "set for 2 Gbps line rate" | 34 |
| • Changed the frequency value from 52 MHz to range value (48.4 MHz to 51 MHz) | 34 |
| • Added "set for 4 Gbps line rate" | 34 |
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| • Added DVP information to register 0x10. | 37 |
| • Added DVP information to register 0x11. | 37 |
| • 已删除 the value -25dB and added -20dB in typical | 71 |
| • 已更改 $-26.4+14.4f$ to log equation $-12+8*\log(f)$ | 71 |
| • Moved Return Loss, S11 MAX values to TYP | 71 |
| • 已添加 Typical connection diagram for STP | 72 |
| • 已更改 the capacitance value from 33nF to 33nF – 100 nF. | 73 |
| • 已更改 the capacitance value from 15 nF to 15 nF – 47 nF. | 73 |
| • 已更改 the capacitance value from 33nF to 33nF – 100 nF. | 73 |

Changes from Original (September 2017) to Revision A
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| | |
|---|----|
| • Changed RES1 pin description from "Leave OPEN" to "Do not connect" | 5 |
| • Added "Internal 1-MΩ pulldown" text to PDB pin description | 5 |
| • Expanded MODE pin description | 6 |
| • Changed "Requires" to "Typically connected to" in the Power and Ground pin descriptions | 6 |
| • Changed "and should not be connected to an external supply" to "Do not connect to an external supply rail" in the Power and Ground pin descriptions | 6 |
| • Changed the CSI_ERR_COUNT (0x5C) text to CSI_ERR_CNT (0x5C) | 18 |
| • Changed DS90UB954-Q1 to DS90UB954-Q1 | 20 |
| • Changed the GPIO_INPUT_CTL text to GPIO_INPUT_CTRL in the <i>GPIO Input Control</i> and <i>GPIO Output Control</i> sections | 21 |
| • Changed CLK_IN lower limit with CLKIN_DIV =1 from 46 MHz to 25 MHz and CLK_IN lower limit from 92 MHz to 50 MHz. | 23 |
| • Corrected typo in MODE description saying the number of modes is 3 to the correct value of 2 | 25 |

| | |
|---|----|
| • Changed I2C START description to "A START occurs when SDA transitions Low while SCLK is High" | 27 |
| • Added registers tables for reserved registers 0x04, 0x0F-0x12, 0x16, 0x1F, 0x25-0x30, 0x34, 0x36, 0x38, 0x4A-0x4F, 0x5B, 0x65-0xAF, and 0xB3-0xEF..... | 32 |
| • Changed bit 6 and bit 7 in the MODE_SEL register to RESERVED..... | 33 |
| • Changed the SENSE_VO_HI and SENSE_VO_LO registers to SENSE_VO_HI and SENSE_VO_LO to match the title in Table 36 | 39 |
| • Changed the SENSE_VO_HI and SENSE_VO_LO bit descriptions | 39 |
| • Changed the SENSOR_VO_THRESH bit description | 39 |
| • Changed the SENSE_T_HI and SENSE_T_LO bit descriptions..... | 39 |
| • Combined the CSI_EN_HSRX register bits 6–0 into one row..... | 41 |
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| • Combined the CSI_EN_RXTERM register bits 7–4 into one row | 42 |
| • Changed serializer to deserializer in SLAVE_ID_ALIAS_x bit descriptions | 47 |
| • Changed Slave 0 to Slave 1 in the SLAVE_AUTO_ACK_1 bit description | 48 |
| • Changed Slave 0 to Slave 2 in the SLAVE_AUTO_ACK_2 bit description | 48 |
| • Changed Slave 0 to Slave 3 in the SLAVE_AUTO_ACK_3 bit description | 48 |
| • Changed Slave 0 to Slave 4 in the SLAVE_AUTO_ACK_4 bit description | 49 |
| • Changed Slave 0 to Slave 5 in the SLAVE_AUTO_ACK_5 bit description | 49 |
| • Changed Slave 0 to Slave 6 in the SLAVE_AUTO_ACK_6 bit description | 49 |
| • Changed Slave 0 to Slave 7 in the SLAVE_AUTO_ACK_7 bit description | 50 |
| • Changed CRC_ERR bit description in GENERAL_STATUS to match CRC_ERR_CLR register name | 51 |
| • Changed the CNTRL_ERR_HSRQST_2 bit description | 54 |
| • Changed 图 17 caption..... | 72 |
| • Added PIN(S) column to 表 178 | 73 |
| • Changed large bulk capacitor typical range lower limit from 50 μ F to 47 μ F, removed mentions of dedicated power plane and tantalum capacitors, and changed recommended power rating for capacitors in layout guidelines | 76 |
| • Changed recommended CSI-2 guidelines on matching trace lengths and routing to help trace impedance | 77 |
| • Changed routing guidelines for the DOUT+ and DOUT– pins | 78 |
| • 在相关文档 部分添加了新链接..... | 80 |

5 Pin Configuration and Functions



Pin Functions

| PIN | | I/O | DESCRIPTION |
|----------------------------------|-----|---------|---|
| NAME | NO. | | |
| CSI INTERFACE | | | |
| CSI_CLKP | 5 | I, DPHY | CSI-2 clock input pins. Connect to a CSI-2 clock source with matched 100-Ω (±5%) impedance interconnects. |
| CSI_CLKN | 6 | I, DPHY | |
| CSI_D0P | 3 | I, DPHY | CSI-2 data input pins. Connect to a CSI-2 data sources with matched 100-Ω (±5%) impedance interconnects. If unused, these pins may be left floating. |
| CSI_D0N | 4 | I, DPHY | |
| CSI_D1P | 1 | I, DPHY | |
| CSI_D1N | 2 | I, DPHY | |
| CSI_D2P | 31 | I, DPHY | |
| CSI_D2N | 32 | I, DPHY | |
| CSI_D3P | 29 | I, DPHY | |
| CSI_D3N | 30 | I, DPHY | |
| SERIAL CONTROL INTERFACE | | | |
| I2C_SDA | 23 | OD | I2C Data and Clock Pins. Typically pulled up by 470-Ω to 4.7-kΩ resistors to either 1.8-V or 3.3-V supply rail depending on IDX setting. See I2C Interface Configuration for further details on the I2C implementation of the DS90UB953-Q1. |
| I2C_SCL | 24 | OD | |
| CONFIGURATION and CONTROL | | | |
| RES0 | 7 | I | Reserved pin – Connect to GND |
| RES1 | 22 | I | Reserved pin – Do not connect (leave floating) |
| PDB | 8 | I, PD | Power-down inverted Input Pin. Internal 1-MΩ pulldown. Typically connected to processor GPIO with pull down. When PDB input is brought HIGH, the device is enabled and internal register and state machines are reset to default values. Asserting PDB signal low will power down the device and consume minimum power. The default function of this pin is PDB = LOW; POWER DOWN. PDB should remain low until after power supplies are applied and reach minimum required levels. See Power Down (PDB) for further details on the function of PDB. PDB INPUT IS NOT 3.3-V TOLERANT. PDB = 1.8 V, device is enabled (normal operation) PDB = 0, device is powered down. |

Pin Functions (continued)

| PIN | | I/O | DESCRIPTION |
|---------------------------------|-----|---------|--|
| NAME | NO. | | |
| MODE | 21 | I, S | Mode select configuration input. Default operational mode will be strapped at start-up based on the MODE input voltage when PDB transitions LOW to HIGH. Typically connected to voltage divider through external pullup to VDD18 and pulldown to GND applying an appropriate bias voltage. See MODE for detail. |
| CLK_OUT/IDX | 19 | I/O, S | IDX pin sets the I2C pullup voltage and device address; connect to external pullup to VDD and pulldown to GND to create a voltage divider. When PDB transitions LOW to HIGH, the strap input voltage is sensed at the CLOCK_OUT/IDX pin to determine functionality and then converted to CLK_OUT. See I2C Interface Configuration for detail. If CLK_OUT is used, the minimum resistance on the pin is 35 kΩ. If unused, CLK_OUT/IDX may be tied to GND. |
| FPD-LINK III INTERFACE | | | |
| DOUT- | 13 | I/O | FPD-Link III Input/Output pins. These pins must be AC-coupled. See 图 19 and 图 20 for typical connection diagrams and 表 178 for recommended capacitor values. |
| DOUT+ | 14 | I/O | |
| POWER AND GROUND | | | |
| VDDD_CAP | 26 | D, P | A connection for internal analog regulator decoupling capacitor. Typically connected to 10-μF, 0.1-μF, and 0.01-μF capacitors to GND. Do not connect to an external supply rail. See Typical Application for more details. |
| VDDDRV_CAP | 15 | D, P | A connection for internal analog regulator decoupling capacitor. Typically connected to 10-μF, 0.1-μF, and 0.01-μF capacitors to GND. Do not connect to an external supply rail. See Typical Application for more details. |
| VDDPLL_CAP | 10 | D, P | A connection for internal analog regulator decoupling capacitor. Typically connected to 10-μF, 0.1-μF, and 0.01-μF capacitors to GND. Do not connect to an external supply rail. See Typical Application for more details. |
| VDDD | 25 | P | 1.8-V (±5%) Power Supply pin. Typically connected to 1-μF and 0.01-μF capacitors to GND. |
| VDDDRV | 16 | P | 1.8-V (±5%) Analog Power Supply pin. Typically connected to 1-μF and 0.01-μF capacitors to GND. |
| VDDPLL | 11 | P | 1.8-V (±5%) Analog Power Supply pin. Typically connected to 1-μF and 0.01-μF capacitors to GND. |
| GND | DAP | G | DAP is the large metal contact at the bottom side, located at the center of the VQFN package. Connect to the ground plane (GND). |
| LOOP FILTER | | | |
| LPF1 | 9 | P | Loop Filter 1: Connect as described in Loop Filter Decoupling . |
| LPF2 | 12 | P | Loop Filter 2: Connect as described in Loop Filter Decoupling . |
| CLOCK INTERFACE and GPIO | | | |
| GPIO_0 | 17 | I/O, PD | General-Purpose Input/Output pins. At power-up these GPIO pins default to inputs with a 300 kΩ (typical) internal pulldown resistor. If unused, these pins may be left floating, however, it is recommended to disable them by setting the GPIOx_INPUT_EN to 0. See GPIO Support for programmability. |
| GPIO_1 | 18 | I/O, PD | |
| GPIO_2 | 27 | I/O, PD | |
| GPIO_3 | 28 | I/O, PD | |
| CLKIN | 20 | I | Reference Clock Input pin. If operating in Non Sync external clock mode, connect this pin to a local clock source. If unused (other clocking modes), this pin may be left open. See 表 6 for more information on clocking modes. |

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾

| | PIN OR FREQUENCY | MIN | MAX | UNIT |
|---------------------------------------|---|------|-----------------------|------|
| Supply voltage, VDD | VDDD, VDDDRV, VDDPLL | -0.3 | 2.16 | V |
| Input voltage | GPIO[3:0], PDB, CLKIN, IDX, MODE, CSI_CLKP/N, CSI_D0P/N, CSI_D1P/N, CSI_D2P/N, CSI_D3P/N | -0.3 | V _{DD} + 0.3 | V |
| FPD-Link III output voltage | DOUT+, DOUT- | -0.3 | 1.21 | V |
| Open-drain voltage | I2C_SDA, I2C_SCL | -0.3 | 3.96 | V |
| Junction temperature, T _J | | | 150 | °C |
| Storage temperature, T _{stg} | | -65 | 150 | °C |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

| | | | VALUE | UNIT |
|---------------------------------|--|---|-------|------|
| V _(ESD) | Electrostatic discharge | Human body model (HBM) ESD Classification Level 3A, per AEC Q100-002 ⁽¹⁾ | ±4000 | V |
| | | All pins except Media Dependent Interface Pins | | |
| | | Media Dependent Interface Pins | | |
| | | Charged-device model (CDM) ESD Classification Level C6, per AEC Q100-011 | ±1500 | V |
| | | IEC 61000-4-2 R _D = 330 Ω, C _S = 150 pF | ±8000 | V |
| | Contact Discharge (DOUT+ and DOUT-) | | | |
| | ISO 10605 R _D = 330 Ω, C _S = 150 pF and 330 pF R _D = 2 kΩ, C _S = 150 pF and 330 pF | ±18000 | V | |
| Air Discharge (DOUT+ and DOUT-) | | | | |
| | | ±8000 | V | |
| | | ±18000 | V | |

- (1) AEC Q100-002 indicates HBM stressing is done in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

Over operating free-air temperature range (unless otherwise noted)

| | | MIN | NOM | MAX | UNIT |
|--|---------------------------------------|------|-----|------|------|
| Supply voltage | VDD (VDDD, VDDDRV, VDDPLL) | 1.71 | 1.8 | 1.89 | V |
| Open-drain voltage | I2C_SDA, I2C_SCL = V _(I2C) | 1.71 | | 3.6 | V |
| Operating free-air temperature (T _A) | | -40 | 25 | 105 | °C |
| Mipi data rate (per CSI-2 lane) | | 80 | | 832 | Mbps |
| Reference clock input frequency | | 25 | | 104 | MHz |
| Local I ² C frequency (f _{I2C}) | | | | 1 | MHz |

Recommended Operating Conditions (continued)

Over operating free-air temperature range (unless otherwise noted)

| | | MIN | NOM | MAX | UNIT |
|---|---|-----|-----|------|--------------------------|
| Supply noise | VDD (VDDD, VDDDRV, VDDPLL) | | | 25 | mV _{p-p} |
| Differential supply noise between DOUT+ and DOUT- (PSR) | f = 10 KHz - 50 MHz (coax mode only) | | | 25 | mV _{p-p} |
| | f = 30 Hz, 10-90% Rise/Fall Time > 100µs (coax mode only) | | | 25 | mV _{p-p} |
| Input clock jitter for non-synchronous mode (t _{JIT}) | CLKIN | | | 0.05 | UI_CLK_IN ⁽¹⁾ |
| Back channel input jitter (t _{JIT-BC}) | DOUT+, DOUT- | | | 0.4 | UI_BC ⁽²⁾ |

(1) Non-synchronous mode - For a given clock, the UI is defined as 1/clock_freq. For example when the clock = 50Mhz, the typical UI_CLK_IN is 1/50 MHz = 20 ns.

(2) The back channel unit interval (UI_BC) is 1/(BC line-rate). For example, the typical UI_BC is 1/100 MHz = 10 ns. If the jitter tolerance is 0.4 UI, convert the jitter in UI to seconds using this equation: 10 ns × 0.4 UI = 4 ns

6.4 Thermal Information

| THERMAL METRIC ⁽¹⁾ | | DS90UB953Q-Q1 | UNIT |
|-------------------------------|--|---------------|------|
| | | RHB (VQFN) | |
| | | 32 PINS | |
| R _{θJA} | Junction-to-ambient thermal resistance | 31.5 | °C/W |
| R _{θJB} | Junction-to-board thermal resistance | 10.9 | °C/W |
| R _{θJC(top)} | Junction-to-case (top) thermal resistance | 20 | °C/W |
| R _{θJC(bot)} | Junction-to-case (bottom) thermal resistance | 1 | °C/W |
| Ψ _{JT} | Junction-to-top characterization parameter | 0.2 | °C/W |
| Ψ _{JB} | Junction-to-board characterization parameter | 10.9 | °C/W |

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report, SPRA953.

6.5 Electrical Characteristics

Over recommended operating supply and temperature ranges unless otherwise specified.

| PARAMETER | | TEST CONDITIONS | PIN OR FREQUENCY | MIN | TYP | MAX | UNIT |
|---|------------------------------|--|-----------------------|-------------------------|-----|-------------------------|---------|
| POWER CONSUMPTION | | | | | | | |
| I_{DD_TOTAL} | Supply current | 416-MHz CSI Input Clock, 4 Lane Mode, Checkerboard Pattern | VDDPLL, VDDD, VDDDRV | | 160 | 225 | mA |
| I_{DDPLL} | | | VDDPLL | | 55 | 80 | |
| I_{DDD} | | | VDDD | | 45 | 70 | |
| I_{DDDRV} | | | VDDDRV | | 60 | 75 | |
| 1.8-V LVC MOS I/O (VDD) = 1.71 V to 1.89 V | | | | | | | |
| V_{OH} | High level output voltage | $I_{OH} = -4$ mA | GPIO[3:0], CLK_OUT | $V_{(VDD)} - 0.45$ | | $V_{(VDD)}$ | V |
| V_{OL} | Low level output voltage | $I_{OL} = +4$ mA | GPIO[3:0], CLK_OUT | GND | | 0.45 | V |
| V_{IH} | High level input voltage | | GPIO[3:0], PDB, CLKIN | $V_{(VDD)} \times 0.65$ | | $V_{(VDD)}$ | V |
| V_{IL} | Low level input voltage | | GPIO[3:0], PDB, CLKIN | GND | | $V_{(VDD)} \times 0.35$ | V |
| I_{IH} | Input high current | $V_{IN} = V_{(VDD)}$ | GPIO[3:0], PDB, CLKIN | | | 20 | μ A |
| I_{IL} | Input low current | $V_{IN} = GND$ | GPIO[3:0], PDB, CLKIN | -20 | | | μ A |
| I_{OS} | Output short-circuit current | $V_{OUT} = 0$ V | | | -36 | | mA |
| I_{OZ} | TRI-STATE output current | $V_{OUT} = V_{(VDD)}$, $V_{OUT} = GND$ | GPIO[3:0], CLK_OUT | | | ± 20 | μ A |
| C_{IN} | Input capacitance | | | | 5 | | pF |

Electrical Characteristics (continued)

Over recommended operating supply and temperature ranges unless otherwise specified.

| PARAMETER | | TEST CONDITIONS | PIN OR FREQUENCY | MIN | TYP | MAX | UNIT |
|--|--|---|------------------|------|---------|------|-------------------|
| FPD-LINK III INPUT/OUTPUT | | | | | | | |
| V_{IN-BC} | Single-ended input voltage | Coaxial configuration, 50 Ω , maximum cable length | DOUT+, DOUT- | 120 | | | mV |
| V_{ID-BC} | Differential input voltage | STP configuration, 100 Ω , maximum cable length | DOUT+, DOUT- | 240 | | | |
| E_{H-FC} | Forward channel eye height | Coaxial configuration, FPD-Link forward channel = 4.16 Gbps | DOUT+, DOUT- | | 425 | | mVp-p |
| | | STP configuration, FPD-Link forward channel = 4.16 Gbps | DOUT+, DOUT- | | 850 | | |
| t_{TR-FC} | Forward channel output transition time | FPD-Link forward channel = 4.16Gbps; 20% to 80% | DOUT+, DOUT- | | 65 | | ps |
| t_{JIT-FC} | Forward channel output jitter | Synchronous mode, measured with f/15 –3dB CDR Loop BW | DOUT+, DOUT- | | 0.21 | | UI |
| | | Non-synchronous mode, measured with f/15 –3dB CDR Loop BW | DOUT+, DOUT- | | 0.22 | | |
| f_{REF} | Internal reference frequency | Non-synchronous internal clocking mode | | 24.2 | | 25.5 | MHz |
| FPD-LINK III DRIVER SPECIFICATIONS (DIFFERENTIAL) | | | | | | | |
| V_{ODp-p} | Output differential voltage | $R_L = 100 \Omega$ | DOUT+, DOUT- | 1040 | 1150 | 1340 | mV _{p-p} |
| ΔV_{OD} | Output voltage imbalance | | DOUT+, DOUT- | | 5 | 24 | mV |
| V_{OS} | Output differential offset voltage | | DOUT+, DOUT- | | 575 | | mV |
| ΔV_{OS} | Offset voltage imbalance | | DOUT+, DOUT- | | 2 | | mV |
| I_{OS} | Output short-circuit current | DOUT = 0 V | DOUT+, DOUT- | | –22 | | mA |
| R_T | Internal termination resistance | Between DOUT+ and DOUT- | DOUT+, DOUT- | 80 | 100 | 120 | Ω |
| FPD-LINK III DRIVER SPECIFICATIONS (SINGLE-ENDED) | | | | | | | |
| V_{OUT} | Output single-ended voltage | $R_L = 50 \Omega$ | DOUT+, DOUT- | 520 | 575 | 670 | mV _{p-p} |
| I_{OS} | Output short-circuit current | DOUT = 0 V | DOUT+, DOUT- | | –22 | | mA |
| R_T | Single-ended termination resistance | | DOUT+, DOUT- | 40 | 50 | 60 | Ω |
| VOLTAGE AND TEMPERATURE SENSING | | | | | | | |
| V_{ACC} | Voltage accuracy | See Voltage and Temperature Sensing | GPIO[1:0] | | ± 1 | | LSB |
| T_{ACC} | Temperature accuracy | See Voltage and Temperature Sensing | | | ± 1 | | LSB |

Electrical Characteristics (continued)

Over recommended operating supply and temperature ranges unless otherwise specified.

| PARAMETER | | TEST CONDITIONS | PIN OR FREQUENCY | MIN | TYP | MAX | UNIT |
|---|--|-----------------|--|------|-----|-----|----------|
| CSI-2 HS INTERFACE DC SPECIFICATIONS | | | | | | | |
| $V_{CMRX(DC)}$ | Common-mode voltage HS receive mode | | CSI_D3P/N, CSI_D2P/N, CSI_D1P/N, CSI_D0P/N, CSI_CLKP/N | 70 | | 330 | mV |
| V_{IDTH} | Differential input high threshold | | CSI_D3P/N, CSI_D2P/N, CSI_D1P/N, CSI_D0P/N, CSI_CLKP/N | | | 70 | mV |
| V_{IDTL} | Differential input low threshold | | CSI_D3P/N, CSI_D2P/N, CSI_D1P/N, CSI_D0P/N, CSI_CLKP/N | -70 | | | mV |
| Z_{ID} | Differential input impedance | | CSI_D3P/N, CSI_D2P/N, CSI_D1P/N, CSI_D0P/N, CSI_CLKP/N | 80 | 100 | 125 | Ω |
| CSI-2 HS INTERFACE AC SPECIFICATIONS | | | | | | | |
| t_{HOLD} | Data to clock setup time | | CSI_D3P/N, CSI_D2P/N, CSI_D1P/N, CSI_D0P/N, CSI_CLKP/N | 0.15 | | | UI |
| t_{SETUP} | Data to clock hold time | | CSI_D3P/N, CSI_D2P/N, CSI_D1P/N, CSI_D0P/N, CSI_CLKP/N | 0.15 | | | UI |
| CSI-2 LP INTERFACE DC SPECIFICATIONS | | | | | | | |
| V_{IH} | Logic high input voltage | | CSI_D3P/N, CSI_D2P/N, CSI_D1P/N, CSI_D0P/N, CSI_CLKP/N | 880 | 790 | | mV |
| V_{IL} | Logic low input voltage | | CSI_D3P/N, CSI_D2P/N, CSI_D1P/N, CSI_D0P/N, CSI_CLKP/N | | 710 | 550 | mV |
| V_{HYST} | Input hysteresis | | CSI_D3P/N, CSI_D2P/N, CSI_D1P/N, CSI_D0P/N, CSI_CLKP/N | 25 | 75 | | mV |

Electrical Characteristics (continued)

Over recommended operating supply and temperature ranges unless otherwise specified.

| PARAMETER | | TEST CONDITIONS | PIN OR FREQUENCY | MIN | TYP | MAX | UNIT |
|---------------------------|-------------------------------------|---|---------------------|------------------------|-----|------------------------|---------|
| LVC MOS I/O | | | | | | | |
| t_{CLH} | LVC MOS low-to-high transition time | $V_{(VDD)} = 1.71$ to 1.89 V | GPIO[3:0] | | 2 | | ns |
| t_{CHL} | LVC MOS high-to-low transition time | $V_{(VDD)} = 1.71$ to 1.89 V | GPIO[3:0] | | 2 | | ns |
| t_{PDB} | PDB reset pulse width | Voltage supplies applied and stable | PDB | 3 | | | ms |
| SERIAL CONTROL BUS | | | | | | | |
| V_{IH} | Input high level | | I2C_SCL, I2C_SDA | $0.7 \times V_{(I2C)}$ | | $V_{(I2C)}$ | mV |
| V_{IL} | Input low level | | I2C_SCL, I2C_SDA | GND | | $0.3 \times V_{(I2C)}$ | mV |
| V_{HY} | Input hysteresis | | I2C_SCL, I2C_SDA | | >50 | | mV |
| V_{OL} | Output low level | $V_{(I2C)} < 2$ V, $I_{OL} = 3$ mA, Standard-mode/Fast-mode | I2C_SCL, I2C_SDA | 0 | | $0.2 \times V_{(I2C)}$ | V |
| | | $V_{(I2C)} < 2$ V, $I_{OL} = 20$ mA, Fast-mode plus | I2C_SCL, I2C_SDA | 0 | | $0.2 \times V_{(I2C)}$ | V |
| | | $V_{(I2C)} > 2$ V, $I_{OL} = 3$ mA, Standard-mode/Fast-mode | I2C_SCL, I2C_SDA | 0 | | 0.4 | V |
| | | $V_{(I2C)} > 2$ V, $I_{OL} = 20$ mA, Fast-mode plus | I2C_SCL, I2C_SDA | 0 | | 0.4 | V |
| I_{IH} | Input high current | $V_{IN} = V_{(I2C)}$ | I2C_SCL, I2C_SDA | -10 | | 10 | μ A |
| I_{IL} | Input low current | $V_{IN} = 0$ V | I2C_SCL, I2C_SDA | -10 | | 10 | μ A |
| I_{IL} | Input low current | $V_{IN} = 0$ V | I2C_SCL, I2C_SDA | -10 | | 10 | μ A |
| C_{IN} | Input capacitance | | I2C_SCL, I2C_SDA | | 5 | | pf |

6.6 Recommended Timing for the Serial Control Bus

Over I²C supply and temperature ranges unless otherwise specified.

| | | MIN | TYP | MAX | UNIT |
|---------------------|---|----------------|------|------|------|
| f _{SCL} | SCL Clock Frequency | Standard-mode | >0 | 100 | kHz |
| | | Fast-mode | >0 | 400 | kHz |
| | | Fast-mode Plus | >0 | 1 | MHz |
| t _{LOW} | SCL Low Period | Standard-mode | 4.7 | | μs |
| | | Fast-mode | 1.3 | | μs |
| | | Fast-mode Plus | 0.5 | | μs |
| t _{HIGH} | SCL High Period | Standard-mode | 4.0 | | μs |
| | | Fast-mode | 0.6 | | μs |
| | | Fast-mode Plus | 0.26 | | μs |
| t _{HD;STA} | Hold time for a start or a repeated start condition | Standard-mode | 4.0 | | μs |
| | | Fast-mode | 0.6 | | μs |
| | | Fast-mode Plus | 0.26 | | μs |
| t _{SU;STA} | Set up time for a start or a repeated start condition | Standard-mode | 4.7 | | μs |
| | | Fast-mode | 0.6 | | μs |
| | | Fast-mode Plus | 0.26 | | μs |
| t _{HD;DAT} | Data hold time | Standard-mode | 0 | | μs |
| | | Fast-mode | 0 | | μs |
| | | Fast-mode Plus | 0 | | μs |
| t _{SU;DAT} | Data set up time | Standard-mode | 250 | | ns |
| | | Fast -mode | 100 | | ns |
| | | Fast-mode Plus | 50 | | ns |
| t _{SU;STO} | Set up time for STOP condition | Standard-mode | 4.0 | | μs |
| | | Fast-mode | 0.6 | | μs |
| | | Fast-mode Plus | 0.26 | | μs |
| t _{BUF} | Bus free time between STOP and START | Standard-mode | 4.7 | | μs |
| | | Fast-mode | 1.3 | | μs |
| | | Fast-mode Plus | 0.5 | | μs |
| t _r | SCL & SDA rise time | Standard-mode | | 1000 | ns |
| | | Fast-mode | | 300 | ns |
| | | Fast-mode Plus | | 120 | ns |
| t _f | SCL & SDA fall time | Standard-mode | | 300 | ns |
| | | Fast-mode | | 300 | ns |
| | | Fast-mode Plus | | 120 | ns |
| C _b | Capacitive load for each bus line | Standard-mode | | 400 | pF |
| | | Fast-mode | | 400 | pF |
| | | Fast-mode Plus | | 550 | pF |
| t _{VD;DAT} | Data valid time | Standard-mode | | 3.45 | μs |
| | | Fast-mode | | 0.9 | μs |
| | | Fast-mode Plus | | 0.45 | μs |
| t _{VD;ACK} | Data vallid acknowledge time | Standard-mode | | 3.45 | μs |
| | | Fast-mode | | 0.9 | μs |
| | | Fast-mode Plus | | 0.45 | μs |
| t _{SP} | Input filter | Fast-mode | | 50 | ns |
| | | Fast-mode Plus | | 50 | ns |

6.7 Timing Diagrams



图 1. LVC MOS Transition Times

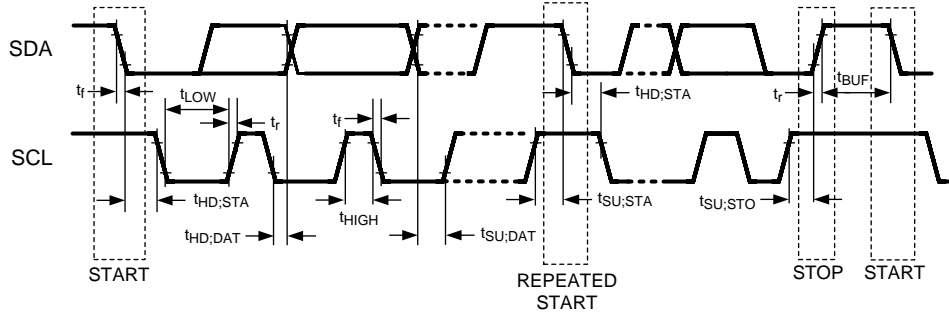


图 2. I²C Serial Control Bus Timing

6.8 Typical Characteristics

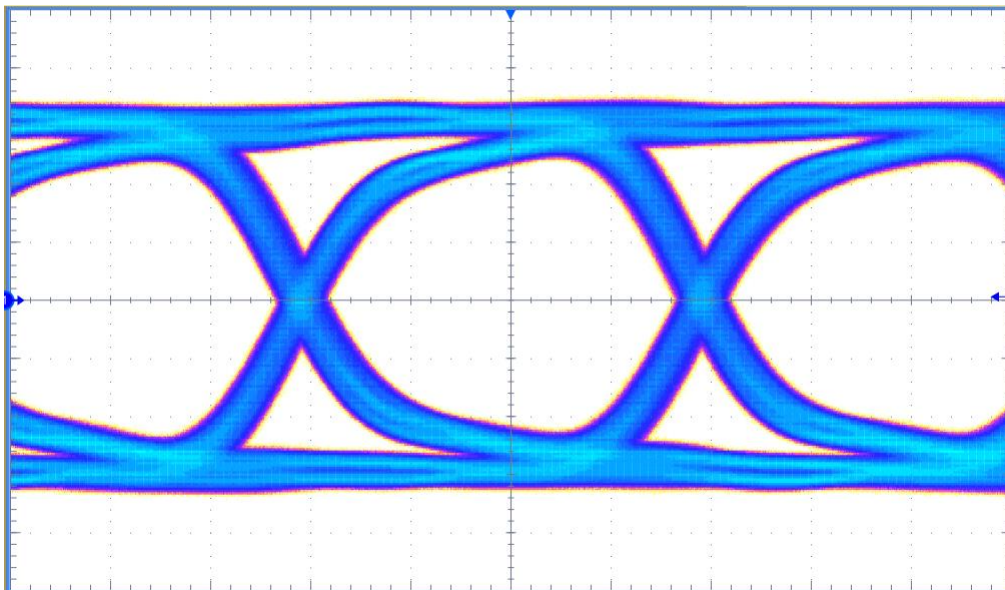


图 3. Eye Diagram at 4-Gbps FPD-Link III Forward Channel Rate From Serializer Output
Vertical Scale: 100 mV/DIV
Horizontal Scale: 62.5 ps/DIV

7 Detailed Description

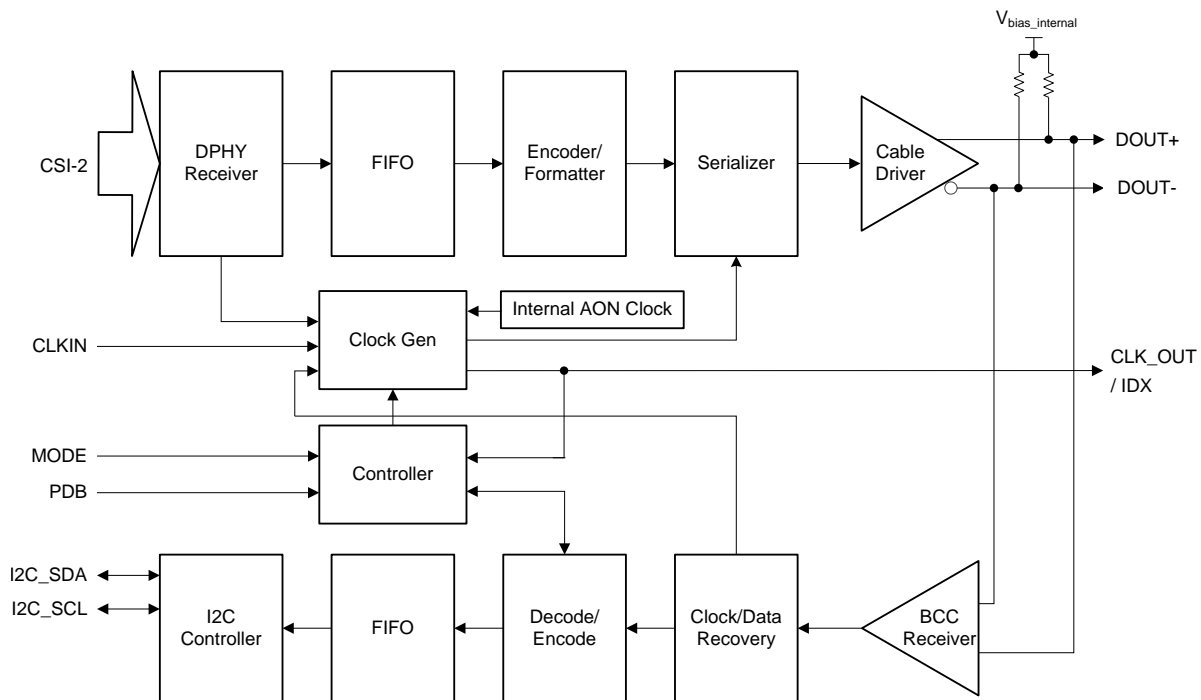
7.1 Overview

The DS90UB953-Q1 serializes data from high-resolution image sensors or other sensors using the MIPI CSI-2 interface. The DS90UB953-Q1 serializer is optimized to interface with the DS90UB954-Q1 deserializer (dual hub) or the DS90UB960-Q1 deserializer (quad hub) as well as potential future deserializers. The interconnect between the serializer and the deserializer can be either a coaxial cable or shielded-twisted pair (STP) cable. The DS90UB953-Q1 was designed to support multi-sensor systems such as surround view, and as such has the ability to synchronize sensors through the DS90UB954-Q1 and DS90UB960-Q1 hubs.

The DS90UB953-Q1 serializer and companion deserializer incorporate an I²C-compatible interface. The I²C-compatible interface allows programming of serializer or deserializer devices from a local host controller. In addition, the devices incorporate a bidirectional control channel (BCC) that allows communication between the serializer and deserializer as well as remote I²C slave devices.

The bidirectional control channel (BCC) is implemented through embedded signaling in the high-speed forward channel (serializer to deserializer) combined with lower speed signaling in the reverse channel (deserializer to serializer). Through this interface, the BCC provides a mechanism to bridge I²C transactions across the serial link from one I²C bus to another.

7.2 Functional Block Diagram



7.3 Feature Description

The DS90UB953-Q1 FPD-Link III serializer is designed to support high-speed raw data sensors including 2-MP imagers at 60 fps as well as 4-MP, 30-fps cameras, satellite RADAR, LIDAR, and Time-of-Flight (ToF) sensors. The chip features a forward channel capable of up to 4.16 Gbps and an ultra-low latency 50-Mbps bidirectional control channel. The transmission of the forward channel, bidirectional control channel, and power is supported over coaxial (Power-over-Coax) or STP cables. The DS90UB953-Q1 features advanced data protection and diagnostic features to support ADAS and autonomous driving. Together with a companion deserializer, the DS90UB953-Q1 delivers precise multi-camera sensor clock and sensor synchronization.

7.3.1 CSI-2 Receiver

The DS90UB953-Q1 receives CSI-2 video data from the Sensor. During CSI-2 operation, the D-PHY consists of a clock lane and one or more data lanes. The DS90UB953-Q1 is a Slave Device and only supports Unidirectional Lane in the Forward direction. Low Power Escape mode is not supported.

7.3.1.1 CSI-2 Receiver Operating Modes

During normal operation a Data Lane will be in either Control or High-Speed mode. In High-Speed mode, the data transmission happens in a burst and starts and ends at a Stop state (LP-11). There is a transition state to take the D-PHY from a Normal mode to the Low-Power state.

The sequence to enter High-Speed mode is: LP-11, LP-01, LP-00. After the sequence is entered, the Data Lane remains in High-Speed mode until a Stop state (LP-11) is received.

7.3.1.2 CSI-2 Receiver High-Speed Mode

During high-speed data transmission, the digital D-PHY will enable termination signal to allow proper termination of the HS RX of the Analog D-PHY, and the LP RX should stay at LP-00 state. Both CSI-2 data lane and clock lane operate in the same manner. The DS90UB953-Q1 supports CSI-2 continuous clock lane mode where the clock lane remains in high-speed mode.

7.3.1.3 CSI-2 Protocol Layer

There are two different types of CSI-2 packets: a short packet and a long packet. Short packets have information such as the Frame Start/ Line Start, and long packets carry the data after the frame start is asserted. [图 4](#) shows the structure of the CSI-2 protocol layer with short and long packets. The DS90UB953-Q1 supports 1, 2, and 4 lane configurations.

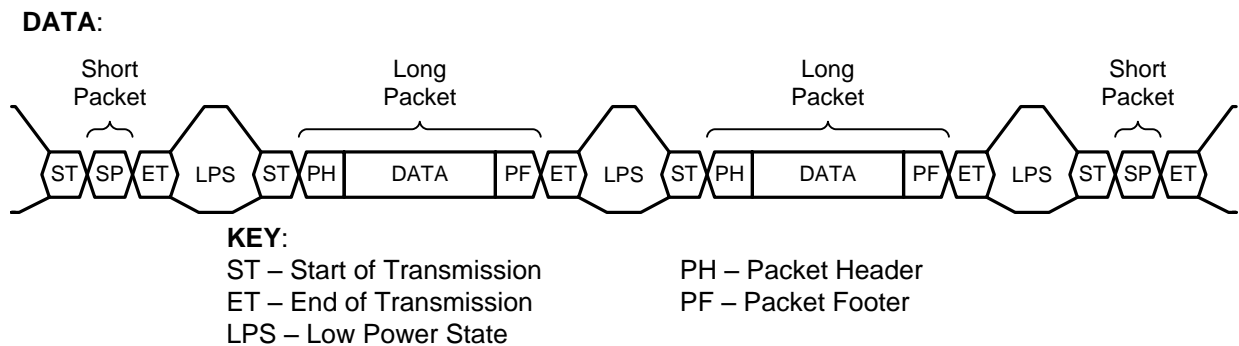
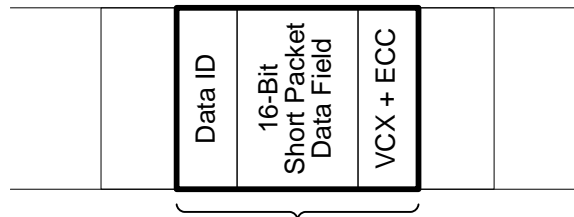


图 4. CSI-2 Protocol Layer With Short and Long Packets

7.3.1.4 CSI-2 Short Packet

The short packet provides frame or line synchronization. [图 5](#) shows the structure of a short packet. A short packet is identified by data types 0x00 to 0x0F.

Feature Description (接下页)



32-bit SHORT PACKET (SH)
Data Type (DT) = 0x00 – 0x0F

图 5. CSI-2 Short Packet Structure

7.3.1.5 CSI-2 Long Packet

A long packet consists of three elements: a 32-bit packet header (PH), an application-specific data payload with a variable number of 8-bit data words, and a 16-bit packet footer (PF). The packet header is further composed of three elements: an 8-bit data identifier, a 16-bit word count field, and an 8-bit ECC. The packet footer only has one element—a 16-bit checksum. 图 6 shows the structure of a long packet.

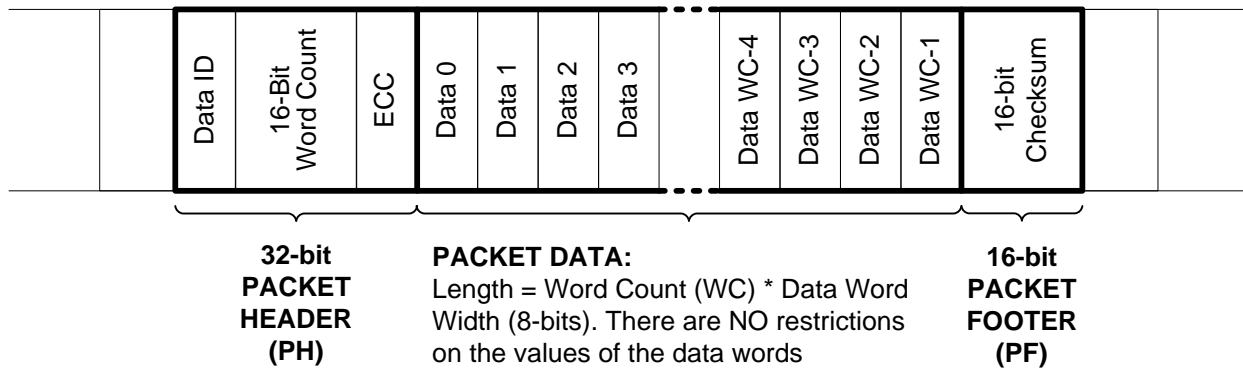


图 6. CSI-2 Long Packet Structure

表 1. CSI-2 Long Packet Structure Description

| PACKET PART | FIELD NAME | SIZE (BIT) | DESCRIPTION |
|-------------|--------------|------------|--|
| Header | VC / Data ID | 8 | Contains the virtual channel identifier and the data-type information. |
| | Word Count | 16 | Number of data words in the packet data. A word is 8 bits. |
| | ECC | 8 | ECC for data ID and WC field. Allows 1-bit error recovery and 2-bit error detection. |
| Data | Data | WC × 8 | Application-specific payload (WC words of 8 bits). |
| Footer | Checksum | 16 | 16-bit cyclic redundancy check (CRC) for packet data. |

7.3.1.6 CSI-2 Errors and Detection

7.3.1.6.1 CSI-2 ECC Detection and Correction

CSI-2 packet header contains 6-bit Error Correction Code (ECC). ECC code in the 32-bit long packet header can be corrected when there is a 1-bit error and detected when there is a 2-bit error. This feature is added to monitor the CSI-2 input for ECC 1-bit error correction. When ECC error is detected, ECC error detection register will be set and an alarm indicator bit can be sent to the Deserializer to indicate the ECC error has been detected. A register control can be used to either enable or disable the alarm. See [Specifications](#).

7.3.1.6.2 CSI-2 Check Sum Detection

A CSI-2 long packet header contains a 16-bit check sum before the end of transmission. The DS90UB953-Q1 calculates the check sum of the incoming CSI-2 data. If a check sum error is detected, the check sum error status will be saved in the CSI_ERR_STATUS register (0x5D) and can also be forwarded to the deserializer through the bidirectional control channel.

7.3.1.6.3 D-PHY Error Detection

DS90UB953-Q1 detect and reports SoT and SoT Sync errors.

7.3.1.6.4 CSI-2 Receiver Status

For the Receive ports, several status functions can be tracked and monitored through register access. The status indications are available for error conditions as well as indications of change in line length measurements. These are available through the CSI_ERR_CNT (0x5C), CSI_ERR_STATUS (0x5D), CSI_ERR_DLANE01 (0x5E), CSI_ERR_DLANE23 (0x5F), and CSI_ERR_CLK_LANE (0x60) registers.

7.3.2 FPD-Link III Forward Channel Transmitter

The DS90UB953-Q1 features a high-speed signal transmitter capable of driving signals at rates of up to 4.16 Gbps.

7.3.2.1 Frame Format

The DS90UB953-Q1 formats the data into 40-bit long frames. Each frame is encoded to ensure DC balance and to ensure sufficient data line transitions. Each frame contains video payload data, I²C forward channel data, CRC information, framing information, and information regarding the state of the CSI-2 interface.

7.3.3 FPD-Link III Back Channel Receiver

The FPD-Link III back channel receives an encoded back channel signal over the FPD-Link III interface. The back channel frame is a 30-bit frame that contains I²C commands and GPIO data. The back channel frame receives an encoded clock and data from the deserializer, thus the data bit rate is one-half the frequency of the highest frequency received.

The back channel frequency is programmable for operation with compatible deserializers. The default setting is determined by the MODE strap pin. For operation with the DS90UB954-Q1 or DS90UB960-Q1, the back channel should be programmed for 50-Mbps operation in DS90UB953-Q1 Synchronous mode and programmed for 10-Mbps operation for non-synchronous modes.

7.3.4 Serializer Status and Monitoring

The DS90UB953-Q1 features enhanced FPD-Link III diagnostics, system monitoring, and Built-In Self Test capabilities. It monitors forward channel and back channel data for errors and reports them in the status registers. It also supports voltage and temperature measurement for system level diagnostics. The Built-In Self Test feature allows testing of the forward channel and back channel data transmissions without external data connections.

7.3.4.1 Forward Channel Diagnostics

The DS90UB953-Q1 monitors the status of the forward channel link. The forward channel high-speed PLL lock status is reported in the HS_PLL_LOCK bit (Register 0x52[2]). When paired with the DS90UB954-Q1, the FPD-Link III deserializer LOCK status is also reported in the RX_LOCK_DETECT bit (Register 0x52[6]).

7.3.4.2 Back Channel Diagnostics

The DS90UB953-Q1 monitors the status of the back channel link. The back channel CRC errors are reported in the CRC_ERR bit (Register 0x52[1]). The number of CRC errors are stored in the CRC error counters and reported in the CRC_ERR_CNT1 (Register 0x55) and CRC_ERR_CNT2 (Register 0x56) registers. The CRC error counters are reset by setting the CRC_ERR_CLR (Register 0x49[3]) to 1.

When running the BIST function, the DS90UB953-Q1 reports if a BIST CRC error is detected in the BIST_CRC_ERR bit (Register 0x52[3]). The number of BIST errors are reported in the BIST_ERR_CNT field (Register 0x54). The BIST CRC error counter is reset by setting the BIST_CRC_ERR_CLR (Register 0x49[5]) to 1.

7.3.4.3 Voltage and Temperature Sensing

The DS90UB953-Q1 supports voltage measurement and temperature measurement. The temperature and voltage sensors are both equipped with a 3-bit ADC. These sensors can be configured to monitor a signal and raise a flag when a signal goes outside of a set limit. For example, a voltage sensor can be used to monitor the 1.8-V line and raise a flag if the voltage goes above 1.85 V or below 1.75 V. This flag can then be transferred to the deserializer and can set an interrupt at the deserializer end of the link. In a similar manner, the temperature sensor will trigger an alarm bit when the internal temperature of DS90UB953-Q1 is outside the range.

Both GPIO0 and GPIO1 can be configured to sense the voltage applied at their inputs. [Table 32](#) through [Table 38](#) cover the registers specific to this section.

For a given voltage or temperature, the measurement accuracy is ± 1 LSB. This means that for a given input voltage or temperature corresponding to the nearest value in [表 2](#) and [表 3](#), the resulting ADC output code will be accurate to the nearest ± 1 code.

表 2. ADC Code vs Input Voltage

| GPIO VIN (V) | CODE |
|-------------------|------|
| VIN < 0.85 | 000 |
| 0.85 < VIN < 0.90 | 001 |
| 0.90 < VIN < 0.95 | 010 |
| 0.95 < VIN < 1.00 | 011 |
| 1.00 < VIN < 1.05 | 100 |
| 1.05 < VIN < 1.10 | 101 |
| 1.10 < VIN < 1.15 | 110 |
| 1.15 < VIN | 111 |

表 3. ADC Code vs Temperature

| TEMPERATURE (°C) | CODE |
|------------------|------|
| T < -30 | 000 |
| -30 < T < -10 | 001 |
| -10 < T < 15 | 010 |
| 15 < T < 35 | 011 |
| 35 < T < 55 | 100 |
| 55 < T < 75 | 101 |
| 75 < T < 100 | 110 |
| 100 < T | 111 |

7.3.4.3.1 Programming Example

This section provides an example of configuring the DS90UB953-Q1 and DS90UB954-Q1 for monitoring the voltage on the DS90UB953-Q1 GPIO1 and setting an alarm which results in the INT pin being asserted on the DS90UB954-Q1.

```
# DS90UB953-Q1 Settings

WriteI2C(0x17,0x3E) # Enable Sensor, Select GPIO1 to sense
WriteI2C(0x18,0xB2) # Enable Sensor Gain Setting (Use Default)
WriteI2C(0x1A,0x62) # Set Sensor Upper and Lower Limits (Use Default)
WriteI2C(0x1D,0x3F) # Enable Sensor Alarms
WriteI2C(0x1E,0x7F) # Enable Sending Alarms over BCC

# Register 0x57 readout (bits 2 and 3), indicates if the voltage on the GPIO1 is below or above the
# thresholds set in the register 0x1A.

# DS90UB954-Q1 Settings

WriteI2C(0x23,0x81) # Enable Interrupts, Enable Interrupts for the camera attached to RX0
WriteI2C(0x4C,0x01) # Enable Writes to RX0 registers
WriteI2C(0xD8,0x08) # Interrupt on change in Sensor Status

# Register 0x51 and 0x52 readouts indicate Sensor data. Register 0x24[7] bit readout indicates the
# Alarm bit. The alarm bit can be routed to GPIO3/INT through GPIO_PIN_CTL and GPIO_OUT_SRC registers.
```

7.3.4.4 Built-In Self Test

An optional At-Speed Built-In Self Test (BIST) feature supports testing of the high-speed serial link and back channel without external data connections. This is useful in the prototype stage, equipment production, in-system test, and system diagnostics.

BIST mode is enabled by BIST configuration register 0xB3[0] on the deserializer and should be run in the synchronous mode. When BIST is activated at the deserializer, a BIST enable signal is sent to the serializer through the back channel. The serializer outputs a continuous stream of a pseudo-random sequence and drives the link at speed. The deserializer detects the test pattern and monitors it for errors. The serializer also tracks errors indicated by the CRC fields in each back channel frame. While the lock indications are required to identify the beginning of proper data reception, the best indication of any link failures or data corruption is the content of the error counter in the BIST_ERR_COUNT register 0x57 for each RX port on the deserializer side. BIST mode is useful in the prototype stage, equipment production, in-system test, and system diagnostics.

7.3.5 FrameSync Operation

When paired with compatible deserializers, any of the DS90UB953-Q1 GPIO pins can be use for frame synchronization. This feature is useful when multiple sensors are connected to a deserializer hub. A frame synchronization signal (FrameSync) can be sent through the back channel using any of the back channel GPIOs. The FrameSync signal arrives at the serializers with limited skew.

7.3.5.1 External FrameSync

In External FrameSync mode, an external signal is input to the deserializer through one of the GPIO pins on the device. The external FrameSync signal may be propagated to one or more of the attached FPD-Link III Serializers through a GPIO signal in the back channel. The expected skew timing for external FrameSync mode is on the order of one back channel frame period or 600 ns when operating at 50 Mbps.

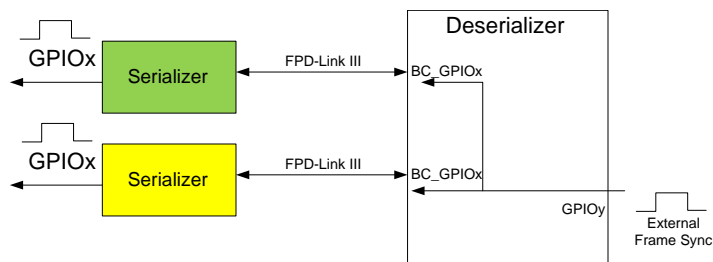


图 7. External FrameSync

Enabling the external FrameSync mode is done on the deserializer side. Refer to the deserializer data sheet for more information.

7.3.5.2 Internally Generated FrameSync

In Internal FrameSync mode, an internally generated FrameSync signal is sent to one or more of the attached FPD-Link III Serializers through a GPIO signal in the back channel.

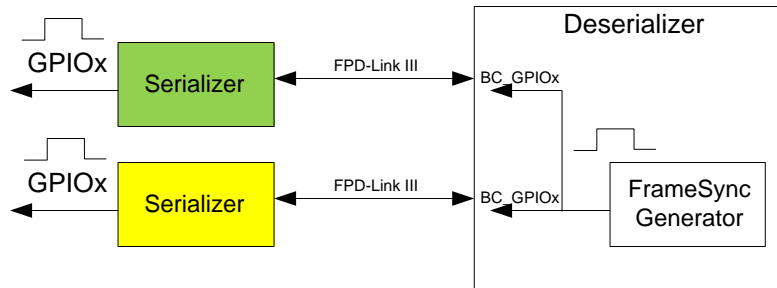


图 8. Internal FrameSync

FrameSync operation is controlled by the deserializer registers. Refer to the deserializer data sheet for more information.

7.3.6 GPIO Support

The DS90UB953-Q1 supports four pins, GPIO0 through GPIO3, which can be monitored, configured, and controlled through the I²C bus in registers 0x0D, 0x0E, and 0x53. These GPIOs are programmable for use in multiple situations. GPIO0 and GPIO1 have additional diagnostics functionality and may be programmed to sense external voltage levels.

7.3.6.1 GPIO Status

The status HIGH or LOW of each GPIO pin 0 through 3 may be read through the GPIO_PIN_STS register 0x53. This register read operation provides the status of the GPIO pin independent of whether the GPIO pin is configured as an input or output.

7.3.6.2 GPIO Input Control

Upon initialization, GPIO0 through GPIO3 are enabled as inputs by default. The GPIO_INPUT_CTRL (0x0E) register, bits 3:0, allows control of the input enable. If a GPIO_INPUT_CTRL[3:0] bit is set to 1, then the corresponding GPIO_INPUT_CTRL[7:4] bit must be set to 0.

7.3.6.3 GPIO Output Control

Individual GPIO output control is programmable through the GPIO_INPUT_CTRL (0x0E) register, bits 7:4 [Table 25](#). If a GPIO_INPUT_CTRL[7:4] bit is set to 1, then the corresponding GPIO_INPUT_CTRL[3:0] bit must be set to 0.

7.3.6.4 Forward Channel GPIO

The input on the DS90UB953-Q1 GPIO pins can be forwarded to compatible deserializers over the FPD-Link III interface. Up to four GPIOs are supported in the forward direction.

The timing for the forward channel GPIO is dependent on the number of GPIOs assigned at the serializer. When a single GPIO input from the DS90UB953-Q1 serializer is linked to a compatible deserializer GPIO output the value is sampled every forward channel transmit frame. Two linked GPIO are sampled every two forward channel frames and three or four linked GPIO are sampled every five frames. The typical minimum latency for the GPIO remains consistent (approximately 225 ns) but as the information gets spread over multiple frames the jitter is typically increased on the order of the sampling period (number of forward channel frames). TI recommends that the user maintains a 4x oversampling ratio for linked GPIO throughput. For example, when operating in 4-Gbps synchronous mode with REFCLK = 25 MHz, the maximum recommended GPIO input frequency based on the number of GPIO linked over the forward channel is shown in [表 4](#).

表 4. Forward Channel GPIO Typical Timing

| NUMBER OF LINKED FORWARD CHANNEL GPIOs (FC_GPIO_EN) | SAMPLING FREQUENCY (MHz) AT FPD-Link III LINE RATE = 4 Gbps | MAXIMUM RECOMMENDED FORWARD CHANNEL GPIO FREQUENCY (MHz) | TYPICAL JITTER (ns) |
|---|---|--|---------------------|
| 1 | 100 | 25 | 12 |
| 2 | 50 | 12.5 | 24 |
| 4 | 20 | 5 | 60 |

7.3.6.5 Back Channel GPIO

When enabled as an output, each DS90UB953-Q1 GPIO pin can be programmed to output remote data coming from the compatible deserializer using the LOCAL_GPIO_DATA register (0x0D). The maximum signal frequency that can be received over the FPD-Link III back channel is dependent on the DS90UB953-Q1 Clocking Mode as shown in [表 5](#).

表 5. Back Channel GPIO Typical Timing

| DS90UB953-Q1 Clocking Mode | BACK CHANNEL RATE (Mbps) | SAMPLING FREQUENCY (kHz) | MAXIMUM RECOMMENDED BACK CHANNEL GPIO FREQUENCY (kHz) | TYPICAL LATENCY (μs) | TYPICAL JITTER (μs) |
|----------------------------|--------------------------|--------------------------|---|----------------------|---------------------|
| Synchronous Mode | 50 | 1670 | 416 | 1.5 | 0.7 |
| Non-Synchronous Modes | 10 | 334 | 83.5 | 3.2 | 3 |
| DVP Mode | 2.5 | 83.5 | 20 | 12.2 | 12 |

7.4 Device Functional Modes

7.4.1 Clocking Modes

The DS90UB953-Q1 supports several clocking schemes, which are selected through the MODE pin. In the DS90UB953-Q1, the forward channel operates at a higher bandwidth than the requirement set by the video data being transported, and the forward channel data rate is set by a reference clock. The clocking mode determines what the device uses as its reference clock, and the most common configuration is Synchronous Mode, in which no local reference oscillator is required. See [表 6](#) for more information.

The default mode of the DS90UB953-Q1 is set by the application of a bias on the MODE pin during power up. More information on setting operation modes can be found in [MODE](#).

Device Functional Modes (接下页)

表 6. Clocking Modes

| MODE | DIVIDE | REFERENCE SOURCE | REF FREQUENCY (MHz) | FC DATA RATE | CSI BANDWIDTH ≤ | CLK_OUT (1) |
|--|-------------------------------|---|---------------------|--------------|-----------------|--|
| Synchronous (Half-rate) | N/A | Back Channel ⁽²⁾ | 23 - 26 | f × 160 | f × 128 | $f \times 160 / HS_CLK_DIV \times (M/N)$ |
| | N/A | Back Channel ⁽²⁾ | 11.5 - 13 | f × 160 | f × 128 | $f \times 160 / HS_CLK_DIV \times (M/N)$ |
| Non-Synchronous external clock | CLKIN_DIV = 1, | Back Channel (Half Rate) ⁽³⁾ | 25 - 52 | f × 80 | f × 64 | $f \times 80 / HS_CLK_DIV \times (M/N)$ |
| | CLKIN_DIV = 2, | External clock ⁽³⁾ | 50 - 104 | f × 40 | f × 32 | $f \times 40 / HS_CLK_DIV \times (M/N)$ |
| Non-Synchronous Internal Clock | CLKIN_DIV = 1, OSCCLK_SEL = 1 | 953 Internal Clock | 48.4 - 51 | f × 80 | f × 64 | N/A |
| DVP External Clock Deserializer Mode: RAW10 | CLKIN_DIV = 1, | External clock | 25 - 66.5 | f × 28 | f × 20 | $f \times 28 / HS_CLK_DIV \times (M/N)$ |
| DVP External Clock Deserializer Mode: RAW12 HF | CLKIN_DIV = 1, | External clock | 25 - 70 | f × 28 | f × 20 | $f \times 28 / HS_CLK_DIV \times (M/N)$ |

- (1) HS_CLK_DIV typically should be set to either 16, 8, or 4 (default).
- (2) The Back Channel is recovered from the FPD-Link III bidirectional control channel. Local reference clock source is not needed. Refer to the Deserializer data sheet for Back Channel frequency settings.
- (3) Local reference clock source is needed. Provide a clock source to the DS90UB953-Q1's CLKIN pin.

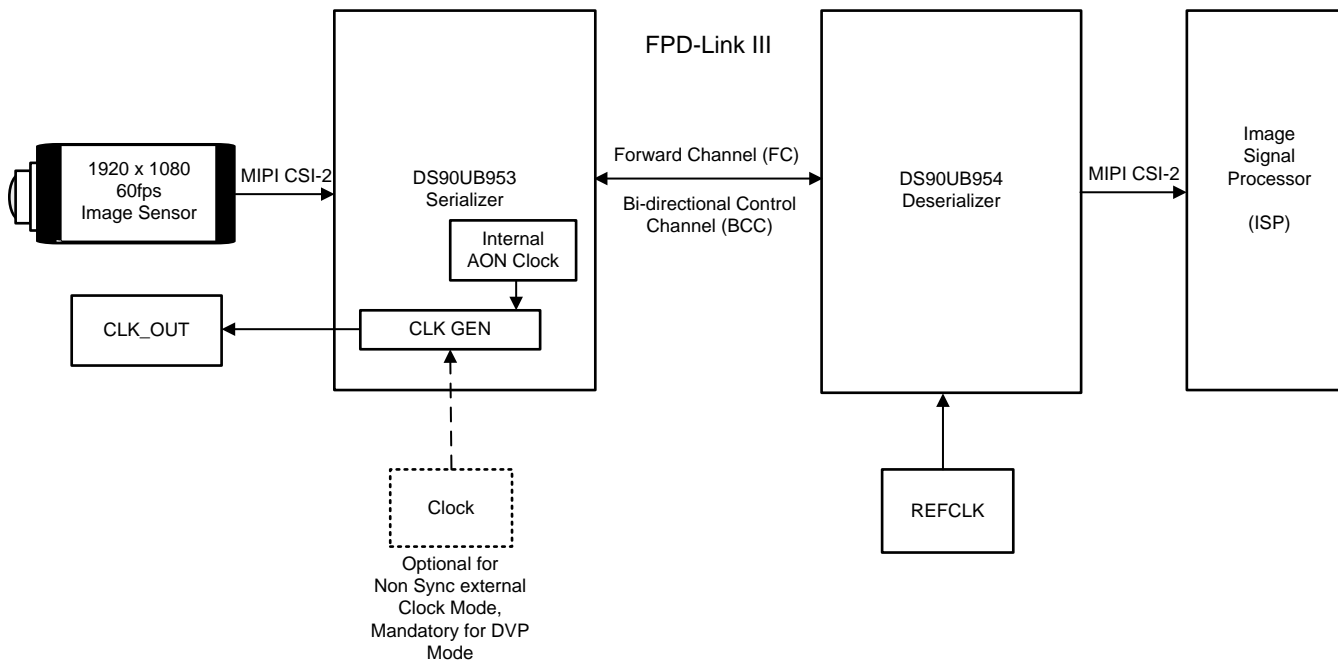


图 9. Clocking System Diagram

7.4.1.1 Synchronous Mode

Operation in synchronous mode offers the advantage that the receiver and all of the sensors in a multi-sensor system are locked to a common clock in the same clock domain, which reduces or eliminates the need for data buffering and resynchronization. The synchronous clocking mode also eliminates the cost, space, and potential failure point of a reference oscillator within the sensor module.

In this mode, a clock is passed from the deserializer to the serializer through the FPD-Link III back channel, and the serializer is able to use this clock both as a reference clock for an attached image sensor, and as a reference clock for the link back to the deserializer (FPD-Link III forward channel). For operation in this mode, the DS90UB953-Q1 must be paired with a deserializer that can support this feature such as the DS90UB954-Q1 or DS90UB60-Q1.

7.4.1.2 Non-Synchronous Clock Mode

In the Non-Synchronous Clock mode, the external reference clock is supplied to the serializer, and it uses this clock to derive the FPD-Link III forward channel and an external reference clock for an attached image sensor. When in CSI-2 mode, the CSI-2 interface may be synchronous to this clock. The CSI-2 rate must be lower than the line rate. For example, with a 50-MHz clock the FPD-Link III forward channel rate is 4 Gbps, the CSI-2 throughput must be ≤ 3.32 Gbps (See [表 6](#)).

7.4.1.3 Non-Synchronous Internal Mode

In the Non-Synchronous Internal Clocking mode, the serializer uses the internal Always on Clock (AON) as the reference clock for the forward channel. The OSCCLK_SEL select must be asserted $0x05[3]=1$, to enable maximum data rate when using internal clock mode, and the CLK_OUT function is disabled. A separate reference is provided to the image sensor or ISP. When in CSI-2 mode, the CSI-2 interface may be synchronous to this clock. The CSI-2 rate must be lower than the line rate. For example, with the internal clock of 24.2 MHz the FPD-Link III forward channel rate is 3.872 Gbps, the CSI-2 throughput must be ≤ 3.1 Gbps (See [表 6](#)).

7.4.1.4 DVP Backwards Compatibility Mode

The DS90UB953-Q1 can be placed into DVP mode to be backwards compatible with the DS90UB934-Q1 or DS90UB914A-Q1. While the Mode should have been configured using the Mode pin on the DS90UB953-Q1, the register MODE_SEL register $0x03[2:0]$ can be used to verify or override the current mode. This field always indicates the MODE setting of the device. When bit 4 of this register is 0, this field is read-only and shows the Mode Setting. Mode is latched from strap value when PDB transitions LOW to HIGH and the value should read back 101 (0x5) if the resistive strap is set correctly to DVP External Clock Backwards Compatible Mode. Alternatively when bit 4 of this register is set to 1, the MODE field is read/write and can be programmed to 101 to assign the correct backwards compatible MODE. This is shown in [Table 14](#).

CSI-2 input data provided to the DS90UB953-Q1 must be synchronized to the input frequency applied to CLKIN when using DVP external clock mode. The PCLK frequency output from the DS90UB934-Q1 or DS90UB914A-Q1 deserializer will also be related to CLKIN when in DVP external clock mode. See [Backwards Compatibility Modes for Operation With Parallel Output Deserializers](#) (SNLA270) for more information.

表 7. List of Registers Used for DVP Configuration

| REGISTER | REGISTER NAME | REGISTER DESCRIPTION |
|----------|--------------------|---|
| 0X03 | MODE_SEL | Used to override and verify strapped value if necessary and configure for DVP with an external clock. |
| 0X04 | BC_MODE_SELE CT | Allows DVP mode overwrites to RAW 10 or RAW 12. |
| 0X10 | DVP_CFG | Allows configuration of data in DVP mode. This includes data types like long, YUV, and specified types. |
| 0X11 | DVP_DT | Allows packets with certain data type regardless of RAW 10 or 12 mode if DVP_DT_MATCH_EN is asserted. |

7.4.1.5 Configuring CLK_OUT

When using the DS90UB953-Q1 in either Synchronous or Non-Synchronous external clock modes, CLK_OUT is intended as a reference clock for the image sensor. CLK_OUT functionality is disabled when operating in Non-Synchronous internal clocking mode. The frequency of the external CLK_OUT is set by [公式 1](#) and [公式 2](#).

$$\text{CLK_OUT} = \text{FC} \times \frac{\text{M}}{\text{HS_CLK_DIV} \times \text{N}}$$

where

- FC is the forward channel data rate, and M, HS_CLK_DIV, and N are parameters set by registers 0x06 and 0x07 (1)

$$\frac{\text{FC}}{\text{HS_CLK_DIV}} < 1.05 \text{ GHz} \quad (2)$$

The PLL that generates CLK_OUT is a digital PLL, and as such, has very low jitter if the ratio N/M is an integer. If N/M is not an integer, then the jitter on the signal is approximately equal to HS_CLK_DIV/FC—so if it is not possible to have an integer ratio of N/M, it is best to select a smaller value for HS_CLK_DIV.

If a particular CLK_OUT frequency such as 37.125 MHz is required for a system, selecting values of M=9, N=0xF2, and HS_CLK_DIV=4 results in an output frequency of 37.190 MHz and a frequency error of 0.175% with an associate jitter of approximately 1 ns. Alternately, the designer could use M=1, N=0x1E, HS_CLK_DIV=4 for CLK_OUT = 37.037 MHz, and a frequency error of 0.24% for less jitter. A third alternative would be to use M=1, N=0x1E, and HS_CLK_DIV=4, but rather than using a 25.000-MHz reference clock frequency (REFCLK) for the deserializer in synchronous mode, use a frequency of 25.059 MHz. The 2x reference then fed to the DS90UB953-Q1 from the deserializer back channel will allow generating CLK_OUT = 37.124 MHz with both low jitter and a low frequency error.

7.4.2 MODE

The DS90UB953-Q1 can operate in one of four different modes. The user can apply the bias voltage to the MODE pin during power up to operate in Default mode. To set this voltage, a potential divider between VDDPLL and GND is used to apply the appropriate bias. This potential divider should be referenced to the potential on the VDDD pin. After power up, the MODE can be read or changed through register access.

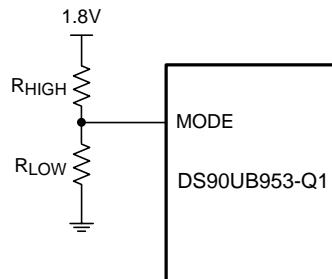


图 10. MODE Configuration

表 8. Strap Configuration Mode Select

| MODE SELECT | | V _{TARGET} VOLTAGE RANGE | | | V _{TARGET} STRAP VOLTAGE | SUGGESTED STRAP RESISTORS (1% TOL) | | DESCRIPTION |
|------------------|--------------------------------|-----------------------------------|----------------------------|----------------------------|-----------------------------------|------------------------------------|-----------------------|--|
| MODE | NAME | RATIO MIN | RATIO TYP | RATIO MAX | V _(VDD) = 1.8 V | R _{HIGH} (kΩ) | R _{LOW} (kΩ) | |
| 0 | Synchronous | 0 | 0 | 0.133 x V _(VDD) | 0 | OPEN | 10 | CSI-2 Synchronous mode – FPD-Link III Clock reference derived from deserializer. |
| 2 | Non-Synchronous External Clock | 0.288 x V _(VDD) | 0.325 x V _(VDD) | 0.367 x V _(VDD) | 0.586 | 75 | 35.7 | CSI-2 Non-synchronous clock – FPD-Link III Clock reference derived from external clock reference input on CLKIN pin. |
| 3 | Non-Synchronous Internal Clock | 0.412 x V _(VDD) | 0.443 x V _(VDD) | 0.474 x V _(VDD) | 0.792 | 71.5 | 56.2 | CSI-2 Non-synchronous – FPD-Link III Clock reference derived from internal AON clock. |
| 5 ⁽¹⁾ | DVP Mode | 0.642 x V _(VDD) | 0.673 x V _(VDD) | 0.704 x V _(VDD) | 1.202 | 39.2 | 78.7 | DVP with External clock. |

(1) The DS90UB934-Q1 and DS90UB914A-Q1 deserializers also contain a Mode pin (21). However, the mode pin on the deserializer determines the expected data format: RAW10, RAW12 LF, or RAW12 HF. Note that RAW12 LF is not supported on the DS90UB953-Q1.

7.5 Programming

7.5.1 I²C Interface Configuration

This serializer may be configured by the use of an I²C-compatible serial control bus. Multiple devices may share the serial control bus (up to two device addresses are supported). The device address is set through a resistor divider (R_{HIGH} and R_{LOW} – see [图 11](#)) connected to the IDX pin.

7.5.1.1 CLK_OUT/IDX

The CLK_OUT/IDX pin serves two functions. At power up, the voltage on the IDX pin is compared to VDD and the ratio sets various parameters for configuration of the DS90UB953-Q1. Once the DS90UB953-Q1 has been configured, the CLK_OUT/IDX pin switches over to a clock source, intended to provide a reference clock to the image sensor. A minimum load impedance at the CLK_OUT/IDX pin of 35 kΩ is required when using the CLK_OUT function.

7.5.1.1.1 IDX

The IDX pin configures the control interface to one of two possible device addresses—either the 1.8-V or 3.3-V referenced I²C address. A pullup resistor and a pulldown resistor must be used to set the appropriate voltage on the IDX input pin (see [图 11](#)). The IDX resistor divider must be referred to Pin #25 (after the ferrite filter on the DS90UB953-Q1 pin side).

表 9. IDX Configuration Setting

| IDX | V _{TARGET} VOLTAGE RANGE | | | V _{IDX} TARGET VOLTAGE | SUGGESTED STRAP RESISTORS (1% TOL) | | I ² C 8-BIT ADDRESS | I ² C 7-BIT ADDRESS | V _(I2C) (I2C I/O VOLTAGE) |
|-----|-----------------------------------|------------------------------|------------------------------|---------------------------------|------------------------------------|-----------------------|--------------------------------|--------------------------------|--------------------------------------|
| | RATIO MIN | RATIO TYP | RATIO MAX | V _{VDD} = 1.8 V | R _{HIGH} (kΩ) | R _{LOW} (kΩ) | | | |
| 1 | 0 | 0 | 0.131 x V _(VDD18) | 0 | Open | 40.2 | 0x30 | 0x18 | 1.8 V |
| 2 | 0.178 x V _(VDD18) | 0.214 x V _(VDD18) | 0.256 x V _(VDD18) | 0.385 | 180 | 47.5 | 0x32 | 0x19 | 1.8 V |
| 3 | 0.537 x V _(VDD18) | 0.564 x V _(VDD18) | 0.591 x V _(VDD18) | 1.015 | 82.5 | 102 | 0x30 | 0x18 | 3.3 V |
| 4 | 0.652 x V _(VDD18) | 0.679 x V _(VDD18) | 0.706 x V _(VDD18) | 1.223 | 68.1 | 137 | 0x32 | 0x19 | 3.3 V |

Programming (接下页)

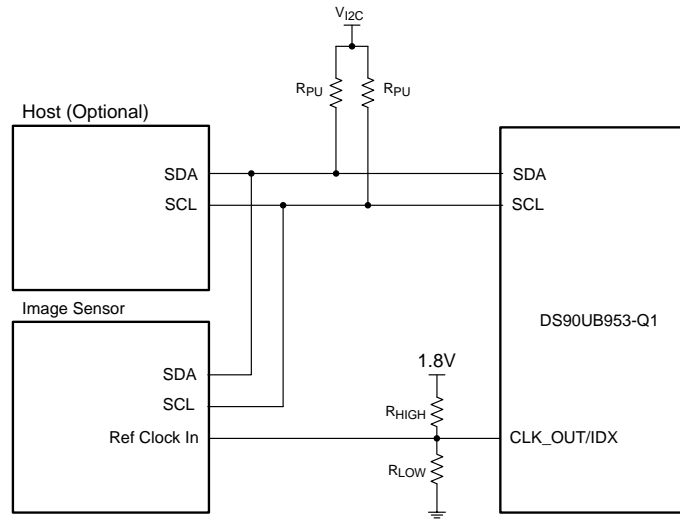


图 11. Circuit to Bias IDX Pin

7.5.2 I²C Interface Operation

The serial control bus consists of two signals: SCL and SDA. SCL is a Serial Bus Clock Input / Output signal and the SDA is the Serial Bus Data Input / Output signal. Both SCL and SDA signals require an external pullup resistor to V_{I2C} , chosen to be either 1.8 V or 3.3 V.

For the standard and fast I²C modes, a pullup resistor $R_{PU} = 4.7\text{ k}\Omega$ is recommended, while a pullup resistor $R_{PU} = 470\ \Omega$ is recommended for the fast plus mode. However, the pullup resistor value may be additionally adjusted for capacitive loading and data rate requirements. The signals are either pulled High or driven Low. The IDX pin configures the control interface to one of two possible device addresses. A pullup resistor (R_{HIGH}) and a pulldown resistor (R_{LOW}) may be used to set the appropriate voltage on the IDX input pin.

The Serial Bus protocol is controlled by START, START-Repeated, and STOP phases. A START occurs when SDA transitions Low while SCL is High. A STOP occurs when SDA transitions High while SCL is also HIGH. See 图 12.

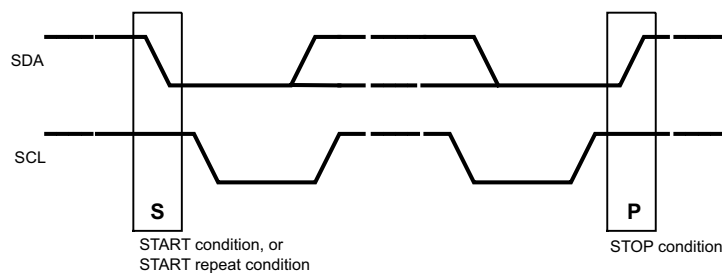


图 12. Start and Stop Conditions

To communicate with an I²C slave, the host controller (master) sends the slave address and listens for a response from the slave. This response is referred to as an acknowledge bit (ACK). If a slave on the bus is addressed correctly, the slave Acknowledges (ACKs) the master by driving the SDA bus low. If the address does not match a slave address of the device, the slave Not-acknowledges (NACKs) the master by letting SDA be pulled High. ACKs also occur on the bus when data is being transmitted. When the master is writing data, the slave ACKs after every data byte is successfully received. When the master is reading data, the master ACKs

Programming (接下页)

after every data byte is received to let the slave know that the master wants to receive another data byte. When the master wants to stop reading, the master NACKs after the last data byte and creates a stop condition on the bus. All communication on the bus begins with either a Start condition or a Repeated Start condition. All communication on the bus ends with a Stop condition. A READ is shown in 图 13 and a WRITE is shown in 图 14.

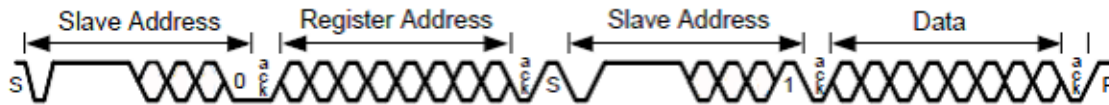


图 13. I²C Bus Read

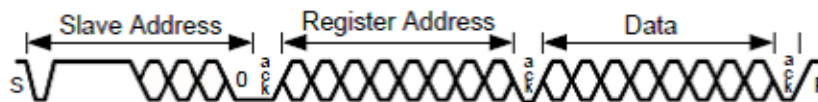


图 14. I²C Bus Write

Any I²C Master located at the serializer must support I²C clock stretching. For more information on I²C interface requirements and throughput considerations, refer to TI Application Note [I2C Communication Over FPD-Link III with Bidirectional Control Channel](#) (SNLA131).

7.5.3 I²C Timing

The proxy master timing parameters are based on the internal reference clock. The I²C Master regenerates the I²C read or write access using timing controls in the registers 0x0B and 0x0C to regenerate the clock and data signals to meet the desired I²C timing in standard, fast, or fast-plus modes of operation.

I²C Master SCL High Time is set in register 0x0B. This field configures the high pulse width of the SCL output when the serializer is the master on the local I²C bus. The default value is set to provide a minimum 5- μ s SCL high time with the internal reference clock at 26.25 MHz including five additional oscillator clock periods or synchronization and response time. Units are 38.1 ns for the nominal oscillator clock frequency, giving $\text{Min_delay} = 38.1 \text{ ns} \times (\text{SCL_HIGH_TIME} + 5)$.

I²C Master SCL Low Time is set in register 0x0C. This field configures the low pulse width of the SCL output when the serializer is the master on the local deserializer I²C bus. This value is also used as the SDA setup time by the I²C Slave for providing data prior to releasing SCL during accesses over the BiDirectional Control Channel. The default value is set to provide a minimum 5- μ s SCL high time with the reference clock at 26.25 MHz including five additional oscillator clock periods or synchronization and response time. Units are 38.1 ns for the nominal oscillator clock frequency, giving $\text{Min_delay} = 38.1 \text{ ns} \times (\text{SCL_HIGH_TIME} + 5)$. See 表 10 example settings for Standard mode, Fast mode, and Fast Mode Plus timing.

表 10. Typical I²C Timing Register Settings

| I ² C MODE | SCL HIGH TIME | | SCL LOW TIME | |
|-----------------------|---------------|---------------|--------------|---------------|
| | 0x0B | NOMINAL DELAY | 0x0C | NOMINAL DELAY |
| Standard | 0x7F | 5.03 μ s | 0x7F | 5.03 μ s |
| Fast | 0x13 | 0.914 μ s | 0x26 | 1.64 μ s |
| Fast - Plus | 0x06 | 0.419 μ s | 0x0B | 0.648 μ s |

7.6 Pattern Generation

The DS90UB953-Q1 supports an internal pattern generation feature to provide a simple way to generate video test patterns for the CSI-2 transmitter outputs. Two types of patterns are supported: Reference Color Bar patterns and Fixed Color patterns accessed by the Pattern Generator page 0 in the indirect register set. See [Indirect Access Registers](#) for more information on internal registers.

Pattern Generation (接下页)

7.6.1 Reference Color Bar Pattern

The Reference Color Bar Patterns are based on the pattern defined in Appendix D of the mipi_CTS_for_D-PHY_v1-1_r03 specification. The pattern is an 8 color bar pattern designed to provide high, low, and medium frequency outputs on the CSI-2 transmit data lanes.

The CSI-2 Reference pattern provides 8 color bars by default with the following byte data for the color bars: X bytes of 0xAA (high-frequency pattern, inverted), X bytes of 0x33 (mid-frequency pattern), X bytes of 0xF0 (low-frequency pattern, inverted), X bytes of 0x7F (lone 0 pattern), X bytes of 0x55 (high-frequency pattern), X bytes of 0xCC (mid-frequency pattern, inverted), X bytes of 0x0F (low-frequency pattern), and Y bytes of 0x80 (long 1 pattern). In most cases, Y will be the same as X. For certain data types, the last color bar may need to be larger than the others to properly fill the video line dimensions.

The Pattern Generator is programmable with the following options:

- Number of color bars (1, 2, 4, or 8)
- Number of bytes per line
- Number of bytes per color bar
- CSI-2 DataType field and VC-ID
- Number of active video lines per frame
- Number of total lines per frame (active plus blanking)
- Line period (possibly program in units of 10 ns)
- Vertical front porch – number of blank lines prior to FrameEnd packet
- Vertical back porch – number of blank lines following FrameStart packet

The pattern generator relies on proper programming by software to ensure the color bar widths are set to multiples of the block (or word) size required for the specified DataType. For example, for RGB888, the block size is 3 bytes which also matches the pixel size. In this case, the number of bytes per color bar must be a multiple of 3. The Pattern Generator is implemented in the CSI-2 Transmit clock domain, providing the pattern directly to the CSI-2 Transmitter. The circuit generates the CSI-2 formatted data.

7.6.2 Fixed Color Patterns

When programmed for Fixed Color Pattern mode, the Pattern Generator can generate a video image with a programmable fixed data pattern. The basic programming fields for image dimensions are the same as used with the Color Bar Patterns. When sending Fixed Color Patterns, the color bar controls allow alternating between the fixed pattern data and the bit-wise inverse of the fixed pattern data.

The Fixed Color patterns assume a fixed block size for the byte pattern to be sent. The block size is programmable through a register and is designed to support most 8-bit, 10-bit, and 12-bit pixel formats. The block size should be set based on the pixel size converted to blocks that are an integer multiple of bytes. For example, an RGB888 pattern would consist of 3-byte pixels and therefore require a 3-byte block size. A 2x12-bit pixel image would also require 3-byte block size, while a 3x12-bit pixel image would require 9 bytes (2 pixels) to send an integer number of bytes. Sending a RAW10 pattern typically requires a 5-byte block size for 4 pixels, so 1x10-bit and 2x10-bit could both be sent with a 5-byte block size. For 3x10-bit, a 15-byte block size would be required.

The Fixed Color patterns support block sizes up to 16 bytes in length, allowing additional options for patterns in some conditions. For example, an RGB888 image could alternate between four different pixels by using a twelve-byte block size. An alternating black and white RGB888 image could be sent with a block size of 6-bytes and setting the first three bytes to 0xFF and the next three bytes to 0x00.

To support up to 16-byte block sizes, a set of sixteen registers are implemented to allow programming the value for each data byte.

7.6.3 Packet Generator Programming

The information in this section provides details on how to program the Pattern Generator to provide a specific color bar pattern, based on datatype, frame size, and line size.

Pattern Generation (接下页)

Most basic configuration information is determined directly from the expected video frame parameters. The requirements should include the datatype, frame rate (frames per second), number of active lines per frame, number of total lines per frame (active plus blanking), and number of pixels per line.

- PGEN_ACT_LPF – Number of active lines per frame
- PGEN_TOT_LPF – Number of total lines per frame
- PGEN_LSIZE – Video line length size in bytes. Compute based on pixels per line multiplied by pixel size in bytes
- CSI-2 DataType field and VC-ID.
- Optional: PGEN_VBP – Vertical back porch. This is the number of lines of vertical blanking following Frame Valid.
- Optional: PGEN_VFP – Vertical front porch. This is the number of lines of vertical blanking preceding Frame Valid.
- PGEN_LINE_PD – Line period in 10-ns units. Compute based on Frame Rate and total lines per frame.
- PGEN_BAR_SIZE – Color bar size in bytes. Compute based on datatype and line length in bytes (see details below).

7.6.3.1 Determining Color Bar Size

The color bar pattern should be programmed in units of a block or word size dependent on the datatype of the video being sent. The sizes are defined in the MIPI CSI-2 specification. For example, RGB888 requires a 3-byte block size which is the same as the pixel size. RAW10 requires a 5-byte block size which is equal to 4 pixels. RAW12 requires a 3-byte block size which is equal to 2 pixels.

When programming the Pattern Generator, software should compute the required bar size in bytes based on the line size and the number of bars. For the standard 8 color bar pattern, that would require the following algorithm:

- Select the desired datatype, and a valid length for that datatype (in pixels).
- Convert pixels/line to blocks/line (by dividing by the number of pixels/block, as defined in the datatype specification).
- Divide the blocks/line result by the number of color bars (8), giving blocks/bar.
- Round result down to the nearest integer.
- Convert blocks/bar to bytes/bar and program that value into the PGEN_BAR_SIZE register.

As an alternative, the blocks/line can be computed by converting pixels/line to bytes/line and dividing by bytes/block.

Pattern Generation (接下页)

7.6.4 Code Example for Pattern Generator

```
#Patgen RGB888 1920x1080p30 Fixed 8 Colorbar

WriteI2C(0xB0,0x00) # Indirect Pattern Gen Registers
WriteI2C(0xB1,0x01) # PGEN_CTL
WriteI2C(0xB2,0x01)

WriteI2C(0xB1,0x02) # PGEN_CFG
WriteI2C(0xB2,0x33)

WriteI2C(0xB1,0x03) # PGEN_CSI_DI
WriteI2C(0xB2,0x24) # RGB888

WriteI2C(0xB1,0x04) # PGEN_LINE_SIZE1
WriteI2C(0xB2,0x16)

WriteI2C(0xB1,0x05) # PGEN_LINE_SIZE0
WriteI2C(0xB2,0x80)

WriteI2C(0xB1,0x06) # PGEN_BAR_SIZE1
WriteI2C(0xB2,0x02)

WriteI2C(0xB1,0x07) # PGEN_BAR_SIZE0
WriteI2C(0xB2,0xD0)

WriteI2C(0xB1,0x08) # PGEN_ACT_LPF1
WriteI2C(0xB2,0x04)

WriteI2C(0xB1,0x09) # PGEN_ACT_LPF0
WriteI2C(0xB2,0x38)

WriteI2C(0xB1,0x0A) # PGEN_TOT_LPF1
WriteI2C(0xB2,0x04)

WriteI2C(0xB1,0x0B) # PGEN_TOT_LPF0
WriteI2C(0xB2,0x65)

WriteI2C(0xB1,0x0C) # PGEN_LINE_PD1
WriteI2C(0xB2,0x0B)

WriteI2C(0xB1,0x0D) # PGEN_LINE_PDO
WriteI2C(0xB2,0x93)

WriteI2C(0xB1,0x0E) # PGEN_VBP
WriteI2C(0xB2,0x21)

WriteI2C(0xB1,0x0F) # PGEN_VFP
WriteI2C(0xB2,0x0A)
```

7.7 Register Maps

In the register definitions under the *TYPE* and *DEFAULT* heading, the following definitions apply:

- R = Read only access
- R/W = Read / Write access
- R/RC = Read only access, Read to Clear
- (R/W)/SC = Read / Write access, Self-Clearing bit
- (R/W)/S = Read / Write access, Set based on strap pin configuration at start-up
- LL = Latched Low and held until read
- LH = Latched High and held until read
- S = Set based on strap pin configuration at start-up

7.7.1 I²C Device ID Register

Table 11. Device ID Register (Address 0x00)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-----------------|--------|---------|---|
| 7:1 | DEVICE_ID | S, R/W | S | 7-bit I2C ID of Serializer. This field always indicates the current value of the I2C ID. When bit 0 of this register is 0, this field is read-only and shows the strapped ID. When bit 0 of this register is 1, this field is read/write and can be used to assign any valid I2C ID. |
| 0 | SER_ID_OVERRIDE | R/W | 0x0 | 0: Device ID is from strap 1: Register I ² C Device ID overrides strapped value |

7.7.2 Reset

Table 12. RESET_CTL Register (Address 0x01)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|----------|---------|---|
| 7:3 | RESERVED | R/W | 0x00 | Reserved |
| 2 | RESTART_AUTOLOAD | (R/W)/SC | 0x0 | Restart ROM Auto-load Setting this bit to 1 causes a reload of the ROM. This bit is self-clearing. |
| 1 | DIGITAL_RESET_1 | (R/W)/SC | 0x0 | Digital Reset 1 Resets the entire digital block including registers. This bit is self-clearing. 1: Reset 0: Normal operation |
| 0 | DIGITAL_RESET_0 | (R/W)/SC | 0x0 | Digital Reset 0 Resets the entire digital block except registers. This bit is self-clearing. 1: Reset 0: Normal operation |

7.7.3 General Configuration

Table 13. General_CFG (Address 0x02)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|---|
| 7 | RESERVED | R/W | 0x0 | Reserved |
| 6 | CONTS_CLK | R/W | 0x0 | CSI-2 Clock Lane Configuration 0 : Non Continuous Clock 1 : Continuous Clock |
| 5:4 | CSI_LANE_SEL | R/W | 0x3 | CSI-2 Data lane configuration 00: 1-lane configuration 01: 2-lane configuration 11: 4-lane configuration |
| 3:2 | RESERVED | R/W | 0x0 | Reserved |

Table 13. General_CFG (Address 0x02) (continued)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------------|--------|---------|---|
| 1 | CRC_TX_GEN_ENABLE | R/W | 0x1 | Transmitter CRC Generator 0: Disable 1: Enable |
| 0 | I2C_STRAP_MODE | S, R/W | S | I2C Strap Mode This field indicates the I2C voltage level of the device. Upon device start-up, this field will display the I2C voltage level setting from the strapped IDX pin. This field is write capable and can be used to assign the I2C voltage level. Programming this bit to change the I2C voltage level should only be performed remotely over the back channel from a connected deserializer. 0: 3.3 V 1: 1.8 V |

7.7.4 Forward Channel Mode Selection

Table 14. MODE_SEL (Address 0x03)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-----------|--------|---------|---|
| 7 | RESERVED | R/W | 0x0 | Reserved |
| 6 | RESERVED | S, R | S | Reserved |
| 5 | RESERVED | R/W | 0x0 | Reserved |
| 4 | MODE_OV | R/W | 0x0 | 0: Serializer Mode from the strapped MODE pin 1: Register Mode overrides strapped value |
| 3 | MODE_DONE | R | 0x0 | Indicates MODE value has stabilized and been latched |
| 2:0 | MODE | S, R/W | S | This field always indicates the MODE setting of the device. When bit 4 of this register is 0, this field is read-only and shows the Mode Setting. When bit 4 of this register is 1, this field is read/write and can be used to assign MODE. Mode is latched from strap value when PDB transitions LOW to HIGH. Mode of operation: 000: CSI-2 Synchronous Mode 001: Reserved 010: CSI-2 Non-synchronous external clock Mode (Requires a local clock source) 011: CSI-2 Non-synchronous Internal AON Clock 101: DVP External Clock Backwards Compatible Mode (Requires local clock source) |

7.7.5 BC_MODE_SELECT

Table 15. BC_MODE_SELECT (Address 0x04)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|---------------------|------|---------|--|
| 7:3 | RESERVED | R/W | 0x0 | Reserved. |
| 2 | MODE_OVERWRITE_100m | R/W | 0x0 | 28-bit RAW 10 Mode operation Backwards compatible RAW 10 DVP mode (28-bit) is automatically configured by the Bidirectional Control Channel once RX lock has been detected. Software may overwrite the value, but must also set the DVP_MODE_OVER_EN to prevent overwriting by the Bidirectional Control Channel |
| 1 | MODE_OVERWRITE_75m | R/W | 0x0 | 28-bit RAW 12 Mode operation Backwards compatible RAW 12 HF DVP mode (28-bit) is automatically configured by the Bidirectional Control Channel once RX lock has been detected. Software may overwrite the value, but must also set the DVP_MODE_OVER_EN to prevent overwriting by the Bidirectional Control Channel |
| 0 | DVP_MODE_OVER_EN | R/W | 0x0 | Prevent auto-loading of the backwards compatible DVP mode (28-bit) operation by the Bidirectional Control Channel |

7.7.6 PLL Clock Control

Table 16. PLLCLK_CTRL Register (Address 0x05)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|---|
| 7 | RESERVED | R/W | 0x0 | Reserved |
| 6:4 | CLKIN_DIV | R/W | 0x0 | CLKIN clock divide ratio to generate internal reference 3'b000 : CLKIN Div by 1 3'b001 : CLKIN Div by 2 3'b010 : CLKIN Div by 4 3'b011 : CLKIN Div by 8 3'b100 - 3'b111 : RESERVED |
| 3 | OSCCLK_SEL | R/W | 0x0 | Internally generated OSC clock reference when operating with Non-Synchronous internal clock or external system clock not detected. 0: 24.2 MHz to 25.5 MHz, set for 2 Gbps line rate 1: 48.4 MHz to 51 MHz, set for 4 Gbps line rate mode |
| 2:0 | RESERVED | R/W | 0x3 | Reserved |

7.7.7 Clock Output Control 0

The DS90UB953-Q1 provides an option for a programmable reference output clock to meet the system clock input requirements of various sensors. The control of the clock output frequency is set by the input divider and M value in register 0x06 and the N value in register 0x07.

Table 17. CLKOUT_CTRL0 (Address 0x06)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|---|
| 7:5 | HS_CLK_DIV | R/W | 0x2 | Clock source of M/N divider is based on the forward channel data rate divided by this register field. 000: Div by 1 001: Div by 2 010: Div by 4 011: Div by 8 100: Div by 16 |
| 4:0 | DIV_M_VAL | R/W | 0x01 | M value for M/N divider for CLKOUT. CLKOUT can be programmed using the M/N ratio of an internal high-speed clock to generate a clock output based on the system sensor requirement. When selecting the M/N ratio, they should be set to yield the CLKOUT frequency less than 100 MHz. The M value should be ≥ 0 . If set to 0, the design will get reset the M internally to default of 1. |

7.7.8 Clock Output Control 1

The DS90UB953-Q1 provides option for a programmable reference output clock to meet the system clock input requirements of various sensors. The control of the clock output frequency is set by the input divider and M value in register 0x06 and the N value in register 0x07.

Table 18. CLKOUT_CTRL1 (Address 0x07)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-----------|------|---------|--|
| 7:0 | DIV_N_VAL | R/W | 0x28 | N value for M/N divider for CLKOUT. CLKOUT can be programmed using the M/N ratio of an internal high-speed clock to generate a clock output based on the system sensor requirement. When selecting the M/N ratio, they should be set to yield the CLKOUT frequency less than 100 MHz. N must be set to non-zero value. |

7.7.9 Back Channel Watchdog Control

Table 19. BCC_WATCHDOG (Address 0x08)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------------------|------|---------|--|
| 7:1 | BCC_WD_TIMER | R/W | 0x7F | BCC_WD_TIMER sets the Bidirectional Control Channel Watchdog Timeout value in units of 2 milliseconds. This field should not be set to 0. The watchdog timer allows termination of a control channel transaction if it fails to complete within a programmed amount of time. |
| 0 | BCC_WD_TIMER_DISABLE | R/W | 0x0 | Disable Bidirectional Control Channel Watchdog Timer 1: Disables BCC Watchdog Timer operation 0: Enables BCC Watchdog Timer operation |

7.7.10 I2C Control 1

Table 20. I2C_CONTROL1 (Address 0x09)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------------|------|---------|---|
| 7 | LCL_WRITE_DISABLE | R/W | 0x0 | Disable Remote Writes to Local Registers Setting this bit to a 1 prevents remote writes to local device registers from across the control channel. This prevents writes to the Serializer registers from an I ² C master attached to the deserializer. Setting this bit does not affect remote access to I ² C slaves at the Serializer. |
| 6:4 | I2C_SDA_HOLD | R/W | 0x1 | Internal SDA Hold Time This field configures the amount of internal hold time provided for the SDA input relative to the SCL input. Units are 50 nanoseconds. |
| 3:0 | I2C_FILTER_DEPTH | R/W | 0xE | I2C Glitch Filter Depth This field configures the maximum width of glitch pulses on the SCL and SDA inputs that are rejected. Units are 5 nanoseconds. |

7.7.11 I2C Control 2

Table 21. I2C_CONTROL2 (Address 0x0A)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-----------------------|------|---------|--|
| 7:4 | SDA_OUTPUT_SETUP | R/W | 0x1 | Remote Ack SDA Output Setup When a Control Channel (remote) access is active, this field configures setup time from the SDA output relative to the rising edge of SCL during ACK cycles. Setting this value increases setup time in units of 640 ns. The nominal output setup time value for SDA to SCL when this field is 0 is 80 ns. |
| 3:2 | SDA_OUTPUT_DELAY | R/W | 0x0 | SDA Output Delay This field configures additional delay on the SDA output relative to the falling edge of SCL. Setting this value increases output delay in units of 40 ns. Nominal output delay values for SCL to SDA are: 00 : 240 ns 01: 280 ns 10: 320 ns 11: 360 ns |
| 1 | I2C_BUS_TIMER_SPEEDUP | R/W | 0x0 | Speed up I ² C Bus Watchdog Timer 1: Watchdog Timer expires after approximately 50 microseconds 0: Watchdog Timer expires after approximately 1 second. |
| 0 | I2C_BUS_TIMER_DISABLE | R/W | 0x0 | Disable I ² C Bus Watchdog Timer When the I ² C Bus Watchdog Timer may be used to detect when the I ² C bus is free or hung up following an invalid termination of a transaction. If SDA is high and no signalling occurs for approximately 1 second, the I ² C bus is assumed free. If SDA is low and no signalling occurs, the device attempts to clear the bus by driving 9 clocks on SCL. |

7.7.12 SCL High Time

Table 22. SCL_HIGH_TIME (Address 0x0B)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|---------------|------|---------|--|
| 7:0 | SCL_HIGH_TIME | R/W | 0x7F | I ² C Master SCL High Time This field configures the high pulse width of the SCL output when the Serializer is the Master on the local I ² C bus. Units are 38.1 ns for the nominal oscillator clock frequency of 26.25 MHz. The default value is set to provide a minimum 5- μ s SCL high time with the internal oscillator clock running at 26.25 MHz. Delay includes 5 additional oscillator clock periods. Min_delay = 38.0952 ns \times (SCL_HIGH_TIME + 5) |

7.7.13 SCL Low Time

Table 23. SCL_LOW_TIME (Address 0x0C)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|--|
| 7:0 | SCL_LOW_TIME | R/W | 0x7F | I ² C SCL Low Time This field configures the low pulse width of the SCL output when the Serializer is the Master on the local I ² C bus. This value is also used as the SDA setup time by the I ² C Slave for providing data prior to releasing SCL during accesses over the Bidirectional Control Channel. Units are 38.1 ns for the nominal oscillator clock frequency of 26.25 MHz. The default value is set to provide a minimum 5- μ s SCL low time with the internal oscillator clock running at 26.25 MHz. Delay includes 5 additional clock periods. Min_delay = 38.0952 ns \times (SCL_LOW_TIME + 5) |

7.7.14 Local GPIO DATA

Table 24. LOCAL_GPIO_DATA (Address 0x0D)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|--|
| 7:4 | GPIO_RMTEN | R/W | 0xF | Enable remote deserializer GPIO data on local GPIO Bit 7: Enable remote GPIO3 when this bit is set to 1 Bit 6: Enable remote GPIO2 when this bit is set to 1 Bit 5: Enable remote GPIO1 when this bit is set to 1 Bit 4: Enable remote GPIO0 when this bit is set to 1 |
| 3:0 | GPIO_OUT_SRC | R/W | 0x0 | GPIO Output Source This register sets the logical output of 4 GPIOs, GPIO_RMTEN must be disabled and GPIOx_OUT_EN must be enabled. Bit 3 write 0/1 on GPIO3 Bit 2 write 0/1 on GPIO2 Bit 1 write 0/1 on GPIO1 Bit 0 write 0/1 on GPIO0 |

7.7.15 GPIO Input Control

Table 25. GPIO_INPUT_CTRL (Address 0x0E)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|--|
| 7 | GPIO3_OUT_EN | R/W | 0x0 | GPIO3 Output Enable 0: Disabled 1: Enabled |
| 6 | GPIO2_OUT_EN | R/W | 0x0 | GPIO2 Output Enable 0: Disabled 1: Enabled |
| 5 | GPIO1_OUT_EN | R/W | 0x0 | GPIO1 Output Enable 0: Disabled 1: Enabled |

Table 25. GPIO_INPUT_CTRL (Address 0x0E) (continued)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------------|------|---------|--|
| 4 | GPIO0_OUT_EN | R/W | 0x0 | GPIO0 Output Enable 0: Disabled 1: Enabled |
| 3 | GPIO3_INPUT_EN | R/W | 0x1 | GPIO3 Input Enable 0: Disabled 1: Enabled |
| 2 | GPIO2_INPUT_EN | R/W | 0x1 | GPIO2 Input Enable 0: Disabled 1: Enabled |
| 1 | GPIO1_INPUT_EN | R/W | 0x1 | GPIO1 Input Enable 0: Disabled 1: Enabled |
| 0 | GPIO0_INPUT_EN | R/W | 0x1 | GPIO0 Input Enable 0: Disabled 1: Enabled |

7.7.16 RESERVED Register

Table 26. RESERVED (Address 0x0F)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:4 | RESERVED | R | 0x0 | Reserved. |
| 3:0 | RESERVED | R/W | 0x0 | Reserved. |

7.7.17 DVP_CFG

Table 27. DVP_CFG (Address 0x10)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-----------------|------|---------|---|
| 7:5 | RESERVED | R/W | 0x0 | Reserved. |
| 4 | DVP_DT_ANY_EN | R/W | 0x0 | When asserted, allows any packet with a Long data type (DT) packet through DVP. |
| 3 | DVP_DT_MATCH_EN | R/W | 0x0 | When asserted, allows data type matching based on the value in the DVP_DT register. Note: When this bit is asserted, writes to the DVP_DT register are blocked. |
| 2 | DVP_DT_YUV_EN | R/W | 0x0 | When asserted, allows YUV 10-bit DTs through DVP when mode_100m is also asserted (YUV 10-bit DTs are 0x19, 0x1d, and 0x1f). |
| 1 | DVP_FV_IN | R/W | 0x0 | Invert Frame Valid Polarity. |
| 0 | DVP_LV_INV | R/W | 0x0 | Invert Line Valid Polarity. |

7.7.18 DVP_DT

Table 28. DVP_DT (Address 0x11)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|------|---------|---|
| 7:6 | RESERVED | R/W | 0x0 | Reserved. |
| 5:0 | DVP_DT_MATCH_VAL | R/W | 0x0 | When the DVP_CFG.dvp_dt_match_en is asserted, the DVP block will allow packets with this DT through regardless of the mode_75m or mode_100m setting. The DT value must be a Long DT value (either bit 5 or 4 must be set) for a match to occur. |

7.7.19 RESERVED Register
Table 29. RESERVED (Address 0x12)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.20 Force BIST Error
Table 30. FORCE_BIST_ERR (Address 0x13)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|---|
| 7 | FORCE_FC_ERR | SC | 0x0 | FORCE_ERR_CNT allows forcing a number of forward channel parity errors based on the value in FORCE_FC_CNT. When in BIST mode, the parity errors will be generated automatically upon entering BIST mode. When in normal operation this bit must be set to one to inject the parity errors. 0: Force Disabled 1: Force Enabled |
| 6:0 | FORCE_FC_CNT | R/W | 0x00 | Force Error Count. Set this value to the desired number of forced parity errors. |

7.7.21 Remote BIST Control
Table 31. REMOTE_BIST_CTRL (Address 0x14)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------------|------|---------|--|
| 7:4 | FORCE_ERR_CNT | R/W | 0x0 | Set to force FC error based on the FORCE_ERR_CNT. 0: Force Disabled 1: Force Enabled |
| 3 | LOCAL_BIST_EN | R/W | 0x0 | Force DS90UB953-Q1 to Enter BIST Mode |
| 2:1 | BIST_CLOCK | R/W | 0x0 | BIST clock source selection 00: External/System clock 01: 50 MHz internal clock 1X: 25 MHz internal clock |
| 0 | REMOTE_BIST_EN | R/W | 0x0 | Backwards-Compatible Remote BIST Enable Register |

7.7.22 Sensor Voltage Gain
Table 32. SENSOR_VGAIN (Address 0x15)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-----------|------|---------|--|
| 7 | RESERVED | R/W | 0x0 | Reserved |
| 6:0 | VOLT_GAIN | R/W | 0x20 | Voltage Sensor Gain Setting. VOLT_GAIN = (128 / REG_VALUE) 0x40 = Gain of 2 0x20 = Gain of 4 0x10 = Gain of 8 |

7.7.23 RESERVED Register
Table 33. RESERVED (Address 0x16)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x18 | Reserved. |

7.7.24 Sensor Control 0

Table 34. SENSOR_CTRL0 (Address 0x17)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|---------------|------|---------|---|
| 7:4 | RESERVED | R/W | 0x0 | Reserved |
| 3:2 | SENSOR_ENABLE | R/W | 0x3 | Temperature and Voltage Sensor Enable 00: Disabled 11: Enabled |
| 1:0 | SENSE_V_GPIO | R/W | 0x0 | Enable GPIO 0/1 for input Voltage Sensor 0/1 measurement 00: No voltage sensing 01: GPIO0 Voltage Sensing 10: GPIO1 Voltage Sensing 11: GPIO0 and GPIO1 Voltage Sensing |

7.7.25 Sensor Control 1

Table 35. SENSOR_CTRL1 (Address 0x18)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|---------------|------|---------|-----------------------------------|
| 7 | SENSE_GAIN_EN | R/W | 0x1 | Enable Gain Setting of the Sensor |
| 6:0 | RESERVED | R/W | 0x00 | Reserved |

7.7.26 Voltage Sensor 0 Thresholds

Table 36. SENSOR_V0_THRESH (Address 0x19)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|--|
| 7 | RESERVED | R/W | 0x0 | Reserved |
| 6:4 | SENSE_V0_HI | R/W | 0x6 | GPIO0/V0 sensor upper limit. When the GPIO0 is configured as a voltage sensor, and the voltage measured is above the SENSE_V0_HI, it triggers the V0_SENSOR_HI alarm in the SENSOR_STATUS register. |
| 3 | RESERVED | R/W | 0x0 | Reserved |
| 2:0 | SENSE_V0_LO | R/W | 0x2 | GPIO0/V0 sensor lower limit. When the GPIO0 is configured as a voltage sensor, and the voltage measured is below the SENSE_V0_LO, it triggers the V0_SENSOR_LOW alarm in the SENSOR_STATUS register. |

7.7.27 Voltage Sensor 1 Thresholds

Table 37. SENSOR_V1_THRESH (Address 0x1A)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|--|
| 7 | RESERVED | R/W | 0x0 | Reserved |
| 6:4 | SENSE_V1_HI | R/W | 0x6 | GPIO1/V1 alarm upper limit. When the GPIO1 is configured as a voltage sensor, V1_MAX sets the upper limit for V1_SENSOR_HI status to be triggered |
| 3 | RESERVED | R/W | 0x0 | Reserved |
| 2:0 | SENSE_V1_LO | R/W | 0x2 | GPIO1/V1 alarm lower limit. When the GPIO1 is configured as a voltage sensor, V1_MIN sets the lower limit for V1_SENSOR_LOW status to be triggered |

7.7.28 Temperature Sensor Thresholds

Table 38. SENSOR_T_THRESH (Address 0x1B)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R/W | 0x0 | Reserved |

Table 38. SENSOR_T_THRESH (Address 0x1B) (continued)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|---|
| 6:4 | SENSE_T_HI | R/W | 0x6 | Temp sensor upper threshold. When the Temp sensor is enabled, and the temperature measured above the SENSE_T_HI limit, it triggers the T_SENSOR_HI alarm in SENSOR_STATUS. |
| 3 | RESERVED | R/W | 0x0 | Reserved |
| 2:0 | SENSE_T_LO | R/W | 0x2 | Temp sensor lower threshold. When the Temp sensor is enabled, and the temperature measured below the SENSE_T_LO limit, it triggers the T_SENSOR_LOW alarm in SENSOR_STATUS. |

7.7.29 CSI-2 Alarm Enable

Table 39. ALARM_CSI_EN (Address 0x1C)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------------|------|---------|--|
| 7:6 | RESERVED | R/W | 0x0 | Reserved |
| 5 | CSI_NO_FV_EN | R/W | 0x1 | CSI-2 No Frame Valid Alarm Enable 1: Enabled 0: Disabled |
| 4 | DPHY_SYNC_ERR_EN | R/W | 0x1 | DPHY_SYNC_ERR Alarm Enable 1: Enabled 0: Disabled |
| 3 | DPHY_CTRL_ERR_EN | R/W | 0x1 | DPHY_CTRL_ERR Alarm Enable 1: Enabled 0: Disabled |
| 2 | CSI_ECC2_EN | R/W | 0x1 | CSI_ECC2 Alarm Enable 1: Enabled 0: Disabled |
| 1 | CSI_CHKSUM_ERR_EN | R/W | 0x1 | CSI-2 Checksum Error Alarm Enable 1: Enabled 0: Disabled |
| 0 | CSI_LENGTH_ERR_EN | R/W | 0x1 | CSI-2 Length Error Alarm Enable 1: Enabled 0: Disabled |

7.7.30 Alarm Sense Enable

Table 40. ALARM_SENSE_EN (Address 0x1D)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|--|
| 7:6 | RESERVED | R/W | 0x0 | Reserved |
| 5 | T_OVER | R/W | 0x0 | Enable Temp Sensor over the high limit alarm |
| 4 | T_UNDER | R/W | 0x0 | Enable Temp Sensor under the low limit alarm |
| 3 | V1_OVER | R/W | 0x0 | Enable Voltage1 Sensor over the high limit alarm |
| 2 | V1_UNDER | R/W | 0x0 | Enable Voltage1 Sensor under the low limit alarm |
| 1 | V0_OVER | R/W | 0x0 | Enable Voltage0 Sensor over the high limit alarm |
| 0 | V0_UNDER | R/W | 0x0 | Enable Voltage0 Sensor under the low limit alarm |

7.7.31 Back Channel Alarm Enable

Table 41. ALARM_BC_EN (Address 0x1E)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------------|------|---------|--------------------------|
| 7:2 | RESERVED | R/W | 0x00 | Reserved |
| 1 | CRC_ERR_EN | R/W | 0x0 | Enable CRC_ERR alarm |
| 0 | LINK_DETECT_EN | R/W | 0x0 | Enable LINK_DETECT alarm |

7.7.32 RESERVED Register

Table 42. RESERVED (Address 0x1F)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.33 CSI-2 Polarity Select

The CSI-2 Polarity Select register allows for changing P/N input polarity for each data lane.

Table 43. CSI_POL_SEL (Address 0x20)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|---------------|------|---------|----------------------------|
| 7:5 | RESERVED | R | 0x0 | Reserved |
| 4 | POLARITY_CLK0 | R/W | 0x0 | CSI-2 CLK lane 0 Polarity |
| 3 | POLARITY_D3 | R/W | 0x0 | CSI-2 Data lane 3 Polarity |
| 2 | POLARITY_D2 | R/W | 0x0 | CSI-2 Data lane 2 Polarity |
| 1 | POLARITY_D1 | R/W | 0x0 | CSI-2 Data lane 1 Polarity |
| 0 | POLARITY_D0 | R/W | 0x0 | CSI-2 Data lane 0 Polarity |

7.7.34 CSI-2 LP Mode Polarity

The CSI-2 LP Mode Polarity register allows for changing polarity for all clocks and data lanes in Low power mode.

Table 44. CSI_LP_POLARITY (Address 0x21)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|------------------------------|
| 7:5 | RESERVED | R/W | 0x0 | Reserved |
| 4 | POL_LP_CLK0 | R/W | 0x0 | LP CSI-2 Clock lane Polarity |
| 3:0 | POL_LP_DATA | R/W | 0x0 | LP CSI-2 Data lane Polarity |

7.7.35 CSI-2 High-Speed RX Enable

The CSI-2 High Speed RX Enable register is intended for system debugging and should be set to 0x00 for normal operation.

Table 45. CSI_EN_HSRX (Address 0x22)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R | 0x0 | Reserved |
| 6:0 | RESERVED | R/W | 0x00 | Reserved |

7.7.36 CSI-2 Low Power Enable

The CSI-2 Low Power Enable register is intended for system debugging.

Table 46. CSI_EN_LPRX (Address 0x23)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R | 0x0 | Reserved |
| 6:0 | RESERVED | R/W | 0x00 | Reserved |

7.7.37 CSI-2 Termination Enable

The CSI-2 Termination Enable register is intended for system debugging.

Table 47. CSI_EN_RXTERM (Address 0x24)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|-------------|
| 7:4 | RESERVED | R/W | 0x0 | Reserved |
| 3 | EN_RXTERM_D3 | R/W | 0x0 | Reserved |
| 2 | EN_RXTERM_D2 | R/W | 0x0 | Reserved |
| 1 | EN_RXTERM_D1 | R/W | 0x0 | Reserved |
| 0 | EN_RXTERM_D0 | R/W | 0x0 | Reserved |

7.7.38 RESERVED Register

Table 48. RESERVED (Address 0x25)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R | 0x0 | Reserved. |
| 6:4 | RESERVED | R/W | 0x0 | Reserved. |
| 3 | RESERVED | R | 0x0 | Reserved. |
| 2:0 | RESERVED | R/W | 0x2 | Reserved. |

7.7.39 RESERVED Register

Table 49. RESERVED (Address 0x26)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R | 0x0 | Reserved. |
| 6:4 | RESERVED | R/W | 0x0 | Reserved. |
| 3 | RESERVED | R | 0x0 | Reserved. |
| 2:0 | RESERVED | R/W | 0x0 | Reserved. |

7.7.40 RESERVED Register

Table 50. RESERVED (Address 0x27)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:3 | RESERVED | R | 0x00 | Reserved. |
| 2:0 | RESERVED | R/W | 0x0 | Reserved. |

7.7.41 RESERVED Register

Table 51. RESERVED (Address 0x28)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R | 0x0 | Reserved. |
| 6:4 | RESERVED | R/W | 0x0 | Reserved. |
| 3 | RESERVED | R | 0x0 | Reserved. |
| 2:0 | RESERVED | R/W | 0x7 | Reserved. |

7.7.42 RESERVED Register
Table 52. RESERVED (Address 0x29)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R | 0x0 | Reserved. |
| 6:4 | RESERVED | R/W | 0x3 | Reserved. |
| 3 | RESERVED | R | 0x0 | Reserved. |
| 2:0 | RESERVED | R/W | 0x3 | Reserved. |

7.7.43 RESERVED Register
Table 53. RESERVED (Address 0x2A)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R | 0x0 | Reserved. |
| 6:4 | RESERVED | R/W | 0x0 | Reserved. |
| 3 | RESERVED | R | 0x0 | Reserved. |
| 2:0 | RESERVED | R/W | 0x1 | Reserved. |

7.7.44 RESERVED Register
Table 54. RESERVED (Address 0x2B-0x2D)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R | 0x0 | Reserved. |
| 6:4 | RESERVED | | 0x0 | Reserved. |
| 3 | RESERVED | R | 0x0 | Reserved. |
| 2:0 | RESERVED | | 0x0 | Reserved. |

7.7.45 RESERVED Register
Table 55. RESERVED (Address 0x2E-0x30)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.46 CSI-2 Packet Header Control
Table 56. CSI_PKT_HDR_TINIT_CTRL (Address 0x31)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------------|------|---------|--|
| 7:6 | PKT_HDR_SEL_VC | R/W | 0x0 | For interleaved VC packet select the VC ID to display the packet header. This is effective only if bit4 is set high (PKT_HDR_VCI_ENABLE) |
| 5 | PKT_HDR_CORRECTED | R/W | 0x1 | 1: Displays the corrected CSI-2 packet header (in case of error) sent to the receiver 0: Displays the received CSI-2 packet header from imager |
| 4 | PKT_HDR_VCI_ENABLE | R/W | 0x0 | Enable the CSI-2 packet header selection based on VC for interleaved mode. For interleaved VC packet set this bit to record the packet headers for each VC. For regular data packet ignore this bit. |
| 3 | RESERVED | R/W | 0x0 | Reserved |

Table 56. CSI_PKT_HDR_TINIT_CTRL (Address 0x31) (continued)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|--|
| 2:0 | TINIT_TIME | R/W | 0x0 | CSI-2 Initial Time after power up. Any LP control data are ignored during this time for all CSI-2 lanes. 000 = 100 µs 001 = 200 µs 010 = 300 µs 111 = 800 µs and so forth |

7.7.47 Back Channel Configuration

Table 57. BCC_CONFIG (Address 0x32)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------------------|------|---------|---|
| 7 | I2C_PASS_THROUGH_ALL | R/W | 0x0 | I2C Pass-Through All Transactions 0: Disabled 1: Enabled |
| 6 | I2C_PASS_THROUGH | R/W | 0x0 | I2C Pass-Through to Deserializer if decode matches 0: Pass-Through Disabled 1: Pass-Through Enabled |
| 5 | AUTO_ACK_ALL | R/W | 0x0 | Automatically Acknowledge all I2C writes independent of the forward channel lock state or status of the remote Acknowledge 1: Enable 0: Disable |
| 4 | RESERVED | R/W | 0x0 | Reserved |
| 3 | RX_PARITY_CHECKER_ENABLE | R/W | 0x1 | Parity Checker Enable 0: Disable 1: Enable |
| 2 | RESERVED | R/W | 0x0 | Reserved |
| 1 | RESERVED | R/W | 0x0 | Reserved |
| 0 | RESERVED | R/W | 0x1 | Reserved |

7.7.48 Datapath Control 1

Table 58. DATAPATH_CTL1 (Address 0x33)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|--|
| 7:3 | RESERVED | R/W | 0x00 | Reserved |
| 2 | DCA_CRC_EN | R/W | 0x1 | DCA CRC Enable If set to a 1, the Forward Channel sends a CRC as part of the DCA sequence. The DCA CRC protects the first 8 bytes of the DCA sequence. The CRC is sent as the 9th byte. |
| 1:0 | FC_GPIO_EN | R/W | 0x0 | Forward Channel GPIO Enable Configures the number of enabled forward channel GPIOs 00: GPIOs disabled 01: One GPIO 10: Two GPIOs 11: Four GPIOs |

7.7.49 RESERVED Register

Table 59. RESERVED (Address 0x34)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:4 | RESERVED | R/W | 0x0 | Reserved. |
| 3 | RESERVED | R/W | 0x0 | Reserved. |

Table 59. RESERVED (Address 0x34) (continued)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 2 | RESERVED | R/W | 0x0 | Reserved. |
| 1:0 | RESERVED | R/W | 0x0 | Reserved. |

7.7.50 Remote Partner Capabilities 1

Table 60. REMOTE_PAR_CAP1 (Address 0x35)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------------|------|---------|--|
| 7 | FREEZE_DES_CAP | R/W | 0x0 | Freeze Partner Capabilities Prevent auto-loading of the Partner Capabilities by the Bidirectional Control Channel. The Capabilities are frozen at the values written in registers 0x1E and 0x1F. |
| 6 | RESERVED | R/W | 0x0 | Reserved |
| 5 | BIST_EN | R/W | 0x0 | Link BIST Enable This bit indicates the remote partner is requesting BIST operation over the FPD-Link III interface. This field is automatically configured by the Bidirectional Control Channel once back channel link has been detected. Software may overwrite this value, but must also set the FREEZE_DES_CAP bit to prevent overwriting by the Bidirectional Control Channel. |
| 4 | MPORT | R/W | 0x0 | Remote Partner Multi-Port capable 0 : Remote partner is a single-port deserializer device 1 : Remote partner is a multi-port deserializer device This field is automatically configured by the Bidirectional Control Channel once back channel link has been detected. Software may overwrite this value, but must also set the FREEZE_DES_CAP bit to prevent overwriting by the Bidirectional Control Channel. |
| 3:0 | PORT_NUM | R/W | 0x0 | Remote Partner port number When connected to a multi-port device, this field indicates the port number to which the Serializer is connected. This field is automatically configured by the Bidirectional Control Channel once back channel link has been detected. Software may overwrite this value, but must also set the FREEZE_DES_CAP bit to prevent overwriting by the Bidirectional Control Channel. |

7.7.51 RESERVED Register

Table 61. RESERVED (Address 0x36)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.52 Partner Deserializer ID

Table 62. DES_ID (Address 0x37)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|------|---------|---|
| 7:1 | DES_ID | R/W | 0x3D | Remote Deserializer ID This field is normally loaded automatically from the remote Deserializer. |
| 0 | FREEZE_DEVICE_ID | R/W | 0x0 | Freeze Deserializer Device ID Prevent auto-loading of the Deserializer Device ID from the back channel. The ID is frozen at the value written. |

7.7.53 RESERVED Register
Table 63. RESERVED (Address 0x38)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.54 Slave 0 ID
Table 64. SLAVE_ID_0 (Address 0x39)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|--|
| 7:1 | SLAVE_ID_0 | R/W | 0x00 | 7-bit Remote Slave Device ID 0 Configures the physical I ² C address of the remote I ² C Slave device attached to the remote Deserializer. If an I ² C transaction is addressed to the Slave Alias ID0, the transaction is remapped to this address before passing the transaction across the Bidirectional Control Channel to the Deserializer. |
| 0 | RESERVED | R | 0x0 | Reserved |

7.7.55 Slave 1 ID
Table 65. SLAVE_ID_1 (Address 0x3A)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|--|
| 7:1 | SLAVE_ID_1 | R/W | 0x00 | 7-bit Remote Slave Device ID 1 Configures the physical I ² C address of the remote I ² C Slave device attached to the remote Deserializer. If an I ² C transaction is addressed to the Slave Alias ID1, the transaction is remapped to this address before passing the transaction across the Bidirectional Control Channel to the Deserializer. |
| 0 | RESERVED | R | 0x0 | Reserved |

7.7.56 Slave 2 ID
Table 66. SLAVE_ID_2 (Address 0x3B)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|--|
| 7:1 | SLAVE_ID_2 | R/W | 0x00 | 7-bit Remote Slave Device ID 2 Configures the physical I ² C address of the remote I ² C Slave device attached to the remote Deserializer. If an I ² C transaction is addressed to the Slave Alias ID2, the transaction is remapped to this address before passing the transaction across the Bidirectional Control Channel to the Deserializer. |
| 0 | RESERVED | R | 0x0 | Reserved |

7.7.57 Slave 3 ID
Table 67. SLAVE_ID_3 (Address 0x3C)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|--|
| 7:1 | SLAVE_ID_3 | R/W | 0x00 | 7-bit Remote Slave Device ID 3 Configures the physical I ² C address of the remote I ² C Slave device attached to the remote Deserializer. If an I ² C transaction is addressed to the Slave Alias ID3, the transaction is remapped to this address before passing the transaction across the Bidirectional Control Channel to the Deserializer. |
| 0 | RESERVED | R | 0x0 | Reserved |

7.7.58 Slave 4 ID
Table 68. SLAVE_ID_4 (Address 0x3D)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|--|
| 7:1 | SLAVE_ID_4 | R/W | 0x00 | 7-bit Remote Slave Device ID 4 Configures the physical I ² C address of the remote I ² C Slave device attached to the remote Deserializer. If an I ² C transaction is addressed to the Slave Alias ID4, the transaction is remapped to this address before passing the transaction across the Bidirectional Control Channel to the Deserializer. |
| 0 | RESERVED | R | 0x0 | Reserved |

7.7.59 Slave 5 ID
Table 69. SLAVE_ID_5 (Address 0x3E)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|--|
| 7:1 | SLAVE_ID_5 | R/W | 0x00 | 7-bit Remote Slave Device ID 5 Configures the physical I ² C address of the remote I ² C Slave device attached to the remote Deserializer. If an I ² C transaction is addressed to the Slave Alias ID5, the transaction is remapped to this address before passing the transaction across the Bidirectional Control Channel to the Deserializer. |
| 0 | RESERVED | R | 0x0 | Reserved |

7.7.60 Slave 6 ID
Table 70. SLAVE_ID_6 (Address 0x3F)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|--|
| 7:1 | SLAVE_ID_6 | R/W | 0x00 | 7-bit Remote Slave Device ID 6 Configures the physical I ² C address of the remote I ² C Slave device attached to the remote Deserializer. If an I ² C transaction is addressed to the Slave Alias ID6, the transaction is remapped to this address before passing the transaction across the Bidirectional Control Channel to the Deserializer. |
| 0 | RESERVED | R | 0x0 | Reserved |

7.7.61 Slave 7 ID
Table 71. SLAVE_ID_7 (Address 0x40)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------|------|---------|--|
| 7:1 | SLAVE_ID_7 | R/W | 0x00 | 7-bit Remote Slave Device ID 7 Configures the physical I ² C address of the remote I ² C Slave device attached to the remote Deserializer. If an I ² C transaction is addressed to the Slave Alias ID7, the transaction is remapped to this address before passing the transaction across the Bidirectional Control Channel to the Deserializer. |
| 0 | RESERVED | R | 0x0 | Reserved |

7.7.62 Slave 0 Alias
Table 72. SLAVE_ID_ALIAS_0 (Address 0x41)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|------|---------|---|
| 7:1 | SLAVE_ID_ALIAS_0 | R/W | 0x00 | 7-bit Remote Slave Device Alias ID 0 Configures the decoder for detecting transactions designated for an I ² C Slave device attached to the remote Deserializer. The transaction is remapped to the address specified in the Slave ID0 register. A value of 0 in this field disables access to the remote I ² C Slave. |

Table 72. SLAVE_ID_ALIAS_0 (Address 0x41) (continued)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|------|---------|---|
| 0 | SLAVE_AUTO_ACK_0 | R/W | 0x0 | Automatically Acknowledge all I2C writes to the remote Slave 0 independent of the forward channel lock state or status of the remote Deserializer Acknowledge 1: Enable 0: Disable This is intended for debugging only and not recommended for normal operation. |

7.7.63 Slave 1 Alias
Table 73. SLAVE_ID_ALIAS_1 (Address 0x42)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|------|---------|---|
| 7:1 | SLAVE_ID_ALIAS_1 | R/W | 0x00 | 7-bit Remote Slave Device Alias ID 1 Configures the decoder for detecting transactions designated for an I ² C Slave device attached to the remote Deserializer. The transaction is remapped to the address specified in the Slave ID1 register. A value of 0 in this field disables access to the remote I ² C Slave. |
| 0 | SLAVE_AUTO_ACK_1 | R/W | 0x0 | Automatically Acknowledge all I2C writes to the remote Slave 1 independent of the forward channel lock state or status of the remote Deserializer Acknowledge 1: Enable 0: Disable This is intended for debugging only and not recommended for normal operation. |

7.7.64 Slave 2 Alias
Table 74. SLAVE_ID_ALIAS_2 (Address 0x43)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|------|---------|---|
| 7:1 | SLAVE_ID_ALIAS_2 | R/W | 0x00 | 7-bit Remote Slave Device Alias ID 2 Configures the decoder for detecting transactions designated for an I ² C Slave device attached to the remote Deserializer. The transaction is remapped to the address specified in the Slave ID2 register. A value of 0 in this field disables access to the remote I ² C Slave. |
| 0 | SLAVE_AUTO_ACK_2 | R/W | 0x0 | Automatically Acknowledge all I2C writes to the remote Slave 2 independent of the forward channel lock state or status of the remote Deserializer Acknowledge 1: Enable 0: Disable This is intended for debugging only and not recommended for normal operation. |

7.7.65 Slave 3 Alias
Table 75. SLAVE_ID_ALIAS_3 (Address 0x44)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|------|---------|---|
| 7:1 | SLAVE_ID_ALIAS_3 | R/W | 0x00 | 7-bit Remote Slave Device Alias ID 3 Configures the decoder for detecting transactions designated for an I ² C Slave device attached to the remote Deserializer. The transaction is remapped to the address specified in the Slave ID3 register. A value of 0 in this field disables access to the remote I ² C Slave. |
| 0 | SLAVE_AUTO_ACK_3 | R/W | 0x0 | Automatically Acknowledge all I2C writes to the remote Slave 3 independent of the forward channel lock state or status of the remote Deserializer Acknowledge 1: Enable 0: Disable This is intended for debugging only and not recommended for normal operation. |

7.7.66 Slave 4 Alias
Table 76. SLAVE_ID_ALIAS_4 (Address 0x45)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|------|---------|---|
| 7:1 | SLAVE_ID_ALIAS_4 | R/W | 0x00 | 7-bit Remote Slave Device Alias ID 4 Configures the decoder for detecting transactions designated for an I ² C Slave device attached to the remote Deserializer. The transaction is remapped to the address specified in the Slave ID4 register. A value of 0 in this field disables access to the remote I ² C Slave. |
| 0 | SLAVE_AUTO_ACK_4 | R/W | 0x0 | Automatically Acknowledge all I2C writes to the remote Slave 4 independent of the forward channel lock state or status of the remote Deserializer Acknowledge 1: Enable 0: Disable This is intended for debugging only and not recommended for normal operation. |

7.7.67 Slave 5 Alias
Table 77. SLAVE_ID_ALIAS_5 (Address 0x46)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|------|---------|---|
| 7:1 | SLAVE_ID_ALIAS_5 | R/W | 0x00 | 7-bit Remote Slave Device Alias ID 5 Configures the decoder for detecting transactions designated for an I ² C Slave device attached to the remote Deserializer. The transaction is remapped to the address specified in the Slave ID5 register. A value of 0 in this field disables access to the remote I ² C Slave. |
| 0 | SLAVE_AUTO_ACK_5 | R/W | 0x0 | Automatically Acknowledge all I2C writes to the remote Slave 5 independent of the forward channel lock state or status of the remote Deserializer Acknowledge 1: Enable 0: Disable This is intended for debugging only and not recommended for normal operation. |

7.7.68 Slave 6 Alias
Table 78. SLAVE_ID_ALIAS_6 (Address 0x47)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|------|---------|---|
| 7:1 | SLAVE_ID_ALIAS_6 | R/W | 0x00 | 7-bit Remote Slave Device Alias ID 6 Configures the decoder for detecting transactions designated for an I ² C Slave device attached to the remote Deserializer. The transaction is remapped to the address specified in the Slave ID6 register. A value of 0 in this field disables access to the remote I ² C Slave. |
| 0 | SLAVE_AUTO_ACK_6 | R/W | 0x0 | Automatically Acknowledge all I2C writes to the remote Slave 6 independent of the forward channel lock state or status of the remote Deserializer Acknowledge 1: Enable 0: Disable This is intended for debugging only and not recommended for normal operation. |

7.7.69 Slave 7 Alias
Table 79. SLAVE_ID_ALIAS_7 (Address 0x48)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|------|---------|---|
| 7:1 | SLAVE_ID_ALIAS_7 | R/W | 0x00 | 7-bit Remote Slave Device Alias ID 7 Configures the decoder for detecting transactions designated for an I ² C Slave device attached to the remote Deserializer. The transaction is remapped to the address specified in the Slave ID7 register. A value of 0 in this field disables access to the remote I ² C Slave. |
| 0 | SLAVE_AUTO_ACK_7 | R/W | 0x0 | Automatically Acknowledge all I2C writes to the remote Slave 7 independent of the forward channel lock state or status of the remote Deserializer Acknowledge 1: Enable 0: Disable This is intended for debugging only and not recommended for normal operation. |

7.7.70 Back Channel Control
Table 80. BC_CTRL (Address 0x49)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|------------------|----------|---------|---|
| 7:6 | RESERVED | R | 0x0 | Reserved |
| 5 | BIST_CRC_ERR_CLR | (R/W)/SC | 0x0 | Clear BIST CRC error counter 0: Disable clear 1: Enable Clear |
| 4 | RESERVED | R/W | 0x0 | Reserved |
| 3 | CRC_ERR_CLR | (R/W)/SC | 0x0 | Clear CRC error 0: Disable clear 1: Enable clear |
| 2:0 | LINK_DET_TIMER | R/W | 0x0 | TX-RX link detect timer val |

7.7.71 Revision ID
Table 81. REV_MASK_ID (Address 0x50)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|-------------|
| 7:4 | REVISION_ID | R | 0x2 | Revision ID |
| 3:0 | MASK_ID | R | 0x0 | Mask ID |

7.7.72 Device Status
Table 82. Device STS (Address 0x51)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|---------------|------|---------|--|
| 7 | CFG_CKSUM_STS | R | 0x0 | Config Checksum Passed This bit is set following initialization if the Configuration data in the eFuse ROM had a valid checksum |
| 6 | CFG_INIT_DONE | R | 0x0 | Power-up initialization complete This bit is set after Initialization is complete. Configuration from eFuse ROM has completed. |
| 5:0 | RESERVED | R | 0x00 | Reserved |

7.7.73 General Status

Table 83. GENERAL_STATUS (Address 0x52)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------------|------|---------|--|
| 7 | RESERVED | R | 0x0 | Reserved |
| 6 | RX_LOCK_DETECT | R | 0x0 | Deserializer LOCK status This bit indicates the LOCK status of the Deserializer. |
| 5 | RESERVED | R | 0x0 | Reserved |
| 4 | LINK_LOST_FLAG | R | 0x0 | Back Channel Link lost Status changed This bit is set if a change in BC LINK DET lost status has been detected. This bit is cleared upon read of CRC ERR CLR register or HS PLL loses lock. |
| 3 | BIST_CRC_ERR | R | 0x0 | BIST Error is detected. The BIST_ERR_CNT register contain the number of Back Channel BIST errors. |
| 2 | HS_PLL_LOCK | R | 0x1 | Forward Channel High speed PLL lock flag |
| 1 | CRC_ERR | R | 0x0 | Back Channel CRC error detected This bit is set when the back channel errors detected when BC LINK DET is asserted. This bit is cleared upon read of CRC_ERR_CLR register. |
| 0 | LINK_DET | R | 0x1 | Back Channel Link detect This bit is set when BC link is valid. |

7.7.74 GPIO Pin Status

Table 84. GPIO_PIN_STS (Address 0x53)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|---|
| 7:4 | RESERVED | R | 0x0 | Reserved |
| 3:0 | GPIO_STS | R | 0x0 | GPIO Pin Status This register reads the current values on GPIO pins. Bit 3 reads GPIO3 pin status Bit 2 reads GPIO2 pin status Bit 1 reads GPIO1 pin status Bit 0 reads GPIO0 pin status |

7.7.75 BIST Error Count

Table 85. BIST_ERR_CNT (Address 0x54)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------------|------|---------|-------------------------------|
| 7:0 | BIST_BC_ERRCNT | R | 0x00 | CRC error count in BIST mode. |

7.7.76 CRC Error Count 1

Table 86. CRC_ERR_CNT1 (Address 0x55)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|-----------------------|
| 7:0 | CRC_ERR_CNT1 | R | 0x00 | CRC Error count (LSB) |

7.7.77 CRC Error Count 2

Table 87. CRC_ERR_CNT2 (Address 0x56)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|-----------------------|
| 7:0 | CRC_ERR_CNT2 | R | 0x00 | CRC Error count (MSB) |

7.7.78 Sensor Status

Table 88. SENSOR_STATUS (Address 0x57)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|---------------|------|---------|---|
| 7:6 | RESERVED | R | 0x0 | Reserved |
| 5 | T_SENSOR_HI | R | 0x0 | When set, this bit indicates that GPIO0 Sensor is above SENSE_T_HI limit. This bit is cleared upon read. |
| 4 | T_SENSOR_LOW | R | 0x0 | When set, this bit indicates that GPIO0 Sensor is below SENSE_T_LO limit. This bit is cleared upon read. |
| 3 | V1_SENSOR_HI | R | 0x0 | When set, this bit indicates that GPIO1 input is above SENSE_V1_HI limit. This bit is cleared upon read. |
| 2 | V1_SENSOR_LOW | R | 0x0 | When set, this bit indicates that GPIO1 input is below SENSE_V1_LO limit. This bit is cleared upon read. |
| 1 | V0_SENSOR_HI | R | 0x0 | When set, this bit indicates that GPIO0 input is above SENSE_V0_HI limit. This bit will be cleared upon read. |
| 0 | V0_SENSOR_LOW | R | 0x0 | When set, this bit indicates that GPIO0 input is below SENSE_V0_LO limit. This bit will be cleared upon read. |

7.7.79 Sensor V0

Table 89. SENSOR_V0 (Address 0x58)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-----------------------|------|---------|--|
| 7 | RESERVED | R/W | 0x0 | Reserved |
| 6:4 | VOLTAGE_SENSOR_V0_MAX | RC | 0x0 | GPIO0 Voltage sensor max reading when the GPIO0 voltage is above SENSE_V0_HI limit. This bit is cleared upon read. 0 indicates alarm has not been triggered. |
| 3 | RESERVED | R/W | 0x0 | Reserved |
| 2:0 | VOLTAGE_SENSOR_V0_MIN | RC | 0x7 | GPIO0 Voltage sensor min reading when GPIO0 voltage is below SENSE_V0_LO limit. This bit is cleared upon read. 7 indicates alarm has not been triggered. |

7.7.80 Sensor V1

Table 90. SENSOR_V1 (Address 0x59)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-----------------------|------|---------|--|
| 7 | RESERVED | R/W | 0x0 | Reserved |
| 6:4 | VOLTAGE_SENSOR_V1_MAX | RC | 0x0 | GPIO1 Voltage sensor max reading when the GPIO1 voltage is above SENSE_V1_HI limit. This bit is cleared upon read. 0 indicates alarm has not been triggered. |
| 3 | RESERVED | R/W | 0x0 | Reserved |
| 2:0 | VOLTAGE_SENSOR_V1_MIN | RC | 0x7 | GPIO1 Voltage sensor min reading when GPIO1 voltage is below SENSE_V1_LO limit. This bit is cleared upon read. 7 indicates alarm has not been triggered. |

7.7.81 Sensor T

Table 91. SENSOR_T (Address 0x5A)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|--|
| 7 | RESERVED | R/W | 0x0 | Reserved |
| 6:4 | TEMP_MAX | RC | 0x0 | Internal Temperature sensor maximum reading when temperature is above SENSE_T_HI limit. This bit is cleared upon read. 0 indicates alarm has not been triggered. |

Table 91. SENSOR_T (Address 0x5A) (continued)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|--|
| 3 | RESERVED | R/W | 0x0 | Reserved |
| 2:0 | TEMP_MIN | RC | 0x7 | Internal Temperature sensor minimum reading when temperature is below SENSE_T_LO limit. This bit is cleared upon read. 7 indicates alarm has not been triggered. |

7.7.82 RESERVED Register

Table 92. RESERVED (Address 0x5B)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:2 | RESERVED | R/W | 0x00 | Reserved. |
| 1 | RESERVED | RC | 0x0 | Reserved. |
| 0 | RESERVED | RC | 0x0 | Reserved. |

7.7.83 CSI-2 Error Count

Table 93. CSI_ERR_CNT (Address 0x5C)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|---|
| 7:0 | CSI_ERR_CNT | RC | 0x00 | CSI-2 Error Counter Register This register counts the number of CSI-2 packets received with errors since the last read of the counter. |

7.7.84 CSI-2 Error Status

Table 94. CSI_ERR_STATUS (Address 0x5D)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------------|------|---------|--|
| 7:4 | RESERVED | R | 0x0 | Reserved |
| 3 | LINE_LEN_MISMATCH | R/RC | 0x0 | Indicates Line length less than the received Packet header Word count |
| 2 | CHKSUM_ERR | R/RC | 0x0 | Indicates a checksum error detected in the incoming data (uncorrectable) |
| 1 | ECC_2BIT_ERR | R/RC | 0x0 | Indicates a 2-Bit Ecc error (uncorrectable) in the Packet header |
| 0 | ECC_1BIT_ERR | R/RC | 0x0 | Indicates a 1-Bit Ecc error detected in the Packet header |

7.7.85 CSI-2 Errors Data Lanes 0 and 1

Table 95. CSI_ERR_DLANE01 (Address 0x5E)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------------|------|---------|--|
| 7 | SOT_ERROR_1 | R | 0x0 | Lane 1: Single-bit Error in SYNC Sequence - Correctable |
| 6 | SOT_SYNC_ERROR_1 | R | 0x0 | Lane 1: Multi-bit Error in SYNC Sequence - Uncorrectable |
| 5 | CNTRL_ERR_HSRQST_1 | R | 0x0 | Lane 1: Control Error in HS Request Mode |
| 4 | RESERVED | R | 0x0 | Reserved |
| 3 | SOT_ERROR_0 | R | 0x0 | Lane 0: Single-bit Error in SYNC Sequence - Correctable |
| 2 | SOT_SYNC_ERROR_0 | R | 0x0 | Lane 0: Multi-bit Error in SYNC Sequence - Uncorrectable |
| 1 | CNTRL_ERR_HSRQST_0 | R | 0x0 | Lane 0: Control Error in HS Request Mode |
| 0 | RESERVED | R | 0x0 | Reserved |

7.7.86 CSI-2 Errors Data Lanes 2 and 3
Table 96. CSI_ERR_DLANE23 (Address 0x5F)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------------|------|---------|--|
| 7 | SOT_ERROR_3 | R | 0x0 | Lane 3: Single-bit Error in SYNC Sequence - Correctable |
| 6 | SOT_SYNC_ERROR_3 | R | 0x0 | Lane 3: Multi-bit Error in SYNC Sequence - Uncorrectable |
| 5 | CNTRL_ERR_HSRQST_3 | R | 0x0 | Lane 3: Control Error in HS Request Mode |
| 4 | RESERVED | R | 0x0 | Reserved |
| 3 | SOT_ERROR_2 | R | 0x0 | Lane 2: Single-bit Error in SYNC Sequence - Correctable |
| 2 | SOT_SYNC_ERROR_2 | R | 0x0 | Lane 2: Multi-bit Error in SYNC Sequence - Uncorrectable |
| 1 | CNTRL_ERR_HSRQST_2 | R | 0x0 | Lane 2: Control Error in HS Request Mode |
| 0 | RESERVED | R | 0x0 | Reserved |

7.7.87 CSI-2 Errors Clock Lane
Table 97. CSI_ERR_CLK_LANE (Address 0x60)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------------------|------|---------|--|
| 7:2 | RESERVED | R | 0x00 | Reserved |
| 1 | CNTRL_ERR_HSRQST_CK0 | R | 0x0 | Clk Lane: Control Error in HS Request Mode |
| 0 | RESERVED | R | 0x0 | Reserved |

7.7.88 CSI-2 Packet Header Data
Table 98. CSI_PKT_HDR_VC_ID (Address 0x61)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------------|------|---------|---|
| 7:6 | LONG_PKT_VCHNL_ID | R | 0x0 | Virtual Channel ID from CSI-2 Packet header |
| 5:0 | LONG_PKT_DATA_ID | R | 0x00 | Data ID from CSI-2 Packet header |

7.7.89 Packet Header Word Count 0
Table 99. PKT_HDR_WC_LSB (Address 0x62)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------------------|------|---------|---|
| 7:0 | LONG_PKT_WRD_CNT_LSB | R | 0x00 | Payload count lower byte from CSI-2 Packet header |

7.7.90 Packet Header Word Count 1
Table 100. PKT_HDR_WC_MSB (Address 0x63)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------------------|------|---------|---|
| 7:0 | LONG_PKT_WRD_CNT_MSB | R | 0x00 | Payload count upper byte from CSI-2 Packet header |

7.7.91 CSI-2 ECC
Table 101. CSI_ECC (Address 0x64)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------------|------|---------|---|
| 7 | LINE_LENGTH_CHANGE | R | 0x0 | Indicates Line length change detected per frame |
| 6 | RESERVED | R | 0x0 | Reserved |
| 5:0 | CSI-2_ECC | R | 0x00 | CSI-2 ECC byte from packet header |

7.7.92 RESERVED Register
Table 102. RESERVED (Address 0x65-67)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R | 0x00 | Reserved. |

7.7.93 RESERVED Register
Table 103. RESERVED (Address 0x68-6F)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | | 0x00 | Reserved. |

7.7.94 RESERVED Register
Table 104. RESERVED (Address 0x70-0x71)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.95 RESERVED Register
Table 105. RESERVED (Address 0x72)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x25 | Reserved. |

7.7.96 RESERVED Register
Table 106. RESERVED (Address 0x73)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.97 RESERVED Register
Table 107. RESERVED (Address 0x74)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:4 | RESERVED | | 0x0 | Reserved. |
| 3:0 | RESERVED | R/W | 0x0 | Reserved. |

7.7.98 RESERVED Register
Table 108. RESERVED (Address 0x75)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:1 | RESERVED | R/W | 0x00 | Reserved. |
| 0 | RESERVED | | 0x0 | Reserved. |

7.7.99 RESERVED Register
Table 109. RESERVED (Address 0x76)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R/W | 0x0 | Reserved. |
| 6:4 | RESERVED | R | 0x0 | Reserved. |
| 3:0 | RESERVED | R/W | 0x0 | Reserved. |

7.7.100 RESERVED Register
Table 110. RESERVED (Address 0x77)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R | 0x0 | Reserved. |
| 6:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.101 RESERVED Register
Table 111. RESERVED (Address 0x78)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R | 0x0 | Reserved. |
| 6 | RESERVED | SC | 0x0 | Reserved. |
| 5:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.102 RESERVED Register
Table 112. RESERVED (Address 0x79)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:5 | RESERVED | R/W | 0x0 | Reserved. |
| 4:0 | RESERVED | R/RC | 0x00 | Reserved. |

7.7.103 RESERVED Register
Table 113. RESERVED (Address 0x7A)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x04 | Reserved. |

7.7.104 RESERVED Register
Table 114. RESERVED (Address 0x7B-0x85)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.105 RESERVED Register
Table 115. RESERVED (Address 0x86)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x90 | Reserved. |

7.7.106 RESERVED Register
Table 116. RESERVED (Address 0x87-0x88)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.107 RESERVED Register
Table 117. RESERVED (Address 0x89-0x8B)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R | 0x00 | Reserved. |

7.7.108 RESERVED Register
Table 118. RESERVED (Address 0x8C-0x8F)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.109 RESERVED Register
Table 119. RESERVED (Address 0x90)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | | 0x0 | Reserved. |
| 6 | RESERVED | R/W | 0x0 | Reserved. |
| 5:0 | RESERVED | R/W | 0x32 | Reserved. |

7.7.110 RESERVED Register
Table 120. RESERVED (Address 0x91)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0xE2 | Reserved. |

7.7.111 RESERVED Register
Table 121. RESERVED (Address 0x92)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7 | RESERVED | R | 0x0 | Reserved. |
| 6:0 | RESERVED | R/W | 0x64 | Reserved. |

7.7.112 RESERVED Register
Table 122. RESERVED (Address 0x93)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x01 | Reserved. |

7.7.113 RESERVED Register
Table 123. RESERVED (Address 0x94-0x99)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.114 RESERVED Register
Table 124. RESERVED (Address 0x9A-0x9E)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:6 | RESERVED | R | 0x0 | Reserved. |
| 5:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.115 RESERVED Register
Table 125. RESERVED (Address 0x9F)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:5 | RESERVED | R | 0x0 | Reserved. |
| 4:0 | RESERVED | R/W | 0x10 | Reserved. |

7.7.116 RESERVED Register
Table 126. RESERVED (Address 0xA0)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | | 0x0 | Reserved. |

7.7.117 RESERVED Register
Table 127. RESERVED (Address 0xA1-0xA4)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:5 | RESERVED | R | 0x0 | Reserved. |
| 4:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.118 RESERVED Register
Table 128. RESERVED (Address 0xA5)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x10 | Reserved. |

7.7.119 RESERVED Register
Table 129. RESERVED (Address 0xA6)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x42 | Reserved. |

7.7.120 RESERVED Register
Table 130. RESERVED (Address 0xA7-0xA9)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x10 | Reserved. |

7.7.121 RESERVED Register
Table 131. RESERVED (Address 0xAA-0xAB)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R/W | 0x00 | Reserved. |

7.7.122 RESERVED Register
Table 132. RESERVED (Address 0xAC-0xAF)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | | 0x00 | Reserved. |

7.7.123 IND_ACC_CTL
Table 133. IND_ACC_CTL (Address 0xB0)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|--|
| 7:5 | RESERVED | R | 0x0 | Reserved |
| 4:2 | IA_SEL | R/W | 0x0 | Indirect Register Select: Selects target for register access 000 : PATGEN 001 : FPD3 TX Registers 010: DIE ID Data |
| 1 | IA_AUTO_INC | R/W | 0x0 | Indirect Access Auto Increment: Enables auto-increment mode. Upon completion of a read or write, the register address is automatically incremented by 1 |
| 0 | IA_READ | R/W | 0x0 | Indirect Access Read: Setting this allows generation of a read strobe to the selected register block upon setting of the IND_ACC_ADDR register. In auto-increment mode, read strobes are also asserted following a read of the IND_ACC_DATA register. This function is only required for blocks that need to pre-fetch register data. |

7.7.124 IND_ACC_ADDR
Table 134. IND_ACC_ADDR (Address 0xB1)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|---|
| 7:0 | IND_ACC_ADDR | R/W | 0x00 | Indirect Access Register Offset: This register contains the 8-bit register offset for the indirect access. |

7.7.125 IND_ACC_DATA
Table 135. IND_ACC_DATA (Address 0xB2)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|--|
| 7:0 | IND_ACC_DATA | R/W | 0x00 | Indirect Access Register Data: Writing this register causes an indirect write of the IND_ACC_DATA value to the selected analog block register. Reading this register returns the value of the selected analog block register. |

7.7.126 RESERVED Register
Table 136. RESERVED (Address 0xB3-0xEF)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R | 0x00 | Reserved. |

7.7.127 FPD3_RX_ID0
Table 137. FPD3_RX_ID0 (Address 0xF0)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|---------------------------------------|
| 7:0 | FPD3_RX_ID0 | R | 0x5F | FPD3_TX_ID0: First byte ID code: ' _' |

7.7.128 FPD3_RX_ID1
Table 138. FPD3_RX_ID1 (Address 0xF1)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|---------------------------------------|
| 7:0 | FPD3_RX_ID1 | R | 0x55 | FPD3_TX_ID1: 2nd byte of ID code: 'U' |

7.7.129 FPD3_RX_ID2
Table 139. FPD3_RX_ID2 (Address 0xF2)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|---------------------------------------|
| 7:0 | FPD3_RX_ID2 | R | 0x42 | FPD3_TX_ID2: 3rd byte of ID code: 'B' |

7.7.130 FPD3_RX_ID3
Table 140. FPD3_RX_ID3 (Address 0xF3)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|---------------------------------------|
| 7:0 | FPD3_RX_ID3 | R | 0x39 | FPD3_TX_ID3: 4th byte of ID code: '9' |

7.7.131 FPD3_RX_ID4
Table 141. FPD3_RX_ID4 (Address 0xF4)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|---------------------------------------|
| 7:0 | FPD3_RX_ID4 | R | 0x35 | FPD3_TX_ID4: 5th byte of ID code: '5' |

7.7.132 FPD3_RX_ID5
Table 142. FPD3_RX_ID5 (Address 0xF5)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|---------------------------------------|
| 7:0 | FPD3_RX_ID5 | R | 0x33 | FPD3_TX_ID5: 6th byte of ID code: '3' |

7.7.133 Indirect Access Registers

Several functional blocks include register sets contained in the Indirect Access map (Table 143); that is, Pattern Generator, and Analog controls. Register access is provided through an indirect access mechanism through the Indirect Access registers (IND_ACC_CTL, IND_ACC_ADDR, and IND_ACC_DATA). These registers are located at offsets 0xB0-0xB2 in the main register space.

The indirect address mechanism involves setting the control register to select the desired block, setting the register offset address, and reading or writing the data register. In addition, an auto-increment function is provided in the control register to automatically increment the offset address following each read or write of the data register.

For writes, the process is as follows:

1. Write to the IND_ACC_CTL register to select the desired register block
2. Write to the IND_ACC_ADDR register to set the register offset
3. Write the data value to the IND_ACC_DATA register

If auto-increment is set in the IND_ACC_CTL register, repeating step 3 writes additional data bytes to subsequent register offset locations.

For reads, the process is as follows:

1. Write to the IND_ACC_CTL register to select the desired register block
2. Write to the IND_ACC_ADDR register to set the register offset
3. Read from the IND_ACC_DATA register

If auto-increment is set in the IND_ACC_CTL register, repeating step 3 reads additional data bytes from subsequent register offset locations.

Table 143. Indirect Register Map Description

| IA SELECT 0xB0[4:2] | PAGE/BLOCK | INDIRECT REGISTERS | ADDRESS RANGE | DESCRIPTION |
|------------------------|------------|-----------------------------------|------------------|---|
| 000 | 0 | Digital Page 0 Indirect Registers | 0x01 - 0x1F | Pattern Gen Registers |
| 010 | 2 | Indirect Registers: Die ID Data | 0x00 - 0x040 | Hold 16 bytes that correspond to Die ID data. |

7.7.133.1 Reserved

Table 144. Reserved (Address 0x00)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|-------------|
| 7:0 | RESERVED | R | 0x00 | Reserved |

7.7.133.2 PGEN_CTL

Table 145. PGEN_CTL (Address 0x01)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|---|
| 7:1 | RESERVED | R/W | 0x0 | Reserved |
| 0 | PGEN_ENABLE | R/W | 0x0 | Pattern Generator Enable 1: Enable Pattern Generator 0: Disable Pattern Generator |

7.7.133.3 PGEN_CFG
Table 146. PGEN_CFG (Address 0x02)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|---------------|------|---------|--|
| 7 | PGEN_FIXED_EN | R/W | 0x0 | Fixed Pattern Enable Setting this bit enables Fixed Color Patterns. 0 : Send Color Bar Pattern 1 : Send Fixed Color Pattern |
| 6 | RESERVED | R/W | 0x0 | Reserved |
| 5:4 | NUM_CBARS | R/W | 0x3 | Number of Color Bars 00 : 1 Color Bar 01 : 2 Color Bars 10 : 4 Color Bars 11 : 8 Color Bars |
| 3:0 | BLOCK_SIZE | R/W | 0x3 | Block Size For Fixed Color Patterns, this field controls the size of the fixed color field in bytes. Allowed values are 1 to 15. |

7.7.133.4 PGEN_CSI_DI
Table 147. PGEN_CSI_DI (Address 0x03)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|---|
| 7:6 | PGEN_CSI_VC | R/W | 0x0 | CSI-2 Virtual Channel Identifier This field controls the value sent in the CSI-2 packet for the Virtual Channel Identifier |
| 5:0 | PGEN_CSI_DT | R/W | 0x24 | CSI-2 Data Type This field controls the value sent in the CSI-2 packet for the Data Type. The default value (0x24) indicates RGB888. |

7.7.133.5 PGEN_LINE_SIZE1
Table 148. PGEN_LINE_SIZE1 (Address 0x04)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------------------|------|---------|--|
| 7:0 | PGEN_LINE_SIZE[15:8] | R/W | 0x07 | Most significant byte of the Pattern Generator line size. This is the active line length in bytes. Default setting is for 1920 bytes for a 640 pixel line width. |

7.7.133.6 PGEN_LINE_SIZE0
Table 149. PGEN_LINE_SIZE0 (Address 0x05)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|---------------------|------|---------|---|
| 7:0 | PGEN_LINE_SIZE[7:0] | R/W | 0x80 | Least significant byte of the Pattern Generator line size. This is the active line length in bytes. Default setting is for 1920 bytes for a 640 pixel line width. |

7.7.133.7 PGEN_BAR_SIZE1
Table 150. PGEN_BAR_SIZE1 (Address 0x06)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|---------------------|------|---------|---|
| 7:0 | PGEN_BAR_SIZE[15:8] | R/W | 0x00 | Most significant byte of the Pattern Generator color bar size. This is the active length in bytes for the color bars. This value is used for all except the last color bar. The last color bar is determined by the remaining bytes as defined by the PGEN_LINE_SIZE value. |

7.7.133.8 PGEN_BAR_SIZE0
Table 151. PGEN_BAR_SIZE0 (Address 0x07)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------------|------|---------|--|
| 7:0 | PGEN_BAR_SIZE[7:0] | R/W | 0xF0 | Least significant byte of the Pattern Generator color bar size. This is the active length in bytes for the color bars. This value is used for all except the last color bar. The last color bar is determined by the remaining bytes as defined by the PGEN_LINE_SIZE value. |

7.7.133.9 PGEN_ACT_LPF1
Table 152. PGEN_ACT_LPF1 (Address 0x08)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------------|------|---------|---|
| 7:0 | PGEN_ACT_LPF[15:8] | R/W | 0x01 | Active Lines Per Frame Most significant byte of the number of active lines per frame. Default setting is for 480 active lines per frame. |

7.7.133.10 PGEN_ACT_LPF0
Table 153. PGEN_ACT_LPF0 (Address 0x09)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------------|------|---------|--|
| 7:0 | PGEN_ACT_LPF[7:0] | R/W | 0xE0 | Active Lines Per Frame Least significant byte of the number of active lines per frame. Default setting is for 480 active lines per frame. |

7.7.133.11 PGEN_TOT_LPF1
Table 154. PGEN_TOT_LPF1 (Address 0x0A)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------------|------|---------|---|
| 7:0 | PGEN_TOT_LPF[15:8] | R/W | 0x02 | Total Lines Per Frame Most significant byte of the number of total lines per frame including vertical blanking |

7.7.133.12 PGEN_TOT_LPF0
Table 155. PGEN_TOT_LPF0 (Address 0x0B)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------------|------|---------|--|
| 7:0 | PGEN_TOT_LPF[7:0] | R/W | 0x0D | Total Lines Per Frame Least significant byte of the number of total lines per frame including vertical blanking |

7.7.133.13 PGEN_LINE_PD1
Table 156. PGEN_LINE_PD1 (Address 0x0C)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------------|------|---------|---|
| 7:0 | PGEN_LINE_PD[15:8] | R/W | 0x0C | Line Period Most significant byte of the line period in 10-ns units. The default setting for the line period registers sets a line period of 31.75 microseconds. |

7.7.133.14 PGEN_LINE_PD0
Table 157. PGEN_LINE_PD0 (Address 0x0D)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------------|------|---------|--|
| 7:0 | PGEN_LINE_PD[7:0] | R/W | 0x67 | Line Period Least significant byte of the line period in 10-ns units. The default setting for the line period registers sets a line period of 31.75 microseconds. |

7.7.133.15 PGEN_VBP
Table 158. PGEN_VBP (Address 0x0E)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|--|
| 7:0 | PGEN_VBP | R/W | 0x21 | Vertical Back Porch This value provides the vertical back porch portion of the vertical blanking interval. This value provides the number of blank lines between the FrameStart packet and the first video data packet. |

7.7.133.16 PGEN_VFP
Table 159. PGEN_VFP (Address 0x0F)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|----------|------|---------|--|
| 7:0 | PGEN_VFP | R/W | 0x0A | Vertical Front Porch This value provides the vertical front porch portion of the vertical blanking interval. This value provides the number of blank lines between the last video line and the FrameEnd packet. |

7.7.133.17 PGEN_COLOR0
Table 160. PGEN_COLOR0 (Address 0x10)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|--|
| 7:0 | PGEN_COLOR0 | R/W | 0xAA | Pattern Generator Color 0 For Reference Color Bar Patterns, this register controls the byte data value sent during color bar 0. For Fixed Color Patterns, this register controls the first byte of the fixed color pattern. |

7.7.133.18 PGEN_COLOR1
Table 161. PGEN_COLOR1 (Address 0x11)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|---|
| 7:0 | PGEN_COLOR1 | R/W | 0x33 | Pattern Generator Color 1 For Reference Color Bar Patterns, this register controls the byte data value sent during color bar 1. For Fixed Color Patterns, this register controls the second byte of the fixed color pattern. |

7.7.133.19 PGEN_COLOR2
Table 162. PGEN_COLOR2 (Address 0x12)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|--|
| 7:0 | PGEN_COLOR2 | R/W | 0xF0 | Pattern Generator Color 2 For Reference Color Bar Patterns, this register controls the byte data value sent during color bar 2. For Fixed Color Patterns, this register controls the third byte of the fixed color pattern. |

7.7.133.20 PGEN_COLOR3
Table 163. PGEN_COLOR3 (Address 0x13)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|---|
| 7:0 | PGEN_COLOR3 | R/W | 0x7F | Pattern Generator Color 3 For Reference Color Bar Patterns, this register controls the byte data value sent during color bar 3. For Fixed Color Patterns, this register controls the fourth byte of the fixed color pattern. |

7.7.133.21 PGEN_COLOR4
Table 164. PGEN_COLOR4 (Address 0x14)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|--|
| 7:0 | PGEN_COLOR4 | R/W | 0x55 | Pattern Generator Color 4 For Reference Color Bar Patterns, this register controls the byte data value sent during color bar 4. For Fixed Color Patterns, this register controls the fifth byte of the fixed color pattern. |

7.7.133.22 PGEN_COLOR5
Table 165. PGEN_COLOR5 (Address 0x15)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|--|
| 7:0 | PGEN_COLOR5 | R/W | 0xCC | Pattern Generator Color 5 For Reference Color Bar Patterns, this register controls the byte data value sent during color bar 5. For Fixed Color Patterns, this register controls the sixth byte of the fixed color pattern. |

7.7.133.23 PGEN_COLOR6
Table 166. PGEN_COLOR6 (Address 0x16)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|--|
| 7:0 | PGEN_COLOR6 | R/W | 0x0F | Pattern Generator Color 6 For Reference Color Bar Patterns, this register controls the byte data value sent during color bar 6. For Fixed Color Patterns, this register controls the seventh byte of the fixed color pattern. |

7.7.133.24 PGEN_COLOR7
Table 167. PGEN_COLOR7 (Address 0x17)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|---|
| 7:0 | PGEN_COLOR7 | R/W | 0x80 | Pattern Generator Color 7 For Reference Color Bar Patterns, this register controls the byte data value sent during color bar 7. For Fixed Color Patterns, this register controls the eighth byte of the fixed color pattern. |

7.7.133.25 PGEN_COLOR8
Table 168. PGEN_COLOR8 (Address 0x18)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|--|
| 7:0 | PGEN_COLOR8 | R/W | 0x00 | Pattern Generator Color 8 For Fixed Color Patterns, this register controls the ninth byte of the fixed color pattern. |

7.7.133.26 PGEN_COLOR9
Table 169. PGEN_COLOR9 (Address 0x19)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|-------------|------|---------|--|
| 7:0 | PGEN_COLOR9 | R/W | 0x00 | Pattern Generator Color 9 For Fixed Color Patterns, this register controls the tenth byte of the fixed color pattern. |

7.7.133.27 PGEN_COLOR10
Table 170. PGEN_COLOR10 (Address 0x1A)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|--|
| 7:0 | PGEN_COLOR10 | R/W | 0x00 | Pattern Generator Color 10 For Fixed Color Patterns, this register controls the eleventh byte of the fixed color pattern. |

7.7.133.28 PGEN_COLOR11
Table 171. PGEN_COLOR11 (Address 0x1B)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|---|
| 7:0 | PGEN_COLOR11 | R/W | 0x00 | Pattern Generator Color 11 For Fixed Color Patterns, this register controls the twelfth byte of the fixed color pattern. |

7.7.133.29 PGEN_COLOR12
Table 172. PGEN_COLOR12 (Address 0x1C)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|--|
| 7:0 | PGEN_COLOR12 | R/W | 0x00 | Pattern Generator Color 12 For Fixed Color Patterns, this register controls the thirteenth byte of the fixed color pattern. |

7.7.133.30 PGEN_COLOR13
Table 173. PGEN_COLOR13 (Address 0x1D)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|--|
| 7:0 | PGEN_COLOR13 | R/W | 0x00 | Pattern Generator Color 13 For Fixed Color Patterns, this register controls the fourteenth byte of the fixed color pattern. |

7.7.133.31 PGEN_COLOR14
Table 174. PGEN_COLOR14 (Address 0x1E)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|---|
| 7:0 | PGEN_COLOR14 | R/W | 0x00 | Pattern Generator Color 14 For Fixed Color Patterns, this register controls the fifteenth byte of the fixed color pattern. |

7.7.133.32 PGEN_COLOR15
Table 175. PGEN_COLOR15 (Address 0x1F)

| BIT | FIELD | TYPE | DEFAULT | DESCRIPTION |
|-----|--------------|------|---------|---|
| 7:0 | PGEN_COLOR15 | R/W | 0x00 | Pattern Generator Color 15 For Fixed Color Patterns, this register controls the sixteenth byte of the fixed color pattern. |

8 Application and Implementation

注

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The link between the DS90UB953-Q1 and the companion deserializer has two distinct data paths. The first path is a forward channel which is nominally running at up to 4.16 Gbps and is encoded such that the channel occupies a bandwidth from 20 MHz to 2.1 GHz. The second path is a back channel from the deserializer to the serializer which occupies a frequency range nominally from 10 MHz to 50 MHz.

For these two communications links to operate properly, the circuit between the serializer and the deserializer must present a characteristic impedance of 50 Ω . Deviations from this 50- Ω characteristic will lead to signal reflections either at the serializer or deserializer, which will result in bit errors.

8.1.1 Power Over Coax

The DS90UB953-Q1 is designed to support the Power-over-Coax (PoC) method of powering remote sensor systems. With this method, the power is delivered over the same medium (a coaxial cable) used for high-speed digital video data and bidirectional control and diagnostics data transmission. This method uses passive networks or filters that isolate the transmission line from the loading of the DC-DC regulator circuits and their connecting power traces on both sides of the link as shown in 图 15.

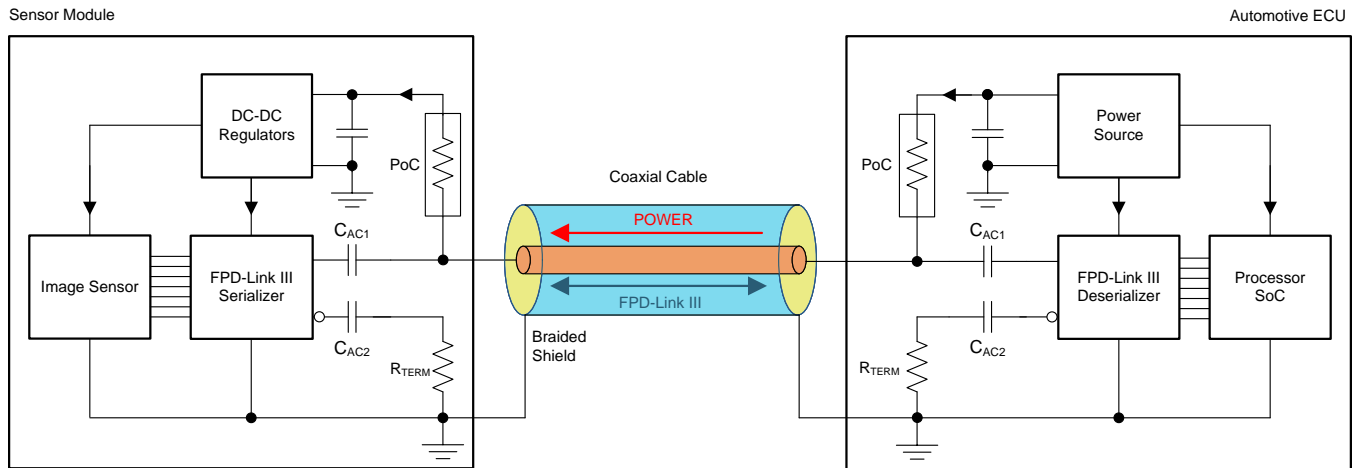


图 15. Power-over-Coax (PoC) System Diagram

The PoC network impedance of $\geq 2 \text{ k}\Omega$ over a specific frequency band is typically sufficient to isolate the transmission line from the loading of the regulator circuits. The lower limit of the frequency band is defined as $\frac{1}{2}$ of the frequency of the bidirectional control channel' (f_{BCC}). The upper limit of the frequency band is the frequency of the forward high-speed channel (f_{FC}).

图 16 shows an example PoC network suitable for a "4G" FPD-Link III consisting of DS90UB953-Q1 and DS90UB954-Q1 or DS90UB960-Q1 pair with the bidirectional channel operating at 50 Mbps ($\frac{1}{2} f_{BCC} = 25 \text{ MHz}$) and the forward channel operating at 4.16 Gbps ($f_{FC} \approx 2.1 \text{ GHz}$). Other PoC networks are possible and may be different on the serializer and the deserializer boards as long as the printed-circuit board return loss requirements given in 表 177 are met.

Application Information (接下页)

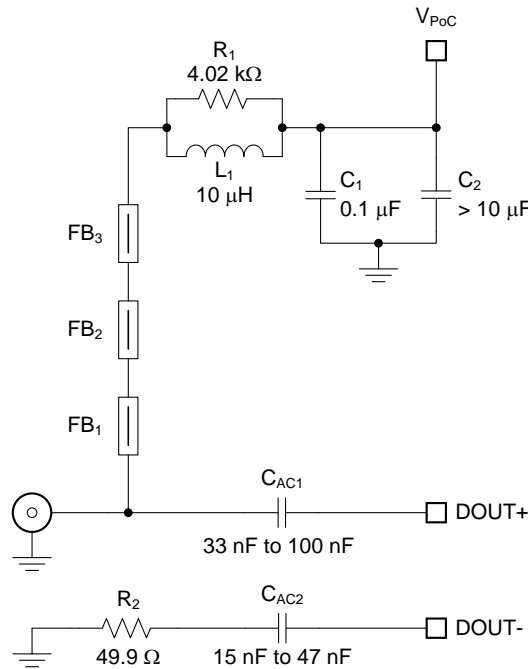


图 16. Typical PoC Network for a "4G" FPD-Link III

表 176 lists essential components for this particular PoC network. Note that the impedance characteristic of the ferrite beads deviates with the bias current. Therefore, keeping the current going through the network below 150 mA is recommended.

表 176. Suggested Components for a "4G" FPD-Link III PoC Network

| Count | Ref Des | Description | Part Number | MFR |
|-------|---------|---|------------------|--------|
| 1 | L1 | Inductor, 10 μH, 0.288 Ω max, 530 mA MIN(Isat, Itemp) 30 MHz SRF min, 3 mm x 3 mm, General Purpose | LQH3NPN100MJR | Murata |
| | | Inductor, 10 μH, 0.288 Ω max, 530 mA MIN(Isat, Itemp) 30 MHz SRF min, 3 mm x 3 mm, AEC-Q200 | LQH3NPZ100MJR | Murata |
| | | Inductor, 10 μH, 0.360 Ω max, 450 mA MIN(Isat, Itemp) 30 MHz SRF min, 3.2 mm x 2.5 mm, AEC-Q200 | NLCV32T-100K-EFD | TDK |
| | | Inductor, 10 μH, 0.400 Ω typ, 550 mA MIN(Isat, Itemp) 39 MHz SRF typ, 3 mm x 3 mm, AEC-Q200 | TYS3010100M-10 | Laird |
| | | Inductor, 10 μH, 0.325 Ω max, 725 mA MIN(Isat, Itemp) 41 MHz SRF typ, 3 mm x 3 mm, AEC-Q200 | TYS3015100M-10 | Laird |
| 3 | FB1-FB3 | Ferrite Bead, 1.5 kΩ at 1 GHz, 0.5 Ω max @ DC 500 mA @ 85°C, 0603 SMD, General Purpose | BLM18HE152SN1 | Murata |
| | | Ferrite Bead, 1.5 kΩ at 1 GHz, 0.5 Ω max @ DC 500 mA at 85°C, 0603 SMD, AEC-Q200 | BLM18HE152SZ1 | Murata |

In addition to the selection of PoC network components, their placement and layout play a critical role as well.

- Place the smallest component, typically a ferrite bead or a chip inductor, as close to the connector as possible. Route the high-speed trace through one of its pads to avoid stubs.
- Use the smallest component pads as allowed by manufacturer's design rules. Add anti-pads in the inner planes below the component pads to minimize impedance drop.
- Consult with the connector manufacturer for optimized connector footprint. If the connector is mounted on the same side as the IC, minimize the impact of the through-hole connector stubs by routing the high-speed signal traces on the opposite side of the connector mounting side.
- Use coupled 100-Ω differential signal traces from the device pins to the AC-coupling caps. Use 50-Ω single-

ended traces from the AC-coupling capacitors to the connector.

- Terminate the inverting signal traces close to the connectors with standard 49.9-Ω resistors.

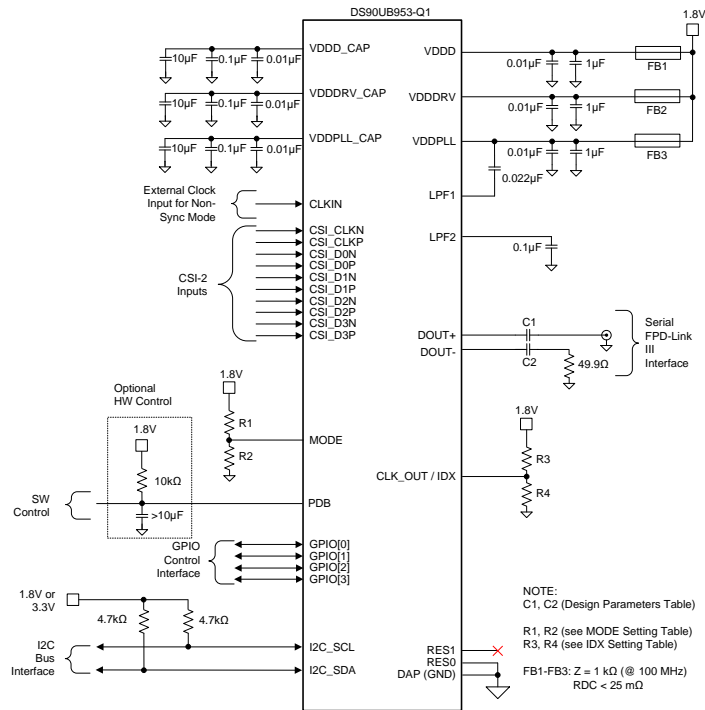
The suggested characteristics for single-ended PCB traces (microstrips or striplines) for serializer or deserializer boards are detailed in 表 177. The effects of the PoC networks must be accounted for when testing the traces for compliance to the suggested limits.

表 177. Suggested Characteristics for Single-Ended PCB Traces With Attached PoC Networks

| PARAMETER | | MIN | TYP | MAX | UNIT |
|--------------------|--|--|-----|-----------------|------|
| L_{trace} | Single-ended PCB trace length from the device pin to the connector pin | | | 5 | cm |
| Z_{trace} | Single-ended PCB trace characteristic impedance | 45 | 50 | 55 | Ω |
| Z_{con} | Connector (mounted) characteristic impedance | 40 | 50 | 60 | Ω |
| RL | Return Loss, S11 | $\frac{1}{2} f_{\text{BCC}} < f < 0.1 \text{ GHz}$ | | -20 | dB |
| | | $0.1 \text{ GHz} < f < 1 \text{ GHz}$ (f in GHz) | | $-12+8*\log(f)$ | dB |
| | | $1 \text{ GHz} < f < f_{\text{FC}}$ | | -12 | dB |
| IL | Insertion Loss, S12 | $f < 0.5 \text{ GHz}$ | | -0.35 | dB |
| | | $f = 1 \text{ GHz}$ | | -0.6 | dB |
| | | $f = 2.1 \text{ GHz}$ | | -1.2 | dB |

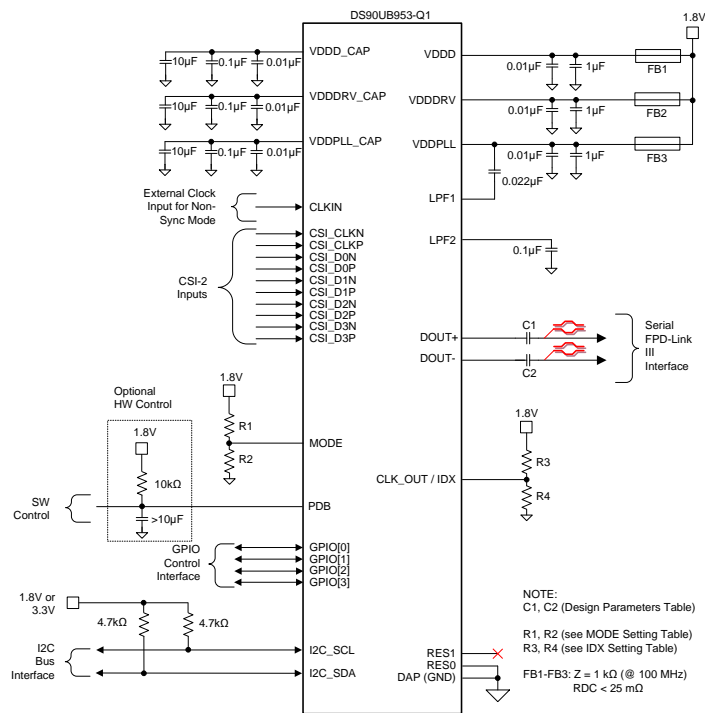
The V_{POC} fluctuations on the serializer side, caused by the transient current draw of the sensor, the DC resistance of cables, and PoC components, must be kept to a minimum as well. Increasing the V_{POC} voltage and adding extra decoupling capacitance (> 10 μF) help reduce the amplitude and slew rate of the V_{POC} fluctuations.

8.2 Typical Applications



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图 17. Typical Connection Diagram Coaxial



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图 18. Typical Connection Diagram STP

Typical Applications (接下页)

8.2.1 Design Requirements

For a typical design application, use the parameters listed in 表 178.

表 178. Design Parameters

| DESIGN PARAMETER | PIN(S) | VALUE |
|--|----------------------|-----------------------------------|
| $V_{(VDD)}$ | VDDD, VDDDRV, VDDPLL | 1.8 V |
| AC-Coupling Capacitor for Synchronous Modes, Coaxial Connection | DOUT+ | 33nF – 100 nF (50 V / X7R / 0402) |
| | DOUT- | 15nF – 47 nF (50 V / X7R / 0402) |
| AC-Coupling Capacitor for Synchronous Modes, STP Connection | DOUT+, DOUT- | 33 – 100 nF (50 V / X7R / 0402) |
| AC-Coupling Capacitor for Non-Synchronous and DVP Backwards Compatible Modes, Coaxial Connection | DOUT+ | 100 nF (50 V / X7R / 0402) |
| | DOUT- | 47 nF (50 V / X7R / 0402) |
| AC-Coupling Capacitor for Non-Synchronous and DVP Backwards Compatible Modes, STP Connection | DOUT+, DOUT- | 100 nF (50 V / X7R / 0402) |

The SER/DES only supports AC-coupled interconnects through an integrated DC-balanced decoding scheme. External AC-coupling capacitors must be placed in series in the FPD-Link III signal path as shown in 图 19 and 图 20. For applications using single-ended 50-Ω coaxial cable, terminate the unused data pins (DOUT+, DOUT-) with an AC-coupling capacitor and a 50-Ω resistor.

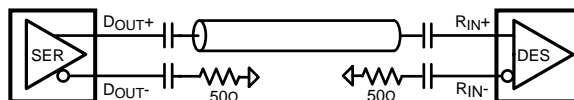


图 19. AC-Coupled Connection (Coaxial)

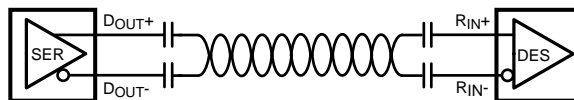


图 20. AC-Coupled Connection (STP)

For high-speed FPD-Link III transmissions, use the smallest available package for the AC-coupling capacitor to help minimize degradation of signal quality due to package parasitics.

8.2.2 Detailed Design Procedure

图 17 shows a typical application circuit of the DS90UB953-Q1. The next sections highlight recommendations for the critical device pins.

8.2.2.1 CSI-2 Interface

The CSI-2 input port on the DS90UB953-Q1 is compliant with the MIPI D-PHY v1.2 and CSI-2 v1.3 specifications. The CSI-2 interface consists of a clock and an option of one, two, or four data lanes. The clock and each of the data lanes are differential lines. The DS90UB953-Q1 CSI-2 input needs to be DC coupled to a compatible CSI-2 transmitter. Follow PCB layout guidelines given in [CSI-2 Guidelines](#).

8.2.2.2 FPD-Link III Input / Output

The DS90UB953-Q1 serial data out signal operates at different data rates depending upon the mode in which the device is operating. In synchronous mode, where the reference clock is provided by the deserializer, the serial data rate is up to 4.16 Gbps.

The signals at DOUT+ and DOUT- must be AC-coupled. The AC-coupling capacitor values used on DOUT+ and DOUT- depends on the mode and cable used as shown in 表 178. When connecting to a coax cable, the AC-coupling capacitor on the negative terminal (DOUT-) should be approximately $\frac{1}{2}$ of the AC-coupling capacitor value on DOUT+ and be terminated to a 50- Ω load. Adhering to the PCB layout guidelines given in [Layout Examples](#) is critical.

8.2.2.3 Internal Regulator Bypassing

The DS90UB953-Q1 features three internal regulators that must be bypassed to GND. The VDDD_CAP, VDDDRV_CAP, and VDDPLL_CAP are the pins that expose the outputs of the internal regulators for bypassing. TI recommends that each pin has a 10- μ F, 0.1- μ F, and a 0.01- μ F capacitor to GND. The 0.01- μ F caps must be placed as close as practical to the bypass pins.

8.2.2.4 Loop Filter Decoupling

The LPF1 and LPF2 pins are for connecting filter capacitors to the internal PLL circuits. LPF1 should have a 0.022- μ F capacitor connected to the VDD_PLL pin (pin 11). The capacitor connected between LPF1 and VDDPLL must enclose as small of a loop as possible. LPF2 must have a 0.1- μ F capacitor connecting the pin to GND. One of these PLLs generates the high-speed clock used in the serialization of the output, while the other PLL is used in the CSI-2 receive port. Noise coupled into these pins degrades the performance of the PLLs in the DS90UB953-Q1, so the caps must be placed close to the pins they are connected to, and the area of the loop enclosed must be minimized.

8.2.3 Application Curve

The falling edge of the blue trace indicates that the device should shift from LP to HS mode – the rise that comes about one division later is when the DS90UB953-Q1 turns on the internal termination so the device is ready to receive HS data. The transitions are the CSI-2 data, and then the drop of the blue trace indicates that the termination has been turned off.

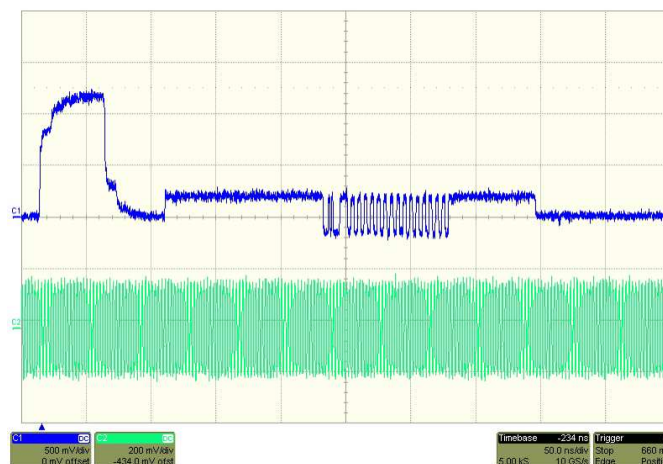


图 21. CSI-2 LP to HS Mode Transition

9 Power Supply Recommendations

This device provides separate power and ground pins for different portions of the circuit. This is done to isolate switching noise effects between different sections of the circuit. Separate planes on the PCB are typically not required. The [Pin Configuration and Functions](#) section provides guidance on which circuit blocks are connected to which power pin pairs. In some cases, an external filter may be used to provide clean power to sensitive circuits such as PLLs.

9.1 Power-Up Sequencing

The power-up sequence for the DS90UB953-Q1 is as follows:

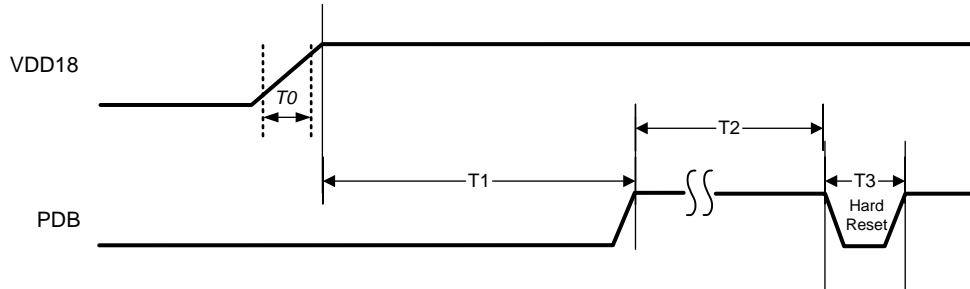


图 22. Power Supply Sequencing

表 179. Timing Diagram for the Power Supply Start-Up and Initialization Sequences

| PARAMETER | MIN | TYP | MAX | UNIT | NOTES |
|-----------|-------------------------------------|------|-----|------|--------------------------|
| T0 | VDD18 rise time | 0.05 | | ms | at 10/90% |
| T1 | VDD18 to PDB | 0 | | ms | After VDD18 is stable |
| T2 | PDB high time before PDB hard reset | 1 | | ms | |
| T3 | PDB high to low pulse width | 3 | | ms | Hard reset |
| T4 | PDB to I2C Ready | 2 | | ms | See 图 23 |

9.1.1 System Initialization

When initializing the communications link between a deserializer hub and a DS90UB953-Q1 serializer, the system timing will depend on the mode selected for generating the serializer reference clock. When synchronous clocking mode is selected, the serializer will relock onto the extracted back channel reference clock when available, so there is no need for local crystal oscillator at the sensor module. The initialization sequence follows the illustration given in [图 23](#).

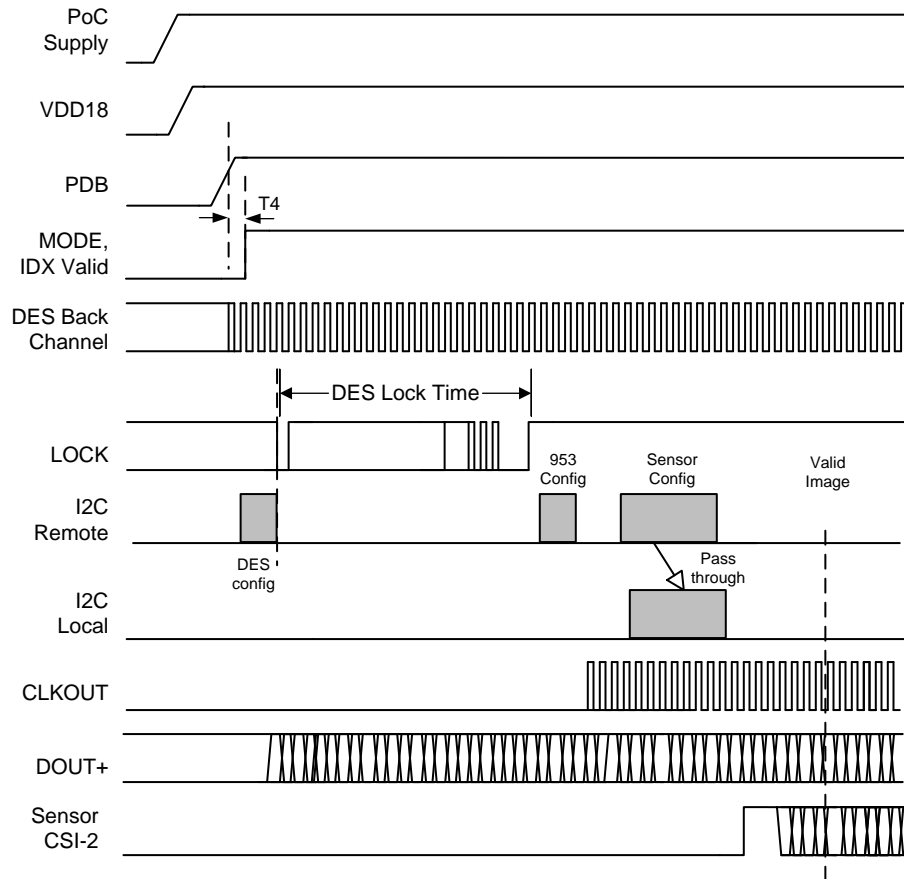


图 23. Initialization Sequence: Synchronous Clocking Mode

9.2 Power Down (PDB)

The Serializer has a PDB input pin to ENABLE or POWER DOWN the device. This pin may be controlled by an external device, or through VDD where $VDD = 1.71\text{ V}$ to 1.89 V . PDB should be brought high after all power supplies on the board have stabilized.

When PDB is driven low, ensure that the pin is driven to 0 V for at least 3 ms before releasing or driving high. In the case where PDB is pulled up to VDD directly, a $10\text{-k}\Omega$ pullup resistor and a $> 1\text{-}\mu\text{F}$ capacitor to ground are required.

toggling PDB low powers down the device and resets all control registers to default. After power up, if there are any errors seen, TI recommends clearing the registers to reset the errors.

Make sure to power up the VDDDRV before or at the same time as the VDDPLL.

10 Layout

10.1 Layout Guidelines

Circuit board layout and stack-up for the FPD-Link III devices must be designed to provide low-noise power feed to the device. Good layout practice also separates high frequency or high-level inputs and outputs to minimize unwanted stray noise pickup, feedback, and interference. External bypassing should be low-ESR ceramic capacitors with high-quality dielectric. The voltage rating of the ceramic capacitors must be at least $2\times$ the power supply voltage being used.

Layout Guidelines (接下页)

TI recommends surface-mount capacitors due to their smaller parasitics. When using multiple capacitors per supply pin, place the smaller value closest to the pin. A large bulk capacitor is recommended at the point of power entry. This is typically in the 47- μ F to 100- μ F range, which smooths low-frequency switching noise. TI recommends connecting power and ground pins directly to the power and ground planes with bypass capacitors connected to the plane. TI also recommends that the user place a via on both ends of the capacitors. Connecting power or ground pins to an external bypass capacitor increases the inductance of the path.

A small body size X7R chip capacitor, such as 0603 or 0402, is recommended for external bypass. The small body size reduces the parasitic inductance of the capacitor. The user must pay attention to the resonance frequency of these external bypass capacitors, usually in the range of 20 to 30 MHz. To provide effective bypassing, multiple capacitors are often used to achieve low impedance between the supply rails over the frequency of interest. At high frequency, it is also a common practice to use two vias from power and ground pins to the planes, reducing the impedance at high frequency.

Some devices provide separate power and ground pins for different portions of the circuit. This is done to isolate switching noise effects between different sections of the circuit. Separate planes on the PCB are typically not required. Pin Description tables typically provide guidance on which circuit blocks are connected to which power pin pairs (see [Pin Configuration and Functions](#) for more information). In some cases, an external filter may be used to provide clean power to sensitive circuits such as PLLs.

Use at least a four-layer board with a dedicated ground plane. Place CSI-2 signals away from the single-ended or differential FPD-Link III RX input traces to prevent coupling from the CSI-2 lines to the Rx input lines. A single-ended impedance of 50 Ω is typically recommended for coaxial interconnect, and a differential impedance of 100 Ω is typically recommended for STP interconnect. The closely coupled lines help to ensure that coupled noise appears as common-mode and thus is rejected by the receivers. The tightly coupled lines also radiate less.

10.1.1 CSI-2 Guidelines

1. Route CSIO_D*P/N pairs with controlled 100- Ω differential impedance ($\pm 20\%$) or 50- Ω single-ended impedance ($\pm 15\%$).
2. Keep away from other high-speed signals.
3. Keep length difference between a differential pair to 5 mils of each other.
4. Length matching should be near the location of mismatch.
5. Match trace lengths between the clock pair and each data pair to be < 25 mils.
6. Separate each pair by at least 3 times the signal trace width.
7. Keep the use of bends in differential traces to a minimum. When bends are used, the number of left and right bends must be as equal as possible, and the angle of the bend should be ≥ 135 degrees. This arrangement minimizes any length mismatch caused by the bends and therefore minimizes the impact that bends have on EMI.
8. Route all differential pairs on the same layer to help match trace impedance characteristics.
9. Keep the number of VIAS to a minimum—TI recommends keeping the VIA count to two or fewer.
10. Keep traces on layers adjacent to ground plane.
11. Do NOT route differential pairs over any plane split.

注

Adding Test points causes impedance discontinuity and therefore negatively impacts signal performance. If test points are used, place them in series and symmetrically. Test points must not be placed in a manner that causes a stub on the differential pair.

10.2 Layout Examples

The board layout for the DS90UB953-Q1EVM is shown in [图 24](#) and [图 25](#). All EVM layers are included in [DS90UB953-Q1EVM User's Guide](#) (SNLU224).

Layout Examples (接下页)

Routing the FPD-Link III signal traces between the DOUT pins and the connector, as well as connecting the PoC filter to these traces, are the most critical pieces of a successful DS90UB953-Q1 PCB layout. The following list provides essential recommendations for routing the FPD-Link III signal traces between the driver output pins and the FAKRA connector, as well as connecting the PoC filter.

- The routing of the FPD-Link III traces may be all on the top layer or partially embedded in middle layers if EMI is a concern.
- The AC-coupling capacitors should be on the top layer and very close to the receiver input pins to minimize the length of coupled differential trace pair between the pins and the capacitors.
- Route the DOUT+ trace between the AC-coupling capacitor and the FAKRA connector as a 50-Ω single-ended micro-strip with tight impedance control ($\pm 10\%$). Calculate the proper width of the trace for a 50-Ω impedance based on the PCB stack-up. Ensure that the trace can carry the PoC current for the maximum load presented by the remote sensor module.
- The PoC filter should be connected to the DOUT+ trace through the ferrite bead or an RF inductor. The ferrite bead should be touching the high-speed trace to minimize the stub length seen by the transmission line. Create an anti-pad or a moat under the ferrite bead pad that touches the trace. The anti-pad should be a plane cutout of the ground plane directly underneath the top layer without cutting out the ground reference under the trace. The purpose of the anti-pad is to maintain the impedance as close to 50 Ω as possible.
- When routing DOUT+ on inner layers, length matching for single-ended traces does not provide a significant benefit. If the user wants to route the DOUT+ on the top or bottom layer, route the DOUT- trace loosely coupled to the DOUT+ trace for the length similar to the DOUT+ trace length. This may help the differential nature of the receiver to cancel out any common-mode noise that may be present in the environment that may couple on to the signal traces.

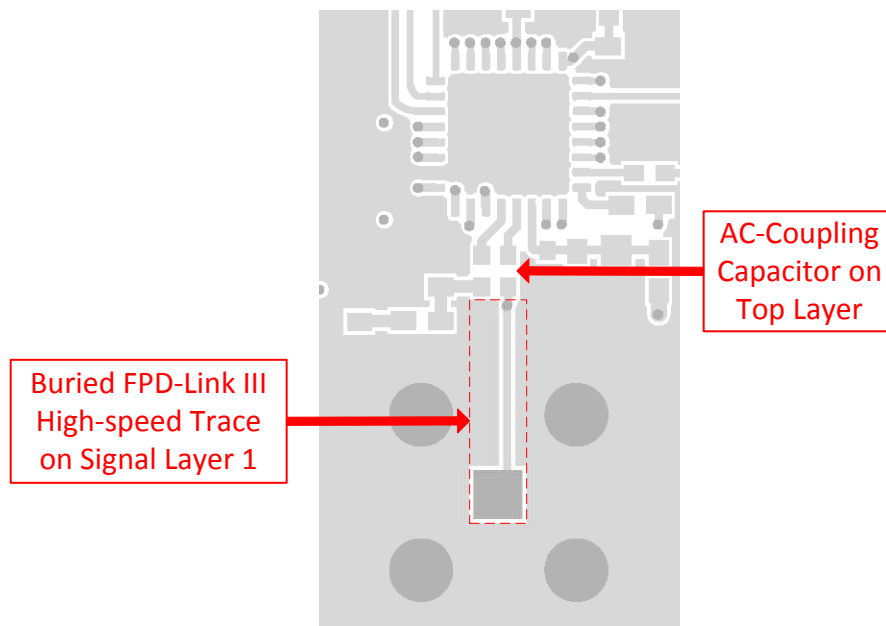


图 24. DS90UB953-Q1 Serializer DOUT+ Trace Layout

Layout Examples (接下页)

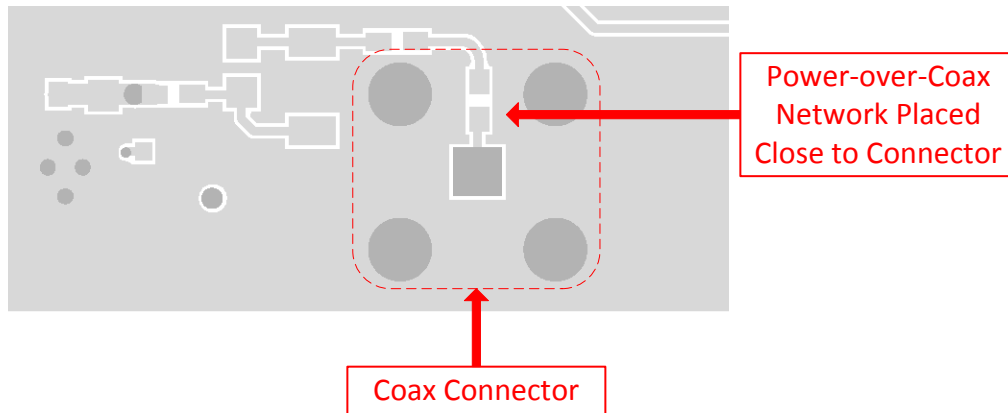


图 25. DS90UB953-Q1 Power-over-Coax Layout

11 器件和文档支持

11.1 器件支持

11.1.1 开发支持

相关开发支持，请参见以下文档：

[DS90UB953-Q1](#)

11.2 文档支持

11.2.1 相关文档

请参阅如下相关文档：

- 《如何设计 *FPD-Link III* 系统》(SNLA267)
- 《通过具有双向控制通道的 *FPD-Link III* 进行 *I2C* 通信》(SNLA131)
- 《*I2C* 总线上拉电阻器计算》(SLVA689)
- *FPD-Link* 学习中心培训材料
- 《一种适用于 *FPD-Link III SerDes* 的 *EMC/EMI* 系统设计和测试方法》(SLYT719)
- 《按照车用 *EMC/EMI* 要求进行成功设计的 10 个技巧》(SLYT636)
- 《可与并行输出解串器搭配运行的后向兼容模式》(SNLA270)
- 《同轴电缆供电设计指南》(SNLA272)
- 《原理图和布局检查清单》(SNLA271)

11.3 接收文档更新通知

要接收文档更新通知，请导航至 TI.com.cn 上的器件产品文件夹。单击右上角的 *通知我* 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

11.4 社区资源

下列链接提供到 TI 社区资源的连接。链接的内容由各个分销商“按照原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的 [《使用条款》](#)。

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设计支持 *TI* 参考设计支持 可帮助您快速查找有帮助的 E2E 论坛、设计支持工具以及技术支持的联系信息。

11.5 商标

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11.6 静电放电警告



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ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

11.7 术语表

SLYZ022 — *TI* 术语表。

这份术语表列出并解释术语、缩写和定义。

12 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。数据如有变更，恕不另行通知，且不会对此文档进行修订。如需获取此数据表的浏览器版本，请查阅左侧的导航栏。

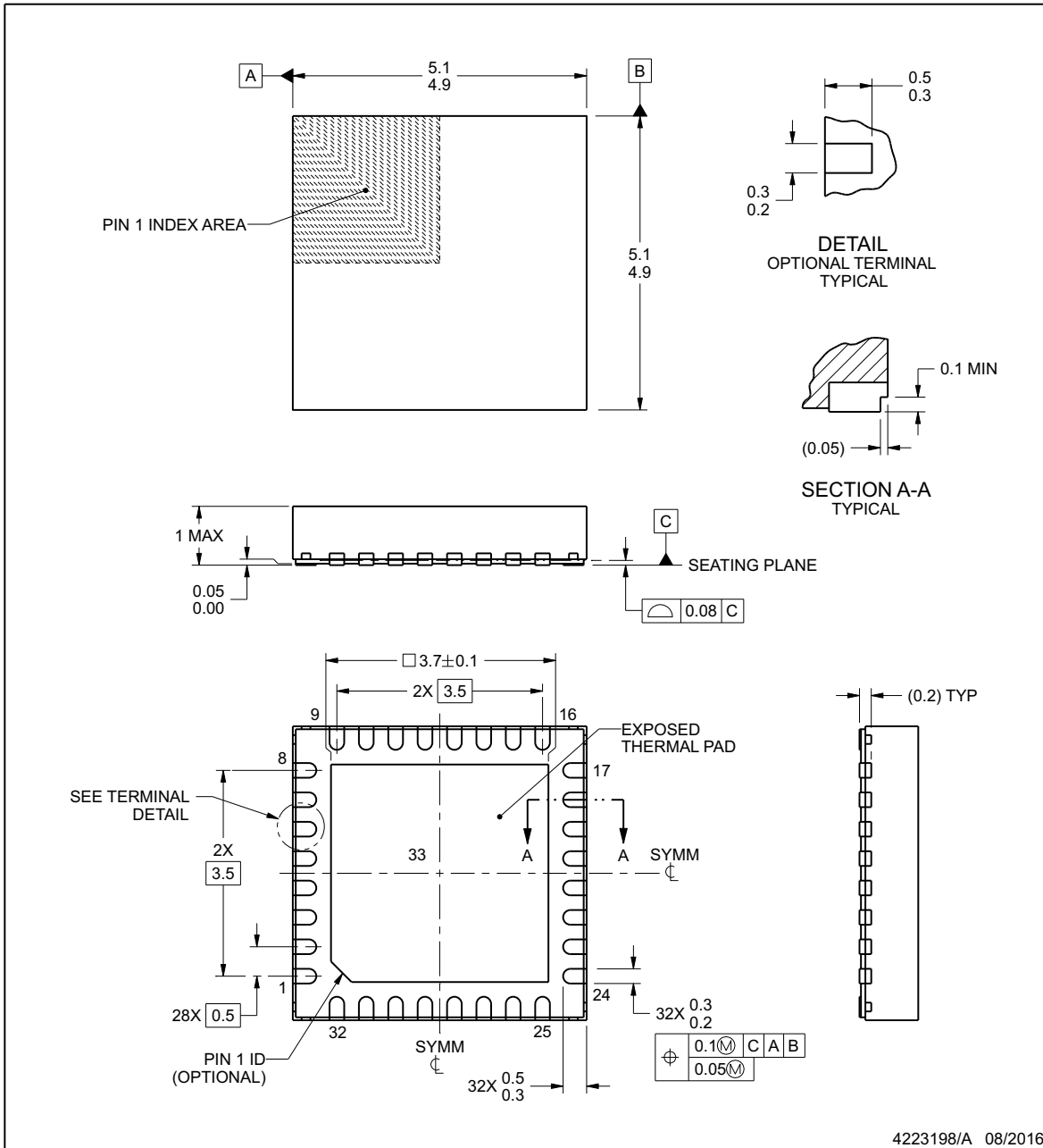


RHB0032P

PACKAGE OUTLINE

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



NOTES:

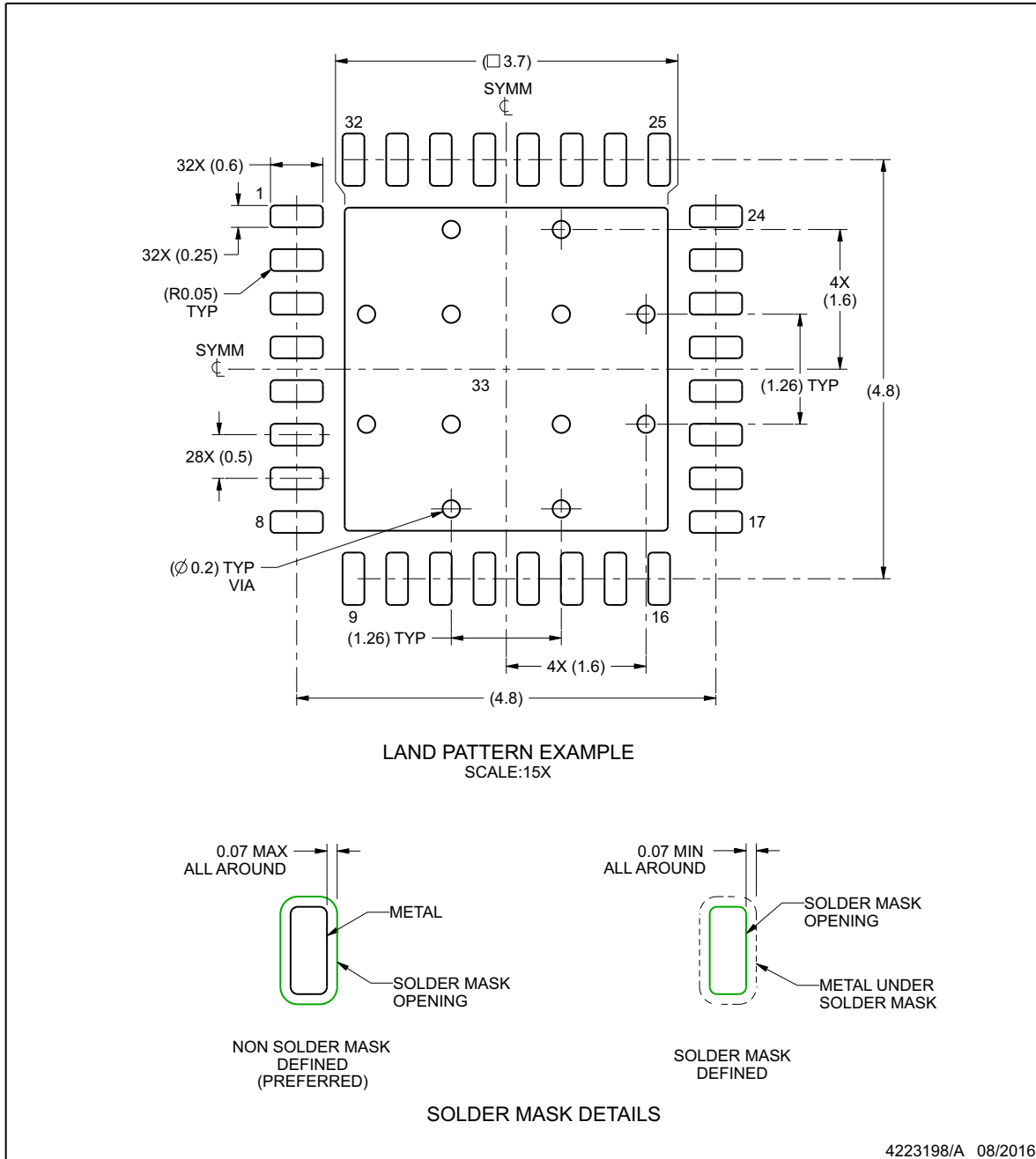
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE BOARD LAYOUT

RHB0032P

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



NOTES: (continued)

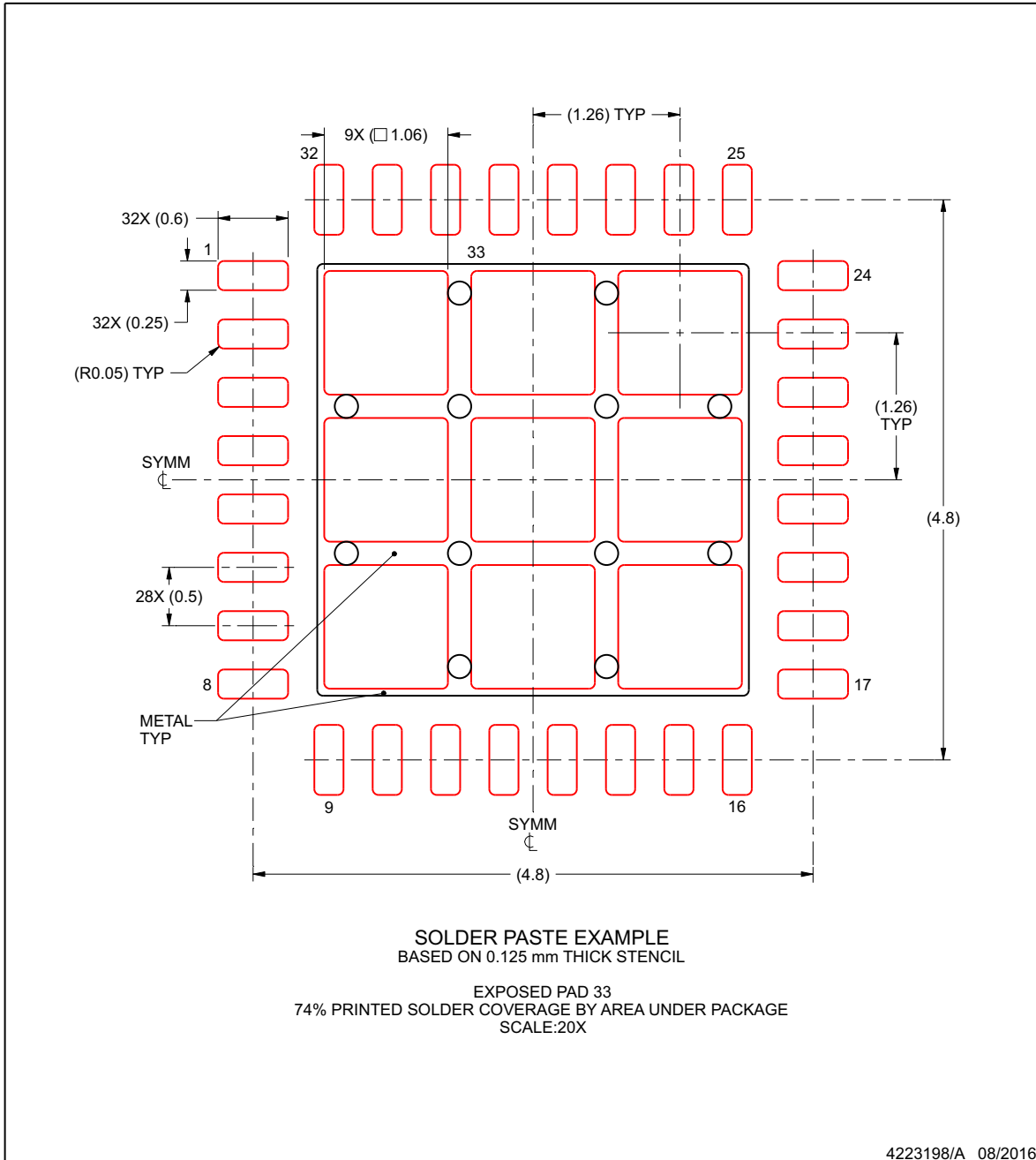
- This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/sluea271).
- Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

EXAMPLE STENCIL DESIGN

RHB0032P

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



NOTES: (continued)

- 6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| DS90UB953TRHBRQ1 | ACTIVE | VQFN | RHB | 32 | 3000 | RoHS & Green | NIPDAU SN | Level-3-260C-168 HR | -40 to 105 | UB953 | Samples |
| DS90UB953TRHBTQ1 | ACTIVE | VQFN | RHB | 32 | 250 | RoHS & Green | NIPDAU SN | Level-3-260C-168 HR | -40 to 105 | UB953 | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

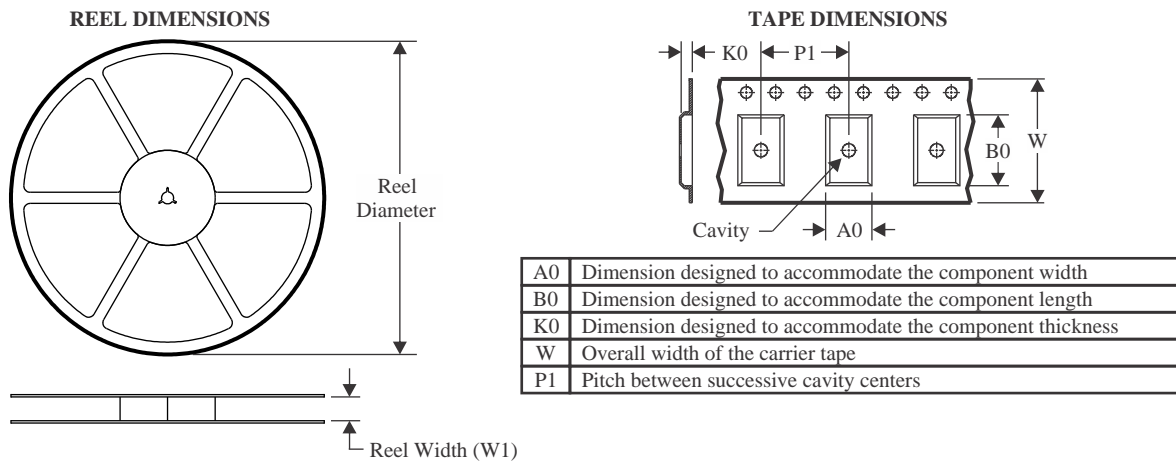
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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TAPE AND REEL INFORMATION

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| DS90UB953TRHBRQ1 | VQFN | RHB | 32 | 3000 | 330.0 | 12.4 | 5.3 | 5.3 | 1.1 | 8.0 | 12.0 | Q2 |
| DS90UB953TRHBTQ1 | VQFN | RHB | 32 | 250 | 180.0 | 12.4 | 5.3 | 5.3 | 1.1 | 8.0 | 12.0 | Q2 |

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| DS90UB953TRHBRQ1 | VQFN | RHB | 32 | 3000 | 367.0 | 367.0 | 35.0 |
| DS90UB953TRHBTQ1 | VQFN | RHB | 32 | 250 | 210.0 | 185.0 | 35.0 |

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