



# Intel® RealSense™ Product Family D400 Series

## Datasheet

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*Intel® RealSense™ Vision Processor D4, Intel® RealSense™ Vision Processor D4 Board, Intel® RealSense™ Vision Processor D4 Board V3, Intel® RealSense™ Depth Module D410, Intel® RealSense™ Depth Module D415, Intel® RealSense™ Depth Camera D415, Intel® RealSense™ Depth Module D430, Intel® RealSense™ Depth Module D450, Intel® RealSense™ Depth Module D401, Intel® RealSense™ Depth Camera D435, Intel® RealSense™ Depth Camera D435i, Intel® RealSense™ Depth Camera D455, Intel® RealSense™ Depth Camera D405, Intel® RealSense™ Depth Camera D435f, Intel® RealSense™ Depth Camera D435if, Intel® RealSense™ Depth Camera D455f, Intel® RealSense™ Depth Camera D456*

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# Contents

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|        |   |    |
|--------|---|----|
| 1      | Description and Features .....  | 15 |
| 2      | Introduction .....  | 17 |
| 2.1    | Purpose and Scope of this Document.....   | 17 |
| 2.2    | Terminology .....   | 17 |
| 2.3    | Stereo Vision Depth Technology Overview .....   | 18 |
| 2.4    | Camera System Block Diagram .....   | 20 |
| 2.5    | Intel® RealSense™ Depth Module D400 series Product SKUs.....                                  | 21 |
| 2.6    | Intel® RealSense™ Depth Camera D400 series Product SKUs .....                                 | 22 |
| 3      | Component Specification .....   | 24 |
| 3.1    | Vision Processor D4 Camera System Components .....  | 24 |
| 3.2    | Host Processor .....  | 24 |
| 3.3    | Intel® RealSense™ Vision Processor D4.....  | 24 |
| 3.3.1  | Vision Processor D4 Features .....  | 25 |
| 3.3.2  | Vision Processor D4 Signal Description .....  | 25 |
| 3.3.3  | Vision Processor D4 Package Mechanical Attributes .....                                       | 31 |
| 3.3.4  | Vision Processor D4 Power Requirements .....  | 36 |
| 3.3.5  | Vision Processor D4 Power Sequencing .....  | 37 |
| 3.3.6  | Vision Processor D4 Spec Code .....   | 38 |
| 3.3.7  | Vision Processor D4 Storage and Operating Conditions .....                                    | 39 |
| 3.3.8  | Vision Processor D4 Thermals.....   | 39 |
| 3.4    | Clock .....   | 39 |
| 3.5    | Serial (SPI) Flash Memory .....   | 39 |
| 3.6    | Stereo Depth Module .....   | 40 |
| 3.6.1  | Left and Right Imagers .....  | 42 |
| 3.6.2  | Infrared Projector.....   | 45 |
| 3.6.3  | Color Sensor .....  | 46 |
| 3.6.4  | Depth Module Connector .....  | 47 |
| 3.6.5  | Stereo Depth Module Label .....   | 48 |
| 3.6.6  | Stiffener .....   | 49 |
| 3.6.7  | Temperature Sensor.....   | 49 |
| 3.6.8  | Other Stereo Depth Module Components .....  | 50 |
| 3.6.9  | Mechanical Dimensions .....   | 50 |
| 3.6.10 | Stereo Depth Module Power Sequence.....   | 52 |
| 3.6.11 | Stereo Depth Module Storage and Powered Conditions .....                                      | 52 |
| 3.7    | Intel® RealSense™ Vision Processor D4 Board .....   | 53 |
| 3.7.1  | Mechanical Dimensions .....   | 54 |
| 3.7.2  | Depth Module Receptacle .....   | 54 |
| 3.7.3  | Flex and Rigid Interposer Interconnect .....  | 55 |
| 3.7.4  | External Sensor Sync Connector .....  | 64 |
| 3.7.5  | USB Peripheral Connector – Type-C – D415, D435, D435i, D435f, D435if, D455, D455f, D456 ..... | 64 |
| 3.7.6  | USB Peripheral Connector – Micro-B (D405) .....   | 66 |
| 3.7.7  | Color Image Signal Processor (ISP) .....  | 67 |
| 3.7.8  | Vision Processor D4 Board Power Requirements .....  | 67 |
| 3.7.9  | Vision Processor D4 Board Thermals .....  | 67 |
| 3.7.10 | Vision Processor D4 Board Storage and Powered Conditions .....                                | 68 |
| 3.7.11 | Intel® RealSense™ Vision Processor D4 Board Product Identifier and Material Code .....        | 68 |

|        |   |     |
|--------|---|-----|
| 3.8    | Intel® RealSense™ Depth Camera D400 Series.....                   | 69  |
| 3.8.1  | Depth Camera D400 Series Mechanical Dimensions .....              | 73  |
| 3.8.2  | Depth Camera D400 Series Thermals .....                           | 74  |
| 3.8.3  | Depth Camera D400 Series Product Identifier and Material Code ... | 76  |
| 3.8.4  | Camera Lens Cleaning Procedure .....                              | 76  |
| 3.8.5  | Stereo Depth Camera Label .....                                   | 77  |
| 4      | Functional Specification .....                                    | 80  |
| 4.1    | Vendor Identification (VID) and Device Identification (DID).....  | 80  |
| 4.2    | Vision Processor D4 Data Streams .....                            | 80  |
| 4.3    | Depth Field of View (FOV).....                                    | 88  |
| 4.4    | Depth Field of View at Distance (Z).....                          | 88  |
| 4.5    | Invalid Depth Band .....  | 89  |
| 4.6    | Minimum-Z Depth.....  | 91  |
| 4.7    | Depth Quality Specification .....                                 | 91  |
| 4.8    | Depth Start Point (Ground Zero Reference) .....                   | 93  |
| 4.8.1  | Depth Origin X-Y Coordinates .....                                | 97  |
| 4.9    | Depth Camera Functions .....                                      | 100 |
| 4.10   | Color Camera Functions .....                                      | 101 |
| 4.11   | IMU Specifications.....   | 102 |
| 5      | Firmware .....  | 104 |
| 5.1    | Update .....  | 104 |
| 5.1.1  | Update Limits .....   | 104 |
| 5.2    | Recovery .....  | 104 |
| 6      | Software.....   | 105 |
| 6.1    | Intel® RealSense™ Software Development Kit 2.0 .....              | 105 |
| 7      | System Integration .....  | 106 |
| 7.1    | System Level Block Diagram .....                                  | 106 |
| 7.2    | System Level Block Diagram .....                                  | 107 |
| 7.2.1  | Vision Processor D4 Board .....                                   | 107 |
| 7.2.2  | Vision Processor D4 on Motherboard .....                          | 108 |
| 7.3    | D4 Camera System Power Delivery .....                             | 109 |
| 7.4    | Thermals .....  | 110 |
| 7.5    | Stereo Depth Module Flex .....                                    | 115 |
| 7.6    | Stereo Depth Module Mounting Guidance .....                       | 115 |
| 7.6.1  | Screw Mounting/End Mounting .....                                 | 116 |
| 7.6.2  | Bracket Mounting/Mid-Module Mounting.....                         | 116 |
| 7.6.3  | Stereo Depth Module Air gap.....                                  | 118 |
| 7.7    | Thermal Interface Material.....                                   | 119 |
| 7.8    | Heat Sink.....  | 119 |
| 7.9    | Cover Design and Material Guidance .....                          | 119 |
| 7.10   | Gaskets .....   | 120 |
| 7.10.1 | Optical Isolation .....   | 122 |
| 7.10.2 | Dust Protection .....   | 122 |
| 7.11   | Firmware Recovery .....   | 122 |
| 7.12   | Calibration Support .....   | 123 |
| 7.13   | Multi-Camera Hardware Sync .....                                  | 123 |
| 7.14   | Handling Conditions .....   | 124 |
| 8      | Platform Design Guidelines .....                                  | 125 |

|        |  |     |
|--------|--|-----|
| 8.1    | Vision Processor D4 on Motherboard .....   | 125 |
| 8.2    | Kaby Lake U and Kaby Lake Y platforms .....  | 126 |
| 8.2.1  | Kaby Lake Platform Introduction .....  | 126 |
| 8.2.2  | Supported PCB Stack-Up and Routing Geometries.....   | 126 |
| 8.2.3  | Vision Processor D4 on Motherboard with USB Host Interface .....   | 127 |
| 8.2.4  | Vision Processor D4 on Motherboard with MIPI Host Interface.....   | 128 |
| 8.2.5  | Vision Processor D4 Board for Integrated Peripheral (USB 3.1 Gen 1<br>Host to Vision Processor D4 Routing) ..... | 130 |
| 8.2.6  | USB2.0 Design Guidelines (USB2 Host to Vision Processor D4<br>Routing) .....                                     | 131 |
| 8.2.7  | Ingress Protection Rating: IP65 .....  | 132 |
| 8.3    | Cherry Trail T4 Platform .....   | 132 |
| 8.3.1  | Cherry Trail T4 Platform Introduction .....  | 132 |
| 8.3.2  | Vision Processor D4 Platform Design Guidelines.....  | 133 |
| 9      | Regulatory Compliance .....  | 134 |
| 9.1    | System Laser Compliance .....  | 134 |
| 9.1.1  | Certification Statement .....  | 134 |
| 9.1.2  | Explanatory Label.....   | 134 |
| 9.1.3  | Cautionary Statements .....  | 134 |
| 9.1.4  | US FDA Accession Number.....   | 135 |
| 9.2    | Regulatory Compliance .....  | 135 |
| 9.2.1  | Manufacturer's Information.....  | 135 |
| 9.2.2  | EU Single Place of Contact .....   | 135 |
| 9.2.3  | UK Single Place of Contact.....  | 136 |
| 9.2.4  | NRTL Statement.....  | 136 |
| 9.2.5  | FCC Part 15 Declaration of Conformity.....   | 136 |
| 9.2.6  | Canada .....   | 137 |
| 9.2.7  | European Directives .....  | 137 |
| 9.2.8  | UK .....   | 138 |
| 9.2.9  | Australia.....   | 138 |
| 9.2.10 | Japan.....   | 138 |
| 9.2.11 | South Korea .....  | 138 |
| 9.3    | Ecology Compliance.....  | 139 |
| 9.3.1  | China RoHS Declaration .....   | 139 |
| 9.3.2  | Waste Electrical and Electronic Equipment (WEEE) .....   | 140 |
| 9.3.3  | Turkey .....   | 140 |
| 10     | Mechanical Drawings .....  | 141 |
| 11     | Connector Drawings .....   | 157 |
| 12     | Appendix A – Vision Processor D4 on Motherboard Schematic Checklist.....   | 159 |
| 12.1   | Power Delivery .....   | 166 |
| 13     | Appendix B – Cover Material.....   | 169 |

## Figures

|             |   |    |
|-------------|---|----|
| Figure 2-1. | Active Infrared (IR) Stereo Vision Technology .....   | 19 |
| Figure 2-2. | Depth Measurement (Z) versus Range (R) .....          | 19 |
| Figure 2-3. | Vision Processor D4 Camera System Block Diagram ..... | 20 |
| Figure 3-1. | Vision Processor D4 Package Drawing .....             | 32 |

|  |     |
|--|-----|
| Figure 3-2. Vision Processor D4 Ball-out .....   | 34  |
| Figure 3-3. Vision Processor D4 Power Sequencing .....   | 38  |
| Figure 3-4. Stereo Depth Module (Intel® RealSense™ Depth Module D410) .....  | 40  |
| Figure 3-5. Stereo Depth Module (Intel® RealSense™ Depth Module D430) .....  | 40  |
| Figure 3-6. Stereo Depth Module (Intel® RealSense™ Depth Module D450) .....  | 41  |
| Figure 3-7. Stereo Depth Module (Intel® RealSense™ Depth Module D401) .....  | 41  |
| Figure 3-8. Stereo Depth Module Power Sequence .....   | 52  |
| Figure 3-9. Vision Processor D4 Board (V1 and V3) (USB Peripheral Type-C) .....  | 53  |
| Figure 3-10. Vision Processor D4 Board (V4) (USB3 Peripheral Micro-B) .....  | 54  |
| Figure 3-11. Flex Interposer – D415, D435, D435i, D435f, D435if, D455, D455f, D456 (Illustration) .....                          | 55  |
| Figure 3-12. Rigid Interposer – D415, D435, D435i, D435f, D435if, D455, D455f, D456 (Illustration) .....                         | 56  |
| Figure 3-13. Depth Module Receptacle and Plug Connector Pin Position – D415, D435, D435i, D435f, D435if, D455, D455f, D456 ..... | 57  |
| Figure 3-14. Depth Module Connector Orientation and Pin Position – D415, D435, D435i, D435f, D435if, D455, D455f, D456 .....     | 59  |
| Figure 3-15. Flex Interposer – D401 (Illustration) .....   | 60  |
| Figure 3-16. Depth Module Receptacle and Plug Connector Pin Position – D401 .....  | 60  |
| Figure 3-17. Depth Module Connector Orientation and Pin Position – D401 .....  | 62  |
| Figure 3-18. USB Type-C Receptacle Pin Map .....   | 65  |
| Figure 3-19. USB3 Micro-B Receptacle Pin Map .....   | 66  |
| Figure 3-20. Intel® RealSense™ Depth Camera D415 .....   | 69  |
| Figure 3-21. Intel® RealSense™ Depth Camera D435/D435i .....   | 69  |
| Figure 3-22. Intel® RealSense™ Depth Camera D435f .....  | 69  |
| Figure 3-23. Intel® RealSense™ Depth Camera D455 .....   | 69  |
| Figure 3-24. Intel® RealSense™ Depth Camera D405 .....   | 70  |
| Figure 3-25. Intel® RealSense™ Depth Camera D435if .....   | 70  |
| Figure 3-26. Intel® RealSense™ Depth Camera D455f .....  | 70  |
| Figure 3-27. Intel® RealSense™ Depth Camera D456 .....   | 70  |
| Figure 3-28. Intel® RealSense™ Depth Cameras D435f, D435if and D455f NIR Filter Optical Properties .....                         | 72  |
| Figure 4-1. Depth Field of View to Depth Map illustration .....  | 89  |
| Figure 4-2. Left Invalid Depth Band .....  | 90  |
| Figure 4-3. Depth Module Depth Start Point Reference .....   | 94  |
| Figure 4-4. Depth Camera Depth Start Point Reference .....   | 96  |
| Figure 4-5. Depth Module X-Y Depth Origin Reference – D410, D415, D430, D450 .....   | 97  |
| Figure 4-6. Depth Module X-Y Depth Origin Reference – D401 .....   | 98  |
| Figure 4-7. Depth Camera X-Y Depth Origin Reference – D415, D435/D435i/D435f/D435if, D455/D455f/D456 .....                       | 99  |
| Figure 4-8. Depth Camera X-Y Depth Origin Reference – D405 .....   | 100 |
| Figure 7-1. System Block Diagram – D415, D435, D435i, D455 .....   | 106 |
| Figure 7-2. System Block Diagram – D405 .....  | 107 |
| Figure 7-3. Intel® RealSense™ Vision Processor D4 Board – V1, V3 .....   | 108 |
| Figure 7-4. Intel® RealSense™ Vision Processor D4 Board – V4 .....   | 108 |
| Figure 7-5. Vision Processor D4 on Motherboard (Illustration) .....  | 109 |
| Figure 7-6. D4 Camera System Power Scheme .....  | 110 |
| Figure 7-7. Bottom Stiffener Depth Module D410/D415 .....  | 114 |
| Figure 7-8. Bottom Stiffener Depth Module D430 .....   | 114 |
| Figure 7-9. Bottom Stiffener Depth Module D450 .....   | 115 |
| Figure 7-10. Bottom Stiffener Depth Module D401 .....  | 115 |
| Figure 7-11. Stereo Depth Module Screw Mounting/End Mounting – D410 .....  | 116 |
| Figure 7-12. Stereo Depth Module Screw Mounting/End Mounting – D430 .....  | 116 |
| Figure 7-13. Stereo Depth Module Bracket example for D415 .....  | 117 |
| Figure 7-14. Stereo Depth Module Bracket Mount – D415 .....  | 117 |

|  |     |
|--|-----|
| Figure 7-15. Stereo Depth Module Mid-Mounting – D401 .....   | 118 |
| Figure 7-16. Stereo Depth Module Air Gap .....   | 119 |
| Figure 7-17. Illustration of Gasket Placement and Cover Material .....   | 121 |
| Figure 7-18. Example of Light Leakage Effects .....  | 122 |
| Figure 7-19. Firmware Recovery Sequence.....   | 123 |
| Figure 7-20. External Sensor Sync Connector Location on D4 Vision Processor V1 and V3 Board ..                   | 123 |
| Figure 7-21. External Sensor Sync Connector Location on Depth Camera D435/D435i/D455 .....                       | 124 |
| Figure 8-1. Vision Processor D4 with USB Host Interface .....  | 125 |
| Figure 8-2. Vision Processor D4 with MIPI Host Interface.....  | 125 |
| Figure 8-3. Vision Processor D4 on Board for USB Integrated Peripheral .....                                     | 126 |
| Figure 8-4. Host Processor - Vision Processor D4 .....   | 127 |
| Figure 8-5. Vision Processor D4 Transmit - Host Receive .....  | 128 |
| Figure 8-6. Stereo Depth Transmit - Vision Processor D4 Receive.....   | 129 |
| Figure 8-7. Flex Interposer PCB Stack-Up .....   | 130 |
| Figure 8-8. USB 3.1 Gen 1 Host to Vision Processor D4 Topology .....   | 130 |
| Figure 8-9. USB2.0 Host to Vision Processor D4 .....   | 131 |
| Figure 9-1. NRTL Certifications .....  | 136 |
| Figure 10-1. Intel® RealSense™ Depth Module D410 .....   | 141 |
| Figure 10-2. Intel® RealSense™ Depth Module D415 .....   | 142 |
| Figure 10-3. Intel® RealSense™ Depth Module D430 .....   | 143 |
| Figure 10-4. Intel® RealSense™ Depth Module D450 .....   | 144 |
| Figure 10-5. Intel® RealSense™ Depth Module D401 .....   | 145 |
| Figure 10-6. Vision Processor D4 Board USB Type-C (Intel® RealSense™ Vision Processor D4 Board – V1 and V3)..... | 146 |
| Figure 10-7. Vision Processor D4 Board USB Micro-B (Intel® RealSense™ Vision Processor D4 Board – V4) .....      | 147 |
| Figure 10-8. Intel® RealSense™ Depth Camera D415 .....   | 148 |
| Figure 10-9. Intel® RealSense™ Depth Camera D435/D435i .....   | 149 |
| Figure 10-10. Intel® RealSense™ Depth Camera D435f/D435if NIR Filter .....                                       | 150 |
| Figure 10-11. Intel® RealSense™ Depth Camera D455.....   | 151 |
| Figure 10-12. Intel® RealSense™ Depth Camera D455f/ NIR Filter .....   | 154 |
| Figure 10-13. Intel® RealSense™ Depth Camera D405.....   | 155 |
| Figure 10-14. Intel® RealSense™ Depth Camera D456.....   | 156 |
| Figure 11-1. Receptacle Mechanical Drawing (50-Pin Depth Module Receptacle) .....                                | 157 |
| Figure 11-2. Plug Mechanical Drawing (50-Pin Depth Module Plug) .....  | 158 |
| Figure 12-1. Vision Processor D4 Laser PWM Reference Platform Schematic.....                                     | 166 |
| Figure 12-2. Vision Processor D4 24 MHz Crystal Clock Reference Platform Schematic .....                         | 166 |
| Figure 12-3. DC-DC Reference Platform Schematic (3.3 V, 1.8 V, 0.9 V) .....                                      | 167 |
| Figure 12-4. Vision Processor D4 VDD_PG and AVDD Reference Platform Schematic.....                               | 168 |

## Tables

|   |    |
|---|----|
| Table 2-1. Depth Module Product SKU Descriptions .....                  | 21 |
| Table 2-2. Depth Camera Product SKU Descriptions .....                  | 22 |
| Table 3-1. Component Descriptions .....                                 | 24 |
| Table 3-2. Vision Processor D4 Signal Descriptions .....                | 25 |
| Table 3-3. Hardware Straps .....  | 30 |
| Table 3-4. Vision Processor D4 Package Mechanical Attributes .....      | 32 |
| Table 3-5. Vision Processor D4 Ball-out by Signal Name .....            | 34 |
| Table 3-6. Vision Processor D4 Power Requirements.....                  | 37 |
| Table 3-7. Vision Processor D4 Power Sequencing Timing Parameters ..... | 38 |
| Table 3-8. Vision Processor D4 SPEC Code .....                          | 39 |
| Table 3-9. Vision Processor D4 Storage and Operating Conditions .....   | 39 |

|   |    |
|---|----|
| Table 3-10. Stereo Depth Module .....   | 40 |
| Table 3-11. Stereo Depth Module SKU Properties.....   | 41 |
| Table 3-12. Standard Left and Right Imager Properties – D410/D415.....  | 43 |
| Table 3-13. Wide Left and Right Imager Properties – D430 .....  | 43 |
| Table 3-14. Wide Left and Right Imager Properties – D450 .....  | 43 |
| Table 3-15. Wide Left and Right Imager Properties – D401 .....  | 44 |
| Table 3-16. Standard (D41x) Infrared Projector Parameters.....  | 45 |
| Table 3-17. Wide (D43x, D45x) Infrared Projector Parameters .....   | 45 |
| Table 3-18. Color Sensor Properties – D415 .....  | 46 |
| Table 3-19. Color Sensor Properties – D450 .....  | 46 |
| Table 3-20. Color Sensor Properties – D401*.....  | 47 |
| Table 3-21. Depth Module 50-pin Connector Plug Details.....   | 48 |
| Table 3-22. Stereo Depth Module Product Labeling – D410, D415, D430.....  | 48 |
| Table 3-23. Stereo Depth Module Product Labeling – D401, D450 .....   | 48 |
| Table 3-24. Stereo Depth Module Label Fields .....  | 48 |
| Table 3-25. Intel® RealSense™ Depth Module D400 Series Product Identifier Code and Product Material Code.....     | 49 |
| Table 3-26. Other Stereo Depth Module Components.....   | 50 |
| Table 3-27. Intel® RealSense™ Depth Module D410 Mechanical Dimensions .....                                       | 50 |
| Table 3-28. Intel® RealSense™ Depth Module D415 Mechanical Dimensions .....                                       | 50 |
| Table 3-29. Intel® RealSense™ Depth Module D430 Mechanical Dimensions .....                                       | 50 |
| Table 3-30. Intel® RealSense™ Depth Module D450 Mechanical Dimensions .....                                       | 51 |
| Table 3-31. Intel® RealSense™ Depth Module D401 Mechanical Dimensions .....                                       | 51 |
| Table 3-32. Stereo Depth Module Storage and Powered Conditions .....  | 52 |
| Table 3-33. Vision Processor D4 Board .....   | 53 |
| Table 3-34. Vision Processor D4 Board Components .....  | 53 |
| Table 3-35. Vision Processor D4 USB Type-C V1/V3 Board Mechanical Dimensions .....                                | 54 |
| Table 3-36. Vision Processor D4 USB3 Micro-B V4 Board Mechanical Dimensions .....                                 | 54 |
| Table 3-37. Depth Module Receptacle Details.....  | 55 |
| Table 3-38. Interposer Interconnect Signal Description – D415, D435, D435i, D435f, D435if, D455, D455f, D456..... | 57 |
| Table 3-39. Interposer Interconnect Signal Description - D401 .....   | 61 |
| Table 3-40. Custom Flex Interposer Ordering Logistics.....  | 63 |
| Table 3-41. External Sensor Connector Details.....  | 64 |
| Table 3-42. External Sensor Sync Connector Pin List .....   | 64 |
| Table 3-43. USB Peripheral Connector Pin List.....  | 65 |
| Table 3-44. USB Peripheral Connector Pin List – D405 .....  | 66 |
| Table 3-45. ISP Properties.....   | 67 |
| Table 3-46. Vision Processor D4 Board Power Requirements.....   | 67 |
| Table 3-47. Vision Processor D4 Board Storage and Powered Conditions .....  | 68 |
| Table 3-48. Vision Processor D4 Board Product Identifier and Material Code .....                                  | 68 |
| Table 3-49. Depth Camera SKU Properties .....   | 71 |
| Table 3-50. D435/D435i and D435f/D435if Comparison .....  | 72 |
| Table 3-51. Intel® RealSense™ Depth Camera D415 Mechanical Dimensions .....                                       | 73 |
| Table 3-52. Intel® RealSense™ Depth Camera D435, D435i, D435f, D435if Mechanical Dimensions                       | 73 |
| Table 3-53. Intel® RealSense™ Depth Camera D455, D455f, D456 Mechanical Dimensions .....                          | 73 |
| Table 3-54. Intel® RealSense™ Depth Camera D405 Mechanical Dimensions .....                                       | 73 |
| Table 3-55. Depth Camera D400 Series Storage and Powered Conditions .....   | 74 |
| Table 3-56. Depth Camera D400 Series Product Identifier and Material Code .....                                   | 76 |
| Table 3-57. Stereo Depth Camera Product Labeling – D415 .....   | 77 |
| Table 3-58. Stereo Depth Camera Product Labeling – D435, D435i, D435f, D435if .....                               | 77 |
| Table 3-59. Stereo Depth Camera Product Labeling – D455, D455f, D456 .....  | 78 |
| Table 3-60. Stereo Depth Camera Product Labeling – D405 .....   | 78 |
| Table 4-1. Vendor ID and Device ID Table.....   | 80 |
| Table 4-2. Image Formats (USB 3.1 Gen 1) – D410/D415/D430/D435/D435i/D435f/D435if .....                           | 81 |

|   |     |
|---|-----|
| Table 4-3. Image Formats (USB 3.1 Gen 1) – D450/D455/D455f/D456 .....   | 82  |
| Table 4-4. Image Formats (USB 3.1 Gen1) – D401/D405 .....   | 83  |
| Table 4-5. Simultaneous Image Streams (USB 3.1 Gen 1) –<br>D410/D415/D430/D435/D435i/D435f/D435if/D450/D455 .....               | 84  |
| Table 4-6. Simultaneous Image Streams (USB 3.1 Gen 1) – D401/D405.....  | 85  |
| Table 4-7. Image Formats (USB 2.0) – D410/D415/D430/D435/D435i/D435f/D435if .....   | 85  |
| Table 4-8. Image Formats (USB 2.0) – D450/D455/D455f/D456.....  | 86  |
| Table 4-9. Image Formats (USB 2.0) – D405 .....   | 86  |
| Table 4-10. Simultaneous Image Streams (USB 2.0) .....  | 87  |
| Table 4-11. Minimum-Z Depth.....  | 91  |
| Table 4-12. Depth Quality Metric.....   | 92  |
| Table 4-13. Depth Quality Metric Illustration.....  | 92  |
| Table 4-14. Depth Quality Specification .....   | 92  |
| Table 4-15. Depth Module Depth Start Point .....  | 95  |
| Table 4-16. Depth Cameras Depth Start Point.....  | 97  |
| Table 4-17. Depth Module X-Y Depth Origin Coordinates .....   | 97  |
| Table 4-18. Depth Module X-Y Depth Origin Coordinates – D401.....   | 98  |
| Table 4-19. Depth Camera X-Y Depth Origin Coordinates .....   | 99  |
| Table 4-20. Depth Camera X-Y Depth Origin Coordinates – D405 .....  | 100 |
| Table 4-21. Depth Camera Controls.....  | 100 |
| Table 4-22. RGB Exposed Controls .....  | 101 |
| Table 4-23. IMU Specifications – BMI055 .....   | 102 |
| Table 4-24. IMU Specifications – BMI085 .....   | 102 |
| Table 7-1. Vision Processor D4 Board V1/V2/V3 – Component Power and TDP at Max Operating<br>Mode <sup>(1)</sup> .....           | 111 |
| Table 7-2. Vision Processor D4 Board V4 – Component Power and TDP at Max Operating Mode <sup>(1)</sup> .....                    | 111 |
| Table 7-3. Stereo Depth Module (D410/D415) – Component Power and TDP at Max Operating<br>Mode <sup>(1)</sup> .....              | 111 |
| Table 7-4. Stereo Depth Module (D430) – Component Power and TDP at Max Operating Mode <sup>(1)</sup> ..                         | 111 |
| Table 7-5. Stereo Depth Module (D450) – Component Power and TDP at Max Operating Mode <sup>(1)</sup> ..                         | 112 |
| Table 7-6. Stereo Depth Module (D401) – Component Power and TDP at Max Operating Mode <sup>(1)</sup> ..                         | 112 |
| Table 7-7. Stereo Depth Camera (D415) – Component Power and TDP at Max Operating Mode <sup>(1)</sup> .                          | 113 |
| Table 7-8. Stereo Depth Camera (D435/D435f/D435i/D435f) – Component Power and TDP at Max<br>Operating Mode <sup>(1)</sup> ..... | 113 |
| Table 7-9. Stereo Depth Camera (D455/D455f/D456) – Component Power and TDP at Max Operating<br>Mode <sup>(1)</sup> .....        | 113 |
| Table 7-10. Stereo Depth Camera (D405) – Component Power and TDP at Max Operating Mode <sup>(1)</sup>                           | 114 |
| Table 7-11. Vision Processor D4 Board Components – Case Temperature Limits (Still Air).....                                     | 114 |
| Table 7-12. Component Transmission .....  | 120 |
| Table 7-13. Electrostatic Discharge Caution .....   | 124 |
| Table 8-1. Host Transmit – Vision Processor D4 Receive Routing Guidelines.....  | 127 |
| Table 8-2. Vision Processor D4 Transmit - Host Receive Routing Guidelines .....   | 127 |
| Table 8-3. Vision Processor D4 Transmit – Host Receive Routing Guidelines.....  | 128 |
| Table 8-4. Stereo Depth Module Transmit - Vision Processor D4 Receive Routing Guidelines.....                                   | 129 |
| Table 8-5. USB 3.1 Gen 1 Host to Vision Processor D4 Routing Guidelines .....   | 131 |
| Table 9-1. U.S. FDA Accession Number .....  | 135 |
| Table 12-1. Vision Processor D4 on Motherboard Schematic Checklist .....  | 159 |
| Table 12-2. Vision Processor D4 Decoupling and Filter Requirements .....  | 168 |
| Table 13-1. Example: Cover Material Parameters.....   | 169 |

# Revision History

---

| Revision Number | Description  | Revision Date |
|-----------------|--|---------------|
| 001             | Initial release  | January 2018  |
| 002             | Tracking Module 1 removal, NRTL certification, 7.2.2.1 Firmware Update   | March 2018    |
| 003             | <ul style="list-style-type: none"><li>• Added USB2.0 support</li><li>• Removed VBUS0 from Table 3 6. Vision Processor D4 Power Requirements</li><li>• Table 3 12. Standard Left and Right Imager Properties</li><li>• Table 3 13. Wide Left and Right Imager Properties</li><li>• Table 3 9. Vision Processor D4 Storage and Operating Conditions</li><li>• Table 3 27 Stereo Depth Module Storage and Operating Conditions</li><li>• Table 3 38. Vision Processor D4 Board Storage and Operating Conditions</li><li>• Table 3 44. Depth Camera D400 Series Storage and Operating Conditions</li><li>• Table 4 3. Image Formats (USB 2.0)</li><li>• Table 4 5. Simultaneous Image Streams (USB3.1 Gen1, USB 2.0)</li><li>• 4.7 Depth Origin Point (Ground Truth Zero)</li><li>• 7.14 Multi-camera hardware sync for multi-camera configuration</li></ul> | July 2018     |
| 004             | <ul style="list-style-type: none"><li>• Description and Features</li><li>• Terminology</li><li>• Table 2-2. Depth Camera Product SKU Descriptions</li><li>• Table 3-11. Stereo Depth Module SKU Properties</li><li>• Table 3-33. Custom Flex Interposer Ordering Logistics</li><li>• Table 3-35. External Sensor Sync Connector Pin List</li><li>• Table 3-42. Depth Camera SKU properties</li><li>• Table 3-47. Depth Camera D400 Series Product Identifier and Material Code</li><li>• Table 4-1. Vendor ID and Device ID Table</li><li>• Table 4-2. Image Formats (USB 3.1 Gen1)</li><li>• Table 4-3. Image Formats (USB 2.0)</li><li>• Table 4-9. Depth Quality Specification</li><li>• Section 4-12 IMU Specification</li></ul>   | November 2018 |
| 005             | <ul style="list-style-type: none"><li>• Table 3-11. Stereo Depth Module SKU Properties</li><li>• Table 3-42. Depth Camera SKU Properties</li><li>• Table 4-4. Simultaneous Image Streams (USB 3.1 Gen 1 &amp; USB 2.0)</li><li>• Table 4-18. IMU Specifications</li></ul>  | January 2019  |

| Revision Number | Description  | Revision Date |
|-----------------|--|---------------|
| 006             | <ul style="list-style-type: none"> <li>•Table 3-28. Vision Processor D4 Board</li> <li>•Table 4-2. Image Formats (USB 3.1 Gen1)</li> <li>•Table 4-4. Simultaneous Image Streams (USB 3.1 Gen1 &amp; USB 2.0)</li> <li>•Table 4-17. RGB Exposed Controls</li> <li>•Figure 10-7. Intel® RealSense™ Depth Camera D415</li> <li>•Figure 10-8. Intel® RealSense™ Depth Camera D435/D435i</li> <li>•Figure 4-1. Depth Field of View to Depth Map illustration</li> </ul>   | June 2019     |
| 007             | <ul style="list-style-type: none"> <li>•Table 3-19. Stereo Depth Module Label Fields</li> <li>•Table 3-43. Intel® RealSense™ Depth Camera D415 Mechanical Dimensions</li> <li>•Table 3-44. Intel® RealSense™ Depth Camera D435, D435i Mechanical Dimensions</li> <li>•Table 4-9. Depth Quality Specification</li> <li>•Section 7.6. Stereo Depth Module Flex</li> <li>•Remove Table 7-11. Bracket Ordering Logistics</li> </ul>  | October 2019  |
| 008             | <ul style="list-style-type: none"> <li>•Support for Intel® RealSense™ Vision Processor D4 Board V2 (IMU version for MM#954010)</li> <li>•Table 2-1. Depth Module Product SKU Descriptions</li> <li>•Table 3-9. Vision Processor D4 Storage and Operating Conditions</li> <li>•Table 3-15. Wide Infrared Projector Parameters</li> <li>•Table 3-27. Stereo Depth Module Storage and Powered Conditions</li> <li>•Table 3-37. Recommended USB Type C cable Assemblies Ordering Logistics</li> <li>•Table 3-40. Vision Processor D4 Board Storage and Powered Conditions</li> <li>•Table 3-41. Vision Processor D4 Board Product Identifier and Material Code</li> <li>•Table 3-45. Depth Camera D400 Series Storage and Powered Conditions</li> <li>•Table 4-2. Image Formats (USB 3.1 Gen 1)</li> <li>•Table 4-15. RGB Exposed Controls</li> <li>•Table 4-16. IMU Specifications</li> <li>•Table 7-10. Vision Processor D4 Board Components – Case Temperature Limits (Still Air)</li> <li>•Table 13-1. Example: Cover Material Parameters</li> <li>•Section 1. Description and Features</li> <li>•Section 3.6.7. Temperature Sensor</li> <li>•Section 3.7.5. USB Peripheral Connector – Type-C</li> <li>•Section 3.8.2.2. Depth Camera D400 Series Thermal Solution Guidance</li> <li>•Remove Table 4-3. Image Formats (USB 2.0)</li> <li>•Remove Section 4.8. Measured Power</li> </ul> | April 2020    |

| Revision Number | Description   | Revision Date |
|-----------------|---|---------------|
| 009             | <ul style="list-style-type: none"> <li>•Section 1. Description and Features</li> <li>•Section 3.8.4. Camera Lens Cleaning Procedure</li> <li>•Section 9. Regulatory Compliance</li> <li>•Table 2-2. Depth Camera Product SKU Descriptions</li> <li>•Table 3-42. Depth Camera SKU properties</li> <li>•Table 3-45. Intel® RealSense™ Depth Camera D455 Mechanical Dimensions</li> <li>•Table 3-47. Depth Camera D400 Series Product Identifier and Material Code</li> <li>•Table 4-3. Image Formats (USB 3.1 Gen1) – D455</li> <li>•Table 4-1. Vendor ID and Device ID Table</li> <li>•Table 4-4. Simultaneous Image Streams (USB 3.1 Gen1 &amp; USB2.0)</li> <li>•Table 4-5. Depth Field of View</li> <li>•Table 4-6. Minimum-Z Depth</li> <li>•Table 4-9. Depth Quality Specification</li> <li>•Table 4-13. Depth Camera X-Y Depth Origin Coordinates</li> <li>•Table 4-11. Depth Cameras Depth Start Point</li> <li>•Table 4-16. IMU Specifications</li> <li>•Figure 3-15. Intel® RealSense™ Depth Camera D455</li> <li>•Figure 10-9. Intel® RealSense™ Depth Camera D455</li> </ul>  | June 2020     |
| 010             | <ul style="list-style-type: none"> <li>•Figure 3-6. Stereo Depth Module (Intel® RealSense™ Depth Module D450)</li> <li>•Table 3-11. Stereo Depth Module SKU Properties</li> <li>•Table 3-14. Wide Left and Right Imager Properties – D450</li> <li>•Table 3-22. Intel® RealSense™ Depth Module D400 Series Product Identifier Code and Product Material Code</li> <li>•Table 3-29. Intel® RealSense™ Depth Module D450 Mechanical Dimensions</li> <li>•Table 3-43. Vision Processor D4 Board Product Identifier and Material Code</li> <li>•Table 3-48. Depth Camera D400 Series Storage and Powered Conditions – Notes</li> <li>•Table 3-49. Depth Camera D400 Series Product Identifier and Material Code</li> <li>•Table 4-1. Vendor ID and Device ID Table</li> <li>•Table 4-5. Depth Field of View</li> <li>•Table 4-9. Depth Quality Specification</li> <li>•Table 4-10. Depth Module Depth Start Point</li> <li>•Table 4-12. Depth Module X-Y Depth Origin Coordinates</li> <li>•Table 4-16. IMU Specifications</li> <li>•Table 7-10. Stereo Depth Module (D450) – Component Power and TDP at Max Operating Mode(1)</li> <li>•Figure 7-9. Bottom Stiffener Depth Module D450</li> <li>•Figure 10-6. Intel® RealSense™ Depth Module D450</li> </ul> | February 2021 |

| Revision Number | Description  | Revision Date |
|-----------------|--|---------------|
| 011             | <ul style="list-style-type: none"> <li>•General: typos, rephrasing, removing D420</li> <li>•Table 2-2. Depth Camera Product SKU Descriptions</li> <li>•Table 3-10. Stereo Depth Module</li> <li>•Table 3-11. Stereo Depth Module SKU Properties</li> <li>•Table 3-15. Standard Infrared Projector Parameters</li> <li>•Table 3-16. Wide Infrared Projector Parameters</li> <li>•Table 3-18. Color Sensor Properties</li> <li>•Tables 3-24 to 3-29 3-45 to 3-47 flatness</li> <li>•Table 3-43. Depth Camera SKU properties</li> <li>•Table 3-48. Case temperature</li> <li>•4.11 IMU Specifications - removing Vision Processor D4 Board V2 (PCN #1180-5 - 00)</li> <li>•Table 4-2. Image Formats (USB 3.1 Gen1)</li> <li>•Table 4-3. Image Formats (USB 3.1 Gen1) – D450/D455</li> <li>•Table 4-4. Simultaneous Image Streams (USB 3.1 Gen1 &amp; USB2.0)</li> <li>•Table 4-8. Adding lifetime</li> <li>•Table 4-9. Depth Quality Specification</li> <li>•Table 7-4. Stereo depth module D450 component power</li> <li>•4.3 Depth Field of View (FOV)</li> <li>•7.4. Update thermal data and add cameras</li> <li>•7.6 Stereo Depth Module Mounting Guidance</li> <li>•9.1 Regulatory laser compliance</li> <li>•9.2 Regulatory compliance</li> <li>•Figure 10-6. Intel® RealSense™ Depth Module D450</li> </ul> | August 2021   |
| 012             | <ul style="list-style-type: none"> <li>• General: Add D401/D405</li> </ul>   | March 2022    |
| 013             | <ul style="list-style-type: none"> <li>• General: Add D435f</li> </ul>   | April 2022    |
| 014             | <ul style="list-style-type: none"> <li>•Table 3-25. Added D430</li> <li>•Figure 3-22. Updated D455 pictures and added D435f</li> <li>•3.6.5. Added D401 &amp; D450 Stereo Depth Module Label</li> <li>•3.8.5. Added Stereo Depth Camera Label</li> <li>•Table 7-12. Update transmission rate</li> <li>•Table 7-5. Update total power number</li> </ul>   | November 2022 |
| 015             | <ul style="list-style-type: none"> <li>• General: Add D435if</li> <li>• 3.6.1: Update the Left and Right Imagers' FOV</li> <li>• 3.6.9: Update the Modules' weight</li> <li>• 3.8.1: Update the cameras' weight</li> </ul>   | March 2023    |

| <b>Revision Number</b> | <b>Description</b>  | <b>Revision Date</b> |
|------------------------|---|----------------------|
| 016                    | <ul style="list-style-type: none"> <li>• Add D455f</li> <li>• Table 4-14: Add a comment for D405</li> <li>• Table 13-1: remove distance from lens to cover and add air gap</li> <li>• Table 3-49: add filter row</li> <li>• Chapter 9: update EU certification and label, update KCC and the new camera models</li> </ul> | July 2023            |
| 017                    | <ul style="list-style-type: none"> <li>• Add D456</li> <li>• Table 4-48: Correct a typo in ASIC V1 compatibility</li> <li>• Tables 7-8 and 7-9: add missing SKUs</li> </ul>   | September 2023       |

# 1 Description and Features

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The Intel® RealSense™ Product Family D400 Series is a stereo vision depth camera system. The subsystem assembly contains a stereo depth module and vision processor with USB 2.0/USB 3.1 Gen 1 or MIPI<sup>1</sup> connection to host processor.

The small size and ease of integration of the camera subsystem provides system integrators flexibility to design into a wide range of products.

The Intel® RealSense™ D400 series also offers complete depth cameras integrating the vision processor, stereo depth module, RGB sensor with color image signal processing, and an Inertial Measurement Unit<sup>2</sup> (IMU). The depth cameras are designed for easy setup and portability making them ideal for makers, educators, hardware prototypes and software development.

The Intel® RealSense™ D400 series is supported with the cross-platform and open source Intel® RealSense™ SDK 2.0.

|  |   |
|--|---|
| Usages/Markets                               | <ul style="list-style-type: none"><li>• Autonomous Mobile Robots (AMR)</li><li>• Automated Guided Vehicles (AGV)</li><li>• Drones</li><li>• Collision avoidance</li><li>• Home surveillance</li><li>• 3D scanning</li><li>• Digital signage</li><li>• Volumetric measurement</li></ul>  |
| Minimum System Requirements                  | <ul style="list-style-type: none"><li>• USB 2.0/USB 3.1 Gen 1</li><li>• Ubuntu*16.xx/Windows*10</li></ul>   |
| General Features                             | <ul style="list-style-type: none"><li>• 2<sup>nd</sup> Generation Stereo Depth Camera System</li><li>• 2<sup>nd</sup> Generation dedicated Intel® RealSense™ Vision Processor D4 with advanced algorithms</li><li>• Infrared (IR) Laser Projector System</li><li>• Full HD resolution Image sensors</li><li>• Active power management</li><li>• Selection of Stereo Depth Module options to meet your usage requirements<ul style="list-style-type: none"><li>1. MIPI is not currently supported. Please contact your Intel representative on MIPI enablement timelines.</li><li>2. Module and Camera SKU dependent</li></ul></li></ul> |
| Intel® RealSense™ Depth Camera D415 Features | <ul style="list-style-type: none"><li>• Intel® RealSense™ Vision Processor D4</li><li>• Up to 1280 x 720 stereo depth resolution</li><li>• Up to 1920 x 1080 RGB resolution</li><li>• Depth diagonal field of view over 70°</li><li>• Dual rolling shutter sensors for up to 90 FPS depth streaming</li></ul>   |

|   |   |
|---|---|
|   | <ul style="list-style-type: none"> <li>Range 0.3 m to over 4 m (varies with lighting conditions)</li> </ul>   |
| Intel® RealSense™ Depth Camera D435/D435i D435f/D435if Features   | <ul style="list-style-type: none"> <li>Intel® RealSense™ Vision Processor D4</li> <li>Up to 1280 x 720 stereo depth resolution</li> <li>Up to 1920 x 1080 RGB resolution</li> <li>Depth diagonal field of view over 90°</li> <li>Dual global shutter sensors for up to 90 FPS depth streaming</li> <li>Range 0.2 m to over 3 m (varies with lighting conditions)</li> <li>D435i/D435if includes Inertial Measurement Unit (IMU) for 6 Degrees of Freedom (6DoF) data</li> <li>D435f/D435if cameras have IR-pass filter.</li> </ul>  |
| <ul style="list-style-type: none"> <li>Intel® RealSense™ Depth Camera D455/D455f/D456 Features</li> </ul> | <ul style="list-style-type: none"> <li>Intel® RealSense™ Vision Processor D4</li> <li>Up to 1280 x 720 stereo depth resolution</li> <li>Up to 1280 x 800 RGB resolution</li> <li>Diagonal field of view over 90°</li> <li>Dual global shutter sensors for up to 90 FPS depth streaming</li> <li>RGB global shutter sensor for up to 90 FPS</li> <li>Range 0.4 m to over 6 m (varies with lighting conditions)</li> <li>Inertial Measurement Unit (IMU) for 6 Degrees of Freedom (6DoF) data</li> <li>D455f camera has IR-pass filter</li> <li>D456 is similar to D455 with an IP65 enclosure</li> </ul> |
| <ul style="list-style-type: none"> <li>Intel® RealSense™ Depth Camera D405 Features</li> </ul>            | <ul style="list-style-type: none"> <li>Intel® RealSense™ Vision Processor D4</li> <li>Up to 1280 x 720 stereo depth resolution</li> <li>Up to 1280 x 720 RGB resolution</li> <li>Diagonal field of view over 90°</li> <li>Dual global shutter sensors for up to 90 FPS depth streaming</li> <li>RGB global shutter sensor for up to 90 FPS</li> <li>Range 7 cm to 1 m (varies with lighting conditions)</li> </ul>  |

## 2 Introduction

---

### 2.1 Purpose and Scope of this Document

This document captures the specifications and the design-in details for the Intel® RealSense™ D400 series family of products. This document provides information necessary to understand and implement an Intel® RealSense™ D400 series-based camera system.

**Note:** Intel® RealSense™ D400 series is alternately referred to as "D4 Camera System" in this document. Intel® RealSense™ Vision Processor D4 is alternately referred to as "D4" in this document.

### 2.2 Terminology

| Term                  | Description   |
|-----------------------|---|
| 6DOF                  | Six Degrees of Freedom (6DoF) refers to the freedom of movement of a rigid body in three-dimensional space. Forward/back, up/down, left/right, pitch, yaw, roll   |
| Stereo Depth Baseline | The distance between the center of the left and right imagers in a stereo camera  |
| MIPI CSI-2            | The Camera Serial Interface (CSI) is a specification of the Mobile Industry Processor Interface (MIPI) Alliance and CSI-2 is the 2 <sup>nd</sup> generation specification defining the interface between a camera and a host processor  |
| Depth                 | Depth video streams are similar to color video streams except that each pixel has a value representing the distance away from the camera instead of color information   |
| D4                    | If the term D4 is used alone, it refers to the entire D4 camera system consisting of various modules and components.<br>If the term D4 is used with an appropriate qualifier (i.e., D4 Vision Processor, D4 Vision Processor Board), it refers to the specific module or component within the D4 camera system. |
| FOV                   | Field Of View (FOV) describes the angular extent of a given scene that is imaged by a camera. A camera's FOV can be measured horizontally, vertically, or diagonally.   |
| Host System           | Computer or SOC connected to D4 camera  |
| I2C                   | I <sup>2</sup> C (Inter-Integrated Circuit), pronounced I-squared-C, is a multi-master, multi-slave, single-ended, serial computer bus invented by Philips Semiconductor (now NXP Semiconductors). It is typically used to allow easy control and data communication between components.                        |

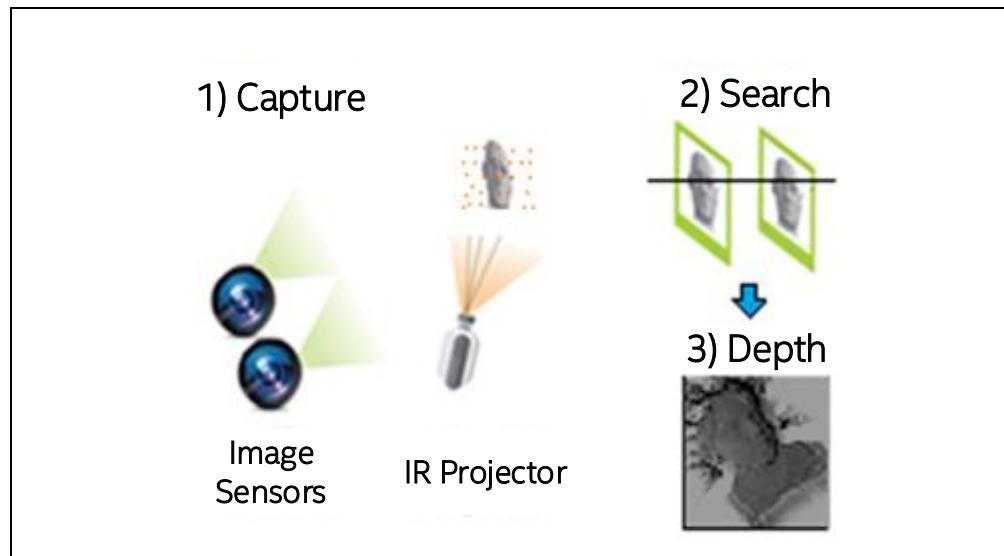
| <b>Term</b>                  | <b>Description</b>  |
|------------------------------|---|
| IR Projector                 | This refers to the source of infrared (IR) light used for illuminating a scene, object, or person to collect depth data.  |
| Imagers                      | Depth camera system uses a pair of cameras referred as imagers to calculate depth. They are identical cameras configured with identical settings.   |
| Image Signal Processor (ISP) | Image processing functions to enhance color image quality   |
| Left imager                  | From the perspective of the stereo camera looking out at the world, the left imager is on the left side of the camera module. Thus, when the user is facing the front of the camera, the left imager is on the right side of the camera module.                     |
| Lens                         | This refers to the optical component of an imager in the D4 camera. Its purpose is to focus the incoming light rays onto the CMOS chip in the imager.   |
| MIPI                         | MIPI (Mobile Industry Processor Interface) is a global, open membership organization that develops interface specifications for the mobile ecosystem  |
| Platform camera              | This refers to the two-dimensional (2D) color camera on a platform  |
| System on Chip (SoC)         | Integrated circuit (IC) that integrates all components of a computer  |
| Stereo Depth Module          | This refers to a stiffened module containing at least two imagers. The distance between the imagers, which is referred to as the baseline or intraocular spacing, is typically in the range of 18 mm to 95 mm.  |
| Stereo camera                | This refers to a pair of imagers looking at the same subject from slightly different perspectives. The difference in the perspectives is used to generate a depth map by calculating a numeric value for the distance from the imagers to every point in the scene. |
| SKU                          | Stock Keeping Unit (SKU) is a unique identifier for distinct products. It is often used in the scope of naming different versions of a device.  |
| TBD                          | To Be Determined. In the context of this document, information will be available in a later revision.   |

## 2.3 Stereo Vision Depth Technology Overview

The Intel® RealSense™ D400 series depth camera uses stereo vision to calculate depth. The stereo vision implementation consists of a left imager, right imager, and an optional infrared projector. The infrared projector projects a non-visible static IR pattern to improve depth accuracy in scenes with low texture. The left and right imagers capture the scene and send imager data to the depth imaging (vision) processor, which calculates depth values for each pixel in the image by

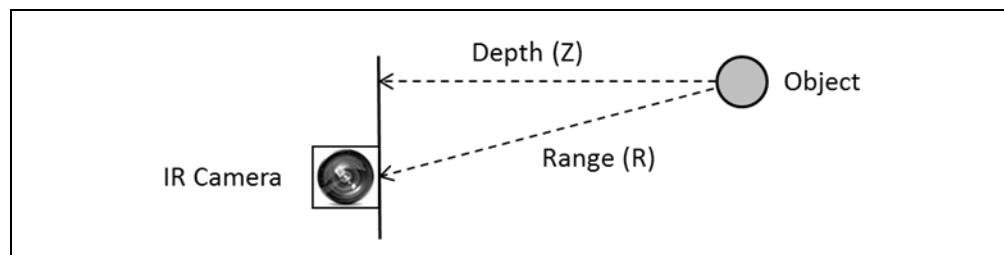
correlating points on the left image to the right image and via the shift between a point on the Left image and the Right image. The depth pixel values are processed to generate a depth frame. Subsequent depth frames create a depth video stream.

**Figure 2-1. Active Infrared (IR) Stereo Vision Technology**



The depth pixel value is a measurement from the parallel plane of the imagers and not the absolute range as illustrated.

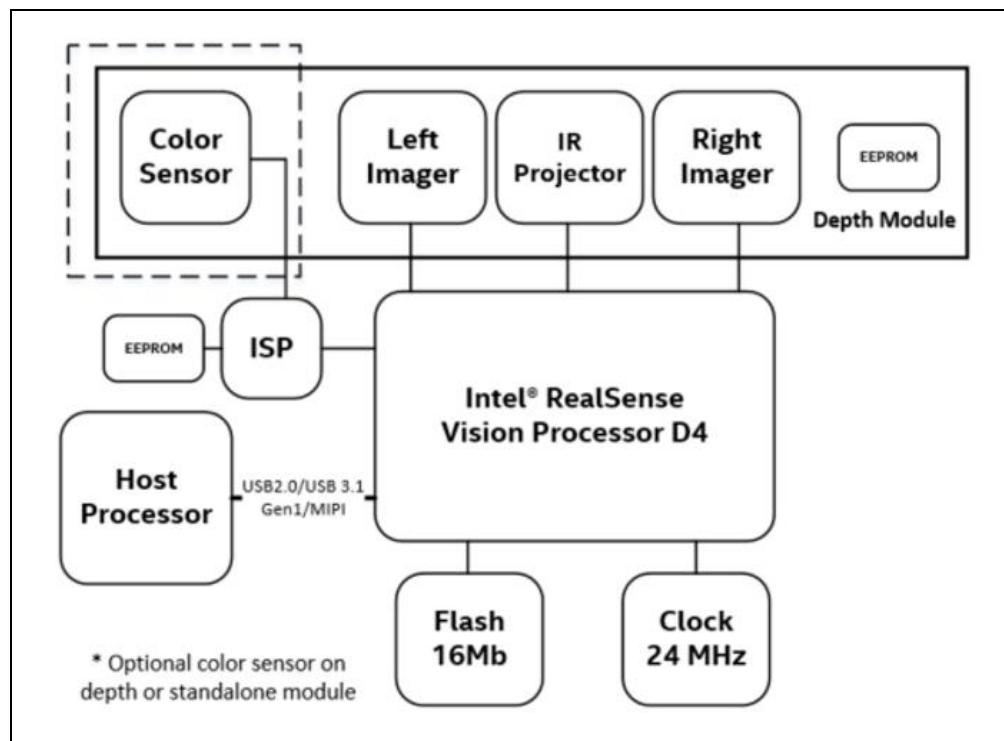
**Figure 2-2. Depth Measurement (Z) versus Range (R)**



## 2.4 Camera System Block Diagram

The camera system has two main components, Vision Processor D4 and Depth module. The Vision Processor D4 is either on the host processor motherboard or on a discrete board with either a USB2.0/USB 3.1 Gen 1 or a MIPI connection to the host processor. The Depth module incorporates left and right imagers for stereo vision with the optional IR projector and RGB color sensor. The RGB color sensor data is sent to Vision Processor D4 via the color Image Signal Processor (ISP) on the Host Processor motherboard or D4 Board.

**Figure 2-3. Vision Processor D4 Camera System Block Diagram**



## 2.5 Intel® RealSense™ Depth Module D400 series Product SKUs

The Table below describes the main components that make up the different depth module SKUs.

**Table 2-1. Depth Module Product SKU Descriptions**

| Component                                   | Subcomponent                | D410                    | D415                    | D430                                     | D450                    | D401                    |
|---|-----------------------------|-------------------------|-------------------------|--|-------------------------|-------------------------|
| Intel® RealSense™ Vision Processor D4       | -                           | ✓                       | ✓                       | ✓  | ✓                       | ✓                       |
| Intel® RealSense™ Vision Processor D4 Board | -                           | <b>V1<sup>(1)</sup></b> | <b>V1<sup>(1)</sup></b> | <b>V1<sup>(1)</sup>/V3<sup>(2)</sup></b> | <b>V3<sup>(2)</sup></b> | <b>V4<sup>(3)</sup></b> |
| Intel® RealSense™ Depth Module              | Standard Stereo Imagers     | ✓                       | ✓                       | ✗  | ✗                       | ✗                       |
|   | Wide Stereo Imagers         | ✗                       | ✗                       | ✓  | ✓                       | ✓                       |
|   | Standard Infrared Projector | ✓                       | ✓                       | ✗  | ✗                       | ✗                       |
|   | Wide Infrared Projector     | ✗                       | ✗                       | ✓  | ✓                       | ✗                       |
|   | RGB Color Sensor            | ✗                       | ✓                       | ✗  | ✓                       | ✓ <sup>(4)</sup>        |

**Definitions:**

- D410 = Intel® RealSense™ Depth Module D410
- D415 = Intel® RealSense™ Depth Module D415
- D430 = Intel® RealSense™ Depth Module D430
- D450 = Intel® RealSense™ Depth Module D450
- D401 = Intel® RealSense™ Depth Module D401

**Notes:**

- (1) Intel® RealSense™ Vision Processor D4 Board V1
- (2) Intel® RealSense™ Vision Processor D4 Board V3 (IMU Version of V1)
- (3) Intel® RealSense™ Vision Processor D4 Board V4
- (4) Left depth sensor provides RGB data to color ISP

## 2.6 Intel® RealSense™ Depth Camera D400 series Product SKUs

The Table below describes the main components that make up the different camera SKUs.

**Table 2-2. Depth Camera Product SKU Descriptions**

| Component                             | Sub component               | Intel® RealSense™ Depth Camera D415 | Intel® RealSense™ Depth Camera D435/ D435f | Intel® RealSense™ Depth Camera D435i / D435if | Intel® RealSense™ Depth Camera D455/ D455f/ D456 | Intel® RealSense™ Depth Camera D405 |
|---------------------------------------|-----------------------------|-------------------------------------|--|---|--|-------------------------------------|
| Intel® RealSense™ Vision Processor D4 | -                           | √                                   | √  | √   | √  | √                                   |
| Intel® RealSense™ Depth Module        | Standard Stereo Imagers     | √                                   | ✗  | ✗   | ✗  | ✗                                   |
|                                       | Wide Stereo Imagers         | ✗                                   | √  | √   | √  | √                                   |
|                                       | Standard Infrared Projector | √                                   | ✗  | ✗   | ✗  | ✗                                   |
|                                       | Wide Infrared Projector     | ✗                                   | √  | √   | √  | ✗                                   |
|                                       | RGB color sensor            | √                                   | √  | √   | √  | √                                   |
| Inertial Measurement Unit (IMU)       |                             | ✗                                   | ✗  | √   | √  | ✗                                   |

**Notes:**

1. For information regarding USB interoperability, refer to whitepaper "USB Interoperability Testing for Intel® RealSense™ Cameras" - <https://www.intelrealsense.com/usb-interoperability-testing-for-intel-realsense-cameras>
2. D435f = D435 with CLAREX® NIR-75N near-infrared filter () applied to cover glass, with holes over projector and RGB sensor openings. Filter transmits near-infrared light and absorbs visible light. Filter's thickness = 0.5 mm.
3. D435if = D435i with CLAREX® NIR-75N near-infrared filter applied to cover glass, with holes over projector and RGB sensor openings. Filter transmits near-infrared light and absorbs visible light. Filter's thickness = 0.5 mm.
4. D455f = D455 with CLAREX® NIR-75N near-infrared filter applied to cover glass, with holes over projector and RGB sensor openings. Filter transmits near-infrared light and absorbs visible light. Filter's thickness = 0.5 mm.



# 3 Component Specification

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## 3.1 Vision Processor D4 Camera System Components

**Table 3-1. Component Descriptions**

| Component                             | Description  |
|---------------------------------------|--|
| Host Processor                        | Host Processor that receives Depth and other data streams from Vision Processor D4   |
| Vision Processor D4                   | Depth Imaging Processor with USB 2.0/USB 3.1 Gen 1 or MIPI interface connection to Host Processor                              |
| Clock                                 | 24 MHz clock source for Vision Processor D4  |
| Serial Flash Memory                   | SPI 16 Mb Serial Flash memory for firmware storage   |
| Stereo Depth Module                   | Camera module with left and right imager, color sensor†, IR projector† enclosed in a stiffener                                 |
| Power Delivery                        | Circuitry on motherboard/Vision Processor D4 Board to deliver and manage power to Vision Processor D4 and Stereo Depth Module. |
| Stereo Depth Connector and Interposer | 50-pin connector on motherboard/Vision Processor D4 Board and Stereo Depth module with interposer for connection               |

**Note:**

(†) SKU dependent

## 3.2 Host Processor

The host processor interface to Vision Processor D4 is either USB 2.0/USB 3.1 Gen 1 or MIPI. To ensure the best of quality of service, the Vision Processor D4 must be connected to a dedicated USB 3.1 Gen 1 root port within the host processor system.

## 3.3 Intel® RealSense™ Vision Processor D4

The primary function of Vision Processor D4 is to perform depth stereo vision processing. The Vision Processor D4 on the Host Processor motherboard or on the Vision Processor D4 Board communicates to the host processor through USB2.0/USB 3.1 Gen 1 or MIPI and receives sensor data from the stereo depth module. The Vision Processor D4 supports MIPI CSI-2 channels for the connection to the image sensors.

### 3.3.1 Vision Processor D4 Features

- 28 nm CMOS process technology
- 5 MIPI camera ports with each MIPI lane capable of handling data transfers of up to 750 Mbps
- USB 2.0/USB 3.1 Gen 1 or MIPI interface to host system
- Image rectification for camera optics and alignment compensation
- IR Projector (laser) controls
- Serial Peripheral Interface for fast data transfer with external SPI flash
- Integrated I2C ports
- General purpose Input/Output pins
- Active power gating

### 3.3.2 Vision Processor D4 Signal Description

**Table 3-2. Vision Processor D4 Signal Descriptions**

**RESERVED** – Signal reserved for future usage

**IO Type**- Input/Output Buffer type

**A** – Analog

**I** – Input

**O** - Output

| Signal Name          | Description   | IO Type | After RESET |
|----------------------|---|---------|-------------|
| <b>Host MIPI</b>     |   |         |             |
| H_DATAP0<br>H_DATAN0 | Host MIPI Data Lane 0 Differential Pair                             | A       | I           |
| H_DATAP1<br>H_DATAN1 | Host MIPI Data Lane 1 Differential Pair                             | A       | I           |
| H_DATAP2<br>H_DATAN2 | Host MIPI Data Lane 2 Differential Pair                             | A       | I           |
| H_DATAP3<br>H_DATAN3 | Host MIPI Data Lane 3 Differential Pair                             | A       | I           |
| H_CLKP<br>H_CLKN     | Host MIPI Clock Differential Transmit Pair                          | A       | I           |
| H_SDA<br>H_SCL       | Host I <sup>2</sup> C Bus Data and Clock                            | I/O     | IO          |
| H_REXT               | Host MIPI External Reference 6.04K 1% resistor pull down to ground) | A       | I           |
| <b>Imager A MIPI</b> |   |         |             |
| A_DATAP0             | Imager A MIPI Data Lane 0 Differential Receive Pair                 | A       | I           |

| <b>Signal Name</b>   | <b>Description</b>   | <b>IO Type</b> | <b>After RESET</b> |
|----------------------|--|----------------|--------------------|
| A_DATAN0             |  |                |                    |
| A_DATAP1<br>A_DATAN1 | Imager A MIPI Data Lane 1 Differential Receive Pair                      | A              | I                  |
| A_CLKP<br>A_CKLN     | Imager A MIPI Clock Differential Receive Pair                            | A              | I                  |
| A_SDA<br>A_SCL       | Imager A I <sup>2</sup> C Bus Data and Clock                             | I/O            | IO                 |
| A_RCLK               | Imager A Reference Clock   | I/O            | O                  |
| A_PDOWN              | (RESERVED) Imager A Power Down Signal                                    | I/O            | O                  |
| A_VSYNC              | Imager A Vertical/Frame Sync   | I/O            | I                  |
| A_RESETN             | Imager A Reset   | I/O            | O                  |
| A_REXT               | Imager A MIPI External Reference (6.04K 1% resistor pull down to ground) | A              | I                  |
| <b>Imager B MIPI</b> |  |                |                    |
| B_DATAP0<br>B_DATAN0 | (RESERVED) Imager B MIPI Data Lane 0 Differential Receive Pair           | A              | I                  |
| B_DATAP1<br>B_DATAN1 | (RESERVED) Imager B MIPI Data Lane 1 Differential Receive Pair           | A              | I                  |
| B_CLKP<br>B_CKLN     | (RESERVED) Imager B MIPI Clock Differential Receive Pair                 | A              | I                  |
| B_SDA<br>B_SCL       | (RESERVED) Imager B I <sup>2</sup> C Bus Data and Clock                  | I/O            | IO                 |
| B_RCLK               | (RESERVED) Imager B Reference Clock                                      | I/O            | O                  |
| B_PDOWN              | (RESERVED) Imager B Power Down   | I/O            | O                  |
| B_VSYNC              | (RESERVED) Imager B Vertical/Frame Sync                                  | I/O            | I                  |
| B_RESETN             | (RESERVED) Imager B Reset  | I/O            | O                  |
| B_REXT               | Imager B MIPI External Reference (6.04K 1% resistor pull down to ground) | A              | I                  |
| <b>Imager M MIPI</b> |  |                |                    |
| M_DATAP0<br>M_DATAN0 | Imager M MIPI Data Lane 0 Differential Receive Pair                      | A              | I                  |
| M_DATAP1<br>M_DATAN1 | Imager M MIPI Data Lane 1 Differential Receive Pair                      | A              | I                  |
| M_CLKP<br>M_CKLN     | Imager M MIPI Clock Differential Receive Pair                            | A              | I                  |
| M_SDA<br>M_SCL       | Imager M I <sup>2</sup> C Bus Data and Clock                             | I/O            | IO                 |

| <b>Signal Name</b>                          | <b>Description</b>   | <b>IO Type</b> | <b>After RESET</b> |
|---|--|----------------|--------------------|
| M_RCLK                                      | Imager M Reference Clock   | I/O            | O                  |
| M_PDOWN                                     | (RESERVED) Imager M Power Down   | I/O            | O                  |
| M_VSYNC                                     | Imager M Vertical/Frame Sync   | I/O            | I                  |
| M_RESETN                                    | Imager M Reset   | I/O            | O                  |
| M_REXT                                      | Imager M MIPI External Reference (6.04K 1% resistor pull down to ground) | A              | I                  |
| <b>Imager Y MIPI</b>                        |  |                |                    |
| Y_DATAP0<br>Y_DATAN0                        | Imager Y MIPI Data Lane 0 Differential Receive Pair                      | A              | I                  |
| Y_DATAP1<br>Y_DATAN1                        | Imager Y MIPI Data Lane 1 Differential Receive Pair                      | A              | I                  |
| Y_CLKP<br>Y_CKLN                            | Imager Y MIPI Clock Differential Receive Pair                            | A              | I                  |
| Y_SDA<br>Y_SCL                              | Imager Y I <sup>2</sup> C Bus Data and Clock                             | I/O            | IO                 |
| Y_RCLK                                      | Imager Y Reference Clock   | I/O            | O                  |
| Y_PDOWN                                     | (RESERVED) Imager Y Power Down   | I/O            | O                  |
| Y_VSYNC                                     | Imager Y Vertical/Frame Sync   | I/O            | I                  |
| Y_RESETN                                    | Imager Y Reset   | I/O            | O                  |
| Y_REXT                                      | Imager Y MIPI External Reference (6.04K 1% resistor pull down to ground) | A              | I                  |
| <b>Imager Z MIPI</b>                        |  |                |                    |
| Z_DATAP0<br>Z_DATAN0                        | (RESERVED) Imager Z MIPI Data Lane 0 Differential Receive Pair           | A              | I                  |
| Z_DATAP1<br>Z_DATAN1                        | (RESERVED) Imager Z MIPI Data Lane 1 Differential Receive Pair           | A              | I                  |
| Z_CLKP<br>Z_CKLN                            | (RESERVED) Imager Z MIPI Clock differential Receive Pair                 | A              | I                  |
| Z_SDA<br>Z_SCL                              | (RESERVED) Imager Z I <sup>2</sup> C Bus Data and Clock                  | I/O            | IO                 |
| Z_RCLK                                      | (RESERVED) Imager Z Reference Clock                                      | I/O            | O                  |
| Z_PDOWN                                     | (RESERVED) Imager Z Power Down   | I/O            | O                  |
| Z_VSYNC                                     | Depth Vertical/Frame Sync  | I/O            | O                  |
| Z_RESETN                                    | (RESERVED) Imager Z Reset  | I/O            | O                  |
| Z_REXT                                      | Imager Z MIPI External Reference (6.04K 1% resistor pull down to ground) | A              | I                  |
| <b>Serial Peripheral Interconnect (SPI)</b> |  |                |                    |

| <b>Signal Name</b>                         | <b>Description</b>   | <b>IO Type</b> | <b>After RESET</b> |
|--|--|----------------|--------------------|
| SPI_DI                                     | SPI Data Input   | I/O            | I                  |
| SPI_DO                                     | SPI Data Output  | I/O            | O                  |
| SPI_CLK                                    | SPI Clock  | O              | O                  |
| SPI_CS                                     | SPI Chip Select  | O              | O                  |
| SPI_WP                                     | Flash Write Protect  | O              | O                  |
| <b>General Purpose Input Output (GPIO)</b> |  |                |                    |
| GPIO[0]                                    | (RESERVED) Not Defined   | I/O            | I                  |
| GPIO[1]                                    | (RESERVED) Not Defined   | I/O            | I                  |
| GPIO[2]                                    | Laser PWM – Controls Laser Power for IR projector on Stereo Module | I/O            | O                  |
| GPIO[3]                                    | (RESERVED) Not Defined   | I/O            | I                  |
| GPIO[4]                                    | (RESERVED) Not Defined   | I/O            | I                  |
| GPIO[5]                                    | (RESERVED) Not Defined   | I/O            | I                  |
| GPIO[6]                                    | (RESERVED) Not Defined   | I/O            | I                  |
| GPIO[7]                                    | (RESERVED) Not Defined   | I/O            | I/O                |
| EGPIO[0]                                   | (RESERVED) Not Defined   | I/O            | I/O                |
| EGPIO[1]                                   | (RESERVED) Not Defined   | I/O            | I/O                |
| EGPIO[2]                                   | (RESERVED) Not Defined   | I/O            | I/O                |
| EGPIO[3]                                   | Laser_PWRDN - IR projector Power Down Signal                       | I/O            | O                  |
| EGPIO[4]                                   | (RESERVED) Not Defined   | I/O            | I/O                |
| EGPIO[5]                                   | FLAGB – IR Projector Fault Detect                                  | I/O            | I                  |
| EGPIO[6]                                   | (RESERVED) Not Defined   | I/O            | I/O                |
| EGPIO[7]                                   | (RESERVED) Not Defined   | I/O            | I/O                |
| EGPIO[8]                                   | ISP_FCS (Color ISP)  | I/O            | O                  |
| EGPIO[9]                                   | (RESERVED) Not Defined   | I/O            | I/O                |
| EGPIO[10]                                  | (RESERVED) Not Defined   | I/O            | I/O                |
| EGPIO[11]                                  | (RESERVED) Not Defined   | I/O            | I/O                |
| EGPIO[12]                                  | (RESERVED) Not Defined   | I/O            | I/O                |
| EGPIO[13]                                  | (RESERVED) - For Intel test purpose only                           | I/O            | I/O                |
| <b>Miscellaneous</b>                       |  |                |                    |
| LD_ON_OUT_XX                               | (RESERVED) Laser Enable  | O              | O                  |
| MODSTROB                                   | (RESERVED) Modulation current strobe                               | O              | O                  |
| MODSIGN                                    | (RESERVED) Modulation current sign                                 | O              | O                  |
| LD_ERR                                     | Laser Error (Active High)  | I              | I                  |
| CLKXI                                      | 24 MHz XTAL  | I              | I                  |

| <b>Signal Name</b>      | <b>Description</b>                              | <b>IO Type</b> | <b>After RESET</b> |
|-------------------------|---|----------------|--------------------|
| CLKXO                   | 24MHz XTAL                                      | I              | I                  |
| PRSTN                   | D4 Reset  | I              | I                  |
| CW_CSR_PRSTn            | Hardware reset without debug port reset         | I/O            | I                  |
| PMU_PWR_EN              | Switchable domain (VDD_PG) power control signal | I/O            | O                  |
| DFU                     | Dynamic FW update, used for FW recovery         | I/O            | I                  |
| ISP_SCL<br>ISP_SDA      | I <sup>2</sup> C Bus Data and Clock             | I/O            | IO                 |
| VQPSQ                   | (RESERVED) – For Intel test purpose only        | O              | O                  |
| VQPSM                   | (RESERVED) – For Intel test purpose only        | O              | O                  |
| REFPADCLKP              | (RESERVED) – For Intel test purpose only        | I              | I                  |
| REFPADCLKM              | (RESERVED) – For Intel test purpose only        | I              | I                  |
| <b>JTAG</b>             |   |                |                    |
| TDI                     | Test Data Input                                 | I/O            | I                  |
| TDO                     | Test Data Output                                | I/O            | O                  |
| TCLK                    | Test Clock Input                                | I/O            | I                  |
| TMS                     | Test Mode Select                                | I/O            | I                  |
| TRSTN                   | Test Reset                                      | I/O            | I                  |
| <b>USB</b>              |   |                |                    |
| USB_RXP                 | USB 3.1 Gen 1 receive, positive side            | A              | I                  |
| USB_RXN                 | USB 3.1 Gen 1 receive, negative side            | A              | I                  |
| USB_TXP                 | USB 3.1 Gen 1 Transmit, positive side           | A              | O                  |
| USB_TXN                 | USB 3.1 Gen 1 Transmit, negative side           | A              | O                  |
| USB_DP                  | USB 2.0 D+ line                                 | A              | IO                 |
| USB_DN                  | USB 2.0 D- line                                 | A              | IO                 |
| USB_ID                  | Mini-receptacle identifier and test point       |                |                    |
| USB_RESREF              | Reference Resistor input. 200 Ohm 1%            | A              | I                  |
| <b>Power and Ground</b> |   |                |                    |
| VDD                     | 0.9 V (Core Voltage)                            | Power          |                    |
| VDD_PG                  | 0.9 V (Switched Core Voltage)                   | Power          |                    |
| USB_DVDD                | 0.9 V (USB Core Voltage)                        | Power          |                    |
| VPTX0                   | 0.9 V (USB Core Voltage)                        | Power          |                    |
| VP                      | 0.9 V (USB Core Voltage)                        | Power          |                    |
| *_AVDD                  | 1.8 V (MIPI Core and IO Voltage)                | Power          |                    |
| VDDPLL                  | 0.9 V (PLL Voltage)                             | Power          |                    |

| Signal Name | Description                        | IO Type | After RESET |
|-------------|------------------------------------|---------|-------------|
| VDDTS       | 1.8 V (Temperature Sensor Voltage) | Power   |             |
| VDDPST18    | 1.8 V (IO Voltage)                 | Power   |             |
| USB_VDD330  | 3.3 V (USB Core Voltage)           | Power   |             |
| VBUS0       | 3.3 V (VBUS power monitor)         | Power   |             |
| VSS         | Ground                             | GND     |             |
| *_AGND      | Ground                             | GND     |             |

**Table 3-3. Hardware Straps**

| Pin      | Boot Load | HW/FW | Description  |
|----------|-----------|-------|--|
| EPGPIO0  | No        | FW    | USB connection type:<br>0: Peripheral (default)<br>1: Integrated   |
| EGPIO4   | Yes       | HW    | SPI Interface:<br>0: SPI on "Z"<br>1: SPI connected (default)      |
| EPGPIO7  | Yes       | FW    | Flash<br>00: 64 Mb<br>01: 8 Mb                                     |
| EPGPIO8  |           |       | 10: 16 Mb (default)<br>11: 32 Mb                                   |
| EPGPIO9  | No        | FW    | Host interface:<br>0: USB (default)<br>1: MIPI                     |
| EPGPIO10 | No        | FW    | Board version [0] (default: 0)                                     |
| EPGPIO11 | No        | FW    | Board version [1] (default: 0)                                     |
| EPGPIO12 | No        | FW    | Board version [2] (default: 0)                                     |
| DFU      | Yes       | HW    | Go to DFU<br>0: Disabled (default)<br>1: Go to DFU mode (Recovery) |

**Notes:**

1. Boot Load – Read during Boot
2. Hardware (HW) Strap – External hardware pin state directly configures D4 functionality
3. Firmware (FW) Strap – External hardware pin state is read by firmware and firmware configures D4 functionality

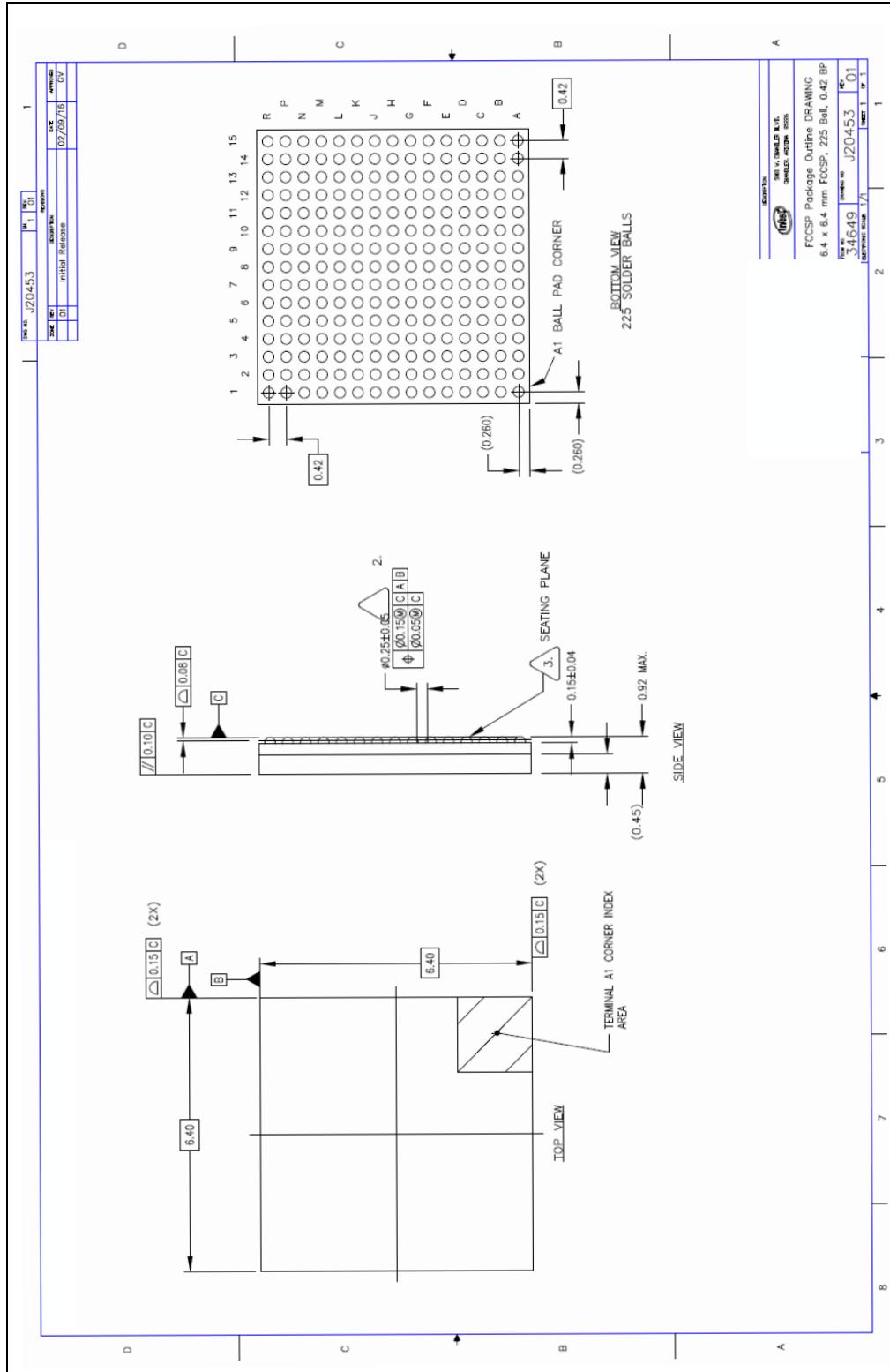
### **3.3.3 Vision Processor D4 Package Mechanical Attributes**

The Table below provides an overview of the mechanical attributes of the package.

**Table 3-4. Vision Processor D4 Package Mechanical Attributes**

| Parameter             | Description                      | Value                              |
|-----------------------|----------------------------------|------------------------------------|
| Package Technology    | Package Type                     | Flip Chip CSP (Chip Scale Package) |
|                       | Interconnect                     | Ball Grid Array (BGA) Ball         |
|                       | Lead Free                        | Yes                                |
|                       | Halogenated Flame Retardant Free | Yes                                |
| Package Configuration | Solder Ball Composition          | SAC125Ni                           |
|                       | Ball/Pin Count                   | 225 solder balls                   |
|                       | Grid Array Pattern               | 15 x 15                            |
| Package Dimensions    | Nominal Package Size (mm)        | 6.40 x 6.40                        |
|                       | Min Ball/Pin pitch (mm)          | 0.42                               |
| Weight                |                                  | ~1 g                               |

**Figure 3-1. Vision Processor D4 Package Drawing**



**Figure 3-2. Vision Processor D4 Ball-out**

|           | A        | B        | C          | D          | E          | F        | G            | H        | J             | K            | L        | M        | N        | P           | R        |           |
|-----------|----------|----------|------------|------------|------------|----------|--------------|----------|---------------|--------------|----------|----------|----------|-------------|----------|-----------|
| <b>15</b> | VSS      | Y_DATANO | Y_RECT     | Y_SCL      | GPIO_0     | GPIO_1   | GPIO_5       | GPIO_6   | MODSTROB      | TMS          | TRSTN    | SPI_WPN  | SPI_MISO | CW_CSR_RSTN | VSS      | <b>15</b> |
| <b>14</b> | Y_CLKN   | Y_CLKP   | Y_DATAP0   | Y_RCLK     | Y_SDA      | Y_RESETN | GPIO_2       | GPIO_3   | MODSIGN       | TCLK         | TDO      | SPI_CLK  | SPI_MOSI | Z_RESETN    | Z_VSYNC  | <b>14</b> |
| <b>13</b> | Y_DATAN1 | Y_DATAP1 | VSS        | VSS        | Y_PDOWN    | Y_VSYNC  | GPIO_4       | GPIO_7   | LD_ERR        | LD_ON_OUT_XX | TDI      | SPI_CS   | Z_SDA    | Z_DATAP0    | Z_RCLK   | <b>13</b> |
| <b>12</b> | B_DATANO | B_SCL    | B_SDA      | Y_AVDD     | VSS        | VSS      | VDDST18_LEFT | VSS      | VSS           | VDDST18_LEFT | VSS      | VSS      | Z_SCL    | Z_CLKP      | Z_DATANO | <b>12</b> |
| <b>11</b> | B_CLKN   | B_DATAP0 | B_RECT     | VSS        | VSS        | VSS      | VDD          | VDD      | VDD           | VSS          | VSS      | Z_AVDD   | Z_PDOWN  | Z_DATAP1    | Z_CLKN   | <b>11</b> |
| <b>10</b> | B_DATAN1 | B_CLKP   | B_RESETN   | B_AVDD     | VDD_PG     | VDD_PG   | VDD_PG       | VDD      | VDD           | VDD_PG       | VDD_PG   | ISP_SCL  | Z_RECT   | M_DATAP1    | Z_DATAN1 | <b>10</b> |
| <b>9</b>  | H_DATAN3 | H_DATAP1 | B_PDOWN    | VSS        | VDD_PG     | VDD_PG   | VDD_PG       | VSS      | VSS           | VDD_PG       | VDD_PG   | VSS      | ISP_SDA  | M_CLKP      | M_DATAN1 | <b>9</b>  |
| <b>8</b>  | H_DATAN2 | H_DATAP3 | B_VSYNC    | VSS        | VSS        | VDD_PG   | VDD_PG       | VSS      | VSS           | VSS          | VSS      | VSS      | VSS      | M_DATAP0    | M_CLKN   | <b>8</b>  |
| <b>7</b>  | H_CLKN   | H_DATAP2 | B_RCLK     | H_AVDD     | VSS        | VSS      | VSS          | VSS      | VSS           | VDD_PG       | VDD_PG   | M_AVDD   | M_RESETN | M_PDOWN     | M_DATANO | <b>7</b>  |
| <b>6</b>  | H_DATAN1 | H_CLKP   | H_AVDD     | REFPADCLKP | REFPADCLKM | VSS      | VDD          | VDD      | VSS           | VDD_PG       | VDD_PG   | M_RECT   | M_VSYNC  | M_SDA       | M_RCLK   | <b>6</b>  |
| <b>5</b>  | H_DATANO | H_DATAP1 | H_RECT     | VP         | USB_ID     | VDD      | VDD          | VDD      | VSS           | VSS          | VSS      | VSS      | VSS      | A_DATAP1    | M_SCL    | <b>5</b>  |
| <b>4</b>  | H_SCL    | H_DATAP0 | USB_VDD330 | VPTX0      | USB_RESREF | USB_DVDD | VSS          | VSS      | VDDST18_RIGHT | VSS          | VSS      | A_AVDD   | A_RECT   | A_CLKP      | A_DATAN1 | <b>4</b>  |
| <b>3</b>  | USB_RXN  | H_SDA    | PRSTN      | USB_DP     | EGPIO_1    | EGPIO_11 | VDDTS        | VSSTS    | VDDST18_RIGHT | PMU_PWR_EN   | VQPSQ    | VQPSM    | A_PDOWN  | A_DATAP0    | A_CLKN   | <b>3</b>  |
| <b>2</b>  | USB_TXN  | USB_RXP  | DFU        | USB_DN     | EGPIO_9    | EGPIO_13 | VDDPLL       | VSSPLL   | EGPIO_5       | EGPIO_12     | EGPIO_3  | EGPIO_4  | A_SCL    | A_RCLK      | A_DATANO | <b>2</b>  |
| <b>1</b>  | VSS      | USB_TXP  | VBUSO      | EGPIO_6    | EGPIO_7    | EGPIO_8  | CLK_XIN      | CLK_XOUT | EGPIO_10      | EGPIO_2      | EGPIO_0  | A_VSYNC  | A_SDA    | A_RESETN    | VSS      | <b>1</b>  |
|           | <b>A</b> | <b>B</b> | <b>C</b>   | <b>D</b>   | <b>E</b>   | <b>F</b> | <b>G</b>     | <b>H</b> | <b>J</b>      | <b>K</b>     | <b>L</b> | <b>M</b> | <b>N</b> | <b>P</b>    | <b>R</b> |           |

**Table 3-5. Vision Processor D4 Ball-out by Signal Name**

| Ball | Name     | Ball | Name     | Ball | Name       |
|------|----------|------|----------|------|------------|
| A01  | H_AGND   | B01  | USB_TXP  | C01  | VBUS0      |
| A02  | USB_TXN  | B02  | USB_RXP  | C02  | DFU        |
| A03  | USB_RXN  | B03  | H_SDA    | C03  | PRSTN      |
| A04  | H_SCL    | B04  | H_DATAP0 | C04  | USB_VDD330 |
| A05  | H_DATANO | B05  | H_DATAP1 | C05  | H_RECT     |
| A06  | H_DATAN1 | B06  | H_CLKP   | C06  | H_AVDD     |
| A07  | H_CLKN   | B07  | H_DATAP2 | C07  | B_RCLK     |

| <b>Ball</b> | <b>Name</b>   | <b>Ball</b> | <b>Name</b> | <b>Ball</b> | <b>Name</b>    |
|-------------|---------------|-------------|-------------|-------------|----------------|
| A08         | H_DATAN2      | B08         | H_DATAP3    | C08         | B_VSYNC        |
| A09         | H_DATAN3      | B09         | B_DATAP1    | C09         | B_PDOWN        |
| A10         | B_DATAN1      | B10         | B_CLKP      | C10         | B_RESETN       |
| A11         | B_CLKN        | B11         | B_DATAP0    | C11         | B_REXT         |
| A12         | B_DATAN0      | B12         | B_SCL       | C12         | B_SDA          |
| A13         | Y_DATAN1      | B13         | Y_DATAP1    | C13         | Y_AGND         |
| A14         | Y_CLKN        | B14         | Y_CLKP      | C14         | Y_DATAP0       |
| A15         | Y_AGND        | B15         | Y_DATAN0    | C15         | Y_REXT         |
| D01         | EGPIO_6       | E01         | EGPIO_7     | F01         | EGPIO_8        |
| D02         | USB_DN        | E02         | EGPIO_9     | F02         | EGPIO_13       |
| D03         | USB_DP        | E03         | EGPIO_1     | F03         | EGPIO_11       |
| D04         | VPTX0         | E04         | USB_RESREF  | F04         | USB_DVDD       |
| D05         | VP            | E05         | USB_ID      | F05         | VDD            |
| D06         | REFPADCLKP    | E06         | REFPADCLKM  | F06         | VSS            |
| D07         | H_AVDD        | E07         | H_AGND      | F07         | VSS            |
| D08         | B_AGND        | E08         | VSS         | F08         | VDD_PG         |
| D09         | B_AGND        | E09         | VDD_PG      | F09         | VDD_PG         |
| D10         | B_AVDD        | E10         | VDD_PG      | F10         | VDD_PG         |
| D11         | VSS           | E11         | VSS         | F11         | VSS            |
| D12         | Y_AVDD        | E12         | VSS         | F12         | VSS            |
| D13         | VSS           | E13         | Y_PDOWN     | F13         | Y_VSYNC        |
| D14         | Y_RCLK        | E14         | Y_SDA       | F14         | Y_RESETN       |
| D15         | Y_SCL         | E15         | GPIO_0      | F15         | GPIO_1         |
| G01         | CLK_XIN       | H01         | CLK_XOUT    | J01         | EGPIO_10       |
| G02         | VDDPLL        | H02         | VSSPLL      | J02         | EGPIO_5        |
| G03         | VDDTS         | H03         | VSSTS       | J03         | VDDPST18_RIGHT |
| G04         | VSS           | H04         | VSS         | J04         | VDDPST18_RIGHT |
| G05         | VDD           | H05         | VDD         | J05         | VSS            |
| G06         | VDD           | H06         | VDD         | J06         | VSS            |
| G07         | VSS           | H07         | VSS         | J07         | VSS            |
| G08         | VDD_PG        | H08         | VSS         | J08         | VSS            |
| G09         | VDD_PG        | H09         | VSS         | J09         | VSS            |
| G10         | VDD_PG        | H10         | VDD         | J10         | VDD            |
| G11         | VDD           | H11         | VDD         | J11         | VDD            |
| G12         | VDDPST18_LEFT | H12         | VSS         | J12         | VSS            |

| <b>Ball</b> | <b>Name</b>   | <b>Ball</b> | <b>Name</b> | <b>Ball</b> | <b>Name</b> |
|-------------|---------------|-------------|-------------|-------------|-------------|
| G13         | GPIO_4        | H13         | GPIO_7      | J13         | LD_ERR      |
| G14         | GPIO_2        | H14         | GPIO_3      | J14         | MODSIGN     |
| G15         | GPIO_5        | H15         | GPIO_6      | J15         | MODSTROB    |
| K01         | EGPIO_2       | L01         | EGPIO_0     | M01         | A_VSYNC     |
| K02         | EGPIO_12      | L02         | EGPIO_3     | M02         | EGPIO_4     |
| K03         | PMU_PWR_EN    | L03         | VQPSQ       | M03         | VQPSM       |
| K04         | VSS           | L04         | VSS         | M04         | A_AVDD      |
| K05         | VSS           | L05         | VSS         | M05         | VSS         |
| K06         | VDD_PG        | L06         | VDD_PG      | M06         | M_REXT      |
| K07         | VDD_PG        | L07         | VDD_PG      | M07         | M_AVDD      |
| K08         | VSS           | L08         | VSS         | M08         | M_AGND      |
| K09         | VDD_PG        | L09         | VDD_PG      | M09         | M_AGND      |
| K10         | VDD_PG        | L10         | VDD_PG      | M10         | ISP_SCL     |
| K11         | VSS           | L11         | VSS         | M11         | Z_AVDD      |
| K12         | VDDPST18_LEFT | L12         | VSS         | M12         | VSS         |
| K13         | LD_ON_OUT_XX  | L13         | TDI         | M13         | SPI_CS      |
| K14         | TCLK          | L14         | TDO         | M14         | SPI_CLK     |
| K15         | TMS           | L15         | TRSTN       | M15         | SPI_WPN     |
| N01         | A_SDA         | P01         | A_RESETN    | R01         | A_AGND      |
| N02         | A_SCL         | P02         | A_RCLK      | R02         | A_DATAN0    |
| N03         | A_PDOWN       | P03         | A_DATAP0    | R03         | A_CLKN      |
| N04         | A_REXT        | P04         | A_CLKP      | R04         | A_DATAN1    |
| N05         | A_AGND        | P05         | A_DATAP1    | R05         | M_SCL       |
| N06         | M_VSYNC       | P06         | M_SDA       | R06         | M_RCLK      |
| N07         | M_RESETN      | P07         | M_PDOWN     | R07         | M_DATAN0    |
| N08         | VSS           | P08         | M_DATAP0    | R08         | M_CLKN      |
| N09         | ISP_SDA       | P09         | M_CLKP      | R09         | M_DATAN1    |
| N10         | Z_REXT        | P10         | M_DATAP1    | R10         | Z_DATAN1    |
| N11         | Z_PDOWN       | P11         | Z_DATAP1    | R11         | Z_CLKN      |
| N12         | Z_SCL         | P12         | Z_CLKP      | R12         | Z_DATAN0    |
| N13         | Z_SDA         | P13         | Z_DATAP0    | R13         | Z_RCLK      |
| N14         | SPI_MOSI      | P14         | Z_RESETN    | R14         | Z_VSYNC     |
| N15         | SPI_MISO      | P15         | CW_CSR_RSTN | R15         | Z_AGND      |

### 3.3.4 Vision Processor D4 Power Requirements

The Vision Processor D4 requires the following power supplies for operation.

**Table 3-6. Vision Processor D4 Power Requirements**

| Voltage Ball Name         | Min. (V) | Nominal (V) | Max. (V) | Peak Current (Icc) |
|---------------------------|----------|-------------|----------|--------------------|
| VDD                       | 0.85     | 0.9         | 0.95     | 0.4 A              |
| VDD_PG                    | 0.85     | 0.9         | 0.95     | 1.6 A              |
| USB_DVDD                  | 0.81     | 0.9         | 0.99     | 0.2 A              |
| VPTX0                     | 0.81     | 0.9         | 0.99     | 0.2 A              |
| VP                        | 0.81     | 0.9         | 0.99     | 0.2 A              |
| *AVDD                     | 1.71     | 1.8         | 1.89     | 0.2 A              |
| VDDPLL                    | 0.85     | 0.9         | 0.95     | 0.2 A              |
| VDDTS                     | 1.71     | 1.8         | 1.89     | 0.2 A              |
| VDDPST18 (Left and Right) | 1.71     | 1.8         | 1.89     | 0.2 A              |
| USB_VDD330                | 3.13     | 3.3         | 3.46     | 0.2 A              |

### 3.3.5 Vision Processor D4 Power Sequencing

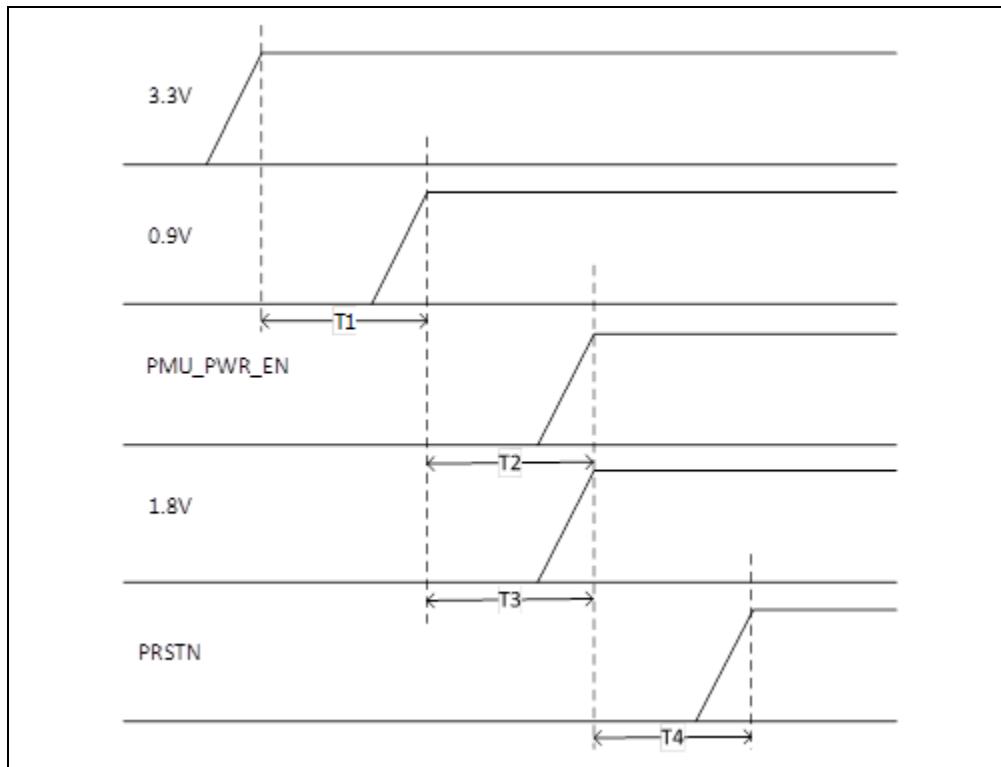
The timing requirement for power sequencing is listed below and shown in the following figure.

1. Hold Vision Processor D4 in reset
2. Ramp up power in the 3.3 V rail
3. Ramp up power in the 0.9 V rail
4. Ramp up power in the 1.8 V rail
5. Release Vision Processor D4 Reset

**Table 3-7. Vision Processor D4 Power Sequencing Timing Parameters**

| Parameter                                  | Value | Units | Label |
|--|-------|-------|-------|
| 0.9 V stable to 3.3 V stable               | >= 50 | us    | T1    |
| PMU_PWR_EN to 0.9 V Stable                 | >= 50 | us    | T2    |
| 1.8 V stable to 0.9 V Stable               | >= 50 | us    | T3    |
| PRSTN (D4 RESET) assertion to 1.8 V stable | 15    | us    | T4    |

**Figure 3-3. Vision Processor D4 Power Sequencing**



**Note:** Vision Processor D4 has no specific power down sequence requirement.

### 3.3.6 Vision Processor D4 Spec Code

The spec code is an identification mark printed on Vision Processor D4.

**Table 3-8. Vision Processor D4 SPEC Code**

| Vision Processor D4                   | SPEC CODE |
|---------------------------------------|-----------|
| Production (Shipped in Tape and Reel) | SLLY5     |
| Production (Shipped in Tray)          | SLM6B     |

### 3.3.7 Vision Processor D4 Storage and Operating Conditions

**Table 3-9. Vision Processor D4 Storage and Operating Conditions**

| Condition  | Description  | Min                         | Max | Unit |
|--|--|-----------------------------|-----|------|
| Storage (Still Air), Not Operating                   | Temperature (Sustained, Controlled) <sup>(1)</sup> | 0                           | 85  | °C   |
|  | Temperature (Short Exposure) <sup>(2)</sup>        | -40                         | 85  | °C   |
|  | Humidity   | Temperature/ RH: 40°C / 90% |     |      |
| Operating, Component Case Temperature <sup>(3)</sup> | Temperature  | 0                           | 85  | °C   |

**Notes:**

1. Controlled conditions should be used for long-term storage of product
2. Short exposure represents temporary max limits acceptable for transportation conditions
3. Component case temperature limits must be met during operation

### 3.3.8 Vision Processor D4 Thermals

The thermal design should be such that Vision Processor D4 does not exceed component case temperature limit. Care must also be taken to make sure that the Vision Processor D4 heat is not transferred to other components of the imaging system or stereo depth module. It is best to thermally isolate Vision Processor D4 from the stereo depth module.

## 3.4 Clock

Vision Processor D4 requires a single 24 MHz clock oscillator. All clocks required by stereo depth module are generated by Vision Processor D4.

## 3.5 Serial (SPI) Flash Memory

Vision Processor D4 requires 16 Mb Serial Flash Memory for its firmware storage. The recommended part number is IS25WP016 ([www.issi.com](http://www.issi.com)) or equivalent.

## 3.6 Stereo Depth Module

The stereo depth module components are described in Table 3-10. The stereo depth printed circuit board and components are encapsulated in a common metal stiffener.

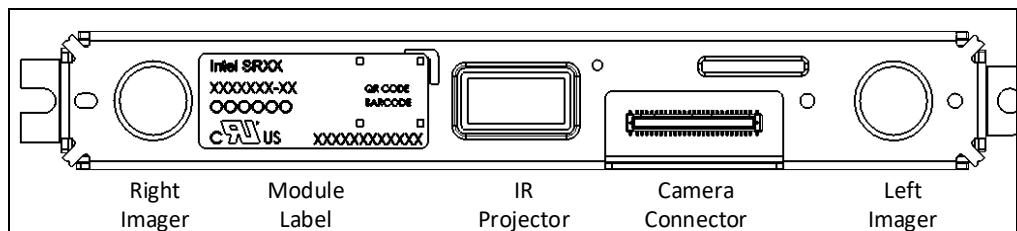
**Table 3-10. Stereo Depth Module**

| Component                              | Description                                    |
|--|--|
| Left and Right Imagers                 | 2 image sensors                                |
| Infrared (IR) Projector <sup>(1)</sup> | Class 1 laser compliant (optional)             |
| Color Sensor                           | RGB image sensor (optional)                    |
| Depth Module Connector                 | 50-pin connector plug                          |
| Stiffener                              | Reinforcement housing to keep imagers aligned  |
| Label                                  | Manufacture and product identifier information |
| Other Components                       | Laser driver, EEPROM, voltage regulators, etc. |

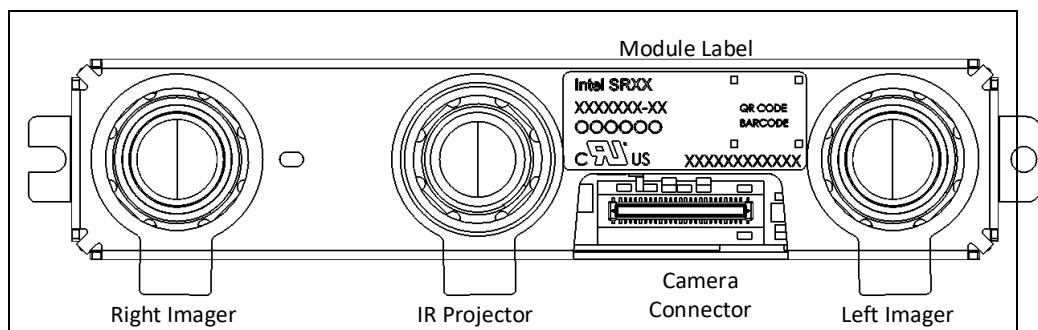
**Note:**

(1) IR projector is considered Class 1 when integrated into Intel® RealSense™ Depth Cameras. Also considered Class 1 when depth module is paired with Intel® RealSense™ Vision Processor D4 Board and integration guidelines in this datasheet are used.

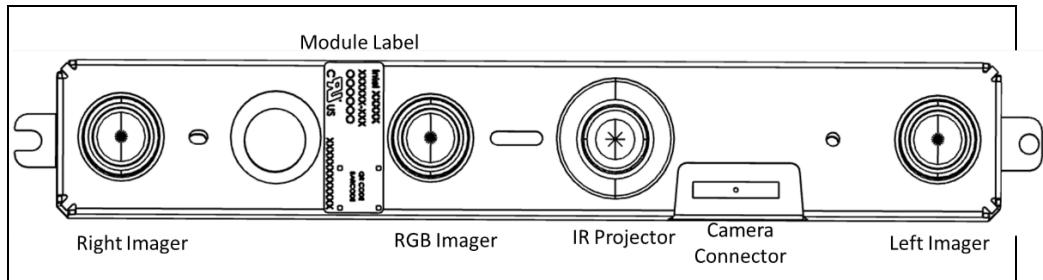
**Figure 3-4. Stereo Depth Module (Intel® RealSense™ Depth Module D410)**



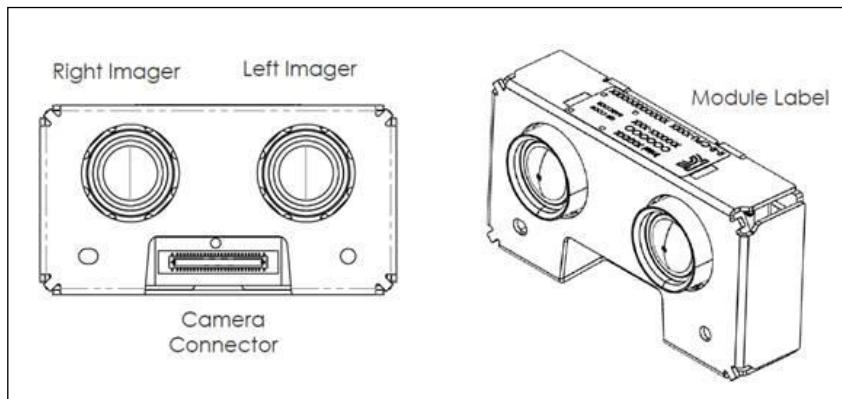
**Figure 3-5. Stereo Depth Module (Intel® RealSense™ Depth Module D430)**



**Figure 3-6. Stereo Depth Module (Intel® RealSense™ Depth Module D450)**



**Figure 3-7. Stereo Depth Module (Intel® RealSense™ Depth Module D401)**



**Table 3-11. Stereo Depth Module SKU Properties**

| Stereo Module                 | Intel® RealSense™ Depth Module D410 | Intel® RealSense™ Depth Module D415 | Intel® RealSense™ Depth Module D430 | Intel® RealSense™ Depth Module D450 | Intel® RealSense™ Depth Module D401 |
|-------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| Baseline                      | 55 mm                               | 55 mm                               | 50 mm                               | 95 mm                               | 18 mm                               |
| Left/Right Imagers Type       | Standard                            | Standard                            | Wide                                | Wide                                | Wide                                |
| Depth FOV HD (16:9) (degrees) | H:65 / V:40 / D:72                  | H:65 / V:40 / D:72                  | H:87 / V:58 / D:95                  | H:87 / V:58 / D:95                  | H:84 / V:58 / D:92                  |
| Depth FOV VGA (4:3) (degrees) | H:50 / V:40 / D:61                  | H:50 / V:40 / D:61                  | H:75 / V:62 / D:89                  | H:75 / V:62 / D:89                  | -                                   |
| IR Projector                  | Standard                            | Standard                            | Wide                                | Wide                                | -                                   |
| IR Projector FOV              | H:67 / V:41 / D:75                  | H:67 / V:41 / D:75                  | H:90 / V:63 / D:99                  | H:90 / V:63 / D:99                  | -                                   |
| Color Sensor                  | -                                   | OV2740                              | -                                   | OV9782                              | OV9782                              |

|                        |                                  |                                  |                                    |                                       |                                     |
|------------------------|----------------------------------|----------------------------------|------------------------------------|---------------------------------------|-------------------------------------|
| Color Camera FOV       | -                                | H:69 / V:42 / D:77               | -                                  | H:90 / V:65 / D:98                    | H:84 / V:58 / D:92                  |
| Module Dimensions (mm) | X=74.7 mm<br>Y=10 mm<br>Z=4.7 mm | X=83.7 mm<br>Y=10 mm<br>Z=4.7 mm | X=70.7 mm<br>Y=14 mm<br>Z=10.53 mm | X=119.5 mm<br>Y=17.4 mm<br>Z=10.53 mm | X=36.5 mm<br>Y=19.4 mm<br>Z=10.5 mm |

**Notes:**

1. H = Horizontal FOV, V = Vertical FOV, D = Diagonal FOV, X = Length, Y = Breadth, Z = Thickness
2. Depth FOV specified at 0.2 m for D401 and at 2 m for other modules
3. Due to mechanical tolerances of  $\pm 5\%$ , Max and Min FOV values can vary from lens to lens and module to module by  $\sim \pm 3$  degrees

### 3.6.1 Left and Right Imagers

The stereo depth module has two camera sensors referred to here as imagers; they are identical parts and are configured with identical settings. The imagers are labeled “left” and “right” from the perspective of the camera module looking outward. The stereo imager pairs are referred as Standard or Wide based on imager field of view.

**Table 3-12. Standard Left and Right Imager Properties – D410/D415**

| Parameter                | Camera Sensor Properties       |
|--------------------------|--------------------------------|
| Image Sensor             | OmniVision Technologies OV2740 |
| Active Pixels            | 1920 × 1080                    |
| Sensor Aspect Ratio      | 16:9                           |
| Format                   | 10-bit RAW                     |
| F Number                 | f/2.0                          |
| Focal Length             | 1.88 mm                        |
| Filter Type              | None                           |
| Focus                    | Fixed                          |
| Shutter Type             | Rolling Shutter                |
| Signal Interface         | MIPI CSI-2, 2X Lanes           |
| Horizontal Field of View | 71°± 1°                        |
| Vertical Field of View   | 44°± 1°                        |
| Diagonal Field of View   | 79°± 1°                        |
| Distortion               | <= 1.5%                        |

**Table 3-13. Wide Left and Right Imager Properties – D430**

| Parameter                | Camera Sensor Properties       |
|--------------------------|--------------------------------|
| Image Sensor             | OmniVision Technologies OV9282 |
| Active Pixels            | 1280 × 800                     |
| Sensor Aspect Ratio      | 8:5                            |
| Format                   | 10-bit RAW                     |
| F Number                 | f/2.0                          |
| Focal Length             | 1.93 mm                        |
| Filter Type              | None                           |
| Focus                    | Fixed                          |
| Shutter Type             | Global Shutter                 |
| Signal Interface         | MIPI CSI-2, 2X Lanes           |
| Horizontal Field of View | 90° ± 1°                       |
| Vertical Field of View   | 64 ° ± 1°                      |
| Diagonal Field of View   | 98 ± 1°                        |
| Distortion               | <= 1.5%                        |

**Table 3-14. Wide Left and Right Imager Properties – D450**

| <b>Parameter</b>         | <b>Camera Sensor Properties</b> |
|--------------------------|---------------------------------|
| Image Sensor             | OmniVision Technologies OV9782  |
| Active Pixels            | 1280 x 800                      |
| Sensor Aspect Ratio      | 8:5                             |
| Format                   | 10-bit RAW                      |
| F Number                 | f/2.0                           |
| Focal Length             | 1.93 mm                         |
| Filter Type              | None                            |
| Focus                    | Fixed                           |
| Shutter Type             | Global Shutter                  |
| Signal Interface         | MIPI CSI-2, 2X Lanes            |
| Horizontal Field of View | 90° ± 1°                        |
| Vertical Field of View   | 64 ° ± 1°                       |
| Diagonal Field of View   | 98 ± 1°                         |
| Distortion               | <= 1.5%                         |

**Table 3-15. Wide Left and Right Imager Properties – D401**

| <b>Parameter</b>         | <b>Camera Sensor Properties</b> |
|--------------------------|---------------------------------|
| Image Sensor             | OmniVision Technologies OV9782  |
| Active Pixels            | 1280 x 800                      |
| Sensor Aspect Ratio      | 8:5                             |
| Format                   | 10-bit RAW                      |
| F Number                 | f/2.0                           |
| Focal Length             | 1.93 mm                         |
| Filter Type              | IR Cut Filter                   |
| Focus                    | Fixed                           |
| Shutter Type             | Global Shutter                  |
| Signal Interface         | MIPI CSI-2, 2X Lanes            |
| Horizontal Field of View | 90 ± 1°                         |
| Vertical Field of View   | 64 ± 1°                         |
| Diagonal Field of View   | 98 ± 1°                         |
| Distortion               | <= 1.5%                         |

**Note:**

1. D401 Depth FOV specified at 200 mm

### 3.6.2 Infrared Projector

The infrared projector improves the ability of the stereo camera system to determine depth by projecting a static infrared pattern on the scene to increase texture on low texture scenes. The infrared projector meets the Class 1 laser safety standard under normal operation. The power delivery and laser safety circuits are on the stereo depth module. The infrared projector is referred as Standard or Wide based on field of projection.

**Table 3-16. Standard (D41x) Infrared Projector Parameters**

| Parameter  | Properties  |
|--|---|
| Projector  | Infrared  |
| Pattern Type   | Static  |
| Illuminating Component   | Vertical-cavity surface-emitting laser (VCSEL) + Optics         |
| Laser Controller   | PWM   |
| Optical Power  | 360 mW average  |
| Laser Wavelength   | 850 nm ± 10 nm nominal @ 20°C                                   |
| Laser Compliance(*)  | Class 1, IEC 60825-1:2007 Edition 2, IEC 60825-1:2014 Edition 3 |
| Horizontal Field of Projection   | 64°±3°  |
| Vertical Field of Projection   | 41°±3°  |
| Diagonal Field of Projection   | 72°±3°  |
| <b>Note:</b>   |   |
| (*) IR projector is considered Class 1 when integrated into Intel® RealSense™ Depth Cameras. Also considered Class 1 when depth module is paired with Intel® RealSense™ Vision Processor D4 Board and integration guidelines are used. |   |

**Table 3-17. Wide (D43x, D45x) Infrared Projector Parameters**

| Parameter                      | Properties  |
|--------------------------------|---|
| Projector                      | Infrared  |
| Pattern Type                   | Static  |
| Illuminating Component         | Vertical-cavity surface-emitting laser (VCSEL) + optics         |
| Laser Controller               | PWM   |
| Optical Power                  | 360mW average   |
| Laser Wavelength               | 850nm ± 10 nm nominal @ 20°C                                    |
| Laser Compliance(*)            | Class 1, IEC 60825-1:2007 Edition 2, IEC 60825-1:2014 Edition 3 |
| Horizontal Field of Projection | 90°±3°  |
| Vertical Field of Projection   | 63°±3°  |
| Diagonal Field of Projection   | 99°±3°  |

| Parameter  | Properties |
|--|------------|
| <b>Note:</b>   |            |
| (*) IR projector is considered Class 1 when integrated into Intel® RealSense™ Depth Cameras. Also considered Class 1 when depth module is paired with Intel® RealSense™ Vision Processor D4 Board and integration guidelines are used. |            |

### 3.6.3 Color Sensor

The color sensor on the stereo depth module, in addition to generating a color image, provides texture information. Usages for the texture information include overlay on a depth image to create a colorized point cloud and overlay on a 3D model for reconstruction.

**Table 3-18. Color Sensor Properties – D415**

| Parameter                    | Camera Sensor Properties       |
|------------------------------|--------------------------------|
| Image Sensor                 | OmniVision Technologies OV2740 |
| Color Image Signal Processor | Discrete                       |
| Active Pixels                | 1920 x 1080                    |
| Sensor Aspect Ratio          | 16:9                           |
| Format                       | 10-bit RAW RGB                 |
| F Number                     | f/2.0                          |
| Focal Length                 | 1.88 mm                        |
| Filter Type                  | IR Cut Filter                  |
| Focus                        | Fixed                          |
| Shutter Type                 | Rolling Shutter                |
| Signal Interface             | MIPi CSI-2, 1 Lane             |
| Horizontal Field of View     | 69.4°                          |
| Vertical Field of View       | 42.5°                          |
| Diagonal Field of View       | 77°                            |
| Distortion                   | <= 1.5%                        |

**Table 3-19. Color Sensor Properties – D450**

| Parameter                    | Camera Sensor Properties       |
|------------------------------|--------------------------------|
| Image Sensor                 | OmniVision Technologies OV9782 |
| Color Image Signal Processor | Discrete                       |
| Active Pixels                | 1280 x 800                     |
| Sensor Aspect Ratio          | 16:10                          |
| Format                       | 10-bit RAW RGB                 |
| F Number                     | f/2.0                          |

|                          |                    |
|--------------------------|--------------------|
| Focal Length             | 1.93 mm            |
| Filter Type              | IR Cut Filter      |
| Focus                    | Fixed              |
| Shutter Type             | Global Shutter     |
| Signal Interface         | MIPi CSI-2, 1 Lane |
| Horizontal Field of View | 90°                |
| Vertical Field of View   | 65°                |
| Diagonal Field of View   | 98°                |
| Distortion               | <= 1.5%            |

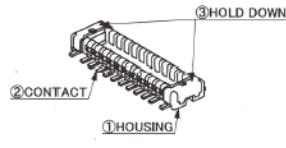
**Table 3-20. Color Sensor Properties – D401\***

| Parameter  | Camera Sensor Properties       |
|--|--------------------------------|
| Image Sensor   | OmniVision Technologies OV9782 |
| Color Image Signal Processor   | Discrete                       |
| Active Pixels  | 1280 x 800                     |
| Sensor Aspect Ratio  | 8:5                            |
| Format   | 10-bit RAW                     |
| F Number   | f/2.0                          |
| Focal Length   | 1.93 mm                        |
| Filter Type  | IR Cut Filter                  |
| Focus  | Fixed                          |
| Shutter Type   | Global Shutter                 |
| Signal Interface   | MIPi CSI-2, 2X lanes           |
| Horizontal Field of View   | 84 ± 1°                        |
| Vertical Field of View   | 58 ± 1°                        |
| Diagonal Field of View   | 92 ± 1°                        |
| Distortion   | <= 1.5%                        |
| <b>Note:</b>   |                                |
| (*) D401 does not contain a dedicated RGB sensor. D401's left depth sensor provides RGB data to the color ISP. |                                |

### 3.6.4 Depth Module Connector

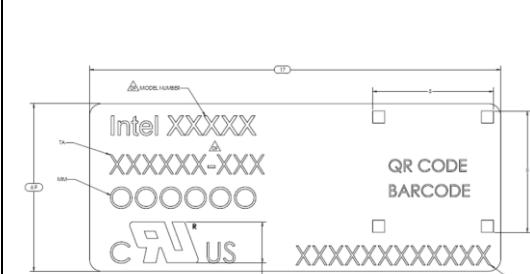
The depth module connector provides the signal and power interface to the stereo depth module. The connector on the stereo depth module is a 50-pin connector plug.

**Table 3-21. Depth Module 50-pin Connector Plug Details**

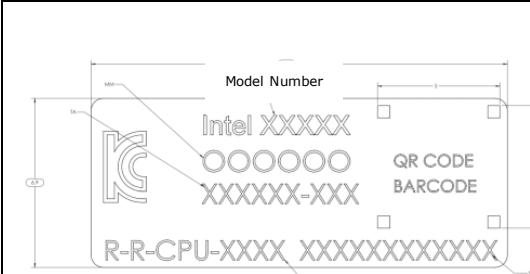
| Parameter            | Description                     | Diagram   |
|----------------------|---------------------------------|---|
| Number of Contacts   | 50                              |  |
| Product Name         | NOVASTACK 35-P<br>Plug Assembly |   |
| Part Number          | 20708-050E                      |   |
| Manufacturer Website | www.i-pex.com                   |   |

### 3.6.5 Stereo Depth Module Label

**Table 3-22. Stereo Depth Module Product Labeling – D410, D415, D430**

|  <p><u>For illustration purpose only, subject to change</u></p> | <table border="1"> <thead> <tr> <th>Dimension</th><th>Value</th><th>Unit</th></tr> </thead> <tbody> <tr> <td>A</td><td>Label Width</td><td>17</td><td>mm</td></tr> <tr> <td>B</td><td>Label Height</td><td>6.9</td><td>mm</td></tr> <tr> <td>C</td><td>Scan Code Width</td><td>5</td><td>mm</td></tr> <tr> <td>D</td><td>Scan Code Height</td><td>5</td><td>mm</td></tr> </tbody> </table> <p><b>Scan Code Format</b><br/>XXXXXXXXXXXXXXOOOOOOXXXXXX-XXX</p> | Dimension | Value | Unit | A | Label Width | 17 | mm | B | Label Height | 6.9 | mm | C | Scan Code Width | 5 | mm | D | Scan Code Height | 5 | mm |
|---|--|-----------|-------|------|---|-------------|----|----|---|--------------|-----|----|---|-----------------|---|----|---|------------------|---|----|
| Dimension   | Value  | Unit      |       |      |   |             |    |    |   |              |     |    |   |                 |   |    |   |                  |   |    |
| A   | Label Width  | 17        | mm    |      |   |             |    |    |   |              |     |    |   |                 |   |    |   |                  |   |    |
| B   | Label Height   | 6.9       | mm    |      |   |             |    |    |   |              |     |    |   |                 |   |    |   |                  |   |    |
| C   | Scan Code Width  | 5         | mm    |      |   |             |    |    |   |              |     |    |   |                 |   |    |   |                  |   |    |
| D   | Scan Code Height   | 5         | mm    |      |   |             |    |    |   |              |     |    |   |                 |   |    |   |                  |   |    |

**Table 3-23. Stereo Depth Module Product Labeling – D401, D450**

|  <p><u>For illustration purpose only, subject to change</u></p> | <table border="1"> <thead> <tr> <th>Dimension</th><th>Value</th><th>Unit</th></tr> </thead> <tbody> <tr> <td>A</td><td>Label Width</td><td>17</td><td>mm</td></tr> <tr> <td>B</td><td>Label Height</td><td>6.9</td><td>mm</td></tr> <tr> <td>C</td><td>Scan Code Width</td><td>5</td><td>mm</td></tr> <tr> <td>D</td><td>Scan Code Height</td><td>5</td><td>mm</td></tr> </tbody> </table> <p><b>Scan Code Format</b><br/>XXXXXXXXXXXXXXOOOOOOXXXXXX-XXX</p> | Dimension | Value | Unit | A | Label Width | 17 | mm | B | Label Height | 6.9 | mm | C | Scan Code Width | 5 | mm | D | Scan Code Height | 5 | mm |
|--|--|-----------|-------|------|---|-------------|----|----|---|--------------|-----|----|---|-----------------|---|----|---|------------------|---|----|
| Dimension  | Value  | Unit      |       |      |   |             |    |    |   |              |     |    |   |                 |   |    |   |                  |   |    |
| A  | Label Width  | 17        | mm    |      |   |             |    |    |   |              |     |    |   |                 |   |    |   |                  |   |    |
| B  | Label Height   | 6.9       | mm    |      |   |             |    |    |   |              |     |    |   |                 |   |    |   |                  |   |    |
| C  | Scan Code Width  | 5         | mm    |      |   |             |    |    |   |              |     |    |   |                 |   |    |   |                  |   |    |
| D  | Scan Code Height   | 5         | mm    |      |   |             |    |    |   |              |     |    |   |                 |   |    |   |                  |   |    |

**Table 3-24. Stereo Depth Module Label Fields**

| Group   | Field                  | Description                    | Type    |
|---|------------------------|--------------------------------|---------|
| Company   | Intel                  | Manufacturer                   | Static  |
| Model Number  | RealSense™ Camera D4XX | Module Model Number            | Static  |
| Product Assembly Number   | XXXXXX                 | Product Identifier Code        | Static  |
|   | -XXX                   | Manufacture Configuration Code | Dynamic |
|   | 000000                 | Product Material Code          | Static  |
| Serial Number   | XXXXXXXXXXXX           | Manufacture Unit Code          | Dynamic |
| KCC ID Number   | R-R-CPU                | KCC logo required format       | Static  |
|   | -XXXX                  |                                |         |
| <b>Note:</b><br>Product Material Code (MM code) within the QR code on the label of the device will read "000000". The QR code MM code will be zero. |                        |                                |         |

**Table 3-25. Intel® RealSense™ Depth Module D400 Series Product Identifier Code and Product Material Code**

| Production        | Product Identifier Code-Manufacture Configuration Code | Product Material Code |
|-------------------|--|-----------------------|
| Depth Module D410 | J32106-100   | 951913                |
| Depth Module D415 | J32114-100   | 952000                |
| Depth Module D420 | J51355-100   | 956826                |
| Depth Module D430 | J42086-100   | 954010                |
| Depth Module D450 | K83121-100/101   | 999WCM                |
| Depth Module D401 | M31768-100   | 99ACXA                |

### 3.6.6 Stiffener

The stiffener maintains the precise alignment of the camera sensors and assists in subassembly rigidity. The stiffener consists of a bottom and a top plate. The stiffener is of stainless steel grade AISI 304.

### 3.6.7 Temperature Sensor

The stereo depth module is equipped with a thermal sensor that is used for laser safety control (IR Projector). The Intel® RealSense™ SDK 2.0 library provides access to the thermal sensor readouts. Temperature information does not reflect the ambient temperature of the module.

### 3.6.8 Other Stereo Depth Module Components

**Table 3-26. Other Stereo Depth Module Components**

| Component                            | Description   |
|--------------------------------------|---|
| Laser (IR Projector) Driver          | The depth module implements a laser driver which controls the infrared laser within the infrared projector system.  |
| Laser (IR projector) Thermal Control | The depth module implements a laser safety control circuit that adjusts laser drive output. When laser power and depth streaming is enabled and if stereo depth module temperature is >60°C, laser power is halved. If temperature is not lowered below temperature limit within a certain interval, the laser is shut off. |
| EEPROM                               | The depth module implements flash memory for storing the calibration data   |
| Fork/Screw Mount                     | Secure placement and mounting to system/chassis/heat sink   |
| Voltage Regulators                   | The stereo depth module implements DC to DC voltage converters  |

### 3.6.9 Mechanical Dimensions

**Table 3-27. Intel® RealSense™ Depth Module D410 Mechanical Dimensions**

| Dimension          | Min  | Nominal          | Max  | Unit |
|--------------------|------|------------------|------|------|
| Width              | 74.5 | 74.7             | 74.9 | mm   |
| Height             | 9.8  | 10               | 10.2 | mm   |
| Depth              | 4.5  | 4.7              | 4.9  | mm   |
| Flatness Tolerance | 0    | -                | 0.2  | mm   |
| Weight             |      | 8 <sup>(1)</sup> |      | g    |

**Table 3-28. Intel® RealSense™ Depth Module D415 Mechanical Dimensions**

| Dimension          | Min  | Nominal           | Max  | Unit |
|--------------------|------|-------------------|------|------|
| Width              | 89.5 | 89.7              | 89.9 | mm   |
| Height             | 9.8  | 10                | 10.2 | mm   |
| Depth              | 4.5  | 4.7               | 4.9  | mm   |
| Flatness Tolerance | 0    | -                 | 0.2  | mm   |
| Weight             |      | 12 <sup>(1)</sup> |      | g    |

**Table 3-29. Intel® RealSense™ Depth Module D430 Mechanical Dimensions**

| Dimension | Min  | Nominal | Max  | Unit |
|-----------|------|---------|------|------|
| Width     | 70.5 | 70.7    | 70.9 | mm   |

|                    |       |                   |       |    |
|--------------------|-------|-------------------|-------|----|
| Height             | 13.8  | 14                | 14.2  | mm |
| Depth              | 10.33 | 10.53             | 10.73 | mm |
| Flatness Tolerance | 0     | -                 | 0.2   | mm |
| Weight             |       | 14 <sup>(1)</sup> |       | g  |

**Table 3-30. Intel® RealSense™ Depth Module D450 Mechanical Dimensions**

| Dimension          | Min   | Nominal           | Max   | Unit |
|--------------------|-------|-------------------|-------|------|
| Width              | 119.3 | 119.5             | 119.7 | mm   |
| Height             | 17.2  | 17.4              | 17.6  | mm   |
| Depth              | 10.33 | 10.53             | 10.73 | mm   |
| Flatness Tolerance | 0     | -                 | 0.25  | mm   |
| Weight             |       | 30 <sup>(1)</sup> |       | g    |

**Table 3-31. Intel® RealSense™ Depth Module D401 Mechanical Dimensions**

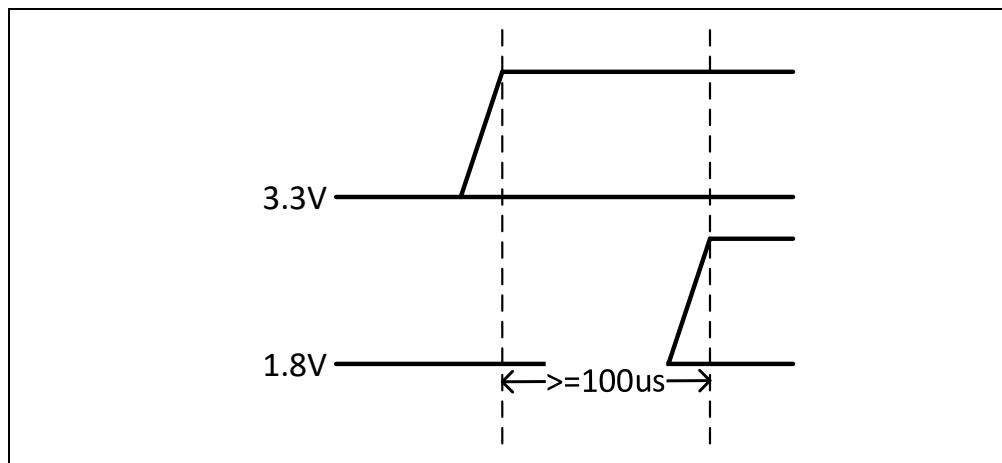
| Dimension          | Min  | Nominal           | Max  | Unit |
|--------------------|------|-------------------|------|------|
| Width              | 36.3 | 36.5              | 36.7 | mm   |
| Height             | 19.2 | 19.4              | 19.6 | mm   |
| Depth              | 10.3 | 10.5              | 10.7 | mm   |
| Flatness Tolerance | -    | 0.15              | -    | mm   |
| Weight             |      | 12 <sup>(1)</sup> |      | g    |

**Note:**

(1) The weight can be +/- 10% from the nominal.

### 3.6.10 Stereo Depth Module Power Sequence

Figure 3-8. Stereo Depth Module Power Sequence



### 3.6.11 Stereo Depth Module Storage and Powered Conditions

Table 3-32. Stereo Depth Module Storage and Powered Conditions

| Condition   | Description  | Min                          | Max | Unit |
|---|--|------------------------------|-----|------|
| Storage (Ambient), Not Powered <sup>(6)</sup>     | Temperature (Sustained, Controlled) <sup>(1)</sup> | 0                            | 50  | °C   |
|   | Temperature (Short Exposure) <sup>(2)</sup>        | -40                          | 70  | °C   |
|   | Humidity   | Temperature / RH: 40°C / 90% |     |      |
| Case Temperature, Powered <sup>(3)(4)(5)(6)</sup> | Temperature  | 0                            | 50  | °C   |

**Notes:**

- (1) Controlled conditions should be used for long term storage of product
- (2) Short exposure represents temporary max limits acceptable for transportation conditions
- (3) Case temperature limits must be met for all temperatures when powered
- (4) Case temperature is specified for the overall depth module
- (5) Case temperature 0° minimum and lower temperatures is non-condensing
- (6) Although all Key Performance Indicators (KPIs) are verified before leaving Intel's factory, KPIs may be negatively impacted by extended exposure to excessive temperatures and humidity

## 3.7 Intel® RealSense™ Vision Processor D4 Board

The Vision Processor D4 Board enables an easy and quick option for system integrators to integrate Vision Processor D4 into a system.

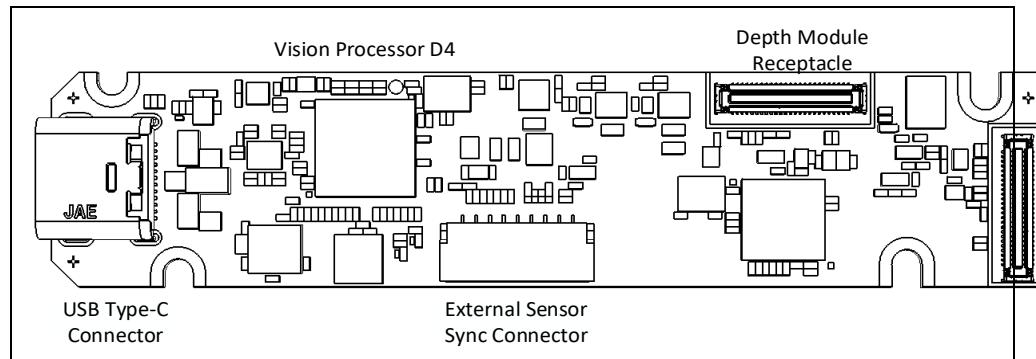
**Table 3-33. Vision Processor D4 Board**

| Type                  | Description  |
|-----------------------|--|
| USB Peripheral Type-C | Connects to Host USB 3.1 Gen 1 port through USB Type-C connector and cable<br>Note: When connecting to host system, connect Type-C cable to camera prior to connecting device to host system port. |

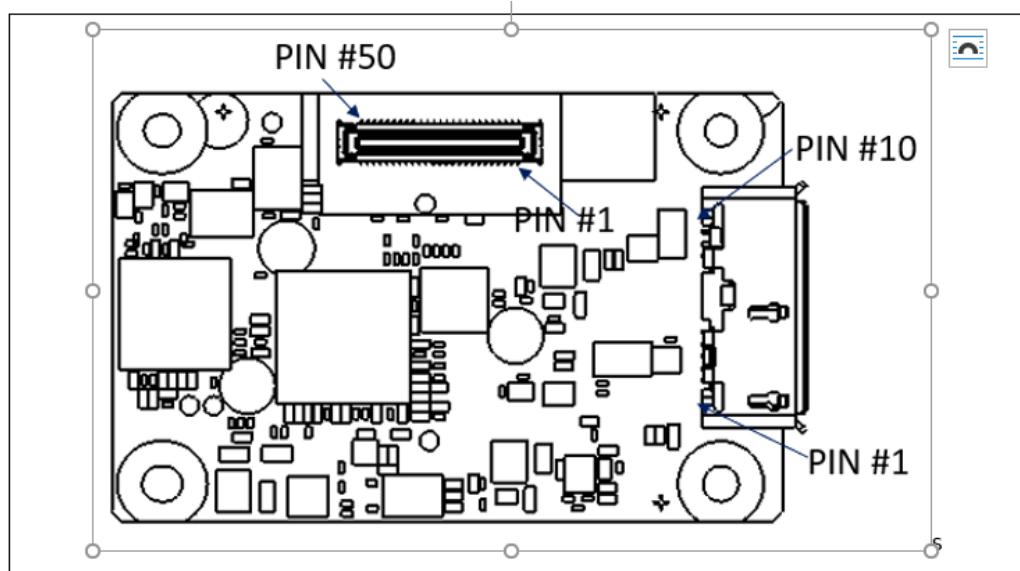
**Table 3-34. Vision Processor D4 Board Components**

| Components                              | Description   |
|---|---|
| Vision Processor D4                     | Stereo Depth Processing ASIC  |
| 16 Mb Serial Flash                      | Vision Processor D4 firmware storage  |
| 24 MHz Crystal                          | Clock source for Vision Processor D4  |
| Realtek* ISP with external serial flash | Color image signal processor  |
| Depth Module Receptacle                 | 50-pin receptacle for connection to Stereo Depth Module                         |
| USB Type-C                              | USB peripheral connector for connection to Host USB 2.0/USB 3.1 Gen 1 port      |
| External Sensor Sync Connector          | Interface to external sensor interrupts/sync signals                            |
| Voltage Regulators                      | DC to DC converters powering Vision Processor D4 Board and stereo depth module. |
| Mounting holes                          | Vision Processor D4 Board secure mounting                                       |

**Figure 3-9. Vision Processor D4 Board (V1 and V3) (USB Peripheral Type-C)**



**Figure 3-10. Vision Processor D4 Board (V4) (USB3 Peripheral Micro-B)**



### 3.7.1 Mechanical Dimensions

**Table 3-35. Vision Processor D4 USB Type-C V1/V3 Board Mechanical Dimensions**

| Dimension | Min  | Nominal | Max  | Unit |
|-----------|------|---------|------|------|
| Width     | 72.2 | 72.4    | 72.6 | mm   |
| Height    | 15.8 | 16      | 16.2 | mm   |
| Depth     | 3.74 | 3.94    | 4.14 | mm   |
| Weight    | 3.56 | 3.96    | 4.36 | g    |

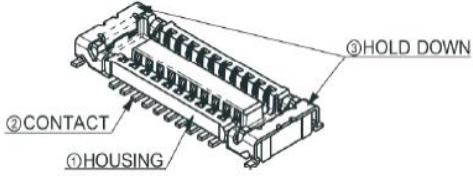
**Table 3-36. Vision Processor D4 USB3 Micro-B V4 Board Mechanical Dimensions**

| Dimension | Min  | Nominal | Max  | Unit |
|-----------|------|---------|------|------|
| Width     | 35.9 | 36      | 36.1 | mm   |
| Height    | 22.9 | 23      | 23.1 | mm   |
| Depth     | 2.48 | 2.63    | 2.78 | mm   |
| Weight    | 1.1  | 2.7     | 3.2  | g    |

### 3.7.2 Depth Module Receptacle

The Vision Processor D4 Board interface to stereo depth module is through 50-pin receptacle on the board.

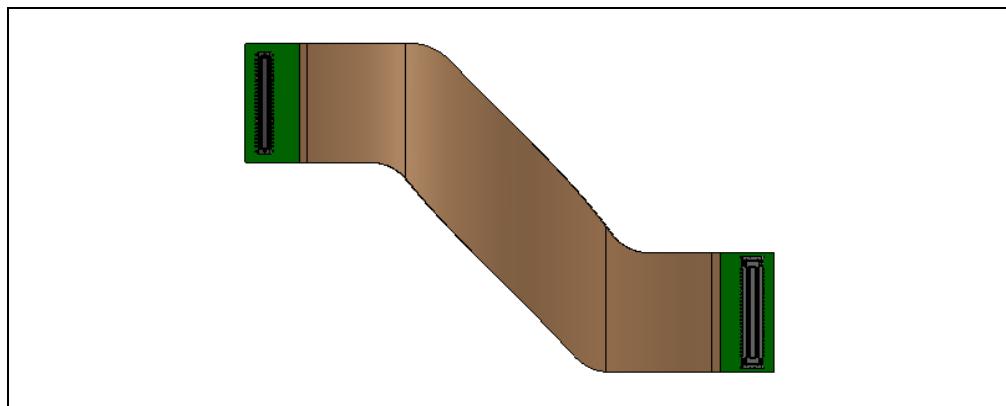
**Table 3-37. Depth Module Receptacle Details**

| Parameter            | Description                         | Diagram  |
|----------------------|-------------------------------------|--|
| Number of Contacts   | 50                                  |  |
| Product Name         | NOVASTACK* 35-P Receptacle Assembly |  |
| Part Number          | 20709-050E                          |  |
| Manufacturer Website | www.i-pex.com                       |  |

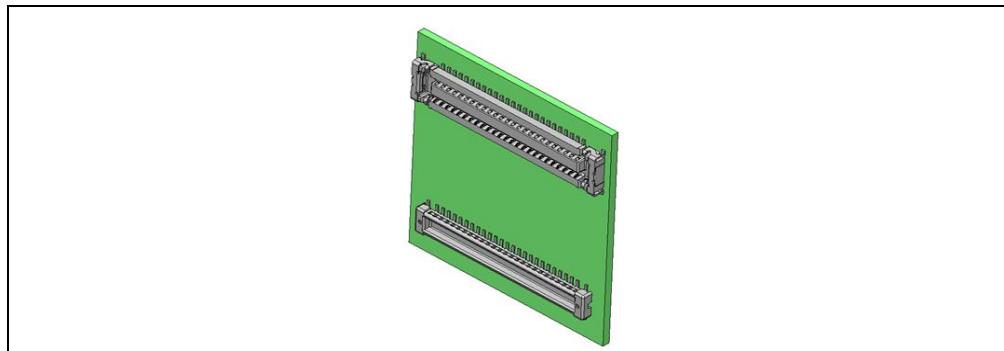
### 3.7.3 Flex and Rigid Interposer Interconnect

The high-speed interposer at one end has the 50-pin depth module receptacle to connect into 50-pin depth module plug on stereo depth module, and at the other end has the 50-pin depth module plug to connect into 50-pin depth module receptacle on Vision Processor D4 Board. The high-speed flex interposer is custom developed and procured by system integrator.

**Figure 3-11. Flex Interposer – D415, D435, D435i, D435f, D435if, D455, D455f, D456 (Illustration)**



**Figure 3-12. Rigid Interposer – D415, D435, D435i, D435f, D435if, D455, D455f, D456 (Illustration)**



**Figure 3-13. Depth Module Receptacle and Plug Connector Pin Position – D415, D435, D435i, D435f, D435if, D455, D455f, D456**

| 52 (VDD 3.3V) |    |
|---------------|----|
| GND           | 2  |
| RGB_MDP0      | 4  |
| RGB_MDN0      | 6  |
| GND           | 8  |
| RGB_MCP       | 10 |
| RGB_MCN       | 12 |
| GND           | 14 |
| MDP0_L        | 16 |
| MDN0_L        | 18 |
| GND           | 20 |
| MCP_L         | 22 |
| MCN_L         | 24 |
| GND           | 26 |
| MDP1_L        | 28 |
| MDN1_L        | 30 |
| GND           | 32 |
| MDP0_R        | 34 |
| MDN0_R        | 36 |
| GND           | 38 |
| MCP_R         | 40 |
| MCN_R         | 42 |
| GND           | 44 |
| MDP1_R        | 46 |
| MDN1_R        | 48 |
| GND           | 50 |
| 51 (GND)      |    |

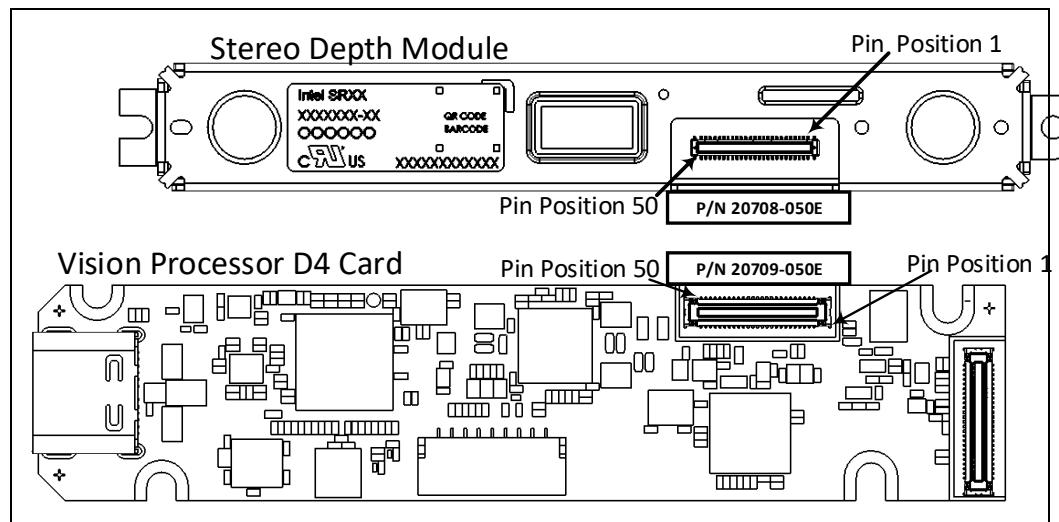
**Table 3-38. Interposer Interconnect Signal Description – D415, D435, D435i, D435f, D435if, D455, D455f, D456**

| Position | ASIC Board/<br>Motherboard | Depth Module | Interconnect Description                               |
|----------|----------------------------|--------------|--|
| 1        | RGB_RSTN_N                 | RGB_RSTN_N   | RGB Sensor Reset                                       |
| 2        | GND                        | GND          | Ground   |
| 3        | RGB_XCL                    | RGB_XCL      | RGB Sensor Clock                                       |
| 4        | RGB_MDP0                   | RGB_MDP0     | RGB Sensor MIPI Data Lane 0 differential pair positive |
| 5        | GND                        | GND          | Ground   |

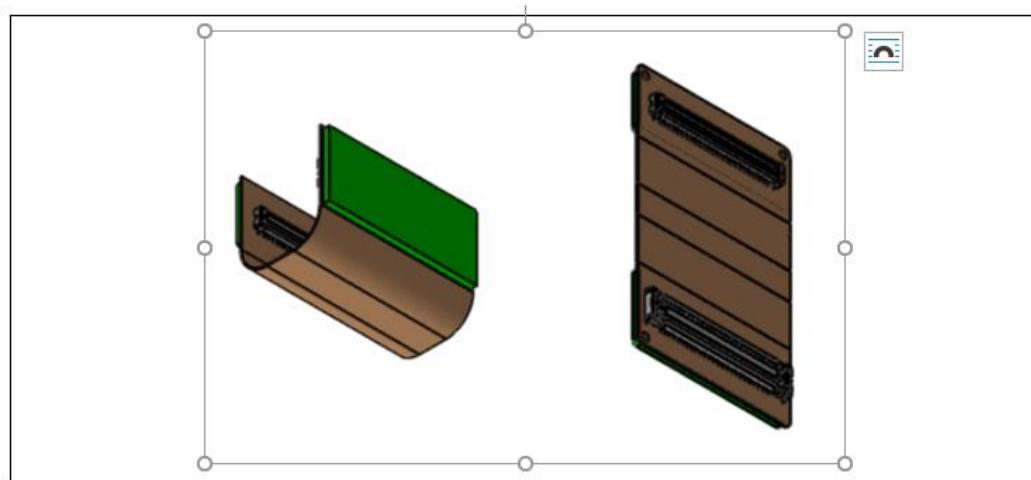
| <b>Position</b> | <b>ASIC Board/<br/>Motherboard</b> | <b>Depth Module</b> | <b>Interconnect Description</b>                          |
|-----------------|------------------------------------|---------------------|--|
| 6               | RGB_MDN0                           | RGB_MDN0            | RGB Sensor MIPI Data Lane 0 differential pair negative   |
| 7               | RGB_FSYNC                          | RGB_FSYNC           | RGB Sensor Sync  |
| 8               | GND                                | GND                 | Ground   |
| 9               | RGB_STROBE                         | RGB_STROBE          | RGB Sensor Strobe  |
| 10              | RGB_MCP                            | RGB_MCP             | RGB Sensor MIPI Clock differential pair positive         |
| 11              | RGB_SDA                            | RGB_SDA             | RGB Sensor I2C Bus Data                                  |
| 12              | RGB_MCN                            | RGB_MCN             | RGB Sensor MIPI Clock differential pair negative         |
| 13              | RGB_SCL                            | RGB_SCL             | RGB Sensor I2C Bus Clock                                 |
| 14              | GND                                | GND                 | Ground   |
| 15              | GND                                | GND                 | Ground   |
| 16              | MDP0_L                             | MDP0_L              | Left Imager MIPI Data Lane 0 differential pair positive  |
| 17              | VDD18V                             | VDD18V              | 1.8 V Power  |
| 18              | MDN0_L                             | MDN0_L              | Left Imager MIPI Data Lane 0 differential pair negative  |
| 19              | VDD18V                             | VDD18V              | 1.8 V Power  |
| 20              | GND                                | GND                 | Ground   |
| 21              | LED_PSY                            | LED_PSY             | Privacy LED control signal                               |
| 22              | MCP_L                              | MCP_L               | Left Imager MIPI Clock differential pair positive        |
| 23              | DVSYNC                             | DVSYNC              | VSYNC  |
| 24              | MCN_L                              | MCN_L               | Left Imager MIPI Clock differential pair negative        |
| 25              | NC                                 | NC                  | No Connect   |
| 26              | GND                                | GND                 | Ground   |
| 27              | XVCLK_L                            | XVCLK_L             | Clock to Left Imager                                     |
| 28              | MDP1_L                             | MDP1_L              | Left Imager MIPI Data Lane 1 differential pair positive  |
| 29              | GND                                | GND                 | Ground   |
| 30              | MDN1_L                             | MDN1_L              | Left Imager MIPI Data Lane 1 differential pair negative  |
| 31              | ST_RST_N                           | ST_RST_N            | Reset signal to Left and Right Imager                    |
| 32              | GND                                | GND                 | Ground   |
| 33              | FF_RSTn                            | FF_RSTn             | Laser Error  |
| 34              | MDP0_R                             | MDP0_R              | Right Imager MIPI Data Lane 0 differential pair positive |
| 35              | GND                                | GND                 | Ground   |
| 36              | MDN0_R                             | MDN0_R              | Right Imager MIPI Data Lane 0 differential pair negative |

| <b>Position</b> | <b>ASIC Board/<br/>Motherboard</b> | <b>Depth Module</b> | <b>Interconnect Description</b>                          |
|-----------------|------------------------------------|---------------------|--|
| 37              | XVCLK_R                            | XVCLK_R             | Clock to Right Imager                                    |
| 38              | GND                                | GND                 | Ground   |
| 39              | I2C_SCL                            | I2C_SCL             | I2C Bus Clock  |
| 40              | MCP_R                              | MCP_R               | Right Imager MIPI Clock differential pair positive       |
| 41              | I2C_SDA                            | I2C_SDA             | I2C Bus Data   |
| 42              | MCN_R                              | MCN_R               | Right Imager MIPI Clock differential pair negative       |
| 43              | LASER_PWM                          | LASER_PWM           | IR Projector Control Signal                              |
| 44              | GND                                | GND                 | Ground   |
| 45              | LASER_PWRDN                        | LASER_PWRDN         | IR Projector Power Down                                  |
| 46              | MDP1_R                             | MDP1_R              | Right Imager MIPI Data Lane 1 differential pair positive |
| 47              | LASER_PWM1                         | LASER_PWM1          | IR Projector Control Signal                              |
| 48              | MDN1_R                             | MDN1_R              | Right Imager MIPI Data Lane 1 differential pair negative |
| 49              | FLAGB                              | FLAGB               | IR Projector Fault Detect                                |
| 50              | GND                                | GND                 | Ground   |
| 51              | GND                                | GND                 | Ground   |
| 52              | VDD33V                             | VDD33V              | 3.3 V power  |

**Figure 3-14. Depth Module Connector Orientation and Pin Position – D415, D435, D435i, D435f, D435if, D455, D455f, D456**



**Figure 3-15. Flex Interposer – D401 (Illustration)**



**Figure 3-16. Depth Module Receptacle and Plug Connector Pin Position – D401**

| 51, 52 (VDD 3.3V) |    |    |         |
|-------------------|----|----|---------|
| GND               | 2  | 1  |         |
|                   | 4  | 3  |         |
|                   | 6  | 5  | GND     |
| GND               | 8  | 7  |         |
|                   | 10 | 9  |         |
|                   | 12 | 11 |         |
| GND               | 14 | 13 |         |
| MDP0_L            | 16 | 15 | GND     |
| MDN0_L            | 18 | 17 | VDD18V  |
| GND               | 20 | 19 | VDD18V  |
| MCP_L             | 22 | 21 |         |
| MCN_L             | 24 | 23 | FSYNC   |
| GND               | 26 | 25 | FSTROBE |
| MDP1_L            | 28 | 27 | XVCLK_L |
| MDN1_L            | 30 | 29 | GND     |
| GND               | 32 | 31 | RST_N   |
| MDP0_R            | 34 | 33 |         |
| MDN0_R            | 36 | 35 | GND     |
| GND               | 38 | 37 | XVCLK_R |
| MCP_R             | 40 | 39 | I2C_SCL |
| MCN_R             | 42 | 41 | I2C_SDA |

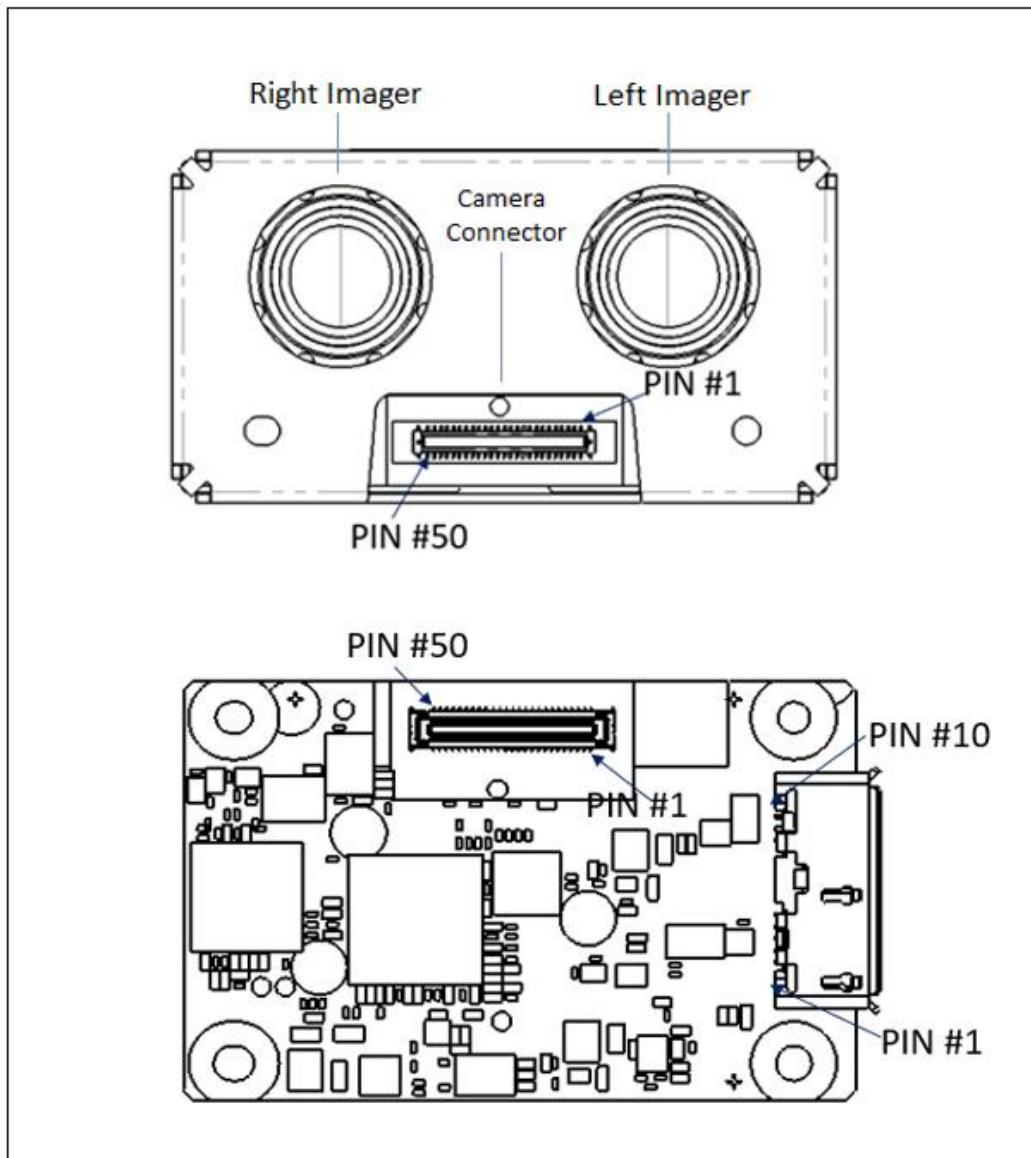
|              |    |    |  |
|--------------|----|----|--|
| <b>GND</b>   | 44 | 43 |  |
| MDP1_R       | 46 | 45 |  |
| MDN1_R       | 48 | 47 |  |
| <b>GND</b>   | 50 | 49 |  |
| 53, 54 (GND) |    |    |  |

**Table 3-39. Interposer Interconnect Signal Description - D401**

| <b>Position</b> | <b>ASIC Board/<br/>Motherboard</b> | <b>Depth Module</b> | <b>Position</b> | <b>Interconnect Description</b>                         |
|-----------------|------------------------------------|---------------------|-----------------|---|
| 1               |                                    |                     | 1               |   |
| 2               | GND                                | GND                 | 2               | Ground  |
| 3               |                                    |                     | 3               |   |
| 4               |                                    |                     | 4               |   |
| 5               | GND                                | GND                 | 5               | Ground  |
| 6               |                                    |                     | 6               |   |
| 7               |                                    |                     | 7               |   |
| 8               | GND                                | GND                 | 8               | Ground  |
| 9               |                                    |                     | 9               |   |
| 10              |                                    |                     | 10              |   |
| 11              |                                    |                     | 11              |   |
| 12              |                                    |                     | 12              |   |
| 13              |                                    |                     | 13              |   |
| 14              | GND                                | GND                 | 14              | Ground  |
| 15              | GND                                | GND                 | 15              | Ground  |
| 16              | MDP0_L                             | MDP0_L              | 16              | Left Imager MIPI Data Lane 0 differential pair positive |
| 17              | VDD18V                             | VDD18V              | 17              | 1.8 V Power   |
| 18              | MDN0_L                             | MDN0_L              | 18              | Left Imager MIPI Data Lane 0 differential pair negative |
| 19              | VDD18V                             | VDD18V              | 19              | 1.8 V Power   |
| 20              | GND                                | GND                 | 20              | Ground  |
| 21              |                                    |                     | 21              |   |
| 22              | MCP_L                              | MCP_L               | 22              | Left Imager MIPI Clock differential pair positive       |
| 23              | DVSYNC                             | DVSYNC              | 23              | VSYNC   |
| 24              | MCN_L                              | MCN_L               | 24              | Left Imager MIPI Clock differential pair negative       |
| 25              | FSTROBE                            | FSTROBE             | 25              | Depth Strobe signal                                     |

| <b>Position</b> | <b>ASIC Board/<br/>Motherboard</b> | <b>Depth Module</b> | <b>Position</b> | <b>Interconnect Description</b>                          |
|-----------------|------------------------------------|---------------------|-----------------|--|
| 26              | GND                                | GND                 | 26              | Ground   |
| 27              | XVCLK_L                            | XVCLK_L             | 27              | Clock to Left Imager                                     |
| 28              | MDP1_L                             | MDP1_L              | 28              | Left Imager MIPI Data Lane 1 differential pair positive  |
| 29              | GND                                | GND                 | 29              | Ground   |
| 30              | MDN1_L                             | MDN1_L              | 30              | Left Imager MIPI Data Lane 1 differential pair negative  |
| 31              | ST_RST_N                           | ST_RST_N            | 31              | Reset signal to Left and Right Imager                    |
| 32              | GND                                | GND                 | 32              | Ground   |
| 33              |                                    |                     | 33              |  |
| 34              | MDP0_R                             | MDP0_R              | 34              | Right Imager MIPI Data Lane 0 differential pair positive |
| 35              | GND                                | GND                 | 35              | Ground   |
| 36              | MDN0_R                             | MDN0_R              | 36              | Right Imager MIPI Data Lane 0 differential pair negative |
| 37              | XVCLK_R                            | XVCLK_R             | 37              | Clock to Right Imager                                    |
| 38              | GND                                | GND                 | 38              | Ground   |
| 39              | I2C_SCL                            | I2C_SCL             | 39              | I <sup>2</sup> C Bus Clock                               |
| 40              | MCP_R                              | MCP_R               | 40              | Right Imager MIPI Clock differential pair positive       |
| 41              | I2C_SDA                            | I2C_SDA             | 41              | I <sup>2</sup> C Bus Data                                |
| 42              | MCN_R                              | MCN_R               | 42              | Right Imager MIPI Clock differential pair negative       |
| 43              |                                    |                     | 43              |  |
| 44              | GND                                | GND                 | 44              | Ground   |
| 45              |                                    |                     | 45              |  |
| 46              | MDP1_R                             | MDP1_R              | 46              | Right Imager MIPI Data Lane 1 differential pair positive |
| 47              |                                    |                     | 47              |  |
| 48              | MDN1_R                             | MDN1_R              | 48              | Right Imager MIPI Data Lane 1 differential pair negative |
| 49              |                                    |                     | 49              |  |
| 50              | GND                                | GND                 | 50              | Ground   |
| 51              | VDD33V                             | VDD33V              | 52              | 3.3 V power  |
| 52              | VDD33V                             |                     |                 |  |
| 53              | GND                                | GND                 | 51              | Ground   |

**Figure 3-17. Depth Module Connector Orientation and Pin Position – D401**



**Table 3-40. Custom Flex Interposer Ordering Logistics**

| <b>Vendor</b>                   | <b>Sales Contact</b>   |
|---------------------------------|--|
| COCOM CONSUMER ELECTRONICS LTD. | Name: Janine Langdale<br>Email: <a href="mailto:Janine.Langdale@cc-e.co.uk">Janine.Langdale@cc-e.co.uk</a><br>Office phone: +44 (0) 1444 461620<br>Mobile phone: +44 (0) 7905 692131 |

### 3.7.4 External Sensor Sync Connector

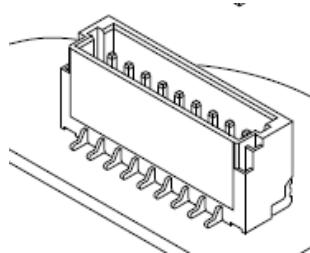
The external sensor connector provides the interface for external sensors to synchronize to depth output.

For D415, D455, D455f and D456 both the depth and RGB sensors can be synced by an external trigger.

For D435, D435i, D435f and D435if, only the depth sensor can be synced by an external trigger.

For D401, the external sync mechanism is not exposed.

**Table 3-41. External Sensor Connector Details**

| Parameter            | Description                            | Diagram   |
|----------------------|--|---|
| Number of Contacts   | 9                                      |  |
| Product Name         | 9 Positions Header, Shrouded Connector |   |
| Part Number          | SM09B-SRSS-TB(LF)(SN)                  |   |
| Manufacturer Website | www.jst-mfg.com                        |   |

**Table 3-42. External Sensor Sync Connector Pin List**

| Pin | Signal     | Function   | Description                        |
|-----|------------|------------|------------------------------------|
| 1   | GPIO3      | GVSYNC0    | Not Defined                        |
| 2   | GPIO4      | GVSYNC1    | IR Projector Power Down signal     |
| 3   | GPIO5      | GVSYNC2    | External IR Projector Fault Detect |
| 4   | GPIO6      | GVSYNC3    | External IR Projector              |
| 5   | Z_VSYNC    | VSYNC      | Depth VSYNC                        |
| 6   | LASER_PWM0 | LASER PWM0 | Laser control signal               |
| 7   | LASER_PWM1 | LASER PWM1 | Laser control signal               |
| 8   | VDD33V     | Power      | 3.3 V                              |
| 9   | GND        | Ground     | Ground                             |

### 3.7.5 USB Peripheral Connector – Type-C – D415, D435, D435i, D435f, D435if, D455, D455f, D456

USB Type-C connector consists of 24 signal pins designed in a symmetrical way. The connector z-height is as low as 3 mm and enables enhanced user experience

by allowing the USB Type-C plug to be plugged into a receptacle either right side up or upside down. Interoperability between USB Type-C and legacy USB is possible through standard legacy cable assemblies defined in USB Type-C Cable and Connector specification.

Recommend using a certified USB Type-C cable with locking connector for use with Intel® RealSense™ Camera D400 Series products.

**Figure 3-18. USB Type-C Receptacle Pin Map**

| A1    | A2   | A3   | A4   | A5   | A6 | A7 | A8   | A9   | A10  | A11  | A12 |
|-------|------|------|------|------|----|----|------|------|------|------|-----|
| GND   | TX1+ | TX1- | VBUS | CC1  | D+ | D- | SBU1 | VBUS | RX2- | RX2+ | GND |
| <hr/> |      |      |      |      |    |    |      |      |      |      |     |
| GND   | RX1+ | RX1- | VBUS | SBU2 | D- | D+ | CC2  | VBUS | TX2- | TX2+ | GND |
| B12   | B11  | B10  | B9   | B8   | B7 | B6 | B5   | B4   | B3   | B2   | B1  |

**Table 3-43. USB Peripheral Connector Pin List**

| Pin | Signal | Function             | Description                                     |
|-----|--------|----------------------|---|
| A1  | GND    | Power Delivery       | Ground  |
| A2  | TX1+   | USB 3.1 Gen 1 Data   | First SuperSpeed TX Differential Pair Positive  |
| A3  | TX1-   | USB 3.1 Gen 1 Data   | First SuperSpeed TX Differential Pair Negative  |
| A4  | VBUS   | Power Delivery       | 5 V   |
| A5  | CC1    | Control              | Configuration Channel 1                         |
| A6  | D+     | USB2.0 Data          | USB 2.0 differential pair positive              |
| A7  | D-     | USB2.0 Data          | USB 2.0 differential pair negative              |
| A8  | SBU1   | Sideband             | Sideband Use Signal 1                           |
| A9  | VBUS   | Power Delivery       | 5 V   |
| A10 | RX2-   | USB 3.1 Gen 1 Data   | Second SuperSpeed RX Differential Pair Negative |
| A11 | RX2+   | USB 3.1 Gen 1 Data   | Second SuperSpeed RX Differential Pair Positive |
| A12 | GND    | Power Delivery       | Ground  |
| B1  | GND    | Power Delivery       | Ground  |
| B2  | TX2+   | USB 3.1 Gen 1 Data   | Second SuperSpeed TX Differential Pair Positive |
| B3  | TX2-   | USB 3.1 Gen 1 Data   | Second SuperSpeed TX Differential Pair Negative |
| B4  | VBUS   | Power Delivery       | 5 V   |
| B5  | CC2    | Control              | Configuration Channel 2                         |
| B6  | D+     | USB 2.0 Data         | USB 2.0 differential pair positive              |
| B7  | D-     | USB 2.0 Data         | USB 2.0 differential pair negative              |
| B8  | SBU2   | Sideband             | Sideband Use Signal 2                           |
| B9  | VBUS   | Power Delivery       | 5 V   |
| B10 | RX1-   | USB 3.1 Gen 1.0 Data | First SuperSpeed RX Differential Pair Negative  |

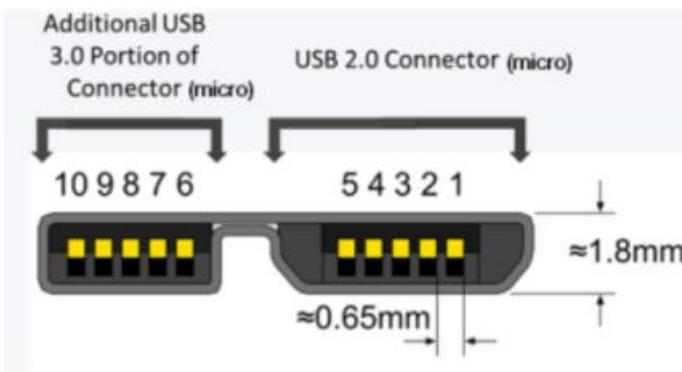
| Pin | Signal | Function             | Description                                    |
|-----|--------|----------------------|--|
| B11 | RX1+   | USB 3.1 Gen 1.0 Data | First SuperSpeed RX Differential Pair Positive |
| B12 | GND    | Power Delivery       | Ground   |

### 3.7.6 USB Peripheral Connector – Micro-B (D405)

USB Micro-B connector consists of 10 signal pins with a connector Z-height of 1.8mm.

Intel recommends using a certified USB Micro-B cable and connector for use with the Intel® RealSense™ Camera D401/405 Series products.

**Figure 3-19. USB3 Micro-B Receptacle Pin Map**



| Pin | Name       | Cable Color       | Function              |
|-----|------------|-------------------|-----------------------|
| 1   | VCC        | Red               | +5V DC                |
| 2   | D-         | White             | Data -                |
| 3   | D+         | Green             | Data +                |
| 4   | ID         | Dark blue (often) | Mode detect           |
| 5   | GND        | Black             | Ground                |
| 6   | USB3 SSTX- | Blue              | SuperSpeed transmit - |
| 7   | USB3 SSTX+ | Yellow            | SuperSpeed transmit + |
| 8   | GND        | N/A               | Ground signal return  |
| 9   | USB3 SSRX- | Purple            | SuperSpeed receive -  |
| 10  | USB3 SSRX+ | Orange            | SuperSpeed receive +  |

**Table 3-44. USB Peripheral Connector Pin List – D405**

| Pin Number | Signal Name | Description               | Mating Sequence |
|------------|-------------|---------------------------|-----------------|
| 1          | VBUS        | Power                     | Second          |
| 2          | D-          | USB 2.0 differential pair | Last            |

|       |            |                                       |        |
|-------|------------|---------------------------------------|--------|
| 3     | D+         |                                       |        |
| 4     | ID         | OTG Identification                    |        |
| 5     | GND        | Ground for power return               | Second |
| 6     | MicB_SSTX- | SuperSpeed transmitter differential   | Last   |
| 7     | MicB_SSTX+ |                                       |        |
| 8     | GND_DRAIN  | Ground for SuperSpeed signal return   | Second |
| 9     | MicB_SSRX- | SuperSpeed receiver differential pair | Last   |
| 10    | MicB_SSRX+ |                                       |        |
| Shell | Shield     | Connector metal shell                 | First  |

### 3.7.7 Color Image Signal Processor (ISP)

The color sensor data is sent to discrete Image Signal Processor (ISP) on the Vision processor D4 Board for image adjustments, image scaling and processing functions to help compensate for inherent inaccuracy in lens and sensor, to provide optimal image quality. The processed color image is sent to the Vision Processor D4.

**Table 3-45. ISP Properties**

| Parameter                                    | ISP Properties                  |
|--|---------------------------------|
| ISP Part Number on Vision Processor D4 Board | RTS5845                         |
| 1Mb Serial Flash for ISP                     | Winbond* W25X10CL or equivalent |
| Interface To Vision Processor D4             | MIPI CSI-2, 2X Lanes            |
| Interface To RGB Sensor                      | MIPI CSI-2, 1X Lane             |

### 3.7.8 Vision Processor D4 Board Power Requirements

The Vision Processor D4 Board is powered through VBUS power of the USB connector. The Vision Processor D4 Board in turn power sources the stereo depth module.

**Table 3-46. Vision Processor D4 Board Power Requirements**

| Parameter                |                | Min  | Nom  | Max  | Unit |
|--------------------------|----------------|------|------|------|------|
| VCC                      | Supply Voltage | 4.75 | 5.00 | 5.25 | V    |
| ICC                      | Supply Current |      |      | 700  | mA   |
| Supply Voltage Ramp Rate |                | 0.5  |      | 5    | ms   |

### 3.7.9 Vision Processor D4 Board Thermals

The Vision Processor D4 Board should be screw mounted onto a heat sink or a heat dissipating structure element using screw forks on Board. Thermal conductive

tape (electrically non-conductive) should cover the entire back side area (non-component side) of the ASIC Board for thermal transfer onto heat sink or heat dissipating structure element.

### 3.7.10 Vision Processor D4 Board Storage and Powered Conditions

**Table 3-47. Vision Processor D4 Board Storage and Powered Conditions**

| Condition   | Description  | Min                         | Max | Unit |
|---|--|-----------------------------|-----|------|
| Storage (Ambient), Not Powered                    | Temperature (Sustained, Controlled) <sup>(1)</sup> | 0                           | 50  | °C   |
|   | Temperature (Short Exposure) <sup>(2)</sup>        | -40                         | 70  | °C   |
|   | Humidity   | Temperature/ RH: 40°C / 90% |     |      |
| Case Temperature, Powered<br><sup>(3)(4)(5)</sup> | Temperature  | 0                           | 50  | °C   |

**Notes:**

- (1) Controlled conditions should be used for long term storage of product
- (2) Short exposure represents temporary max limits acceptable for transportation conditions
- (3) Case temperature limits must be met for all temperatures when powered
- (4) Case temperature is specified for the overall Vision Processor D4 Board
- (5) Case temperature 0° minimum and lower temperatures is non-condensing

### 3.7.11 Intel® RealSense™ Vision Processor D4 Board Product Identifier and Material Code

**Table 3-48. Vision Processor D4 Board Product Identifier and Material Code**

| Production                                  | Product Identifier<br>Code-Manufacture Configuration Code | Product<br>Material Code | IMU<br>Component |
|---|---|--------------------------|------------------|
| Vision Processor D4 Board <sup>(1)</sup>    | J32139-120  | 952019                   | N/A              |
| Vision Processor D4 Board V3 <sup>(2)</sup> | K94249-110  | 99A2NX                   | BMI085           |
| Vision Processor D4 Board V4 <sup>(3)</sup> | M31706-100  | 99AGAR                   | N/A              |

**Notes:**

- (1) The V1 ASIC (without IMU) is validated and supports all D410, D415 and D430 depth modules

- (2) The V3 ASIC is designed for use with the D430 and D450 Modules. Full validation has been done on this combination.
- (3) The V4 ASIC is designed for use with the D401 Module. Full validation has been done on this combination.

## 3.8 Intel® RealSense™ Depth Camera D400 Series

**Figure 3-20. Intel® RealSense™ Depth Camera D415**



**Figure 3-21. Intel® RealSense™ Depth Camera D435/D435i**



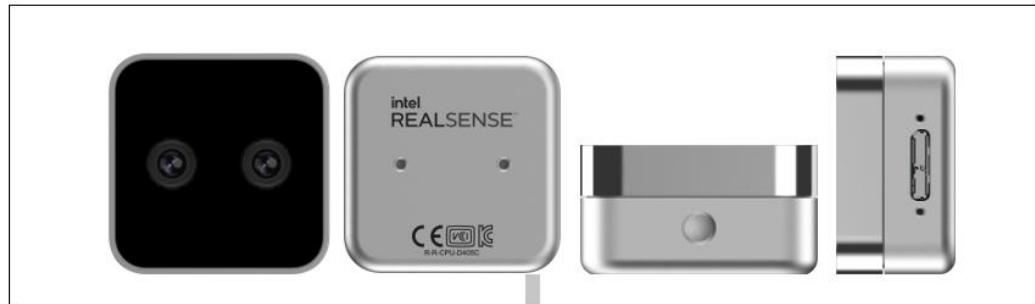
**Figure 3-22. Intel® RealSense™ Depth Camera D435f**



**Figure 3-23. Intel® RealSense™ Depth Camera D455**



**Figure 3-24. Intel® RealSense™ Depth Camera D405**



**Figure 3-25. Intel® RealSense™ Depth Camera D435if**



**Figure 3-26. Intel® RealSense™ Depth Camera D455f**



**Figure 3-27. Intel® RealSense™ Depth Camera D456**



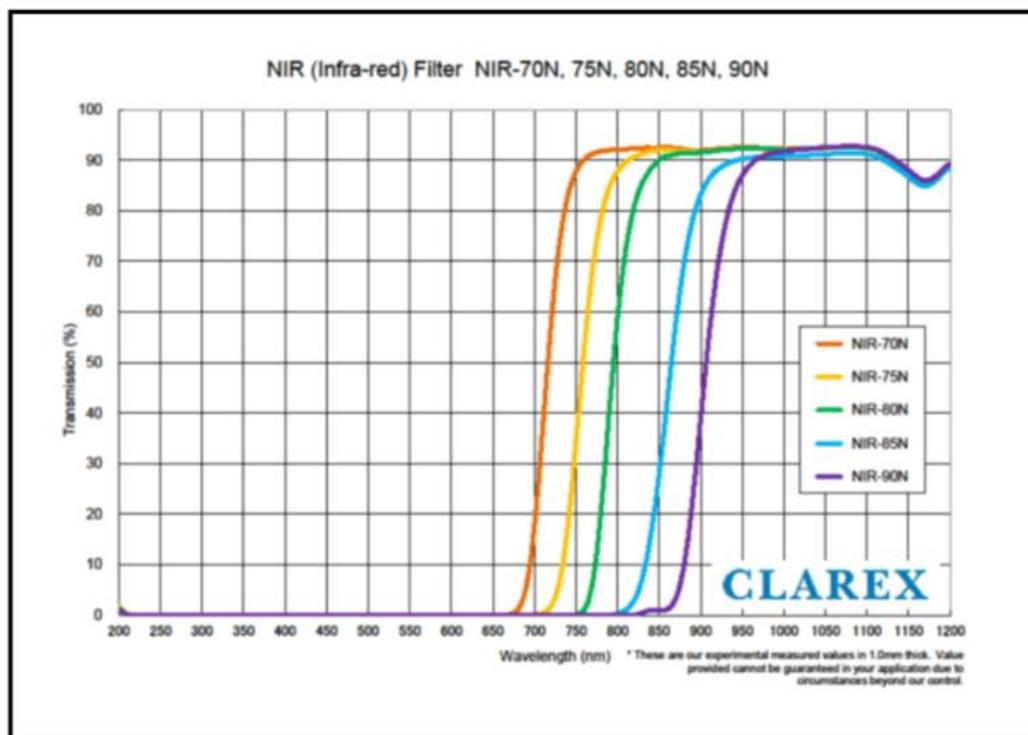
**Table 3-49. Depth Camera SKU Properties**

| D400 series Depth Cameras     | Intel® RealSense™ Depth Camera D415 | Intel® RealSense™ Depth Camera D435/D435i/D435f/D435if | Intel® RealSense™ Depth Camera D455 / D455f/ D456 | Intel® RealSense™ Depth Camera D405 |
|-------------------------------|-------------------------------------|--|---|-------------------------------------|
| Depth module                  | Intel® RealSense™ Depth module D415 | Intel® RealSense™ Depth module D430                    | Intel® RealSense™ Depth module D450               | Intel® RealSense™ Depth module D401 |
| Baseline                      | 55mm                                | 50mm   | 95mm  | 18mm                                |
| Left/Right Imagers Type       | Standard                            | Wide   | Wide  | Wide                                |
| Depth FOV HD (16:9) (degrees) | H:65 / V:40 / D:72                  | H:87 / V:58 / D:95                                     | H:87 / V:58 / D:95                                | H:84 / V:58 / D:92                  |
| Depth FOV VGA (4:3) (degrees) | H:50/ V:40 / D:61                   | H:75 / V:62 / D:89                                     | H:75 / V:62 / D:89                                | N/A                                 |
| IR Projector                  | Standard                            | Wide   | Wide  | N/A                                 |
| IR Projector FOV              | H:67 / V:41 / D:75                  | H:90 / V:63 / D:99                                     | H:90 / V:63 / D:99                                | N/A                                 |
| Color Sensor                  | OV2740                              | OV2740   | OV9782  | OV9782                              |
| Color Camera FOV              | H:69 /V:42 /D:77                    | H:69 /V:42 /D:77                                       | H:90 /V:65 /D:98                                  | H:84 / V:58 / D:92                  |
| IMU                           | None                                | None/6DoF/None/6DoF                                    | 6DoF  | None                                |
| Filter                        | All pass                            | All pass/ All pass/ IR-pass/IR-pass                    | All pass/ IR-pass                                 | IR-cut                              |

**Notes:**

1. H = Horizontal FOV, V = Vertical FOV, D = Diagonal FOV, X = Length, Y = Breadth, Z = Thickness
2. Depth FOV specified at 20 cm for D401 and at 2 m for other modules
3. Due to mechanical tolerances of +/- 5%, Max and Min FOV values can vary from lens to lens and module to module by ~ +/- 3 degrees
4. IR-pass filter is CLAREX® NIR-75N near-infrared filter applied to cover glass, with holes over projector and RGB sensor openings. Filter transmits near-infrared light and absorbs visible light. Filter's thickness = 0.5 mm.

**Figure 3-28. Intel® RealSense™ Depth Cameras D435f, D435if and D455f NIR Filter Optical Properties**



**Table 3-50. D435/D435i and D435f/D435if Comparison**

| Items                                   | D435/ D435i / D455                           | D435f / D435if / D455f                      |
|---|--|---|
| <b>Ambient light spectrum</b>           | Both visible and IR light                    | IR light only                               |
| <b>Repetitive pattern</b>               | May cause false depth                        | False depth mitigated                       |
| <b>Specular reflections</b>             | May cause image saturation                   | Saturation mitigated                        |
| <b>Indoor operating range</b>           | Long (unlimited)                             | Limited by IR projector power               |
| <b>L/R images</b>                       | Available in all lighting conditions         | Availability limited by ambient IR strength |
| <b>Calibration (OEM, Dynamic, Self)</b> | Works in typical ambient lighting conditions | May need additional IR light                |

### 3.8.1 Depth Camera D400 Series Mechanical Dimensions

**Table 3-51. Intel® RealSense™ Depth Camera D415 Mechanical Dimensions**

| Dimension          | Min   | Nominal           | Max   | Unit |
|--------------------|-------|-------------------|-------|------|
| Width              | 98.85 | 99                | 99.15 | mm   |
| Height             | 22.85 | 23                | 23.15 | mm   |
| Depth              | 19.85 | 20                | 20.15 | mm   |
| Weight             |       | 64 <sup>(1)</sup> |       | g    |
| Flatness Tolerance | 0     | -                 | 0.2   | mm   |

**Table 3-52. Intel® RealSense™ Depth Camera D435, D435i, D435f, D435if Mechanical Dimensions**

| Dimension          | Min   | Nominal           | Max                  | Unit |
|--------------------|-------|-------------------|----------------------|------|
| Width              | 89.85 | 90                | 90.15                | mm   |
| Height             | 24.85 | 25                | 25.15                | mm   |
| Depth              | 24.85 | 25                | 25.15 <sup>(2)</sup> | mm   |
| Weight             |       | 75 <sup>(1)</sup> |                      | g    |
| Flatness Tolerance | 0     | -                 | 0.15                 | mm   |

**Table 3-53. Intel® RealSense™ Depth Camera D455, D455f, D456 Mechanical Dimensions**

| Dimension          | Min   | Nominal            | Max                 | Unit |
|--------------------|-------|--------------------|---------------------|------|
| Width              | 123.5 | 124                | 124.5               | mm   |
| Height             | 28.5  | 29                 | 29.5                | mm   |
| Depth              | 25.5  | 26                 | 26.5 <sup>(3)</sup> | mm   |
| Weight             |       | 116 <sup>(1)</sup> |                     | g    |
| Flatness Tolerance | 0     | -                  | 0.2                 | mm   |

**Table 3-54. Intel® RealSense™ Depth Camera D405 Mechanical Dimensions**

| Dimension          | Min   | Nominal           | Max   | Unit |
|--------------------|-------|-------------------|-------|------|
| Width              | 41.85 | 42                | 42.15 | mm   |
| Height             | 41.85 | 42                | 42.15 | mm   |
| Depth              | 22.85 | 23                | 23.15 | mm   |
| Weight             |       | 58 <sup>(1)</sup> |       | g    |
| Flatness Tolerance | -     | 0.15              | -     | mm   |

**Note:**

- (1) The weight can be +/- 10% from the nominal. Bulk cameras are shipped without the USB cap which weighs around 2.3g.
- (2) D435f and D435if depth is around 25.8mm (due to the addition of the filter)
- (3) D455f depth is around 26.8mm (due to the addition of the filter)

## 3.8.2 Depth Camera D400 Series Thermals

### 3.8.2.1 Depth Camera D400 Series Storage and Powered Conditions

**Table 3-55. Depth Camera D400 Series Storage and Powered Conditions**

| Condition                                     | Description  | Min                         | Max | Unit |
|---|--|-----------------------------|-----|------|
| Storage (Ambient), Not Powered <sup>(5)</sup> | Temperature (Sustained, Controlled) <sup>(1)</sup> | 0                           | 50  | °C   |
|   | Temperature (Short Exposure) <sup>(2)</sup>        | -40                         | 70  | °C   |
|   | Humidity   | Temperature/ RH: 40°C / 90% |     |      |
| Ambient, Powered <sup>(3)(4)(5)</sup>         | Temperature, Performance                           | 0                           | 35  | °C   |
| Backside Case Temperature, Powered            | Temperature, Performance                           | 0                           | 50  | °C   |

**Notes:**

- (1) Controlled conditions should be used for long term storage of product
- (2) Short exposure represents temporary max limits acceptable for transportation conditions
- (3) The camera ambient temperature when powered, 0 °C to 35 °C is the validated range in which Intel® qualified the camera. This is a standard range in which Intel® qualifies consumer products. The camera's internal thermal solution was designed to keep the internal components at or below their max powered temperatures. As stated in Table 3-26, the projector temperature and the projector's operation below 60 °C is critical to the use of the projector for camera operations (use of projector can be determined by application developer based on necessity in usage model).
- (4) Ambient means environment while the camera is attached to a tripod using the camera's tripod screw attachment and is not connected to any mechanical or thermal material
- (5) Although all Key Performance Indicators (KPIs) are verified before leaving Intel's factory, KPIs may be negatively impacted by extended exposure to excessive temperatures and humidity

### 3.8.2.2 Depth Camera D400 Series Thermal Solution Guidance

The Intel® RealSense™ Depth Camera D400 Series camera thermal solution was designed taking into account the necessary thermal and mechanical aspects that go into producing a standalone peripheral camera. Those aspects include the

temperatures for all of the components associated with the module (projector, vision processor, IMU and camera sensors) when powered.

The Intel® RealSense™ SDK 2.0 (<https://github.com/IntelRealSense/librealsense>) provides temperature sensor readout based on Intel® RealSense™ camera capabilities. The readout should be used as a reference/guide, but is not to be used as a replacement for thermal solutions that comply with the temperatures of the camera. If monitoring the temperature of the camera is necessary due to thermal concern, it is recommended to monitor librealsense temperature readout from the application level and act upon the data if within < 5 °C of the component max temperatures.

To aid in development of thermal solution and heat dissipation, the recommendations below provide some guidance to system integrators.

#### Passive Cooling Recommendations:

- Mounting Bracket Material – Utilize mounting screws (2X M3 screws) and material that is the same or similar in nature (equal or lower thermal resistance or high conductivity) as the peripheral housing that the D400 Series depth cameras are made from. Material – Aluminum 6000 series.
- Increased Mating Surface – Mounting bracket mating surface with D400 series depth camera can be increased by a factor of 2X. The larger the mounting bracket mating surface area to the depth camera the better.
  - Reduction of mating surface imperfections, defects, roughness and gaps is recommended. Any increase in defects in the material can increase the thermal contact resistance, reducing effectiveness of heat dissipation of the thermal solution. Attachment options should be comprised of epoxy compounds or thermal tape/paste.
- Heat Sink – The addition of a heat sink can also improve heat dissipation from the D400 series depth camera. Use of a material such as Aluminum 6000 series or similar with equal or lower thermal resistance to the mating surface is recommended.

#### Active Cooling Recommendations:

- While heat pipes and liquid cooling solutions offer advantages, they also increase the complexity of system integration substantially. The use of a fan with direct air flow to the depth camera (back mounting surface 2X M3 screws) is preferable.

### 3.8.3 Depth Camera D400 Series Product Identifier and Material Code

**Table 3-56. Depth Camera D400 Series Product Identifier and Material Code**

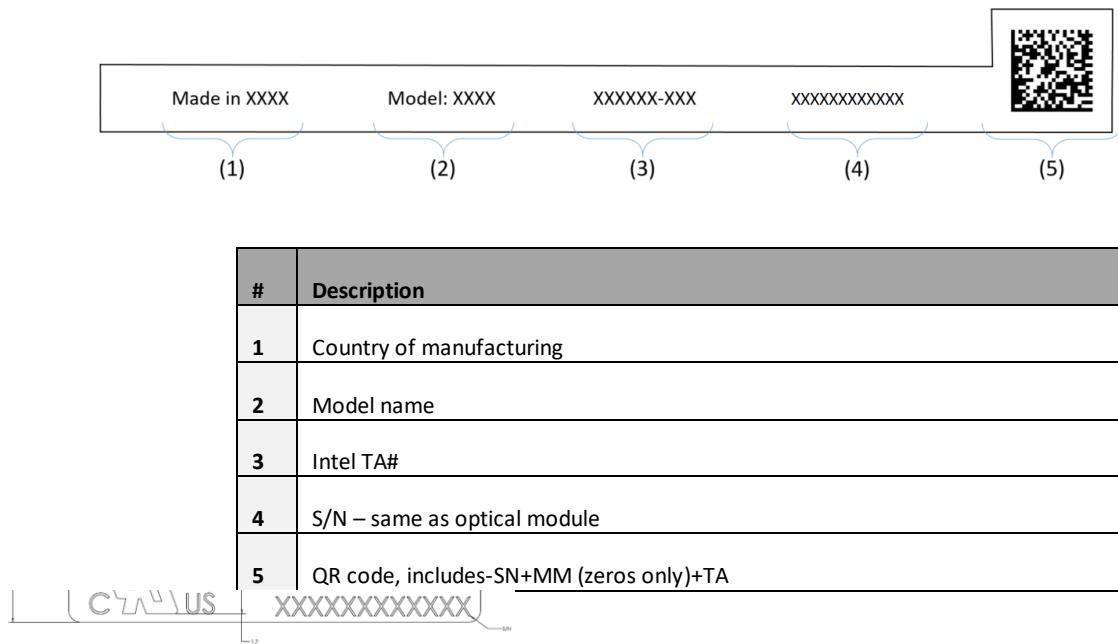
| Production                       | Product Identifier Code-Manufacture Configuration Code | Product Code   | Product Material Code | IMU Component |
|----------------------------------|--|----------------|-----------------------|---------------|
| Depth Camera D415                | J72476-100   | 82635ASRCDVKHV | 961443                | N/A           |
| Depth Camera D415 (Multi Pack)   | J72476-100   | 82635ASRCDVKMP | 962304                | N/A           |
| Depth Camera D435                | J72479-100   | 82635AWGDVKPRQ | 961448                | N/A           |
| Depth Camera D435 (Multi Pack)   | J72479-100   | 82635AWGDVKPMP | 962305                | N/A           |
| Depth Camera D435i               | K38179-100   | 82635D435IDK5P | 999AFR                | BMI055        |
| Depth Camera D435i               | K38179-110   | 82635D435IDK5P | 999AFR                | BMI085        |
| Depth Camera D435i (Multi Pack)  | K38179-100   | 82635D435IDKMP | 999AXG                | BMI055        |
| Depth Camera D435i (Multi Pack)  | K38179-110   | 82635D435IDKMP | 999AXG                | BMI085        |
| Depth Camera D435f               | M52867-100   | 82635D435FDK   | 99ANHK                | N/A           |
| Depth Camera D435f (Multi Pack)  | M52867-100   | 82635D435FDKMP | 99ANHL                | N/A           |
| Depth Camera D435if              | N14280-100   | 82635D435IF    | 99C9LT                | BMI085        |
| Depth Camera D435if (Multi Pack) | N14280-100   | 82635D435IFMP  | 99C9LV                | BMI085        |
| Depth Camera D455                | K83122-100   | 82635DSD455    | 999WCT                | BMI055        |
| Depth Camera D455                | K83122-110/111   | 82635DSD455    | 999WCT                | BMI085        |
| Depth Camera D455 (Multi Pack)   | K83122-100   | 82635DSD455MP  | 999WCR                | BMI055        |
| Depth Camera D455 (Multi Pack)   | K83122-110/111   | 82635DSD455MP  | 999WCR                | BMI085        |
| Depth Camera D455f               | N14281-100   | 82635DSD455F   | 99C9LW                | BMI085        |
| Depth Camera D455f (Multi Pack)  | N14281-100   | 82635DSD455FMP | 99C9LX                | BMI085        |
| Depth Camera D456                | M48865-100   | 82635DSD456    | 99AKLV                | BMI085        |
| Depth Camera D456 (Multi Pack)   | M48865-100   | 82635DSD456MP  | 99AKLW                | BMI085        |
| Depth Camera D405                | M31895-100   | 82635DSD405    | 99ACXC                | N/A           |
| Depth Camera D405 (Multi Pack)   | M31895-100   | 82635DSD405MP  | 99ACXD                | N/A           |

### 3.8.4 Camera Lens Cleaning Procedure

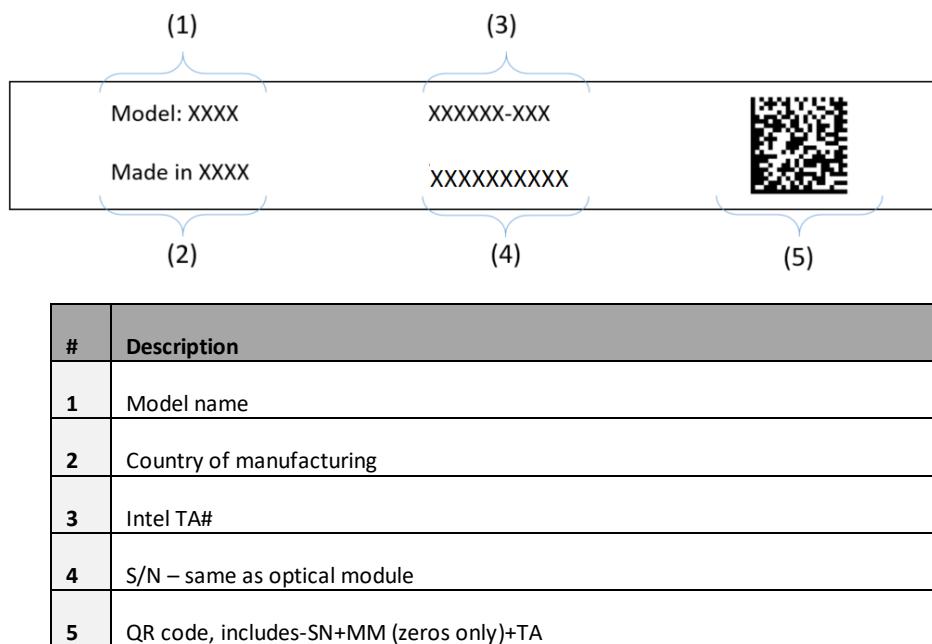
1. Do not use any chemicals or water on the camera lens
2. Remove dust and dirt as much as possible from the lens with a lens blower brush
3. Wipe with a dry, clean micro-fiber cloth

### 3.8.5 Stereo Depth Camera Label

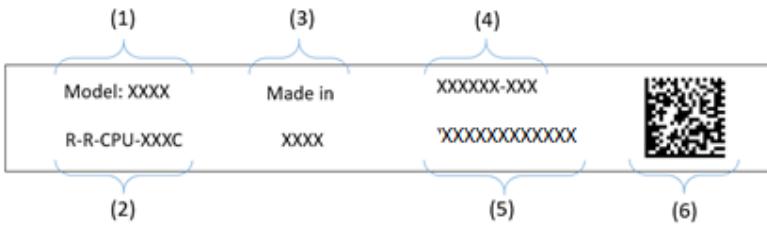
**Table 3-57. Stereo Depth Camera Product Labeling – D415**



**Table 3-58. Stereo Depth Camera Product Labeling – D435, D435i, D435f, D435if**

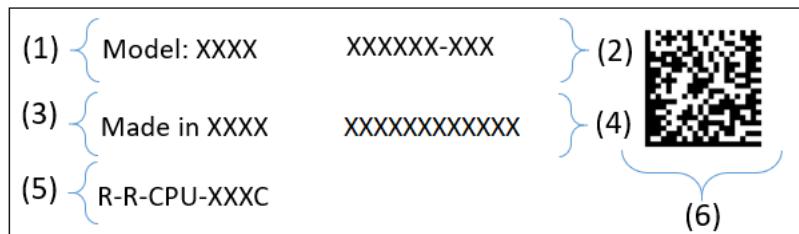


**Table 3-59. Stereo Depth Camera Product Labeling – D455, D455f, D456**



| #        | Description                             |
|----------|---|
| <b>1</b> | Model name                              |
| <b>2</b> | KCC Certification # (unique per SKU)    |
| <b>3</b> | Country of manufacturing                |
| <b>4</b> | Intel TA#                               |
| <b>5</b> | S/N – same as optical module            |
| <b>6</b> | QR code, includes-SN+MM (zeros only)+TA |

**Table 3-60. Stereo Depth Camera Product Labeling – D405**



| #        | Description                             |
|----------|---|
| <b>1</b> | Model name                              |
| <b>2</b> | Intel TA#                               |
| <b>3</b> | Country of manufacturing                |
| <b>4</b> | S/N – same as optical module            |
| <b>5</b> | KCC Certification # (unique per SKU)    |
| <b>6</b> | QR code, includes-SN+MM (zeros only)+TA |



# 4 Functional Specification

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## 4.1 Vendor Identification (VID) and Device Identification (DID)

**Table 4-1. Vendor ID and Device ID Table**

| Depth Module/Depth Camera             | Vendor ID | Device ID |
|---------------------------------------|-----------|-----------|
| Intel® RealSense™ Depth Module D410   | 8086      | 0x0AD2    |
| Intel® RealSense™ Depth Module D415   | 8086      | 0x0AD3    |
| Intel® RealSense™ Depth Camera D415   | 8086      | 0x0AD3    |
| Intel® RealSense™ Depth Module D430   | 8086      | 0x0AD4    |
| Intel® RealSense™ Depth Camera D435   | 8086      | 0x0B07    |
| Intel® RealSense™ Depth Camera D435i  | 8086      | 0x0B3A    |
| Intel® RealSense™ Depth Module D450   | 8086      | 0x0B5C    |
| Intel® RealSense™ Depth Camera D455   | 8086      | 0x0B5C    |
| Intel® RealSense™ Depth Module D401   | 8086      | 0x0B5B    |
| Intel® RealSense™ Depth Camera D405   | 8086      | 0x0B5B    |
| Intel® RealSense™ Depth Camera D435f  | 8086      | 0x0B07    |
| Intel® RealSense™ Depth Camera D435if | 8086      | 0x0B3A    |
| Intel® RealSense™ Depth Camera D455f  | 8086      | 0x0B5C    |
| Intel® RealSense™ Depth Camera D456   | 8086      | 0x0B5C    |

## 4.2 Vision Processor D4 Data Streams

The Intel® RealSense™ Vision Processor D4 depth imaging system provides high quality depth data to a host system. The depth data is generated via stereo vision technology, which is optionally assisted by an infrared projector. The imaging system has the ability to synchronize its depth data stream with its color data stream.

**Table 4-2. Image Formats (USB 3.1 Gen 1) –  
D410/D415/D430/D435/D435i/D435f/D435if**

| Format                                | Resolution  | Frame Rate (FPS)  | Comment  |
|---------------------------------------|-------------|-------------------|--|
| Z [16 bits]                           | 1280 x 720  | 6, 15, 30         | Depth  |
|                                       | 848 x 480   | 6, 15, 30, 60, 90 |  |
|                                       | 640 x 480   | 6, 15, 30, 60, 90 |  |
|                                       | 640 x 360   | 6, 15, 30, 60, 90 |  |
|                                       | 480 x 270   | 6, 15, 30, 60, 90 |  |
|                                       | 424 x 240   | 6, 15, 30, 60, 90 |  |
| Y8 [8 bits]                           | 1280 x 720  | 6, 15, 30         | Luminance<br>Left and Right Imager   |
|                                       | 848 x 480   | 6, 15, 30, 60, 90 |  |
|                                       | 640 x 480   | 6, 15, 30, 60, 90 |  |
|                                       | 640 x 360   | 6, 15, 30, 60, 90 |  |
|                                       | 480 x 270   | 6, 15, 30, 60, 90 |  |
|                                       | 424 x 240   | 6, 15, 30, 60, 90 |  |
| UYVY [16 bits]                        | 1280 x 720  | 6, 15, 30         | Color Stream from Left Imager<br>(D410 & D415 )                            |
|                                       | 848 x 480   | 6, 15, 30, 60, 90 |  |
|                                       | 640 x 480   | 6, 15, 30, 60, 90 |  |
|                                       | 640 x 360   | 6, 15, 30, 60, 90 |  |
|                                       | 480 x 270   | 6, 15, 30, 60, 90 |  |
|                                       | 424 x 240   | 6, 15, 30, 60, 90 |  |
| YUY2 [16 bits]                        | 1920 x 1080 | 6, 15, 30         | Color Stream from RGB camera<br>(Camera D415 &<br>D435/D435i/D435f/D435if) |
|                                       | 1280 x 720  | 6, 15, 30         |  |
|                                       | 960 x 540   | 6, 15, 30, 60     |  |
|                                       | 848 x 480   | 6, 15, 30, 60     |  |
|                                       | 640 x 480   | 6, 15, 30, 60     |  |
|                                       | 640 x 360   | 6, 15, 30, 60     |  |
|                                       | 424 x 240   | 6, 15, 30, 60     |  |
|                                       | 320 x 240   | 6, 30, 60         |  |
| Calibration [24 bits]                 | 320 x 180   | 6, 30, 60         | D410/D415<br>D430/D435/D435i/D435f/D435if                                  |
|                                       | 1920x1080   | 15, 25            |  |
| Intel® RealSense™<br>Self-Calibration | 1280 x 800  | 15, 25            | Intel® RealSense™ Self-<br>Calibration and Tare format<br>(D400 Series)    |
|                                       | 256 x 144   | 90                |  |

**Notes:**

1. Depth and Color are mapped as separated interfaces. Each one of the interfaces operates independently of the other interface (Virtual channel in MIPI and End Point in USB).
2. To ensure proper USB 3.1 device enumeration, connect the cable to the D400 camera first, then insert it into the host system port
3. For information regarding USB interoperability, refer to whitepaper "USB Interoperability Testing for Intel® RealSense™ Cameras" - <https://www.intelrealsense.com/usb-interoperability-testing-for-intel-realsense-cameras>

**Table 4-3. Image Formats (USB 3.1 Gen 1) – D450/D455/D455f/D456**

| Format                                     | Resolution | Frame Rate (FPS)  | Comment   |
|--|------------|-------------------|---|
| Z [16 bits]                                | 1280 x 720 | 5, 15, 30         | Depth   |
|  | 848 x 480  | 5, 15, 30, 60, 90 |   |
|  | 640 x 480  | 5, 15, 30, 60, 90 |   |
|  | 640 x 360  | 5, 15, 30, 60, 90 |   |
|  | 480 x 270  | 5, 15, 30, 60, 90 |   |
|  | 424 x 240  | 5, 15, 30, 60, 90 |   |
| Y8 [8 bits]                                | 1280 x 720 | 5, 15, 30         | Luminance<br>Left and Right Imager  |
|  | 848 x 480  | 5, 15, 30, 60, 90 |   |
|  | 640 x 480  | 5, 15, 30, 60, 90 |   |
|  | 640 x 360  | 5, 15, 30, 60, 90 |   |
|  | 480 x 270  | 5, 15, 30, 60, 90 |   |
|  | 424 x 240  | 5, 15, 30, 60, 90 |   |
| UYVY [16 bits]                             | 1280 x 720 | 5, 15, 30         | Color Stream from Left<br>Imager  |
|  | 848 x 480  | 5, 15, 30, 60, 90 |   |
|  | 640 x 480  | 5, 15, 30, 60, 90 |   |
|  | 640 x 360  | 5, 15, 30, 60, 90 |   |
|  | 480 x 270  | 5, 15, 30, 60, 90 |   |
|  | 424 x 240  | 5, 15, 30, 60, 90 |   |
| YUY2 [16 bits]                             | 1280 x 800 | 5, 15, 30         | Color Stream from RGB<br>camera<br><br>Calibration uses 1280 x<br>720 at 15 or 30 FPS |
|  | 848 x 480  | 5, 15, 30, 60     |   |
|  | 640 x 480  | 5, 15, 30, 60     |   |
|  | 640 x 360  | 5, 15, 30, 60, 90 |   |
|  | 480 x 270  | 5, 15, 30, 60, 90 |   |
|  | 424 x 240  | 5, 15, 30, 60, 90 |   |
| Calibration IR<br>Imager Y12I<br>[24 bits] | 1280 x 800 | 15, 25            |   |

| <b>Format</b>                      | <b>Resolution</b> | <b>Frame Rate (FPS)</b> | <b>Comment</b>                                     |
|------------------------------------|-------------------|-------------------------|--|
| Intel® RealSense™ Self-Calibration | 256 x 144         | 90                      | Intel® RealSense™ Self-Calibration and Tare format |

**Notes:**

1. Depth and Color are mapped as separated interfaces. Each one of the interfaces operates independently of the other interface (Virtual channel in MIPI and End Point in USB).
2. To ensure proper USB 3.1 device enumeration, connect cable to D400 camera first, then insert into host system port
3. For information regarding USB interoperability, refer to whitepaper "USB Interoperability Testing for Intel® RealSense™ Cameras" - <https://www.intelrealsense.com/usb-interoperability-testing-for-intel-realsense-cameras>

**Table 4-4. Image Formats (USB 3.1 Gen1) – D401/D405**

| <b>Format</b>  | <b>Resolution</b> | <b>Frame Rate (FPS)</b> | <b>Comment</b>                     |
|----------------|-------------------|-------------------------|------------------------------------|
| Z [16 bits]    | 1280 x 720        | 5, 15, 30               | Depth                              |
|                | 848 x 480         | 5, 15, 30, 60, 90       |                                    |
|                | 640 x 360         | 5, 15, 30, 60, 90       |                                    |
|                | 480 x 270         | 5, 15, 30, 60, 90       |                                    |
|                | 424 x 240         | 5, 15, 30, 60, 90       |                                    |
| Y8 [8 bits]    | 1280 x 720        | 5, 15, 30               | Luminance Left or Right Imager     |
|                | 848 x 480         | 5, 15, 30, 60, 90       |                                    |
|                | 640 x 360         | 5, 15, 30, 60, 90       |                                    |
|                | 480 x 270         | 5, 15, 30, 60, 90       |                                    |
|                | 424 x 240         | 5, 15, 30, 60, 90       |                                    |
| L8R8 [16 bits] | 1280 x 720        | 5, 15, 30               | Luminance Left and Right Imager    |
|                | 848 x 480         | 5, 15, 30, 60, 90       |                                    |
|                | 640 x 360         | 5, 15, 30, 60, 90       |                                    |
|                | 480 x 270         | 5, 15, 30, 60, 90       |                                    |
|                | 424 x 240         | 5, 15, 30, 60, 90       |                                    |
| UYVY [16 bits] | 1280 x 720        | 5, 15, 30               | Color Stream from Left Imager      |
|                | 848 x 480         | 5, 15, 30, 60, 90       |                                    |
|                | 640 x 360         | 5, 15, 30, 60, 90       |                                    |
|                | 480 x 270         | 5, 15, 30, 60, 90       |                                    |
|                | 424 x 240         | 5, 15, 30, 60, 90       |                                    |
| YUY2 [16 bits] | 1280 x 720        | 5, 15, 30               | Color Stream from Left RGB via ISP |
|                | 848 x 480         | 5, 15, 30, 60, 90       |                                    |

|                                       |            |                   |  |
|---------------------------------------|------------|-------------------|--|
|                                       | 640 x 360  | 5, 15, 30, 60, 90 |  |
|                                       | 480 x 270  | 5, 15, 30, 60, 90 |  |
|                                       | 424 x 240  | 5, 15, 30, 60, 90 |  |
| Calibration L+R imager Y12I [24 bits] | 1288 x 808 | 15, 25            | D401, D405   |
| OC Calibration                        | 256 x 144  | 90                | On Chip and Tare calibration format, all cameras/modules |

**Notes:**

1. Depth and Color are mapped to the same UVC interface
2. To ensure proper USB 3.1 device enumeration, connect cable to D400 camera first, then insert into host system port
3. For information regarding USB interoperability, refer to whitepaper "USB Interoperability Testing for Intel® RealSense™ Cameras" - <https://www.intelrealsense.com/usb-interoperability-testing-for-intel-realsense-cameras>

**Table 4-5. Simultaneous Image Streams (USB 3.1 Gen 1) – D410/D415/D430/D435/D435i/D435f/D435if/D450/D455**

| Depth | Imager | Color<br>(Left Imager)<br>D41x/ D45x | Color<br>(RGB Camera)<br>D415/D435/D435i/<br>D435f/D435if/<br>D450/D455/D455f/D456 | IMU<br>D435i/D435if/D455/<br>D455f/D456 |
|-------|--------|--------------------------------------|--|---|
| Z16   | Y8     |                                      |  | Gyro & Accelerometer                    |
| Z16   |        | UYVY                                 |  | Gyro & Accelerometer                    |
| Z16   | Y8     |                                      | YUY2   | Gyro & Accelerometer                    |
| Z16   |        |                                      | YUY2   | Gyro & Accelerometer                    |

**Notes:**

1. RGB to depth hardware sync is only supported with the same frame rate for all streams
2. For simultaneous Depth and RGB streaming, it is recommended to set color resolution to same value (or higher) as depth resolution
3. USB 3.1 Gen 1 supports all resolution/frame rate combinations in a typical dedicated USB port configuration. When sharing a USB hub with other devices (e.g., additional RealSense cameras), considerations regarding bandwidth requirements have to be taken into account.
4. To ensure proper USB 3.1 device enumeration, connect the cable to the D400 camera first, then insert it into the host system port
5. Streaming of Depth, IR left and IR right concurrently is only supported for calibration in a dedicated format with rectified IR (24-bit), as seen in the section 4.2
6. For information regarding USB interoperability, refer to whitepaper "USB Interoperability Testing for Intel® RealSense™ Cameras" - <https://www.intelrealsense.com/usb-interoperability-testing-for-intel-realsense-cameras>

**Table 4-6. Simultaneous Image Streams (USB 3.1 Gen 1) – D401/D405**

| <b>Depth</b> | <b>Imager</b> | <b>Color<br/>(Left<br/>Imager)<br/>D401/D405</b> | <b>Comment</b> |
|--------------|---------------|--|----------------|
| Z16          | Y8            |  |                |
| Z16          | Y8            | YUY2   |                |

**Notes:**

1. USB 3.1 Gen 1 supports all resolution/frame rate combinations in a typical dedicated USB port configuration. When sharing a USB hub with other devices (e.g., additional RealSense cameras), considerations regarding bandwidth requirements must be taken into account.
2. To ensure proper USB 3.1 device enumeration, connect cable to D400 camera first, then insert into host system port
3. For information regarding USB interoperability, refer to whitepaper “USB Interoperability Testing for Intel® RealSense™ Cameras” - <https://www.intelrealsense.com/usb-interoperability-testing-for-intel-realsense-cameras>

**Table 4-7. Image Formats (USB 2.0) – D410/D415/D430/D435/D435i/D435f/D435if**

| <b>Format</b>                      | <b>Resolution</b> | <b>Frame Rate</b> | <b>Comment</b>   |
|------------------------------------|-------------------|-------------------|--|
| Z [16 bits]                        | 1280 x 720        | 6                 | Depth  |
|                                    | 848 x 480         | 6, 10             |  |
|                                    | 640 x 480         | 6, 15, 30         |  |
|                                    | 640 x 360         | 30                |  |
|                                    | 480 x 270         | 6, 15, 30, 60     |  |
| Y8 [8 bits]                        | 1280 x 720        | 6                 | Luminance Stream from Left Imager                                    |
|                                    | 848 x 480         | 6, 10             |  |
|                                    | 640 x 480         | 6, 15, 30         |  |
|                                    | 480 x 270         | 6, 15, 30, 60     |  |
| UYVY [16 bits]                     | 1280 x 720        | 6                 | Color Stream from Left Imager (D410 & D415)                          |
|                                    | 640 x 480         | 6, 15, 30         |  |
|                                    | 480 x 270         | 6, 15, 30, 60     |  |
| YUY2 [16 bits]                     | 1280 x 720        | 6, 15             | Color Stream from RGB camera (Camera D415 & D435/D435i/D435f/D435if) |
|                                    | 640 x 480         | 6, 15, 30         |  |
|                                    | 424 x 240         | 6, 15, 30, 60     |  |
| Intel® RealSense™ Self-Calibration | 256 x 144         | 90                | Intel® RealSense™ Self-Calibration and Tare format                   |

**Note:**

1. Depth and Color are mapped as separated interfaces. Each one of the interfaces is working independently of the other interface (Virtual channel in MIPI and End Point in USB). Right infrared imager stream is supported for calibration purposes only.

**Table 4-8. Image Formats (USB 2.0) – D450/D455/D455f/D456**

| Format                             | Resolution | Frame Rate    | Comment  |
|------------------------------------|------------|---------------|--|
| Z [16 bits]                        | 1280 x 720 | 5             | Depth  |
|                                    | 848 x 480  | 5, 10         |  |
|                                    | 640 x 480  | 5, 15, 30     |  |
|                                    | 640 x 360  | 30            |  |
|                                    | 480 x 270  | 5, 15, 30, 60 |  |
| Y8 [8 bits]                        | 1280 x 720 | 5             | Luminance Stream from Left Imager                  |
|                                    | 848 x 480  | 5, 10         |  |
|                                    | 640 x 480  | 5, 15, 30     |  |
|                                    | 640 x 360  | 30            |  |
|                                    | 480 x 270  | 5, 15, 30, 60 |  |
| UYVY [16 bits]                     | 1280 x 720 | 5             | Color Stream from Left Imager                      |
|                                    | 848 x 480  | 5, 10         |  |
|                                    | 640 x 480  | 5, 15, 30     |  |
|                                    | 640 x 360  | 30            |  |
|                                    | 480 x 270  | 5, 15, 30, 60 |  |
| YUY2 [16 bits]                     | 1280 x 800 | 15            | Color Stream from RGB camera                       |
|                                    | 1280 x 720 | 5, 10, 15     |  |
|                                    | 640 x 480  | 5, 15, 30     |  |
|                                    | 424 x 240  | 5, 15, 30, 60 |  |
| Intel® RealSense™ Self-Calibration | 256 x 144  | 90            | Intel® RealSense™ Self-Calibration and Tare format |

**Table 4-9. Image Formats (USB 2.0) – D405**

| Format      | Resolution | Frame Rate    | Comment                           |
|-------------|------------|---------------|-----------------------------------|
| Z [16 bits] | 1280 x 720 | 5             | Depth                             |
|             | 848 x 480  | 5, 10         |                                   |
|             | 640 x 480  | 5, 15, 30     |                                   |
|             | 640 x 360  | 30            |                                   |
|             | 480 x 270  | 5, 15, 30, 60 |                                   |
| Y8 [8 bits] | 1280 x 720 | 5             | Luminance Stream from Left Imager |
|             | 848 x 480  | 5, 10         |                                   |
|             | 640 x 480  | 5, 15, 30     |                                   |

| <b>Format</b>                      | <b>Resolution</b> | <b>Frame Rate</b> | <b>Comment</b>                                     |
|------------------------------------|-------------------|-------------------|--|
|                                    | 640 x 360         | 30                |  |
|                                    | 480 x 270         | 5, 15, 30, 60     |  |
| UYVY [16 bits]                     | 1280 x 720        | 5                 | Color Stream from Left Imager                      |
|                                    | 848 x 480         | 5, 10             |  |
|                                    | 640 x 480         | 5, 15, 30         |  |
|                                    | 640 x 360         | 30                |  |
|                                    | 480 x 270         | 5, 15, 30, 60     |  |
| YUY2 [16 bits]                     | 1280 x 720        | 5, 10, 15         | Color Stream from RGB + ISP                        |
|                                    | 848 x 480         | 5, 10             |  |
|                                    | 640 x 480         | 5, 15, 30         |  |
|                                    | 480 x 270         | 5, 15, 30         |  |
|                                    | 424 x 240         | 5, 15, 30, 60     |  |
| Intel® RealSense™ Self-Calibration | 256 x 144         | 90                | Intel® RealSense™ Self-Calibration and Tare format |

**Table 4-10. Simultaneous Image Streams (USB 2.0)**

| <b>Depth</b> | <b>Imager</b> | <b>Color<br/>(Left Imager)<br/>D41x/D45x/D405</b> | <b>Color (RGB Camera)<br/>D415/D435/D435i/<br/>D450/D455/D455f/D456</b> | <b>IMU<br/>D435i/D435if/<br/>D455/D455f/D456</b> | <b>Comment</b> |
|--------------|---------------|---|---|--|----------------|
| Z16          | Y8            |   |   | Gyro & Accelerometer                             |                |
| Z16          |               | UYVY  |   | Gyro & Accelerometer                             |                |
| Z16          | Y8            |   | YUY2  | Gyro & Accelerometer                             |                |
| Z16          |               |   | YUY2  | Gyro & Accelerometer                             |                |

**Notes:**

1. RGB to depth hardware sync is only supported with the same frame rate for all streams
2. For simultaneous Depth and RGB streaming, it is recommended to set the color resolution to the same value (or higher) as the depth resolution
3. USB 2.0 supports a subset of the possible resolution/frame rate combinations due to the bandwidth requirements. Maximum simultaneous stream configurations are:
  - a. Depth: 640 x 480 @ 15FPS; Imager: 640 x 480 @ 15FPS; RGB Camera: 640 x 480 @ 30FPS
  - b. Depth: 480 x 270 @ 60FPS; Imager: 480 x 270 @ 60FPS; RGB Camera: 424 x 240 @ 30FPS
  - c. Depth: 848 x 480; Imager: 848x480; RGB Camera: 1280 x 720 @ 10FPS

## 4.3 Depth Field of View (FOV)

The depth field of view is the shared overlap of the individual left and right imagers' fields of view for which Vision Processor D4 provides depth data.

The FOV changes based on the resolution and aspect ratio. HD resolution's aspect ratio is 16:9, while VGA resolution's aspect ratio is 4:3. Review "Table 3-11. Stereo Depth Module SKU Properties" and "Table 3-48. Depth SKU Properties" to obtain the FOV values associated with each camera SKU.

## 4.4 Depth Field of View at Distance (Z)

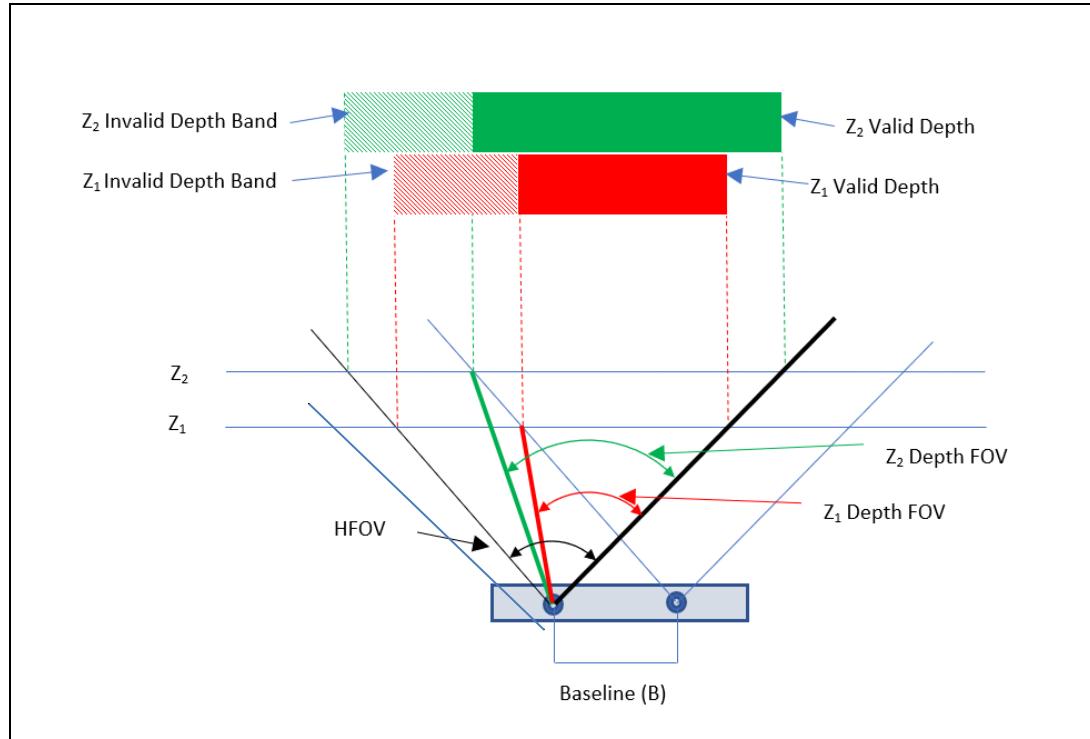
Depth Field of View (Depth FOV) at any distance (Z) can be calculated using the following equation:

$$\text{Depth FOV} = \frac{\text{HFOV}}{2} + \tan^{-1}\left\{\tan\left(\frac{\text{HFOV}}{2}\right) - \frac{B}{Z}\right\}$$

**Definitions:**

1. Depth FOV = Depth Field of View
2. HFOV = Horizontal Field of View of left imager on depth module
3. B = Baseline
4. Z = Distance of scene from depth module

**Figure 4-1. Depth Field of View to Depth Map illustration**



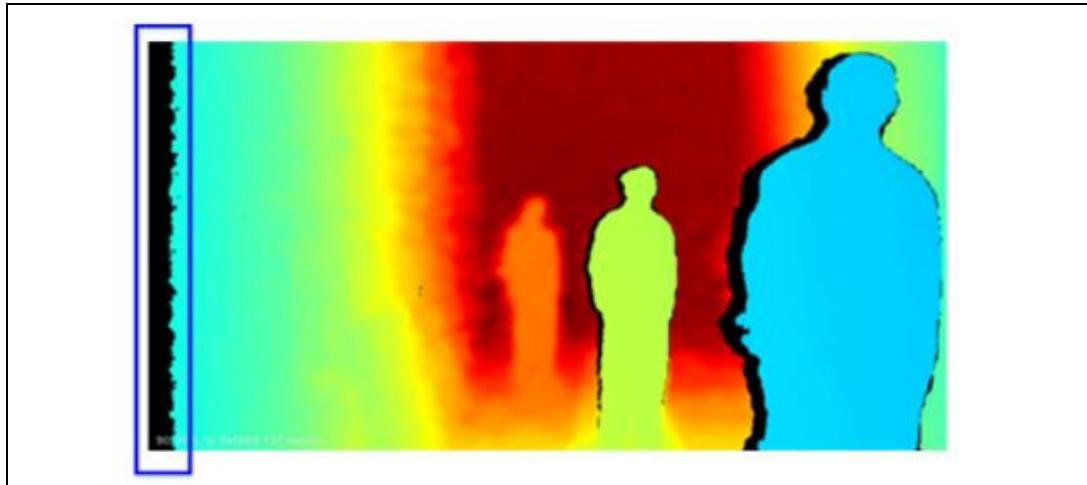
**Note:**

1. As the scene's distance from the depth module increases, the invalid depth band decreases in the overall depth image. Overall depth image is invalid depth band plus valid depth map.

## 4.5 Invalid Depth Band

The depth data generated by the D4 Vision Processor utilizes the left imager as the reference for the stereo matching algorithm, resulting in a non-overlapped region in the camera's field of view. This non-overlapped region (at the left edge of the frame) contains no depth data. The invalid depth data band decreases as the distance from the camera/module to the scene increases.

**Figure 4-2. Left Invalid Depth Band**



The width of the invalid depth band can be calculated using the following equations:

In terms of horizontal FOV:

DBR (Ratio of Invalid Depth Band to Total Horizontal Image)

$$= B / (2 * Z * \tan(\frac{HFOV}{2}))$$

$$\text{Invalid Depth Band (in Pixels)} = HRES * DBR$$

In terms of focal length:

DBR (Ratio of Invalid Depth Band to Total Horizontal Image)

$$= B * F / (Z * HRES)$$

$$\text{Invalid Depth Band (in Pixels)} = B * F / Z$$

**Definitions:**

1. B = Baseline
2. Z = Distance of scene from depth module
3. F = Focal length
4. HFOV = Horizontal Field of View of left imager on depth module
5. HRES = Horizontal Resolution

Note that the equations above are valid for a base configuration of camera settings. The default camera configuration in firmware may have settings optimized for depth performance that impact the actual width of the invalid depth band, as compared to the calculated width of the invalid depth band from the equations.

## 4.6 Minimum-Z Depth

The Minimum-Z Depth is the minimum distance from the depth camera/module to the scene for which the Vision Processor D4 provides depth data.

**Table 4-11. Minimum-Z Depth**

| Resolution | D410/<br>D415 | D430/D435/<br>D435i/D435f/D435if | D450/D455/<br>D455f/D456 | D401/D405  |
|------------|---------------|----------------------------------|--------------------------|------------|
|            | Min-Z (mm)    | Min-Z (mm)                       | Min-Z (mm)               | Min-Z (mm) |
| 1280x720   | 450           | 280                              | 520                      | 100        |
| 848X480    | 310           | 195                              | 350                      | 70         |
| 640x480    | 310           | 175                              | 320                      | -          |
| 640x360    | 240           | 150                              | 260                      | 55         |
| 480x270    | 180           | 120                              | 200                      | 45         |
| 424x240    | 160           | 105                              | 180                      | 40         |

## 4.7 Depth Quality Specification

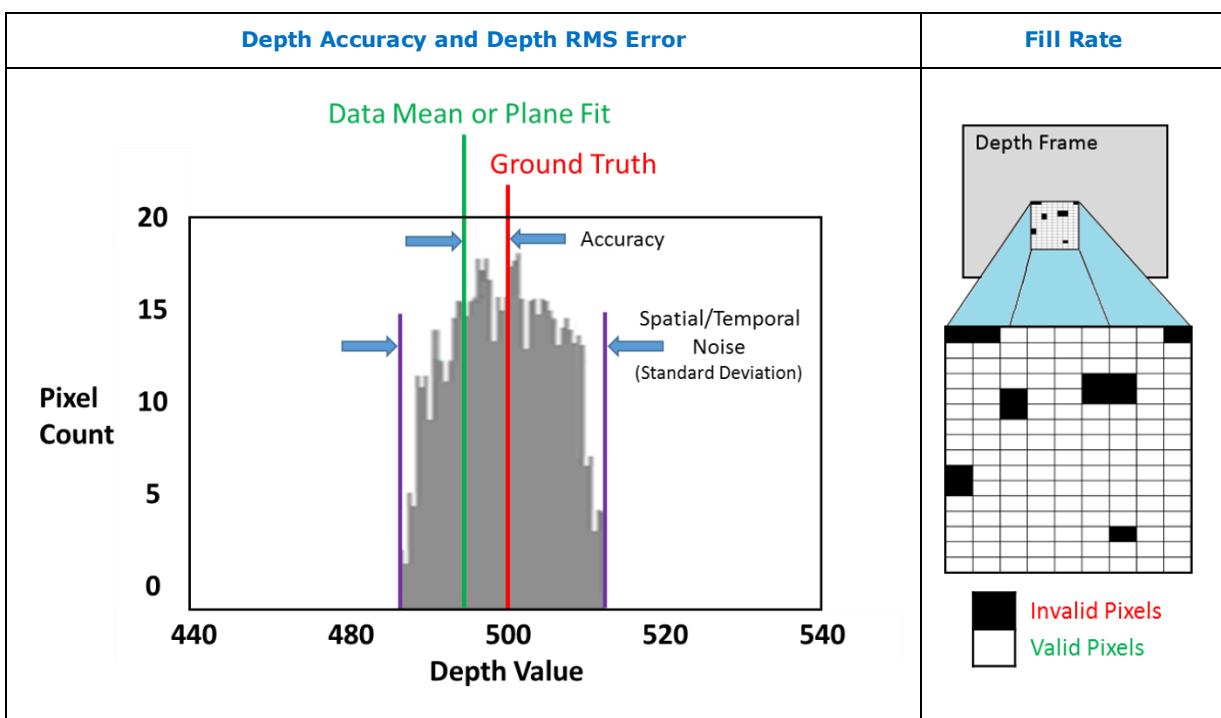
A set of standard metrics based on accuracy, data validity, and temporal stability are used to quantify the depth quality.

Although the modules are designed for a specific depth FOV, the measurements are taken within 80% of this FOV, defined as the Region Of Interest (ROI). This ROI aligns with the practical usage area and the module's qualified optical parameters.

**Table 4-12. Depth Quality Metric**

| Metric                   | Definition <sup>(1)</sup>   |
|--------------------------|---|
| Depth Accuracy           | Measures the difference for valid pixels relative to a ground truth surface   |
| Fill Rate                | Percentage of pixels that have valid depth values   |
| Depth Standard Deviation | Measures total spatial noise for each valid pixel relative to a best fit plane  |
| Pixel Temporal Noise     | Measures total temporal noise for each valid pixel relative to a best fit plane   |
| <b>Note:</b>             |   |
| (1)                      | Each measurement is taken from a predefined region of interest (ROI) which is within 80% of the depth field of view (FOV) |

**Table 4-13. Depth Quality Metric Illustration**



**Table 4-14. Depth Quality Specification**

| Metric                         | D410/D415<br>(<= 2 Meters and 80% ROI, HD Resolution) | D430/D435/<br>D435i/D435f/D435if<br>(<= 2 Meters and 80% ROI, HD Resolution) | D450/D455/<br>D455f/D456<br>(<= 4 Meters and 80% ROI, HD Resolution) | D401/D405<br>(<= 0.5 Meters and 80% ROI, HD Resolution) |
|--------------------------------|---|--|--|---|
| Z-accuracy (or Absolute Error) | $\pm 2\%$   | $\pm 2\%$  | $\pm 2\%$  | $\pm 2\%$   |
| Fill rate                      | $\geq 99\%$   | $\geq 99\%$  | $\geq 99\%$  | $\geq 99.5\%$   |
| RMS Error (or Spatial Noise)   | $\leq 2\%$  | $\leq 2\%$   | $\leq 2\%$   | $\leq 1\%$  |

|                |            |            |            |              |
|----------------|------------|------------|------------|--------------|
| Temporal Noise | $\leq 1\%$ | $\leq 1\%$ | $\leq 1\%$ | $\leq 0.5\%$ |
| Lifetime       | 4 years    | 5 years    | 5 years    | 5 years      |

**Notes:**

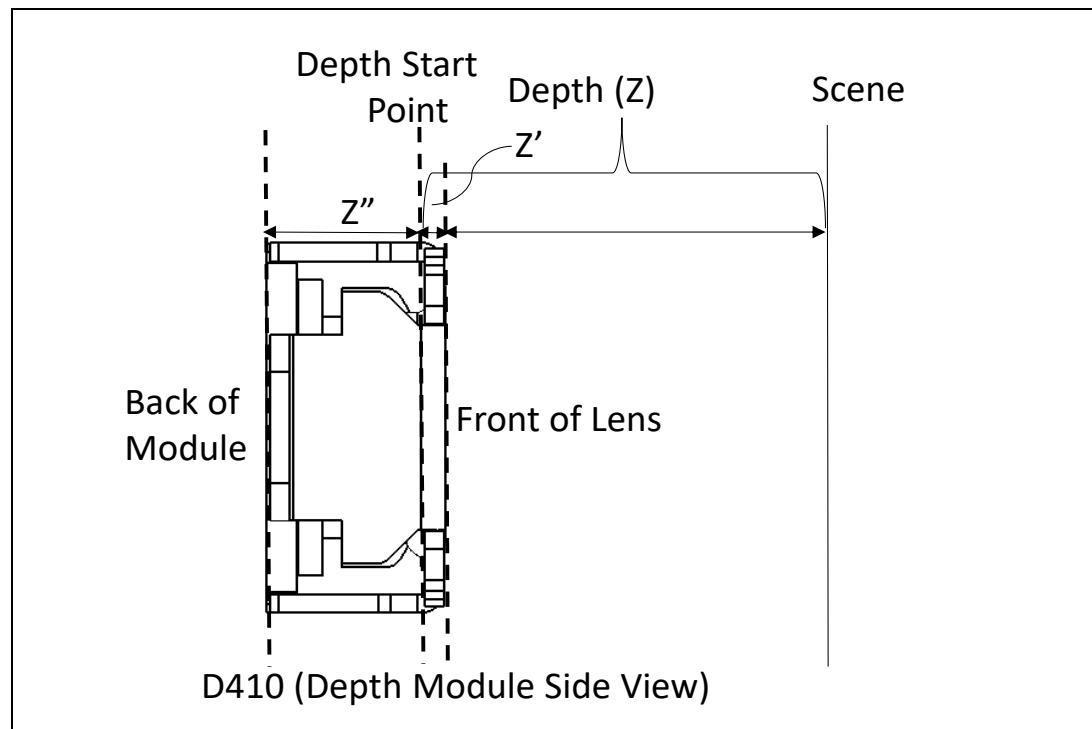
1. Key Performance Indicators (KPIs) are validated at the factory and reflect typical conditions
2. KPIs could be impacted by environmental factors over the camera/module's lifetime
3. Please follow best-known methods to obtain optimal camera/module performance over its lifetime. Refer to white paper "Intel® RealSense™ Stereo Camera Best Known Methods to Get Optimal Camera Performance over Lifetime" - <https://www.intelrealsense.com/best-known-methods-for-optimal-camera-performance-over-lifetime>
4. KPIs for D405, a passive camera, are measured using a textured target and typical ambient room light (~250 Lux). All other models are active and measured using a texture-less (white) target with default laser power (150mW) and auto exposure enabled.
5. For Depth Quality metric definitions and test methodology details, refer to white paper "[Intel® RealSense™ Camera Depth Testing Methodology](#)"
6. Lifetime: operating in default settings within the supported temperature for up to 16 hours a day [66%]

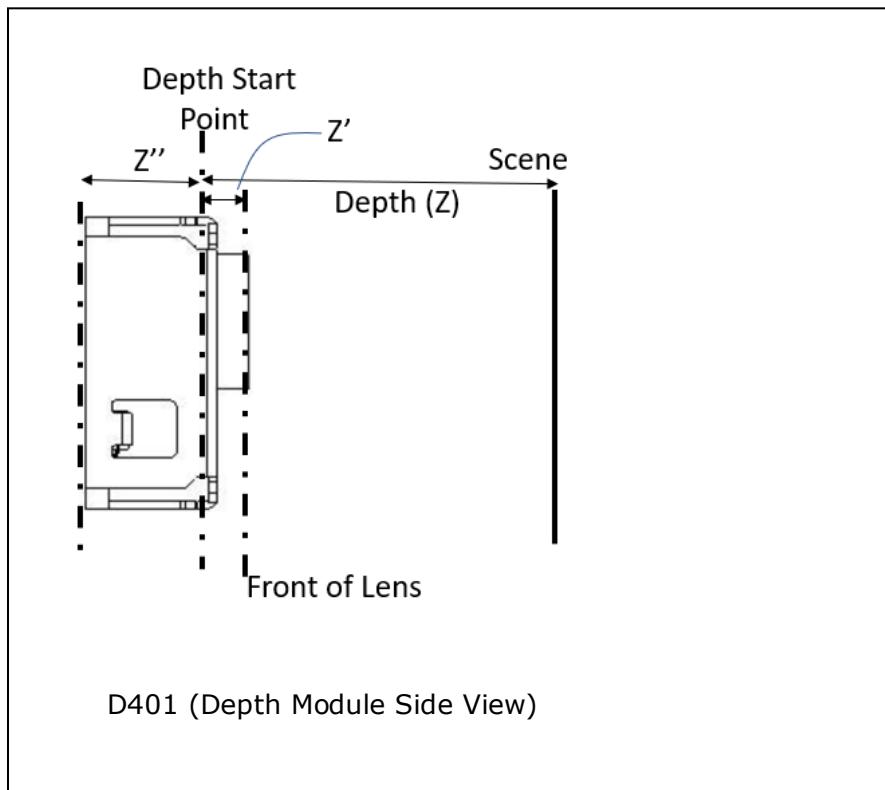
## 4.8

### Depth Start Point (Ground Zero Reference)

The depth start point or the ground zero reference can be described as the starting point or plane where depth = 0. For depth modules (D410 & D415), this point is referenced from front of lens or from backside of module. For depth cameras (D415, D43x, D45x), this point is referenced from front of the camera cover glass.

**Figure 4-3. Depth Module Depth Start Point Reference**





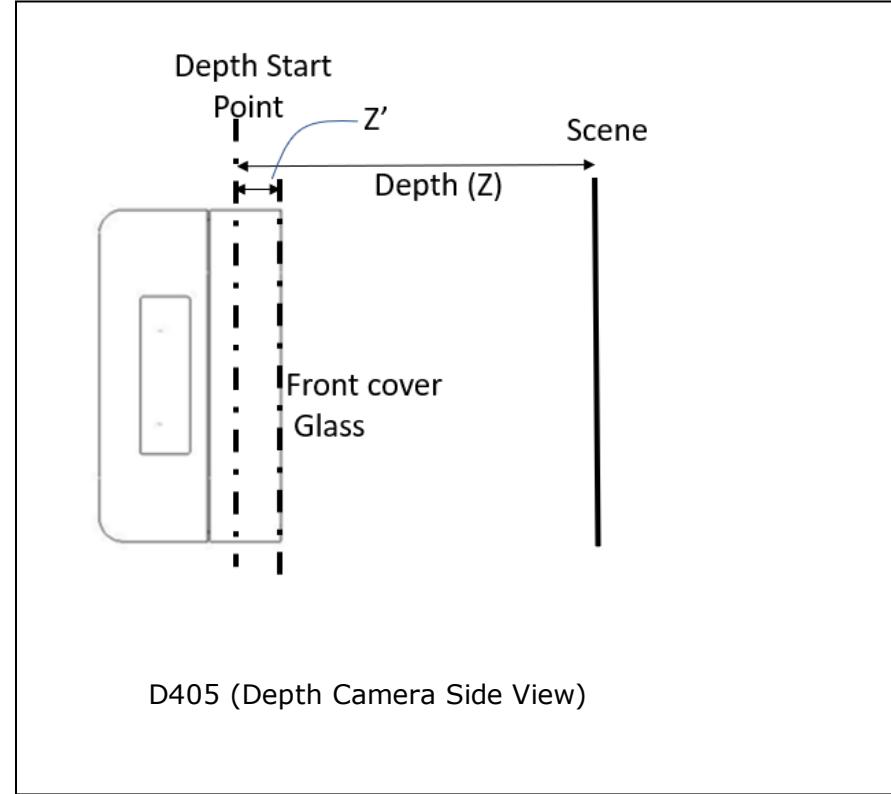
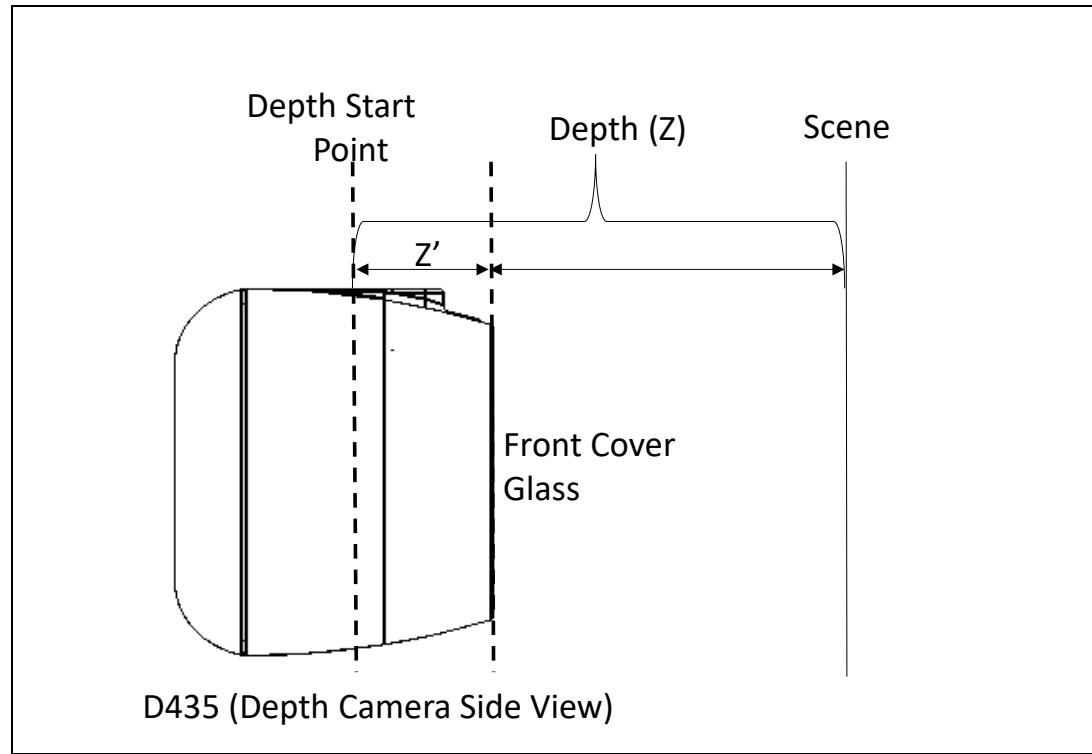
**Table 4-15. Depth Module Depth Start Point**

| Depth Module | Front of Lens ( $Z'$ ) | Back of Module ( $Z''$ ) |
|--------------|------------------------|--------------------------|
| D410/D415    | -0.1 mm                | 4.3 mm                   |
| D430/D450    | -3.2 mm                | 7.5 mm                   |
| D401         | -2.7 mm                | 7.8 mm                   |

**Note:**

1. If depth measurement reference is front of lens, then  $|Z'|$  should be added to measured value to determine Ground Truth. If depth measurement reference is back of module, then  $|Z''|$  should be subtracted to determine Ground Truth.

**Figure 4-4. Depth Camera Depth Start Point Reference**



**Table 4-16. Depth Cameras Depth Start Point**

| Depth Camera | Camera Front Glass (Z') |
|--------------|-------------------------|
| D415         | -1.1 mm                 |
| D435/D435i   | -4.2 mm                 |
| D435f/D435if | -4.7 mm                 |
| D455/D456    | -4.55 mm                |
| D455f        | -5.05 mm                |
| D405         | -3.7 mm                 |

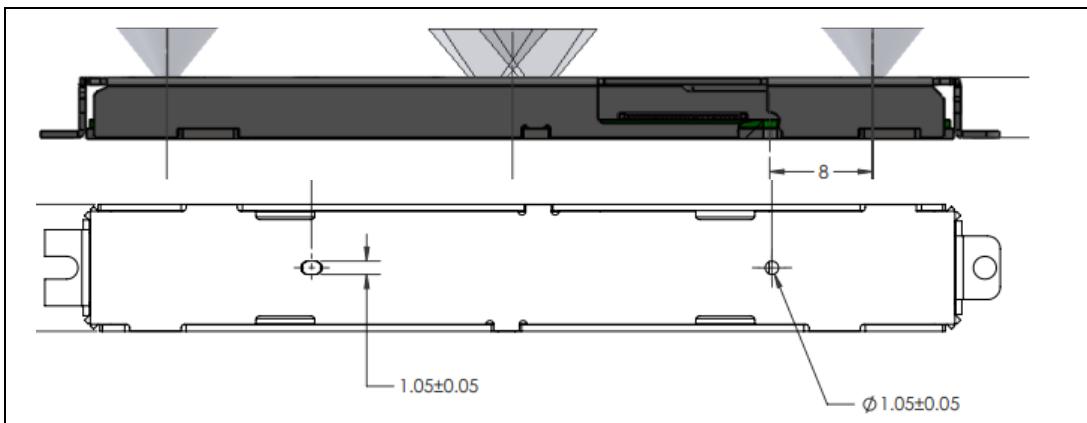
**Note:**

1. If depth measurement reference is front cover glass, then |Z'| should be added to measured value to determine Ground Truth

#### 4.8.1 Depth Origin X-Y Coordinates

The depth origin X-Y coordinates are the X-Y center of the left imager.

**Figure 4-5. Depth Module X-Y Depth Origin Reference – D410, D415, D430, D450**



**Table 4-17. Depth Module X-Y Depth Origin Coordinates**

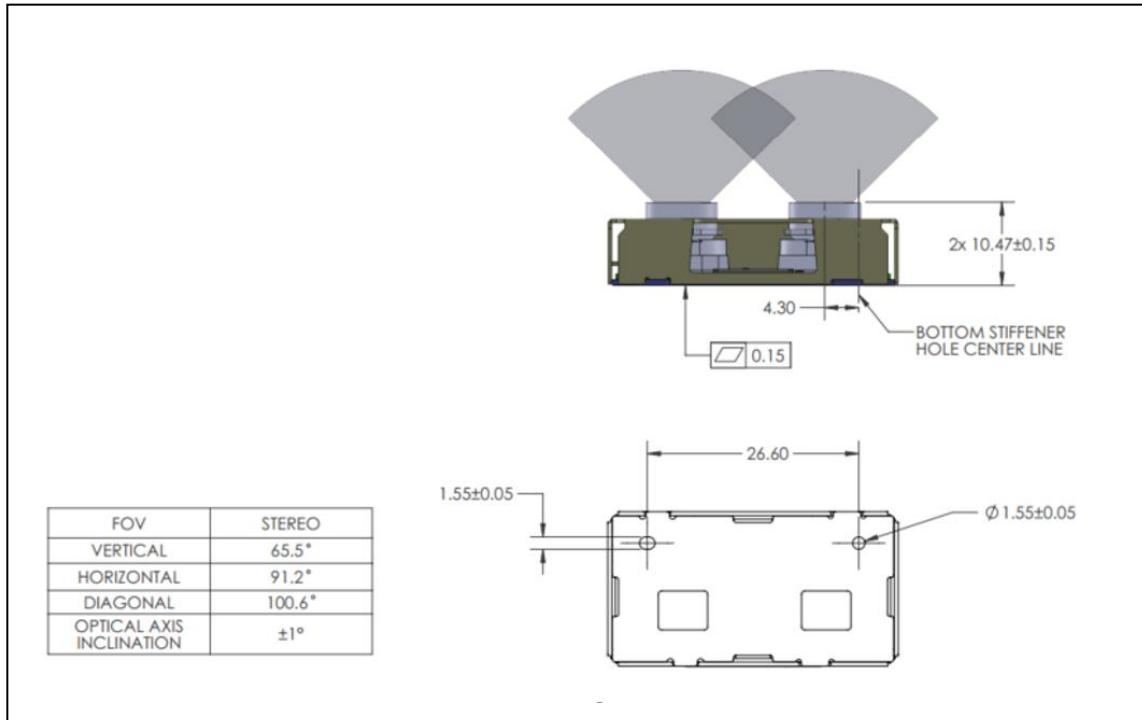
| Depth Module | Left Alignment Hole <sup>1</sup> to Left Imager Center |
|--------------|--|
| D410         | 8 mm   |
| D415         | 8 mm   |
| D430         | 8 mm   |

|      |         |
|------|---------|
| D450 | 12.2 mm |
|------|---------|

**Notes:**

1. Left alignment hole on bottom stiffener of depth module
2. Left alignment hole and left imager center is on depth module centerline

**Figure 4-6. Depth Module X-Y Depth Origin Reference – D401**



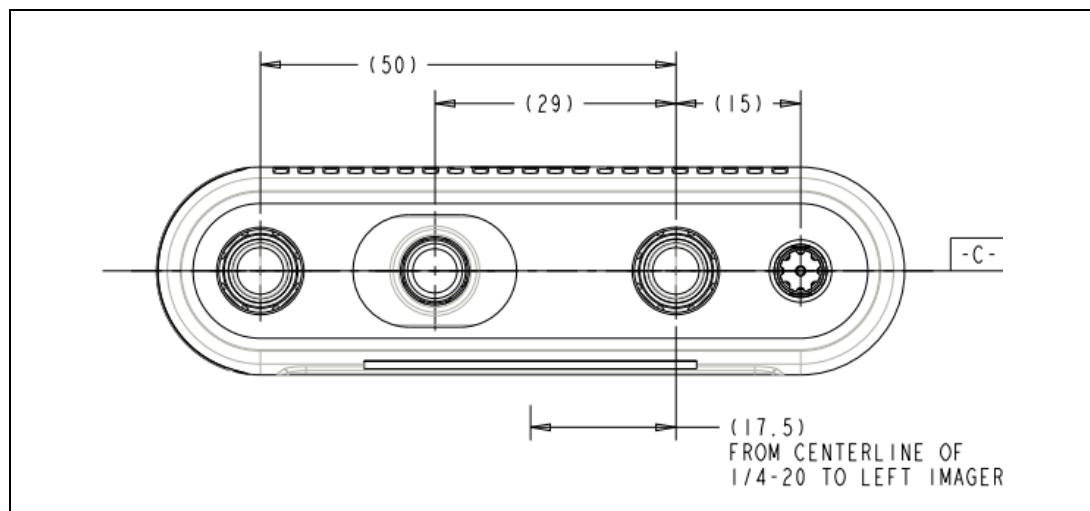
**Table 4-18. Depth Module X-Y Depth Origin Coordinates – D401**

| Depth Module | Left Alignment Hole <sup>(1,2)</sup> to Left Imager Center <sup>(2)</sup> |
|--------------|---|
| D401         | X - 4.3 mm, Y - 8.5 mm  |

**Notes:**

- (1) Left alignment hole on bottom stiffener of depth module
- (2) Left alignment hole and left imager center is on depth module centerline

**Figure 4-7. Depth Camera X-Y Depth Origin Reference – D415, D435/D435i/D435f/D435if, D455/D455f/D456**



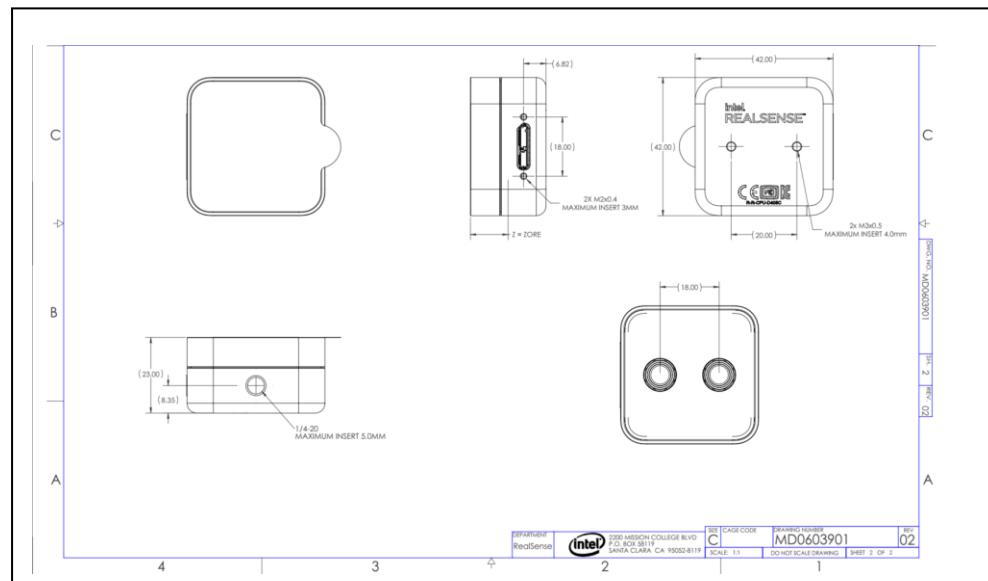
**Table 4-19. Depth Camera X-Y Depth Origin Coordinates**

| Depth Camera            | From Centerline of 1/4-20 <sup>(1)</sup> To Left Imager |
|-------------------------|---|
| D415                    | 20 mm   |
| D435/D435i/D435f/D435if | 17.5 mm   |
| D455/D455f/D456         | 47.5 mm   |

**Note:**

(1) Center of tripod mounting hole (1/4-20)

**Figure 4-8. Depth Camera X-Y Depth Origin Reference – D405**



**Table 4-20. Depth Camera X-Y Depth Origin Coordinates – D405**

| Depth Camera | From Centerline of 1/4-20 <sup>(1)</sup> To Left Imager |
|--------------|---|
| D405         | 9 mm  |

**Note:**

(1) Center of tripod mounting hole (1/4-20)

## 4.9 Depth Camera Functions

D4 exposes the following Depth image settings.

**Table 4-21. Depth Camera Controls**

| Control                                    | Description                              | Min | Max |
|--|--|-----|-----|
| Manual Exposure <sup>(1)</sup> (ms)        | Control sensor exposure period (400/410) | 1   | 166 |
| Manual Exposure <sup>(1)</sup> (ms)        | Control sensor exposure period (430)     | 1   | 166 |
| Manual Gain <sup>(1)</sup> (Gain 1.0 = 16) | Control sensor digital gain              | 16  | 248 |
| Laser Power (On/Off) (On = 1)              | Power to IR Projector                    | 0   | 1   |
| Manual Laser Power (mW)                    | Laser Power setting (30 mW steps)        | 0   | 360 |

| Control                            | Description  | Min                      | Max                                |
|------------------------------------|--|--------------------------|------------------------------------|
| Auto Exposure Mode<br>(Enable = 1) | Auto Exposure Mode. When Auto Exposure is enabled, Exposure and Gain are set based on the environment condition. | 0                        | 1                                  |
| Auto Exposure ROI                  | Perform Auto Exposure on a selected ROI  | T-0<br>L-0<br>B-1<br>R-1 | T-719<br>L-1279<br>B-720<br>R-1280 |
| Preset                             | Set Controls parameters based on Camera Usage  |                          |                                    |
| Meta Data Control                  | Enable/Disable Metadata  | 0                        | 1                                  |

**Note:**

- (1) Not supported in Auto Exposure Mode

**Definitions:**

- T = Top, L = Left, B = Bottom, R = Right

## 4.10 Color Camera Functions

**Table 4-22. RGB Exposed Controls**

| Control              | Description   | Min                      | Max                                  |
|----------------------|---|--------------------------|--------------------------------------|
| Auto-Exposure Mode   | Automatically sets the exposure time and gain for the frame               | 0x1                      | 0x8                                  |
| Auto Exposure ROI    | Perform Auto Exposure on a selected ROI                                   | T-0<br>L-0<br>B-1<br>R-1 | T-1079<br>L-1919<br>B-1080<br>R-1920 |
| Manual Exposure Time | Sets the absolute exposure time when auto-exposure is disabled            | 1                        | 10000                                |
| Brightness           | Sets the amount of brightness applied when auto-exposure is enabled       | -64                      | 64                                   |
| Contrast             | Sets the amount of contrast based on the brightness of the scene          | 0                        | 100                                  |
| Gain                 | Sets the amount of gain applied to the frame if auto-exposure is disabled | 0                        | 128                                  |
| Hue                  | Sets the amount of hue adjustment applied to the frame                    | -180                     | 180                                  |
| Saturation           | Sets the amount of saturation adjustment applied to the frame             | 0                        | 100                                  |

| Control                              | Description   | Min  | Max  |
|--------------------------------------|---|------|------|
| Sharpness                            | Sets the amount of sharpening adjustment applied to the frame           | 0    | 100  |
| Gamma                                | Sets amount of gamma correction applied to the frame                    | 100  | 500  |
| White Balance Temperature Control    | Sets the white balance when AWB is disabled                             | 2800 | 6500 |
| White Balance Temperature Auto (AWB) | Enables or disables the AWB algorithm                                   | 0    | 1    |
| Power Line Frequency                 | Specified based on the local power line frequency for flicker avoidance | 0    | 3    |
| Backlight Compensation               | Sets a weighting amount based on brightness to the frame                | 0    | 1    |
| Low Light Comp                       | Low Light Compensation  | 0    | 1    |

**Definitions:**

- T = Top, L = Left, B = Bottom, R = Right

## 4.11 IMU Specifications

**Table 4-23. IMU Specifications – BMI055**

| Camera   | Parameter                                | Properties     |
|--|--|----------------|
| Intel® RealSense™ Depth Camera D435i, Intel® RealSense™ Depth Camera D455<br><br>Intel® RealSense™ Depth Module D430+Intel® RealSense™ Vision Processor D4 Board V2 <sup>(3)</sup><br><br>Intel® RealSense™ Depth Module D450+Intel® RealSense™ Vision Processor D4 Board V3 | Degrees of Freedom                       | 6              |
|  | Acceleration Range                       | ± 4 g          |
|  | Accelerometer Sample Rate <sup>(1)</sup> | 62.5, 250 (Hz) |
|  | Gyroscope Range                          | ± 1000 deg/s   |
|  | Gyroscope Sample Rate <sup>(2)</sup>     | 200, 400 (Hz)  |
|  | Sample Timestamp Accuracy                | 50 µsec        |

**Notes:**

- (1) The sample rate may differ from the absolute specified sample rate by ± 5%. It is advisable to rely on the sample timestamp.
- (2) The sample rate may differ from the absolute specified sample rate by ± 0.3%
- (3) Intel® RealSense™ Depth Module D430 + Intel® RealSense™ Vision Processor D4 Board V2 and V3 with the BMI055 IMU are no longer available. The BMI085 IMU replaced the BMI055. See PCN #118035 – 00 and Table 4-24 below.

**Table 4-24. IMU Specifications – BMI085**

| Camera | Parameter          | Properties |
|--------|--------------------|------------|
|        | Degrees of Freedom | 6          |

| <b>Camera</b>   | <b>Parameter</b>                         | <b>Properties</b> |
|---|--|-------------------|
| Intel® RealSense™ Depth Camera D435i, Intel® RealSense™ Depth Camera D455<br>Intel® RealSense™ Depth Module D450+Intel® RealSense™ Vision Processor D4 Board V3 | Acceleration Range                       | ±4 g              |
|   | Accelerometer Sample Rate <sup>(1)</sup> | 100, 200 (Hz)     |
|   | Gyroscope Range                          | ±1000 deg/s       |
|   | Gyroscope Sample Rate <sup>(2)</sup>     | 200, 400 (Hz)     |
|   | Sample Timestamp Accuracy                | 50 µsec           |

**Notes:**

- (1) The sample rate may differ from the absolute specified sample rate by ± 5%. It is advisable to rely on the sample timestamp.
- (2) The sample rate may differ from the absolute specified sample rate by ± 0.3%

# 5 Firmware

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The firmware contains the Vision Processor D4's operating instructions. Upon bootup, Vision Processor D4 loads the firmware and programs the components' registers. If the Vision Processor D4 is configured for update or recovery, the unlocked R/W region of the firmware can be changed.

## 5.1 Update

During a firmware update, the firmware utility will issue a device firmware update command to the Vision Processor D4. The Vision Processor D4 will then reset into firmware update mode. The firmware utility uses a single binary file to maintain the firmware image. The firmware utility compares the firmware version installed on the camera to the firmware version file to be updated. Based on the comparison, the firmware utility will downgrade, upgrade, or skip if the versions match.

### 5.1.1 Update Limits

The firmware update engine does not allow infinite update cycles between older and current versions of firmware. The engine will establish a baseline version of firmware based on the latest firmware version installed. The engine will allow a return to a previous version or baseline version of firmware up to 20 times. After the 20th update, the engine will only allow an update to a firmware revision higher than the baseline version.

## 5.2 Recovery

A read-only boot sector is built into firmware which enables basic operation regardless of the integrity of the operating instructions region. This ensures that the imaging system can still function if the update fails or is corrupted. When firmware recovery is required, the firmware utility will communicate with the recovery driver to set the DFU pin low and reset the imaging system to recovery mode.

Firmware Recovery can also be externally triggered via a controllable interrupt connected to the Vision Processor D4 DFU (Device Firmware Update) pin.

The firmware recovery sequence will be triggered by the firmware client utility. This client utility will communicate through ACPI \_DSM to trigger the controllable interrupt (GPIO) at the appropriate times. The firmware recovery requires an ACPI \_DSM interface to control the interrupt GPIO in configuring to firmware recovery state. The ACPI\_DSM methods and BIOS use the Write to GPIO functions to set the controllable interrupt.

# 6 Software

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## 6.1 Intel® RealSense™ Software Development Kit 2.0

Intel® RealSense™ SDK 2.0 is a cross-platform library for working with Intel® RealSense™ D400 Series cameras. It is open source and available on <https://github.com/IntelRealSense/librealsense>

The SDK includes:

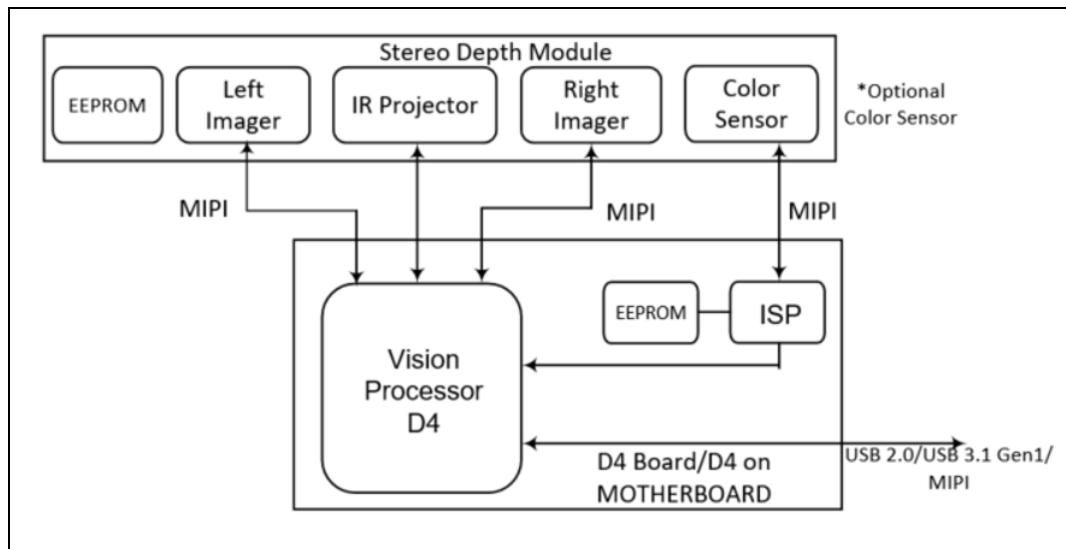
- **Intel® RealSense™ Viewer** - This application can be used view, record, and play back depth streams, set camera configurations, and adjust other controls.
- **Depth Quality Tool** - This application can be used to test depth quality, including: distance to plane accuracy, Z accuracy, standard deviation of the Z accuracy and fill rate.
- **Debug Tools** - These command line tools gather data and generate logs to assist in debug of the camera.
- **Code Examples** - Examples to demonstrate the use of SDK and to enable inclusion of D400 Series camera code snippets into applications.
- **Wrappers** -Software wrappers supporting common programming languages and environments such as ROS, Python, MATLAB, node.js, LabVIEW, OpenCV, PCL, .NET and more.

# 7 System Integration

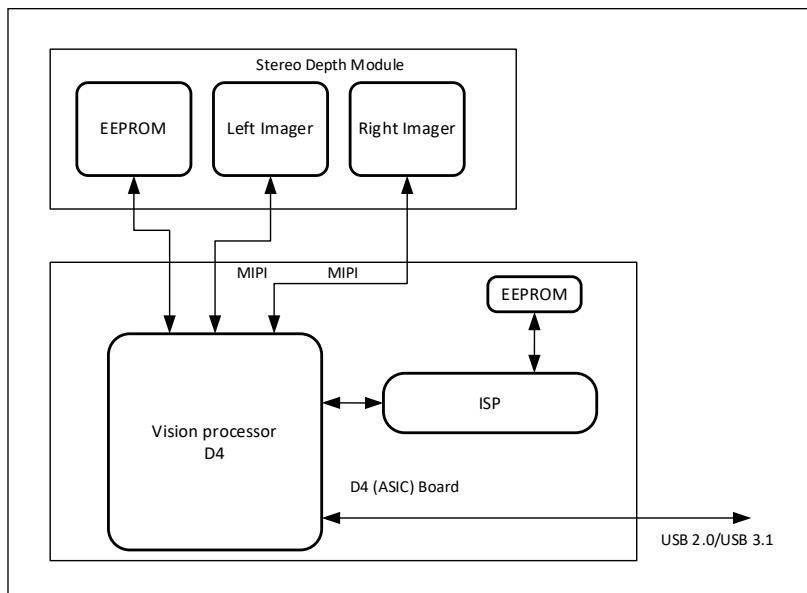
The small size of the stereo depth module and the independent placement of Vision Processor D4 provides system integrators flexibility to design into a wide range of products. Because the camera uses stereo vision technology, it is crucial that the stereo depth module does not flex throughout its service life. This creates unique mechanical and thermal implementation guidance. This section explains how to correctly integrate D4 depth camera into a system.

## 7.1 System Level Block Diagram

Figure 7-1. System Block Diagram – D415, D435, D435i, D455



**Figure 7-2. System Block Diagram – D405**



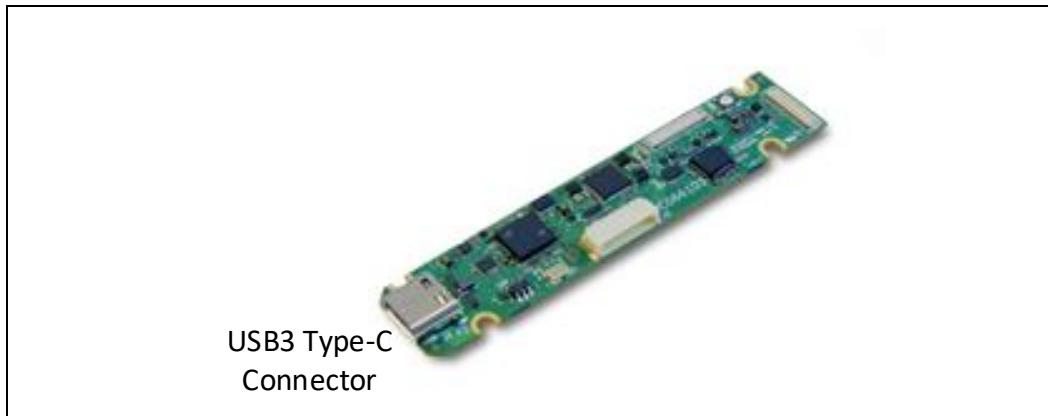
## 7.2 System Level Block Diagram

There are two options to integrate Vision Processor D4 into a system: integration of the Vision Processor D4 Board or by placing the Vision Processor D4 and support components directly on the host processor motherboard. The Vision Processor D4 Board simplifies system design and integration of the D4 depth camera system, whereas integrating the Vision Processor D4 onto the motherboard allows for a space optimized implementation.

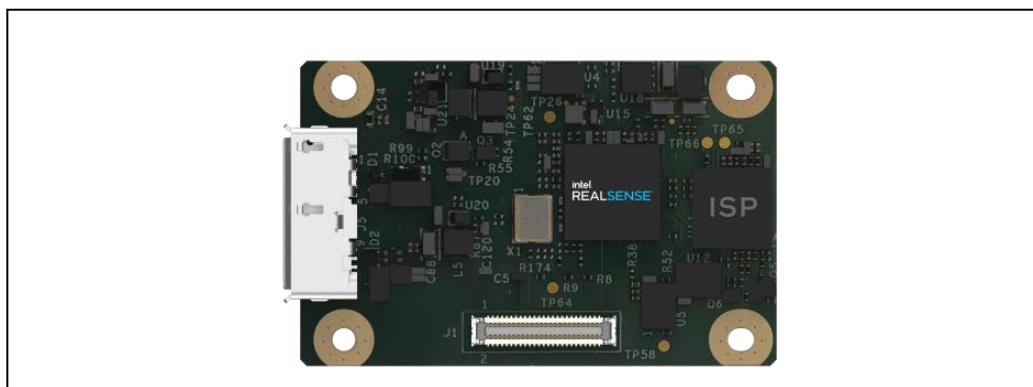
### 7.2.1 Vision Processor D4 Board

The Vision Processor D4 Board has a standard USB Type-C connector and requires an appropriate USB Type-C cable to connect to a standard USB 2.0/USB 3.1 Gen 1 external port.

**Figure 7-3. Intel® RealSense™ Vision Processor D4 Board – V1, V3**



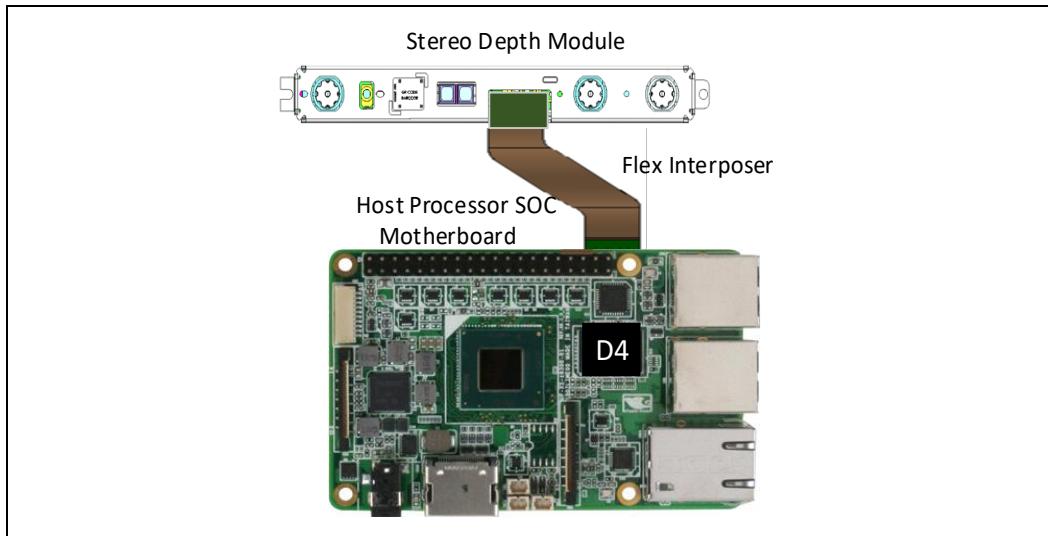
**Figure 7-4. Intel® RealSense™ Vision Processor D4 Board – V4**



### 7.2.2 Vision Processor D4 on Motherboard

In the Vision Processor D4 on Motherboard option, Vision Processor D4 and support components are directly placed on the host processor motherboard. The depth module receptacle is on the host processor motherboard for connection to the stereo depth module.

**Figure 7-5. Vision Processor D4 on Motherboard (Illustration)**



#### 7.2.2.1 Firmware Update

The SPI flash chip assembled onto the motherboard requires a bootable firmware image for Vision Processor D4 to boot or to run the firmware update utility provided by Intel.

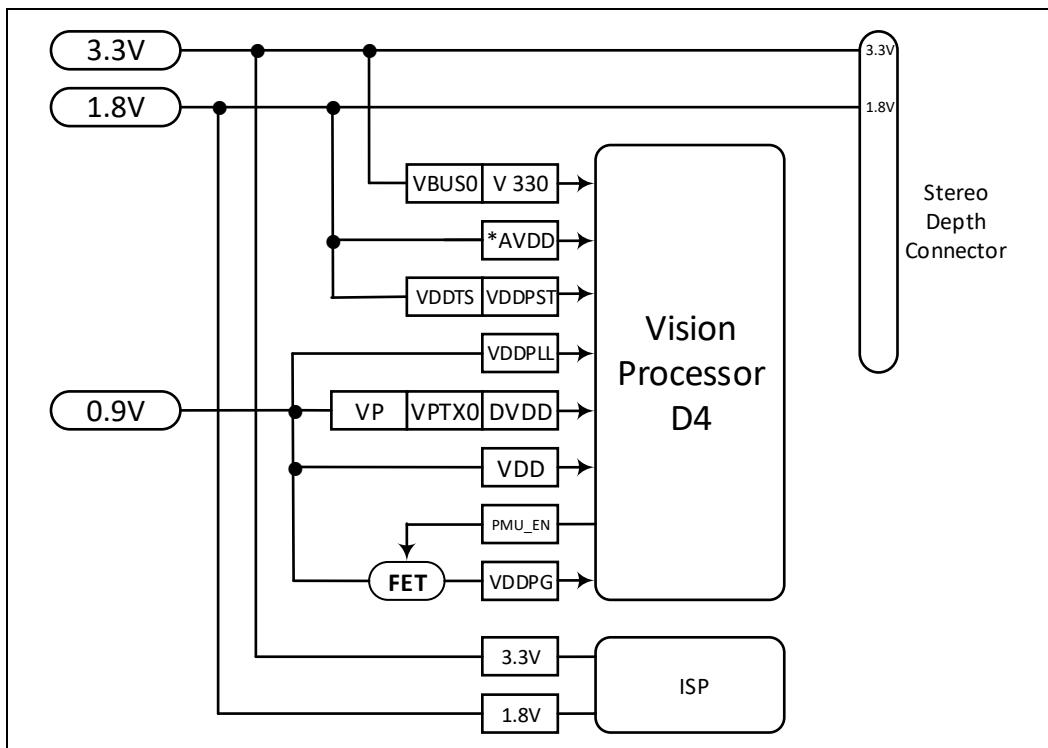
There are two implementation options:

1. Pre-program SPI flash chip with firmware before assembly on to motherboard or replace corrupt image with a good image SPI flash chip. The blank SPI flash chip can pre-programmed using a compatible adapter (i.e., PA8QFN8D) and supporting flash programmer.
2. A header or test points is connected in parallel to the SPI flash chip, then programmed directly with an SPI flash programmer. Vision Processor D4 SPI interface is put in high Z state by strapping EPGPIO4 pin to Ground when programmed directly with an SPI flash programmer.

### 7.3 D4 Camera System Power Delivery

D4 camera system **MUST** keep stereo depth module and the Vision Processor D4 on the same power rails. The stereo depth module holds a safety region in EEPROM that is configured by the firmware's protected region code. Keeping all components on the same rail prevents malicious software reset of the stereo depth module without causing a reset to the ASIC. Through this protection we ensure that all the safety logic is kept locked as long as the device is active. Ensure that power delivery implementation recommendations in Chapter 12 are followed in the design of D4 camera system.

**Figure 7-6. D4 Camera System Power Scheme**



## 7.4 Thermals

The system thermal design must ensure that the component case temperatures are not exceeded. Thermal models for Vision Processor D4 Board and Depth Modules are available to conduct a thermal evaluation and validate the system thermal design.

A few notes for the power and TDP tables below:

1. Max Operating Mode at max resolution of the Depth and RGB imagers at 30 FPS
2. IR projector TDP is lower than power due to a lower percentage of energy dissipated as photonic emissions as opposed to heat
3. Voltage Regulator power is included as part of the individual component power

**Table 7-1. Vision Processor D4 Board V1/V2/V3 – Component Power and TDP at Max Operating Mode<sup>(1)</sup>**

| Component                | Power   | TDP     | Unit |
|--------------------------|---------|---------|------|
| Vision Processor D4      | 618     | 618     | mW   |
| Color Camera ISP         | 196.83  | 196.83  | mW   |
| Voltage Regulators/Other | 491.64  | 491.64  | mW   |
| All Components           | 1306.47 | 1306.47 | mW   |

**Table 7-2. Vision Processor D4 Board V4 – Component Power and TDP at Max Operating Mode<sup>(1)</sup>**

| Component                | Power | TDP  | Unit |
|--------------------------|-------|------|------|
| Vision Processor D4      | 878   | 878  | mW   |
| ISP                      | 165   | 165  | mW   |
| Voltage Regulators/Other | 187   | 187  | mW   |
| All Components           | 1230  | 1230 | mW   |

**Table 7-3. Stereo Depth Module (D410/D415) – Component Power and TDP at Max Operating Mode<sup>(1)</sup>**

| Component                   | Power  | TDP    | Unit |
|-----------------------------|--------|--------|------|
| Left Imager                 | 118.5  | 118.5  | mW   |
| Right Imager                | 118.5  | 118.5  | mW   |
| RGB Imager <sup>(1)</sup>   | 118.5  | 118.5  | mW   |
| IR Projector <sup>(2)</sup> | 1296   | 936    | mW   |
| EEPROM + Thermal Sensor     | 4      | 4      | mW   |
| All Components              | 1655.5 | 1295.5 | mW   |

**Notes:**

(1) Only applies to D415

(2) Only applies to D410 and D415

**Table 7-4. Stereo Depth Module (D430) – Component Power and TDP at Max Operating Mode<sup>(1)</sup>**

| Component               | Power | TDP  | Unit |
|-------------------------|-------|------|------|
| Left Imager             | 177   | 177  | mW   |
| Right Imager            | 177   | 177  | mW   |
| IR Projector            | 1620  | 1260 | mW   |
| EEPROM + Thermal Sensor | 4     | 4    | mW   |

|                |      |      |    |
|----------------|------|------|----|
| All Components | 1978 | 1618 | mW |
|----------------|------|------|----|

**Table 7-5. Stereo Depth Module (D450) – Component Power and TDP at Max Operating Mode<sup>(1)</sup>**

| Component               | Power | TDP  | Unit |
|-------------------------|-------|------|------|
| Left Imager             | 177   | 177  | mW   |
| Right Imager            | 177   | 177  | mW   |
| RGB Imager              | 177   | 177  | mW   |
| IR Projector            | 1620  | 1260 | mW   |
| EEPROM + Thermal Sensor | 4     | 4    | mW   |
| All Components          | 2155  | 1795 | mW   |

**Table 7-6. Stereo Depth Module (D401) – Component Power and TDP at Max Operating Mode<sup>(1)</sup>**

| Component                   | Power | TDP | Unit |
|-----------------------------|-------|-----|------|
| Left Imager <sup>(2)</sup>  | 124   | 124 | mW   |
| Right Imager <sup>(2)</sup> | 124   | 124 | mW   |
| EEPROM + Thermal Sensor     | 4     | 4   | mW   |
| Voltage Regulators          | 78    | 78  | mW   |
| All Components              | 330   | 330 | mW   |

**Note:**

- (2) Max. Operating Mode = Depth Resolution 848 x 480 @ 90 FPS, Color Resolution 848 x 480 @ 90 FPS

**Table 7-7. Stereo Depth Camera (D415) – Component Power and TDP at Max Operating Mode<sup>(1)</sup>**

| Component                 | Power   | TDP     | Unit |
|---------------------------|---------|---------|------|
| Left Imager               | 118.5   | 118.5   | mW   |
| Right Imager              | 118.5   | 118.5   | mW   |
| RGB Imager                | 118.5   | 118.5   | mW   |
| IR Projector              | 1296    | 936     | mW   |
| EEPROM + Thermal Sensor   | 4       | 4       | mW   |
| Vision Processor D4 Board | 1306.47 | 1306.47 | mW   |
| All Components            | 2961.97 | 2601.97 | mW   |

**Table 7-8. Stereo Depth Camera (D435/D435f/D435i/D435if) – Component Power and TDP at Max Operating Mode<sup>(1)</sup>**

| Component                 | Power   | TDP     | Unit |
|---------------------------|---------|---------|------|
| Left Imager               | 177     | 177     | mW   |
| Right Imager              | 177     | 177     | mW   |
| RGB Imager                | 118.5   | 118.5   | mW   |
| IR Projector              | 1620    | 1260    | mW   |
| EEPROM + Thermal Sensor   | 4       | 4       | mW   |
| Vision Processor D4 Board | 1306.47 | 1306.47 | mW   |
| All Components            | 3402.97 | 3042.97 | mW   |

**Table 7-9. Stereo Depth Camera (D455/D455f/D456) – Component Power and TDP at Max Operating Mode<sup>(1)</sup>**

| Component                 | Power   | TDP     | Unit |
|---------------------------|---------|---------|------|
| Left Imager               | 177     | 177     | mW   |
| Right Imager              | 177     | 177     | mW   |
| RGB Imager                | 177     | 177     | mW   |
| IR Projector              | 1620    | 1260    | mW   |
| EEPROM + Thermal Sensor   | 4       | 4       | mW   |
| Vision Processor D4 Board | 1306.47 | 1306.47 | mW   |
| All Components            | 3461.47 | 3101.47 | mW   |

**Note:**

- (1) Max. Operating Mode = Depth Resolution 1280 x 720 @ 30 FPS, Color Resolution - 1920 x 1080p @ 30FPS

**Table 7-10. Stereo Depth Camera (D405) – Component Power and TDP at Max Operating Mode<sup>(1)</sup>**

| Component                   | Power | TDP  | Unit |
|-----------------------------|-------|------|------|
| Left Imager <sup>(2)</sup>  | 124   | 124  | mW   |
| Right Imager <sup>(2)</sup> | 124   | 124  | mW   |
| EEPROM + Thermal Sensor     | 4     | 4    | mW   |
| Vision Processor D4 Board   | 1230  | 1230 | mW   |
| All Components              | 1482  | 1482 | mW   |

**Note:**

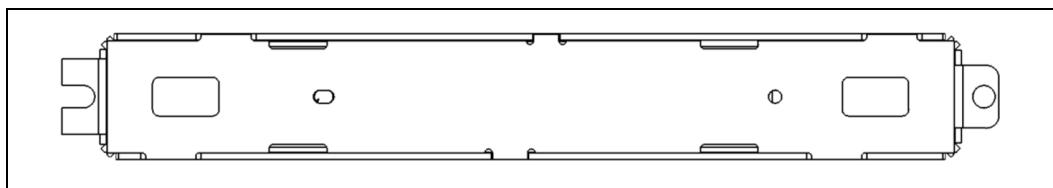
(1) Max. Operating Mode = Depth Resolution 848 x 480 @ 90 FPS, Color Resolution 848 x 480 @ 90 FPS

**Table 7-11. Vision Processor D4 Board Components – Case Temperature Limits (Still Air)**

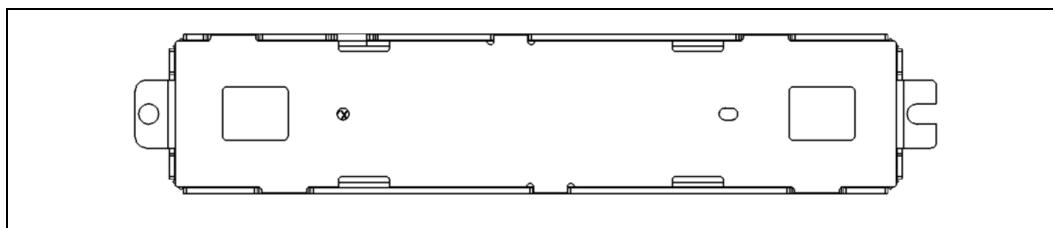
| Component           | Min | Max <sup>(1)</sup> | Unit |
|---------------------|-----|--------------------|------|
| Vision Processor D4 | 0   | 85                 | °C   |
| Color Camera ISP    | 0   | 70                 | °C   |

For the Depth Modules, case temperature is specified for the overall depth module and the thermocouple test location is any point on bottom metal stiffener

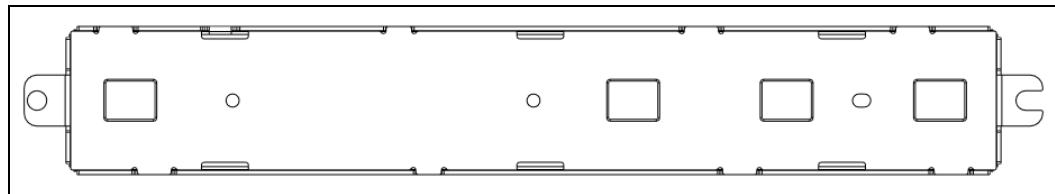
**Figure 7-7. Bottom Stiffener Depth Module D410/D415**



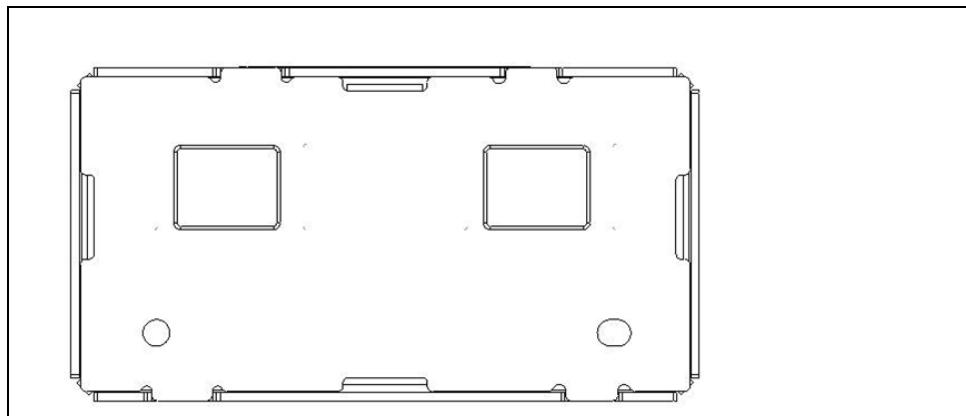
**Figure 7-8. Bottom Stiffener Depth Module D430**



**Figure 7-9. Bottom Stiffener Depth Module D450**



**Figure 7-10. Bottom Stiffener Depth Module D401**



## 7.5 Stereo Depth Module Flex

It is critical that the stereo depth module does not experience flex during system integration or during use after integration. Micron level flexing of the module can render the calibration incorrect and will result in poor performance or nonfunctional depth data. It is important for system designers to isolate the module from any chassis flex the system may encounter. While the module has a reinforcement housing, the housing is not intended to counter loads from chassis flex. The primary function of the housing is to prevent loss of calibration from handling and operating environments.

It is possible for the module to recover depth performance after experiencing permanent deformation. However, the module's ability to recover is dependent on the amount of deformation experienced.

It is required, due to the high probability that some flex will be experienced by the module during system integration, to perform an OEM calibration procedure after the stereo depth module is fully integrated into its final housing/location.

## 7.6 Stereo Depth Module Mounting Guidance

There are a few mounting options depending on the SKU. The sections below describe the various options.

## 7.6.1

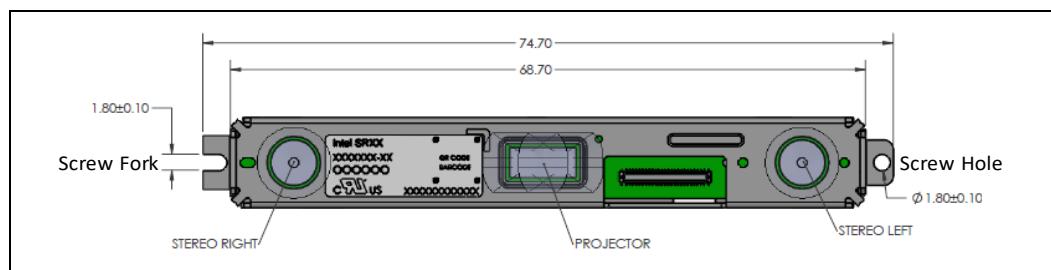
### Screw Mounting/End Mounting

This section applies to the following SKUs: D410, D430 and D450.

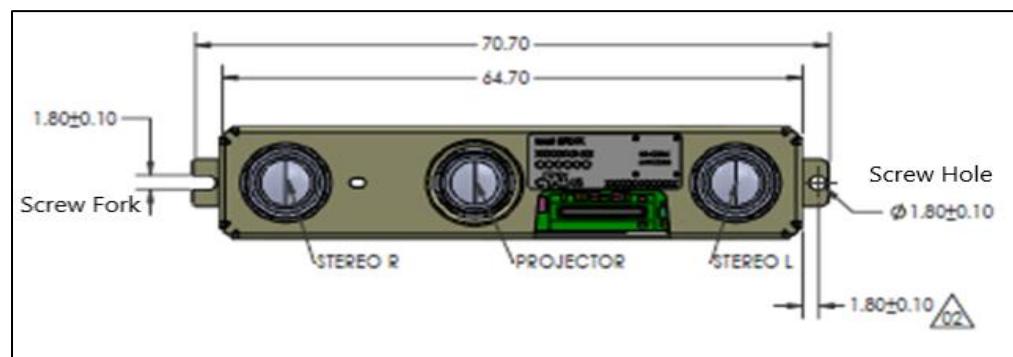
The stereo depth module incorporates a screw hole and a screw fork for module mounting. The stereo depth module should be mounted on a large heat sink or a heat dissipating structure element using a M1.6 screw at the screw hole and fork. The recommended torque for both screws is 1.6Kgf\*cm. Thermal interface material should be used on the backside region of the IR projector and the stereo imagers, between camera module and heat sink or heat dissipating structure being used for thermal transfer.

**Note:** Thermal double-sided adhesive is recommended.

**Figure 7-11. Stereo Depth Module Screw Mounting/End Mounting – D410**



**Figure 7-12. Stereo Depth Module Screw Mounting/End Mounting – D430**



**Note:**

1. For other SKUs, please refer to 10 Mechanical Drawings”.

## 7.6.2

### Bracket Mounting/Mid-Module Mounting

This section applies to all the D400 SKUs, including D415.

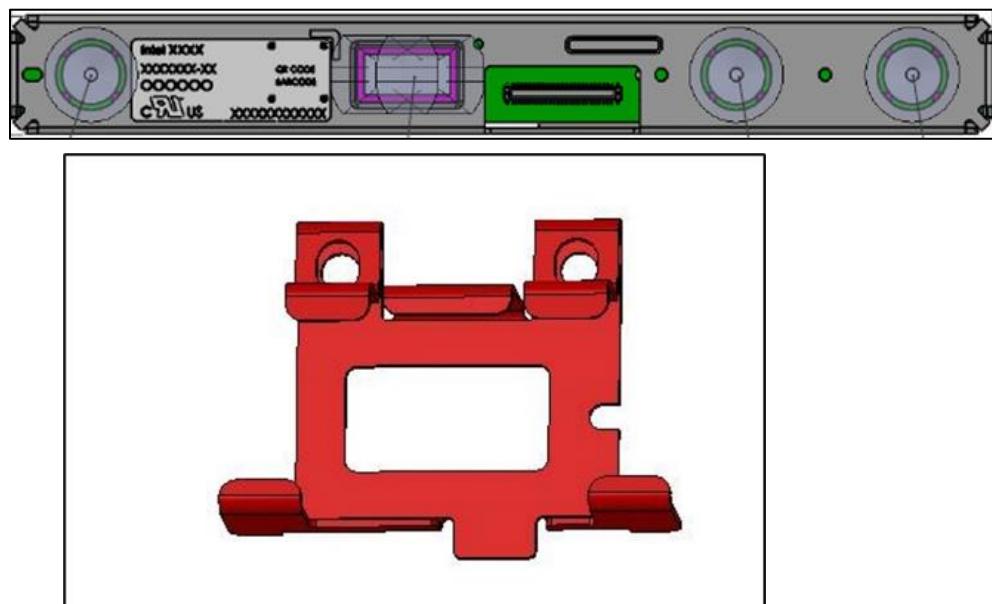
The Stereo Depth module should be mounted on large heat sink or a heat dissipating structure element using the bracket placed at the center of the module. The bracket is secured to the heat sink or structure element using screws. Thermal interface material should be used on the backside region of the IR projector and the two stereo imagers, between the camera module and the heat sink or heat dissipating structure being used for thermal transfer. The camera module should have a minimum of 0.2 mm clearance

from all sides except for the area around the bracket. It is not necessary to insert screws at the screw hole and screw fork when using a mounting bracket.

**Note:**

1. For larger modules, such as Intel® RealSense™ Depth Module D450, if a mounting bracket is used without the screw hole and fork method, it is recommended to use a large bracket

**Figure 7-13. Stereo Depth Module Bracket example for D415**

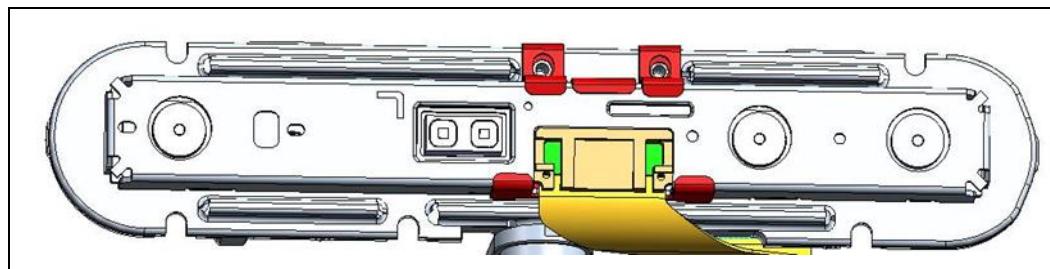


**Note:**

1. Intel does not sell these brackets; they are only used inside the Intel RealSense cameras.

The figure below demonstrates how the D415 module is mounted inside the D415 camera using a bracket.

**Figure 7-14. Stereo Depth Module Bracket Mount – D415**



**Figure 7-15. Stereo Depth Module Mid-Mounting – D401**

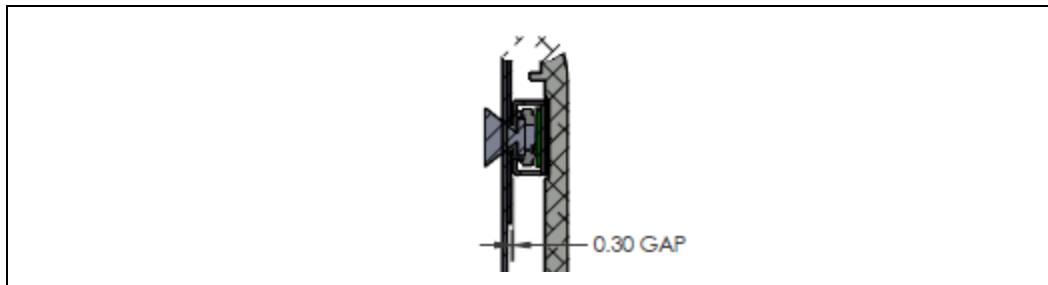


The Stereo Depth module should be mounted on a large heat sink or heat dissipating structure element using a structurally robust plastic bracket placed at the center of module. The bracket will provide surface pressure on the top face of the module. The bracket is secured to the heat sink or structure element using four M1.6 screws with recommended torque of 1.6 Kgf\*cm and double-sided tape in the center to prevent side displacement and to ensure permanent anchoring to the module before adding the four M1.6 screws. Thermal interface material should be used on heat sink or heat dissipating structure element, corresponding with the position of the two stereo imagers. The camera module should have a minimum of 0.2 mm clearance from all sides except for the area around the bracket. The module is precisely located and placed onto the heat sink by using 2 locating features: one precision pin and one locating slot-pin.

### **7.6.3 Stereo Depth Module Air gap**

A minimum air gap of 0.3 mm is recommended between the tallest components on the stereo depth module to the cover window

**Figure 7-16. Stereo Depth Module Air Gap**



## 7.7

### Thermal Interface Material

Thermal interface material, specifically thermal paste/grease is recommended to be inserted between the stereo depth module and the heat dissipating structure (heat sink) to improve the thermal coupling between these two components. A thermal paste with thermal conductivity in the 3 - 4 W/mK range is recommended. This paste must be applied in a thin layer on the back side of the IR projector and also under the left and right imagers, filling up the air gap under the imagers.

## 7.8

### Heat Sink

The heat sink or heat dissipating structure element used to mount the stereo depth module and ASIC Board should be a minimum of 2 – 3 mm in thickness. It is advisable to extend the heat sink by a few mm beyond the edges of the stereo depth module. It is also recommended to have thermal fins on the back side of the heat dissipating structure. In applications where weight is a concern, high thermal conductivity graphite tape can be attached to the back side of the heat sink. This graphite tape must be at least as big as the metal heat sink and extended out beyond the metal as much as possible for optimal cooling. Heat sink metal must be a high conductivity aluminum alloy or copper.

In cases where the module is expected to operate at high ambient temperatures, additional airflow may be required to ensure temperature limits are not exceeded. These are guidelines for thermal integration of the D4 camera in the system. However actual testing or system level thermal modeling is recommended before finalizing the solution.

## 7.9

### Cover Design and Material Guidance

The stereo depth module components must be covered to minimize dust and humidity. The transparent cover material stack-up used must provide acceptable transmission based on the component wavelengths. Anti-reflective coatings can help increase the transmission of the cover material. Cover material that reduces light transmission can result in poor depth performance and will decrease the working range of the camera. Nominally flat, non-distorting and low scattering cover material should be used.

**Table 7-12. Component Transmission**

| Component   | Wavelength  | Unit |
|---|---|------|
| Left and Right Imager (Intel® RealSense™ D410/D415/D430/D450) | 400 to 700 (Visible and Infrared) and 840 to 860 @ 95% transmission rate or higher at all viewing and transmitting angles | nm   |
| Left and Right Imager (Intel® RealSense™ D401)                | 400 to 900 (Visible and Infrared) @ 95% transmission rate or higher at all viewing and transmitting angles                | nm   |
| IR Projector  | 850nm ± 15 nm @ 98% transmission rate or higher at all viewing and transmitting angles                                    | nm   |

**Notes:**

1. Higher transmissions @ 98% transmission rate or higher is recommended and not a requirement
2. Intel RealSense Camera 400 Series provides control over laser power and sensor exposure. Minor loss of transmission due to cover material transmissivity might be compensated by increasing exposure when less light is able to reach the sensors and by increasing laser power for IR projector pattern projection loss.
3. Uncoated clear acrylic (plexiglass) plastic cover is an example for cover material
4. Anti-reflective coatings can help increase the transmission of cover material

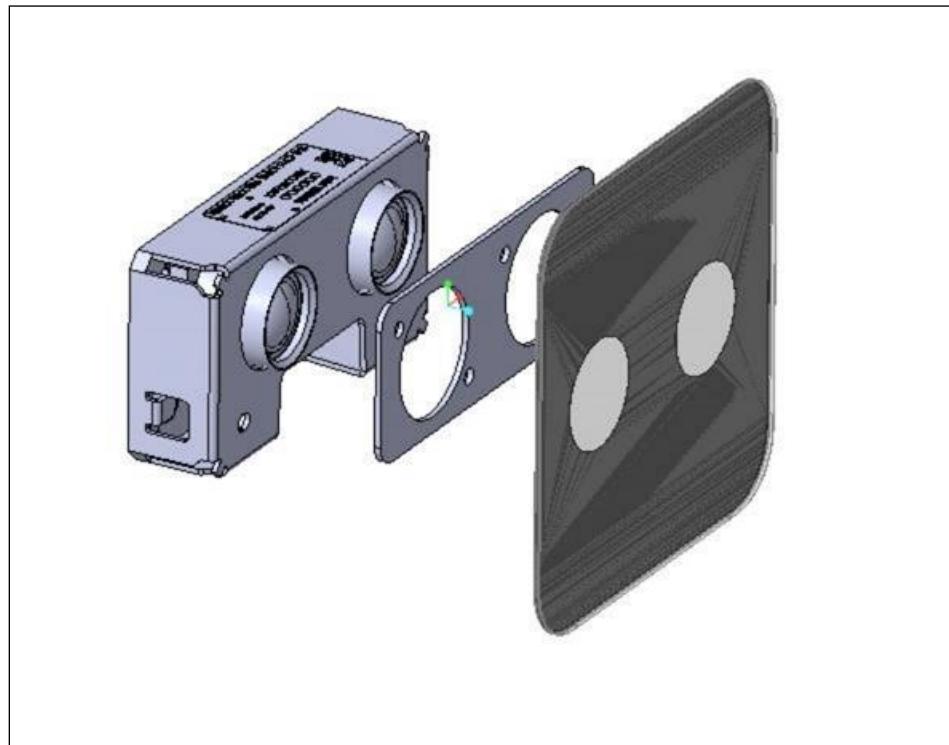
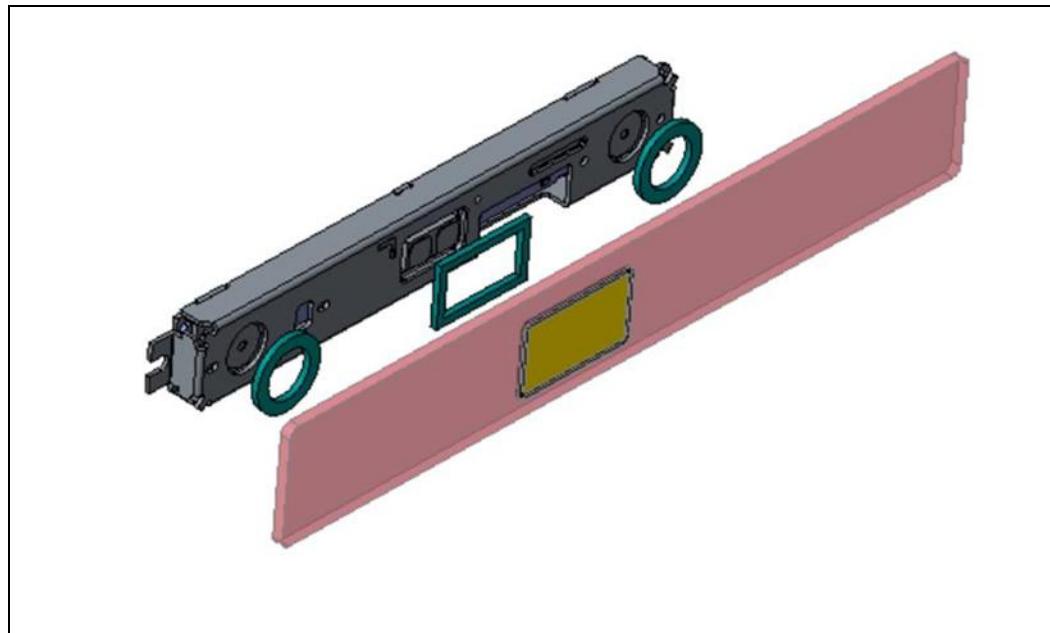
If different cover material is used in front of the cameras and the IR projector to maximize transmission based on component wavelengths, cover design considerations should ensure that the FOV of the cameras and FOP of the IR projector are not impacted.

## 7.10 Gaskets

Gaskets are recommended for providing optical isolation and dust protection. However, gaskets can impede FOV and place unwanted stress on the module or the individual sensor lens holders.

Gasket static force can deform the cosmetic baffle/lens holder resulting in poor image quality and permanent damage to the camera. Gaskets placed on the module stiffener can transfer chassis flex into the camera module causing loss of depth data. Gasket thickness has a large effect on the static force applied to the module surface. The thinner the seal, the greater the static force applied. Once the gasket is compressed, the static force will increase exponentially.

**Figure 7-17. Illustration of Gasket Placement and Cover Material**

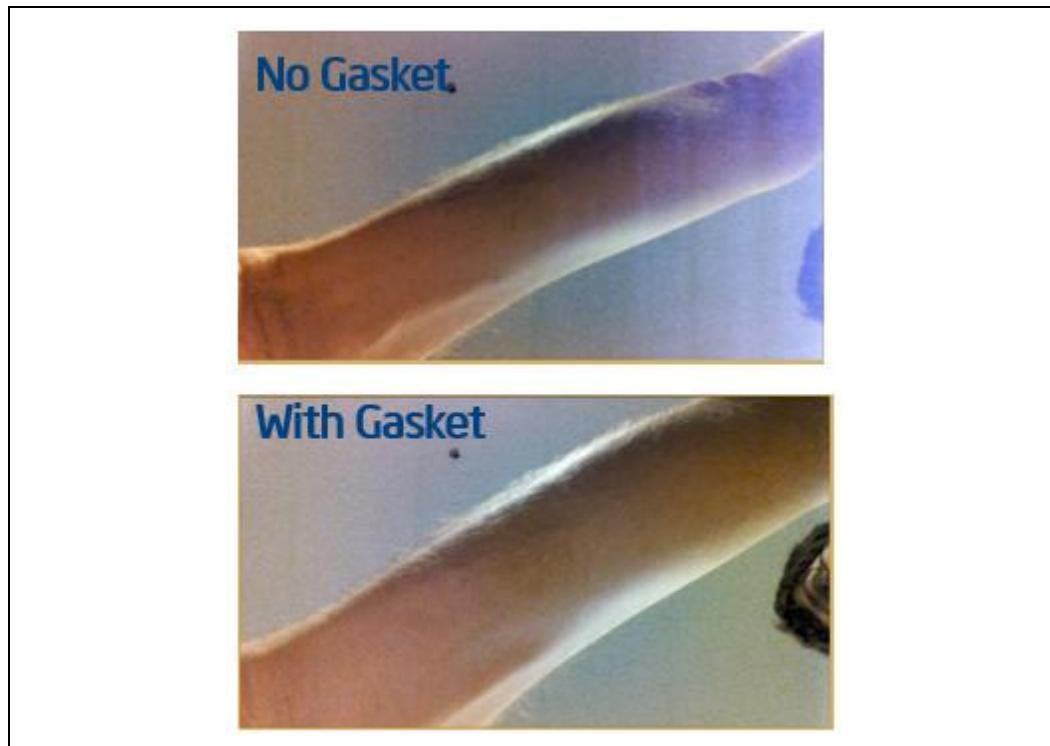


### **7.10.1 Optical Isolation**

It is recommended to isolate the left/right imagers and IR projector from each other to prevent reflections off the cover material. Not properly isolating the cameras can result in leakage light as shown in Figure 7-18. Example of Light Leakage Effects

To prevent light leakage, it is recommended to use a gasket material in between the cover holes and the module. The gasket material needs to be compliant so that it does not transmit chassis flex forces to the module.

**Figure 7-18. Example of Light Leakage Effects**



### **7.10.2 Dust Protection**

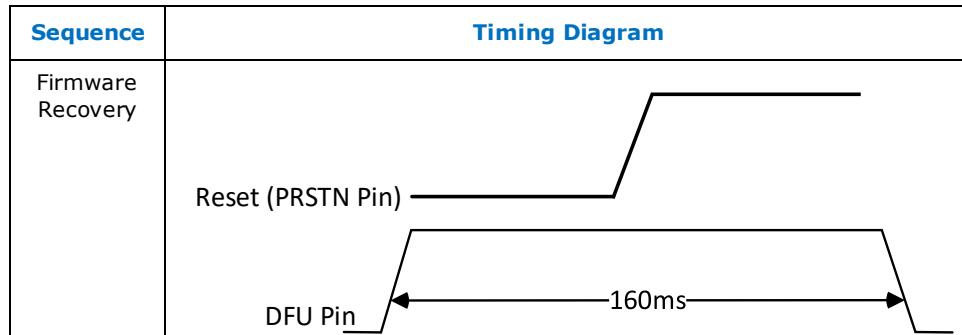
Dust particles can accumulate over the camera lenses which can be visually unappealing and degrade image quality.

## **7.11 Firmware Recovery**

To support firmware recovery, a 3.3 V controllable interrupt must be connected to the Vision Processor D4 DFU (Device Firmware Update) pin .

The ability to recover the image system if the firmware becomes corrupted requires the D4 reset and DFU pins driven high for 160 ms. The DFU pin should remain high when D4 is out of reset for D4 to boot in DFU mode. The 160 ms ensures that the DFU pin is held high throughout the reset sequence.

**Figure 7-19. Firmware Recovery Sequence**



## 7.12 Calibration Support

It is required to have an accessible USB port to access the host system. The accessible USB port would allow for reliable streaming of images to an external PC, to determine the calibration parameters and to write back these parameters via the host system.

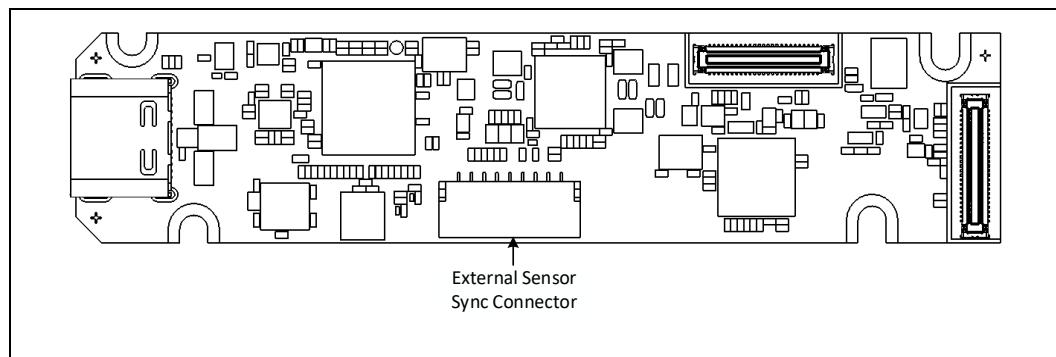
The USB port should be able to be configured in a mode where it can access the host. The access to USB port is required at manufacturing and is not intended to be available on the shipped product or accessible by the end user.

## 7.13 Multi-Camera Hardware Sync

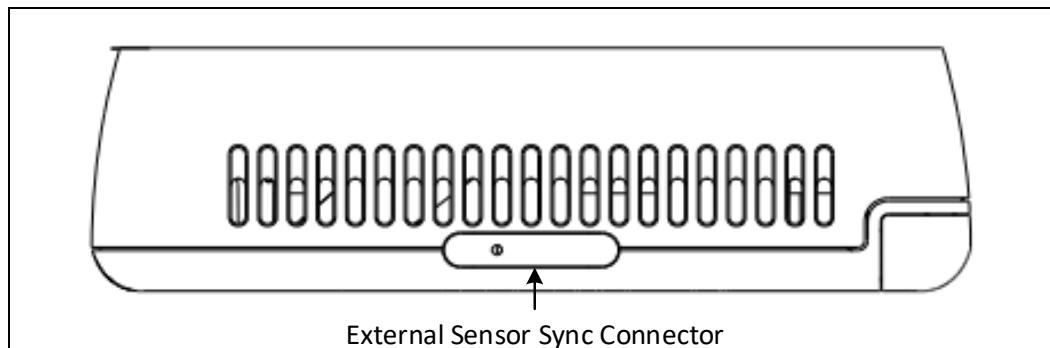
Intel® RealSense™ D400 Series supports a hardware sync signal for multi-camera configuration. For multiple cameras to be hardware synchronized so as to capture data at identical times and frame rates, pins 5 (SYNC) and pins 9 (Ground) on the external sensor sync connector will need to be connected. The external sensor sync connector is located on the Vision Processor D4 V1 and V3 board and is accessible on the Depth Cameras.

D405 does not support the hardware sync signal for multi-camera configuration.

**Figure 7-20. External Sensor Sync Connector Location on D4 Vision Processor V1 and V3 Board**



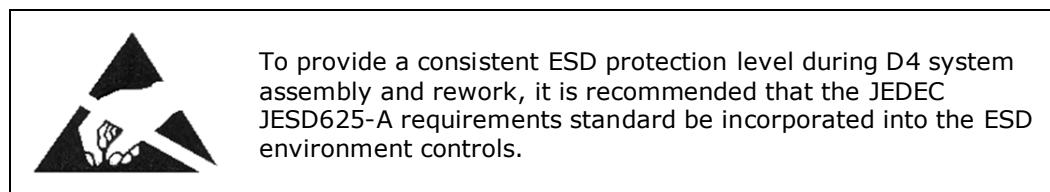
**Figure 7-21. External Sensor Sync Connector Location on Depth Camera D435/D435i/D455**



For additional details on how to implement the multi-camera hardware sync feature, please refer to multi-camera white paper at <https://realsense.intel.com/intel-realsense-downloads/#whitepaper>.

## 7.14 Handling Conditions

**Table 7-13. Electrostatic Discharge Caution**



§ §

# 8 Platform Design Guidelines

The Platform Design Guidelines have been developed to enable maximum flexibility for board designers while reducing the risk of board related issues. Design recommendations are based on Intel's simulations and are strongly recommended.

## 8.1

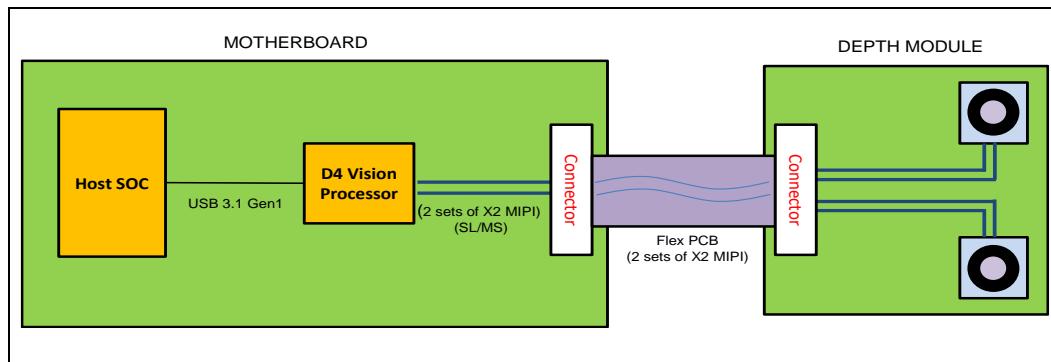
### Vision Processor D4 on Motherboard

This Design Guidelines provide Vision Processor D4 on motherboard implementation recommendations for the Kaby Lake U/Y (7th Generation Intel® Core™ Processors) and Cherry Trail T4 (Intel® Atom™ Z8000 Processor Series) platforms with 8/10 layer Type 4 PCB.

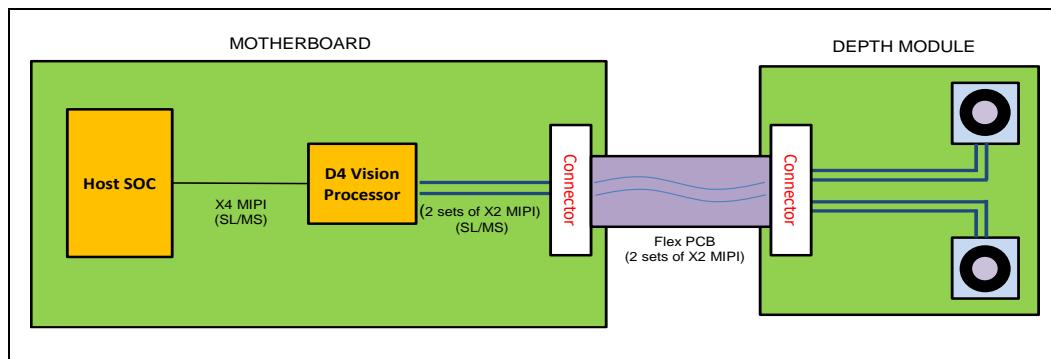
Supported platform topologies are:

1. Vision Processor D4 with USB Host Interface
2. Vision Processor D4 with MIPI Host Interface
3. Vision Processor D4 on Board for USB Integrated Peripheral

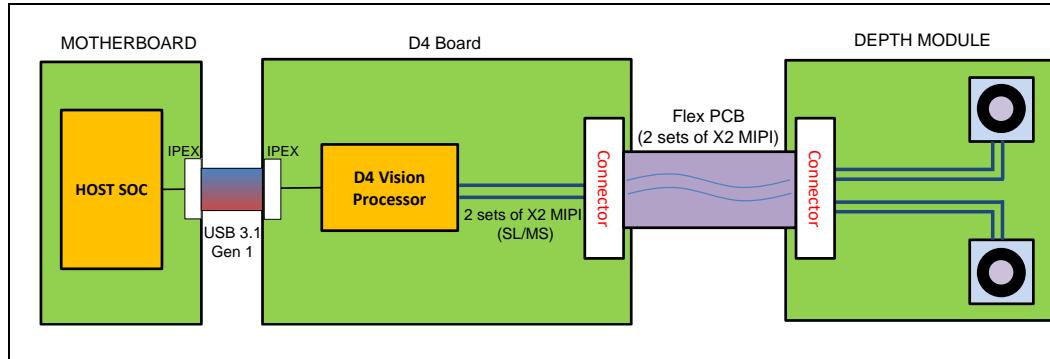
**Figure 8-1. Vision Processor D4 with USB Host Interface**



**Figure 8-2. Vision Processor D4 with MIPI Host Interface**



**Figure 8-3. Vision Processor D4 on Board for USB Integrated Peripheral**



## 8.2 Kaby Lake U and Kaby Lake Y platforms

### 8.2.1 Kaby Lake Platform Introduction

The Kaby Lake U platform consists of a Kaby Lake U processor plus a Kaby Lake Platform Controller Hub (PCH) in the same Multi Chip Package (MCP). Similarly, the Kaby Lake Y platform consists of a Kaby Lake Y processor plus a Kaby Lake PCH in the same Multi Chip Package (MCP).

**Note:**

1. For Kaby Lake U/Y platform design guidelines, refer to Kaby Lake U and Y Platform Design Guide (Doc# 561280)

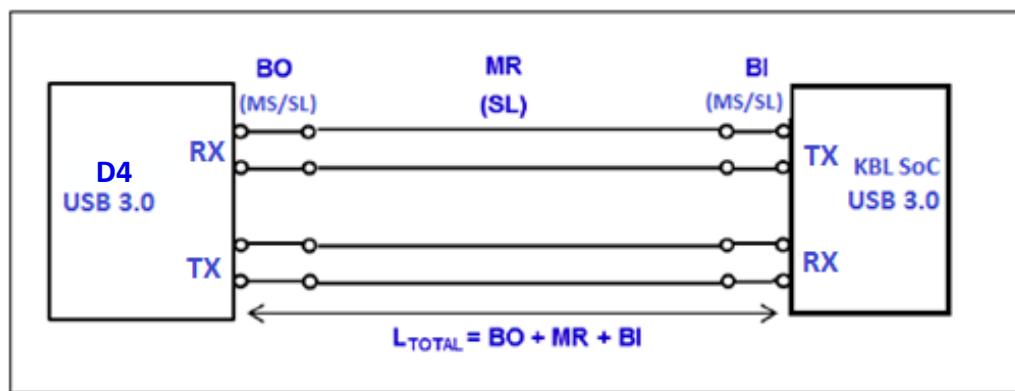
### 8.2.2 Supported PCB Stack-Up and Routing Geometries

Refer to Kaby Lake U/Y Platform Design Guide for type 4 PCB stack up, Break-out/Break-in geometries, Main Route stripline/microstrip geometries and Via recommendations. It is strongly recommended to follow the impedance criteria in the design guide for the given interface.

## 8.2.3 Vision Processor D4 on Motherboard with USB Host Interface

### 8.2.3.1 USB 3.1 Gen 1 Motherboard Routing

**Figure 8-4. Host Processor - Vision Processor D4**



**Table 8-1. Host Transmit – Vision Processor D4 Receive Routing Guidelines**

| Parameter                                   | Break-out (BO) | Main Route (MR) | Break-in (BI) | Total Allowed Length ( $L_{BO} + L_{MR} + L_{BI}$ ) |
|---|----------------|-----------------|---------------|---|
| Maximum Segment Length (Inches)             | 0.25           | 15-BO-BI        | 0.25          | 15  |
| Maximum Allowed Channel Insertion loss (dB) |                |                 |               | <=15 dB @ 2.5 MHz                                   |

**Table 8-2. Vision Processor D4 Transmit - Host Receive Routing Guidelines**

| Parameter                                   | Break-out (BO) | Main Route (MR) | Break-in (BI) | Total Allowed Length ( $L_{BO} + L_{MR} + L_{BI}$ ) |
|---|----------------|-----------------|---------------|---|
| Maximum Segment Length (Inches)             | 0.25           | 15-BO-BI        | 0.25          | 15  |
| Maximum Allowed Channel Insertion loss (dB) |                |                 |               | <=15 dB @ 2.5 MHz                                   |

#### Notes:

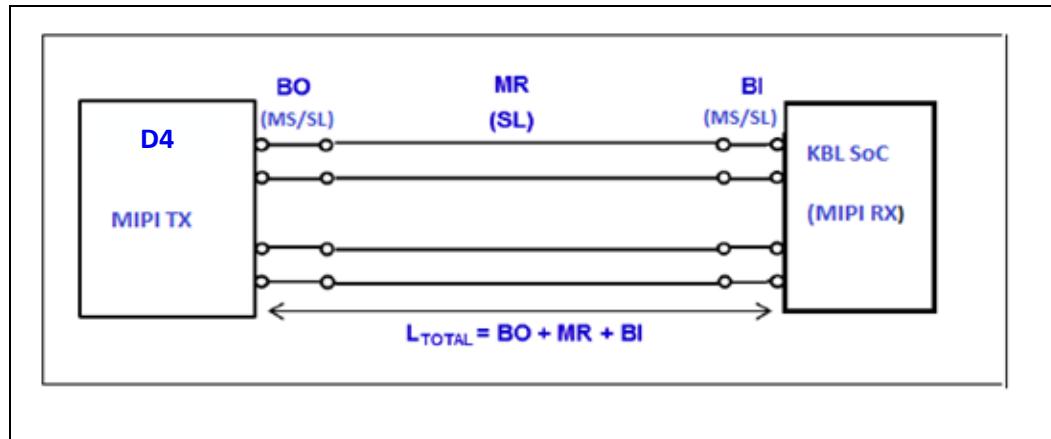
1. Simulation results shows that an overall 15-inch channel routing length is good for the USB 3.1 Gen 1 Vision Processor D4 to Host connection motherboard. This connection does not include any connector or cable.
2. All routing is recommended to be at an 85 ohm impedance

3. Break-out/break-in should be maximum length of 250 mil for 85 ohm routing. If there is any impedance variation due to narrow escape BGA break-out, the maximum routing length should be 150 mil.
4. Maximum number of via count: 4 (including package microvia)
5. It is strongly recommended that overall channel loss is within -15 dB for satisfactory performance

## 8.2.4 Vision Processor D4 on Motherboard with MIPI Host Interface

### 8.2.4.1 MIPI Motherboard Routing

**Figure 8-5. Vision Processor D4 Transmit - Host Receive**



**Table 8-3. Vision Processor D4 Transmit – Host Receive Routing Guidelines**

| Parameter                                   | Break-out (BO)    | Main Route (MR) | Break-in (BI) | Total Allowed Length (L_BO + L_MR + L_BI) |
|---|-------------------|-----------------|---------------|---|
| Maximum Segment Length (inches)             | 0.25              | 15-BO-BI        | 0.25          | 15  |
| Maximum Allowed Channel Insertion loss (dB) |                   |                 |               |   |
|   | <=5.5 dB @ 750MHz |                 |               |   |

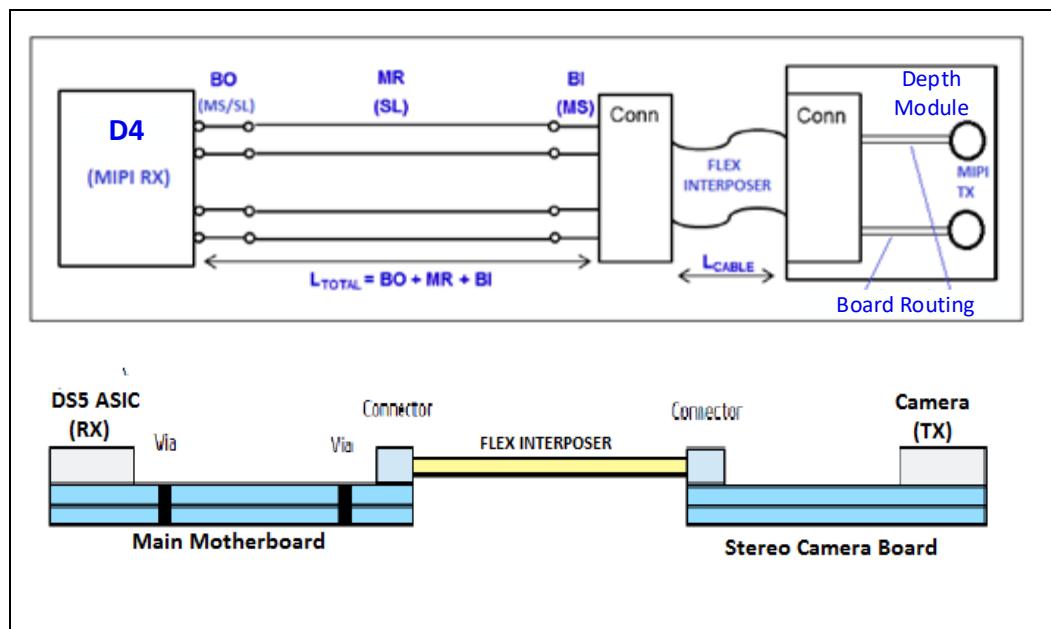
**Notes:**

1. Maximum via count = 4 vias including the first micro-via from package ball
2. Minimum stripline break-out pair-to-pair spacing of 2.36 mils is allowed near package ball out region with maximum length of 250 mils
3. Main route and break-in nominal impedance is required to be consistent. Example: 85 ohm main route and 85 ohm break-in. Mixture of nominal impedance is not recommended.
4. Length matching within a differential pair is +/- 5 mils maximum

5. The maximum allowed channel insertion loss budget dictates the total allowed length. The total insertion loss allowed for interconnect from the D4 package die bump to Kaby Lake SoC package die bump is about 5.5dB at 750 MHz. It should be noted that although only the insertion loss value at the fundamental frequency (750 MHz) is specified, the insertion loss curve up to about 1.5 GHz should be well behaved with no strong resonance or ripple.

### 8.2.4.2 MIPI Motherboard Routing (Stereo Depth Module Transmit to Vision Processor D4 Receive)

**Figure 8-6. Stereo Depth Transmit - Vision Processor D4 Receive**



**Table 8-4. Stereo Depth Module Transmit - Vision Processor D4 Receive Routing Guidelines**

| Parameter                                   | Break-out (BO) | Main Route (MR)                           | Break-in (BI) | Flex Interposer Length ( $L_{Cable}$ ) | Camera Board Length ( $L_{Camera}$ ) | Total Allowed Length ( $L_{MB} + L_{Cable} + L_{Camera}$ ) |
|---|----------------|---|---------------|--|--------------------------------------|--|
| Maximum Segment Length (Inches)             | 0.25           | 15 – $L_{Cable}$ – $L_{Camera}$ – BO – BI | 0.25          | 15-L_MB- $L_{camera}$                  | $L_{Camera}$ (max ~2 inches)         | 15   |
| Maximum Allowed Channel Insertion loss (dB) |                |   |               |  |                                      | <=5.5 dB @ 750MHz  |

**Notes:**

1. Stereo depth module MIPI routing length are assumed to be 2 inches (max)
2. Maximum via count = 3 vias including the first micro-via from package ball

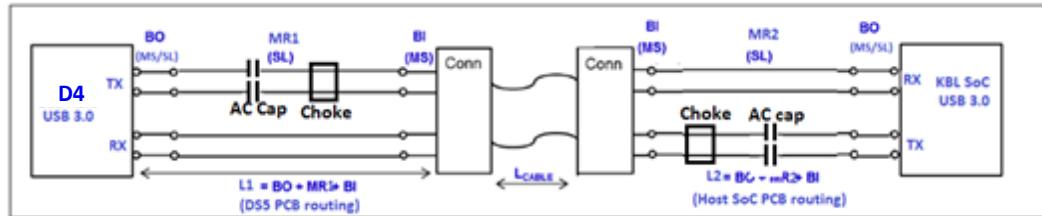
3. Minimum stripline break-out pair-to-pair spacing of 2.36 mils is allowed near package ball out region with maximum length of 250 mils
4. Main route and break-in nominal impedance is required to be consistent. Example: 85 ohm main route and 85 ohm break-in. Mixture of nominal impedance is not recommended.
5. Length matching within a differential pair is +/- 5 mils maximum
6. No length match requirements for signals routed to different camera modules
7. The maximum allowed channel insertion loss budget dictates the total allowed length. The total insertion loss allowed for interconnect from the package die bump to the connector on the camera module is about 5.5 dB at 750 MHz as shown in the table. This recommendation allows the use of any cable type as long as the maximum allowed insertion loss is met. It should be noted that although only the insertion loss value at the fundamental frequency (750 MHz) is specified, the insertion loss curve up to about 1.5 GHz should be well behaved with no strong resonance or ripple.
8. Flex Interposer recommendation: 85-100ohm impedance with maximum length of 4 - 6 inches. The recommended interposer should be Flex PCB based design.

**Figure 8-7. Flex Interposer PCB Stack-Up**

|         |            |        |           |
|---------|------------|--------|-----------|
| TOP     | CONDUCTOR  | COPPER | 0.984252  |
|         | DIELECTRIC | FR-4   | 2.578740  |
| 02_SIG1 | CONDUCTOR  | COPPER | 0.708661  |
|         | DIELECTRIC | FR-4   | 1.968500  |
| 03_PWR1 | CONDUCTOR  | COPPER | 0.708661  |
|         | DIELECTRIC | FR-4   | 31.771700 |
| 04_GND1 | CONDUCTOR  | COPPER | 0.708661  |
|         | DIELECTRIC | FR-4   | 1.968500  |
| 05_SIG2 | CONDUCTOR  | COPPER | 0.708661  |
|         | DIELECTRIC | FR-4   | 2.578740  |
| BOTTOM  | CONDUCTOR  | COPPER | 0.984252  |

## 8.2.5 Vision Processor D4 Board for Integrated Peripheral (USB 3.1 Gen 1 Host to Vision Processor D4 Routing)

**Figure 8-8. USB 3.1 Gen 1 Host to Vision Processor D4 Topology**



**Table 8-5. USB 3.1 Gen 1 Host to Vision Processor D4 Routing Guidelines**

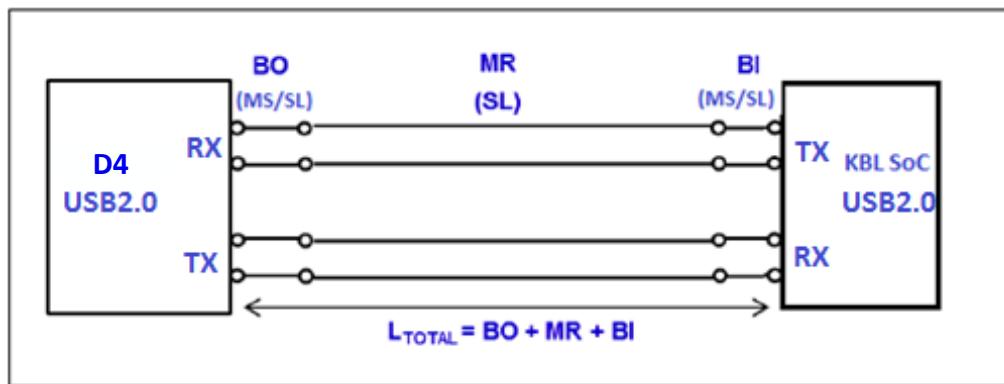
| Parameter                                   | Vision Processor D4 Board  |                    |                  | USB 3.1<br>Gen 1<br>Cable | Host Motherboard  |                    |                  |
|---|--|--------------------|------------------|---------------------------|-------------------|--------------------|------------------|
|   | Break-out<br>(BO)  | Main Route<br>(MR) | Break-in<br>(BI) | Cable Length<br>(L_Cable) | Break-out<br>(BO) | Main Route<br>(MR) | Break-in<br>(BI) |
| Maximum Segment Length (Inches)             | 0.25   | 2                  | 0.25             | 15 (max)                  | 0.25              | 5                  | 0.25             |
| Maximum Allowed Channel Insertion loss (dB) | $\leq 15 \text{ dB @ 2.5GHz}$<br>Max recommended USB 3.1 Gen 1 cable loss $\leq 7.5 \text{ dB @ 2.5GHz}$ |                    |                  |                           |                   |                    |                  |

**Notes:**

1. The maximum allowable motherboard routing of USB 3.1 Gen 1 signals on Host PCB should be 5 – 6 inches and routing on Vision Processor D4 Board should be 2 – 3 inches.
2. It is recommended that an 85 ohm common mode choke (CMC) be designed in-line with both the USB 3.1 Gen 1 signals. The CMC should be placed as close to the connector as possible.
3. It is required that a 0.1  $\mu\text{F}$  AC coupling capacitor is designed in series with both the USB 3.1 Gen 1 signals.
4. The USB 3.1 Gen 1 cable assembly should have a differential impedance of 85 Ohms with a tolerance of  $\pm 10\%$ .
5. The max cable length should not exceed 15 inch with target loss of 7.5 dB @ 2.5 GHz
6. Overall channel loss including cable should not exceed 15 dB @ 2.5 GHz

## 8.2.6 USB2.0 Design Guidelines (USB2 Host to Vision Processor D4 Routing)

**Figure 8-9. USB2.0 Host to Vision Processor D4**



| Parameter                                   | Break-out (BO) | Main Route (MR) | Break-in (BI) | Total Allowed Length (L_BO + L_MR + L BI) |
|---|----------------|-----------------|---------------|---|
| Maximum Segment Length (inches)             | 0.25           | 15-BO-BI        | 0.25          | 15  |
| Maximum Allowed Channel Insertion loss (dB) |                |                 |               |   |

**Notes:**

1. Simulation results shows that an overall 15 inch channel routing is good for USB 2.0 D4 to Host topology on motherboard. This topology does not include any connector or cable.
2. All routing is recommended to be 85 ohm
3. Break-out/break-in should be max of 250 mil for 85 ohm routing. If there is any impedance variation due to narrow escape BGA break-out, the max routing should be 150 mil.
4. Maximum number of via count: 4 (including package microvia)
5. It is strongly recommended that overall channel loss to be within -15dB for satisfactory performance

### 8.2.7 Ingress Protection Rating: IP65

D456 has been tested under IEC 60529 and found to be in compliance with IP6X dust test requirement and IPX5 water test requirement.

IP6X - 13.4/13.6 - Dust-Tight - Category 1, with under pressure

IPX5 - 14.2.5 Protected against Water Jets (6.3mm Spray Nozzle)

**Notes:**

- The USB connector is IP67 rated
- Use of the HW sync trigger via the 9 pin connector is not IP65 certified, therefore the cap covering it must be closed in order to retain the IP65 enclosure rating

## 8.3 Cherry Trail T4 Platform

### 8.3.1 Cherry Trail T4 Platform Introduction

The Cherry Trail T4 is the Intel Architecture (IA) SoC that integrates an Intel® processor core, graphics, memory controller, and I/O interfaces into a single system-on-chip solution.

**Note:** For Cherry Trail T4 platform design guidelines, please refer to Cherry Trail T4 Platform Design Guide. (Doc# 537901)

**Note:** Cherry Trail platform supports 2 SoC SKUs, T3 and T4. The Vision Processor D4 platform design guidelines discussed in this chapter are only applicable to the T4-based Cherry Trail platform. For information on the Cherry Trail T4 SoC, please refer to Intel® Atom™ Z8000 Processor Series - External Design Specification (EDS) (Doc# 539071)

## 8.3.2 Vision Processor D4 Platform Design Guidelines

The Vision Processor D4 platform design guidelines on the Cherry Trail T4 platform follow the same guidelines as specified for the Kaby Lake U and Y platforms.

### 8.3.2.1 Supported PCB Stack-Up and Routing Geometries

Refer to Cherry Trail T4 Platform Design Guide for Type 4 PCB stack up, Break-out/Break-in routing geometry, Main Route stripline/microstrip geometry and Via recommendations. It is strongly recommended to follow the impedance criteria in the design guide for the given interface.

# 9

# Regulatory Compliance

## 9.1 System Laser Compliance

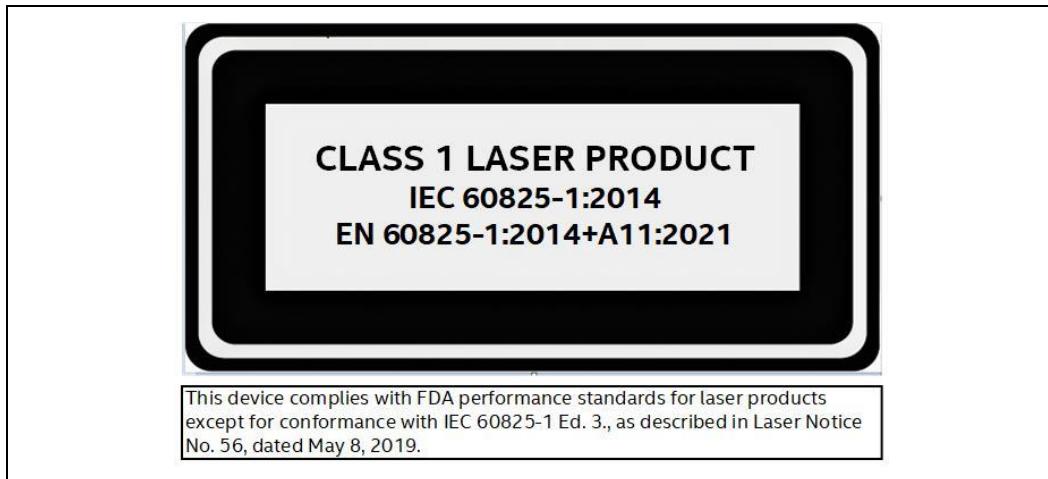
Certification for the Intel® RealSense™ Depth Cameras and Depth Modules, paired with Intel® RealSense™ Vision Processor D4 Board, following integration guidelines, is transferable to the system and no system recertification is required. However, the following statements and labels must be included in the user manual of the end product.

### 9.1.1 Certification Statement

This product is classified as a Class 1 Laser Product under the IEC 60825-1, Edition 3 (2014) internationally and EN 60825-1:2014+A11:2021 in Europe.

This product complies with FDA performance standards for laser products except for conformance with IEC 60825-1 Ed. 3 as described in Laser Notice No. 56, dated May 8, 2019.

### 9.1.2 Explanatory Label



### 9.1.3 Cautionary Statements



System integrators should refer to their respective regulatory and compliance owner to finalize regulatory requirements for a specific geography.



**Caution** - Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.



- Do not power on the product if any external damage was observed.
- Do not attempt to open any portion of this laser product. There are no user serviceable parts.
- Invisible laser radiation when opened. Avoid direct exposure to beam.
- There are no service/maintenance, modification, or disassembly procedures for the stereo module and infrared projector. The system integrator must either notify Intel or return modules before any failure analysis is performed.
- Modification or service of the stereo module, specifically the infrared projector, may cause the emissions to exceed Class 1.
- Do not try to update camera firmware that is not officially released for specific camera module SKU and revision.

## 9.1.4 US FDA Accession Number

**Table 9-1. U.S. FDA Accession Number**

| Component  | U.S. FDA accession numbers |
|--|----------------------------|
| Intel® RealSense™ Depth Module<br>D410/D415/D430/D450                          | 1420260                    |
| Intel® RealSense™ Depth Camera<br>D415/D435/D435f/D435i/D435if/D455/D455f/D456 | 1420260                    |

This accession number should be entered into Box B.1 of the Food and Drug Administration (FDA) 2877 Declaration for Imported Electronic Products Subject to Radiation Control Standards.

## 9.2 Regulatory Compliance

### 9.2.1 Manufacturer's Information

Attn: Corp. Quality  
Intel Corporation  
2200 Mission College Blvd.  
Santa Clara CA 95054-1549  
USA

### 9.2.2 EU Single Place of Contact

Intel Deutschland GmbH  
z. H. Corp. Quality

Am Campeon 10-12  
85579 Neubiberg  
GERMANY

### 9.2.3 UK Single Place of Contact

Intel Corporation (UK) Ltd.  
Attn: Corp. Quality  
Pipers Way  
Swindon  
Wiltshire  
SN3 1RJ  
UNITED KINGDOM

### 9.2.4 NRTL Statement

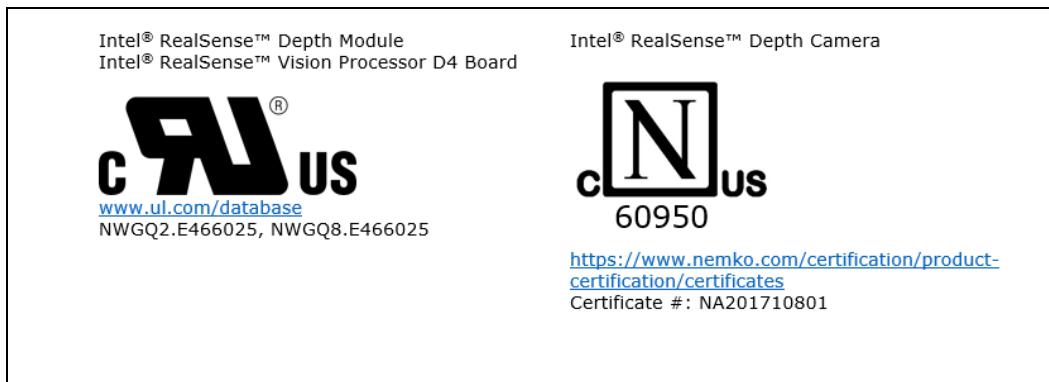
For the US and Canada market, this product has been tested and certified by UL and Nemko, and found to be compliant with all applicable requirements of the specifications below:

UL 60950-1 2<sup>nd</sup> Edition, CAN/CSA C22.2 No. 60950-1-07, Information Technology Equipment – Safety – Part 1: General Requirements

Both UL and Nemko are Nationally Recognized Testing Laboratories (NRTLs), recognized by US Occupational Safety and Health Administration (OSHA) as qualified to perform safety testing and certifications covered within its scope of recognition.

\* Applicable to D40x, D41x (except for D415), D415, D43x, D45x modules and D415x, D435xx, and D455x cameras.

**Figure 9-1. NRTL Certifications**



### 9.2.5 FCC Part 15 Declaration of Conformity



Intel® RealSense™ Depth Camera D405, D415, D435, D435f, D435i, D435if, D455, D455f, D456

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Attn: Corp. Quality, Intel Corporation: 2200Mission College Blvd, Santa Clara, CA 95054-1549, USA

<https://www.intel.com/content/www/us/en/support/contact-intel.html>

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Changes or modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.

CAUTION: To comply with the limits of the Class B digital device, pursuant to Part 15 of the FCC Rules, this device must be installed with computer equipment certified to comply with Class B limits. All cables used to connect to the computer and peripherals must be shielded and grounded. Operation with non-certified computers or non-shielded cables may result in interference to radio or television reception.

## 9.2.6 Canada

CAN ICES-3 (B)/NMB-3(B)

This digital apparatus does not exceed the Class B limits for radio noise emissions from digital apparatus set out in the Interference-Causing Equipment Standard ICES-003.

Le présent appareil numerique n'émet pas de bruits radio électriques dépassant les limites applicables aux appareils numériques de la classe B prescrites dans la présente norme sur le matériel brouilleur, NMB-003.

## 9.2.7 European Directives



This product complies with all applicable European directives.

**CAUTION:** To keep the product in compliance with the European CE requirement, the device must be installed with CE certified computer equipment which meets the Class B limits. Operation with non-certified computers or incorrect cables may result in interference to other devices or undesired effect to the product.

## 9.2.8

### UK



This product complies with all applicable UK regulations.

Due to the very small size of the product, the marking has been placed in this datasheet.

## 9.2.9

### Australia



Due to the very small size of the product, the marking has been placed in this datasheet.

## 9.2.10

### Japan

この装置は、クラスB機器です。この装置は、住宅環境で使用することを目的としていますが、この装置がラジオやテレビジョン受信機に近接して使用されると、受信障害を引き起こすことがあります。取扱説明書に従って正しい取り扱いをして下さい。 VCCI-B

This device is a Class B information technology device. This device is intended for use in a home environment, but if this device is used close to a radio or television receiver it may cause reception interference. Please handle according to the instruction manual correctly. VCCI-B

## 9.2.11

### South Korea

인증 번호: MSIP-REM-CPU-D415C, MSIP-REM-CPU-D435C, R-R-CPU-D435iC, R-R-CPU-D455C, R-R-CPU-D405C, R-R-CPU-D456C

제조자: Intel Corporation

상품명: Intel® RealSense™ Depth Camera

모델: D415, D435, D435f, D435i, D435if, D455, D455f, D405, D456

제조국: 태국, 중국



인증 번호: R-REM-CPU-D410, R-REM-CPU-D415, R-REM-CPU-D430, R-R-CPU-D450, R-R-CPU-D401

제조자: Intel Corporation

상품명: Intel® RealSense™ Depth Module

모델: D410, D415, D430, D450, D401

제조국: 중국



인증 번호: R-REM-CPU-D4BOARD



제조자: Intel Corporation  
상품명: Intel® RealSense™ Vision Processor Card  
모델: D4BOARD  
제조국: 중국

## 9.3 Ecology Compliance

### 9.3.1 China RoHS Declaration

# intel. China RoHS Declaration

## 产品中有毒有害物质的名称及含量 Hazardous Substances Table

| 部件名称<br>Component Name              | 有毒有害物质或元素 Hazardous Substance |         |         |                |             |               |
|-------------------------------------|-------------------------------|---------|---------|----------------|-------------|---------------|
|                                     | 铅<br>Pb                       | 汞<br>Hg | 镉<br>Cd | 六价铬<br>Cr (VI) | 多溴联苯<br>PBB | 多溴二苯醚<br>PBDE |
| 相机<br>Camera                        | ○                             | ○       | ○       | ○              | ○           | ○             |
| 印刷电路板组件<br>Printed Board Assemblies | X                             | ○       | ○       | ○              | ○           | ○             |
| 三角架<br>Tripod                       | ○                             | ○       | ○       | ○              | ○           | ○             |
| 电缆<br>Cable                         | X                             | ○       | ○       | ○              | ○           | ○             |

○：表示该有毒有害物质在该部件所有均质材料中的含量均在GB/T 26572标准规定的限量要求以下。

○： Indicates that this hazardous substance contained in all homogeneous materials of such component is within the limits specified in GB/T 26572.

×： 表示该有毒有害物质至少在该部件的某一均质材料中的含量超出GB/T 26572标准规定的限量要求。

×： Indicates that the content of such hazardous substance in at least a homogeneous material of such component exceeds the limits specified in GB/T 26572.

对销售之目的所售产品,本表显示我公司供应链的电子信息产品可能包含这些物质。注意:在所售产品中可能会也可能不会含有所有所列的部件。

This table shows where these substances may be found in the supply chain of our electronic information products, as of the date of sale of the enclosed product. Note that some of the component types listed above may or may not be a part of the enclosed product.

除非另外特别的标注,此标志为针对所涉及产品的环保使用期限标志. 某些可更换的零部件可能会有一个不同的环保使用期限(例如,电池单元模块).

此环保使用期限只适用于产品在产品手册中所规定的条件下工作.



The Environment-Friendly Use Period (EFUP) for all enclosed products and their parts are per the symbol shown here, unless otherwise marked. Certain field-replaceable parts may have a different EFUP (for example, battery modules) number. The Environment-Friendly Use Period is valid only when the product is operated under the conditions defined in the product manual.

### 9.3.2 Waste Electrical and Electronic Equipment (WEEE)



"In the EU, this symbol means that this product must not be disposed of with household waste. It is your responsibility to bring it to a designated collection point for the recycling of waste electrical and electronic equipment. For more information, contact the local waste collection center or your point of purchase of this product."

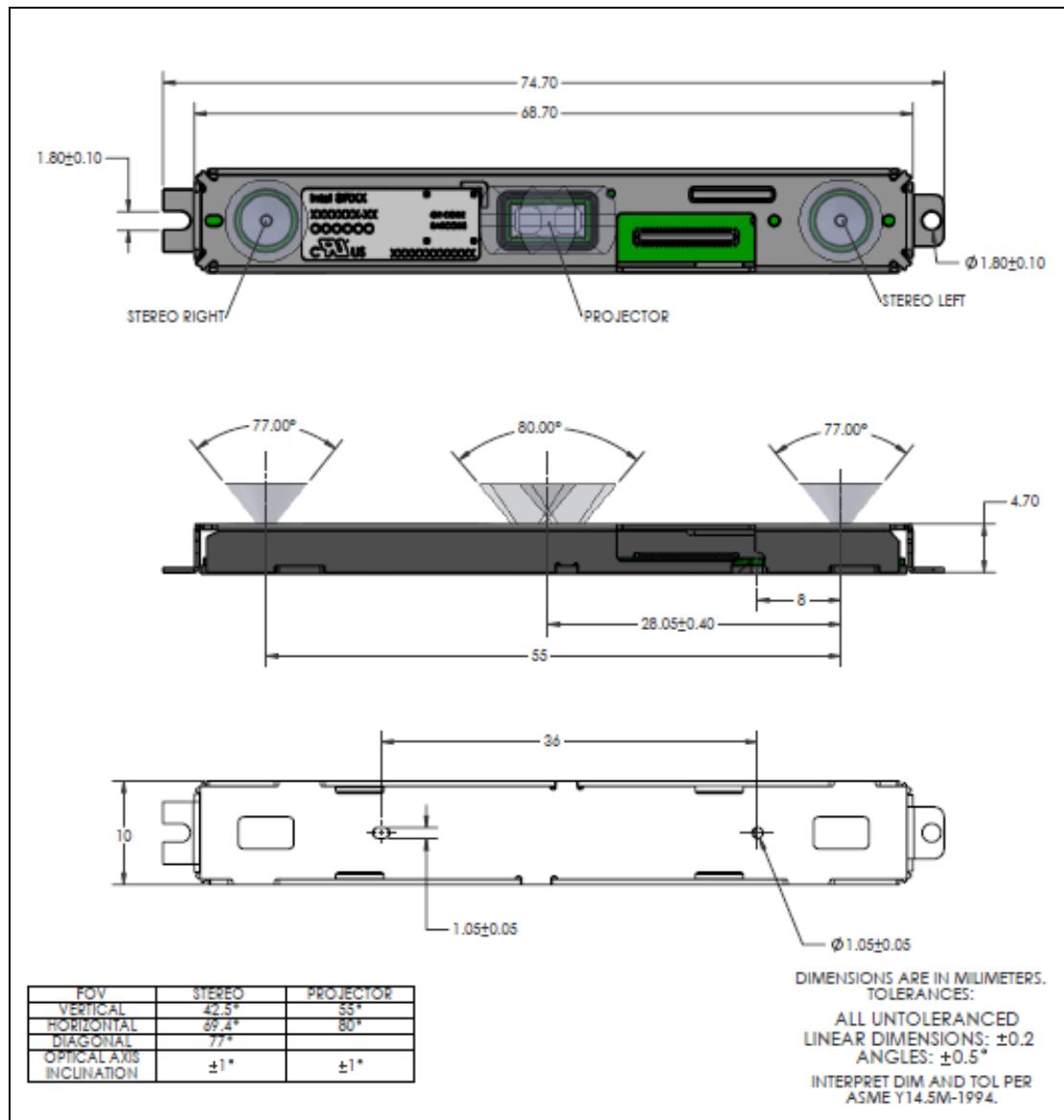
### 9.3.3 Turkey

Türkiye Cumhuriyeti: EEE Yönetmeliğine Uygundur

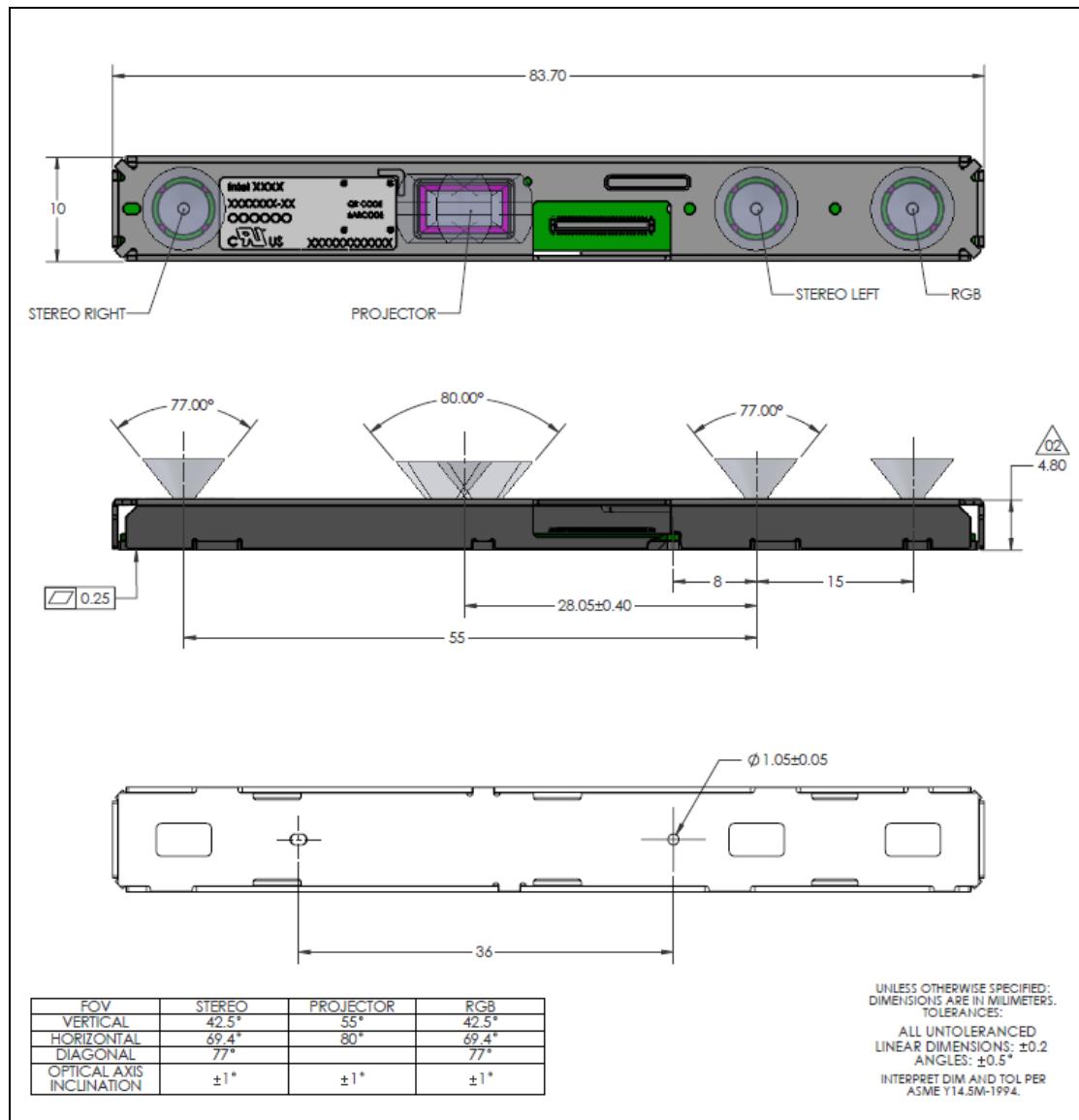
§ §

# 10 Mechanical Drawings

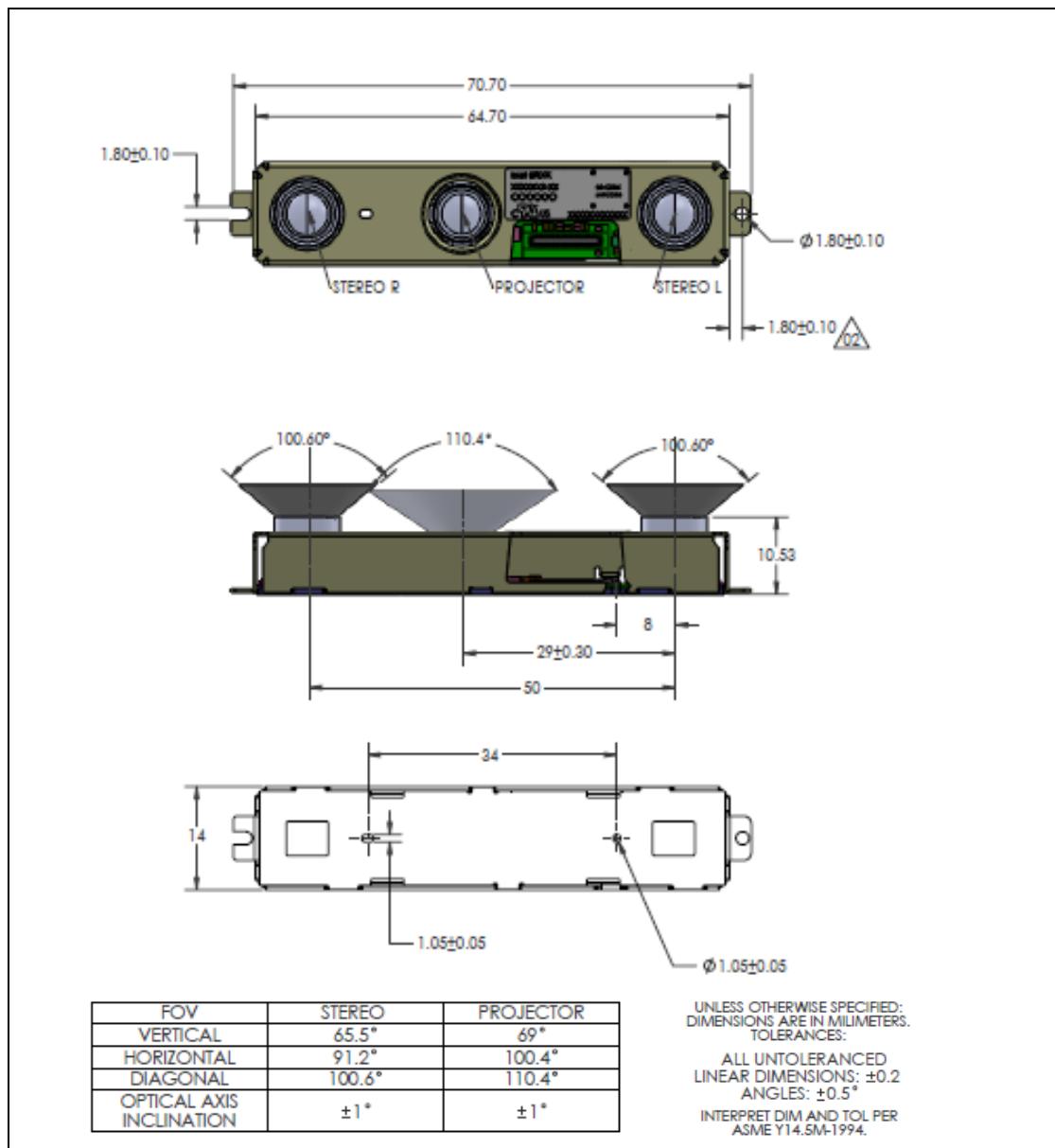
Figure 10-1. Intel® RealSense™ Depth Module D410



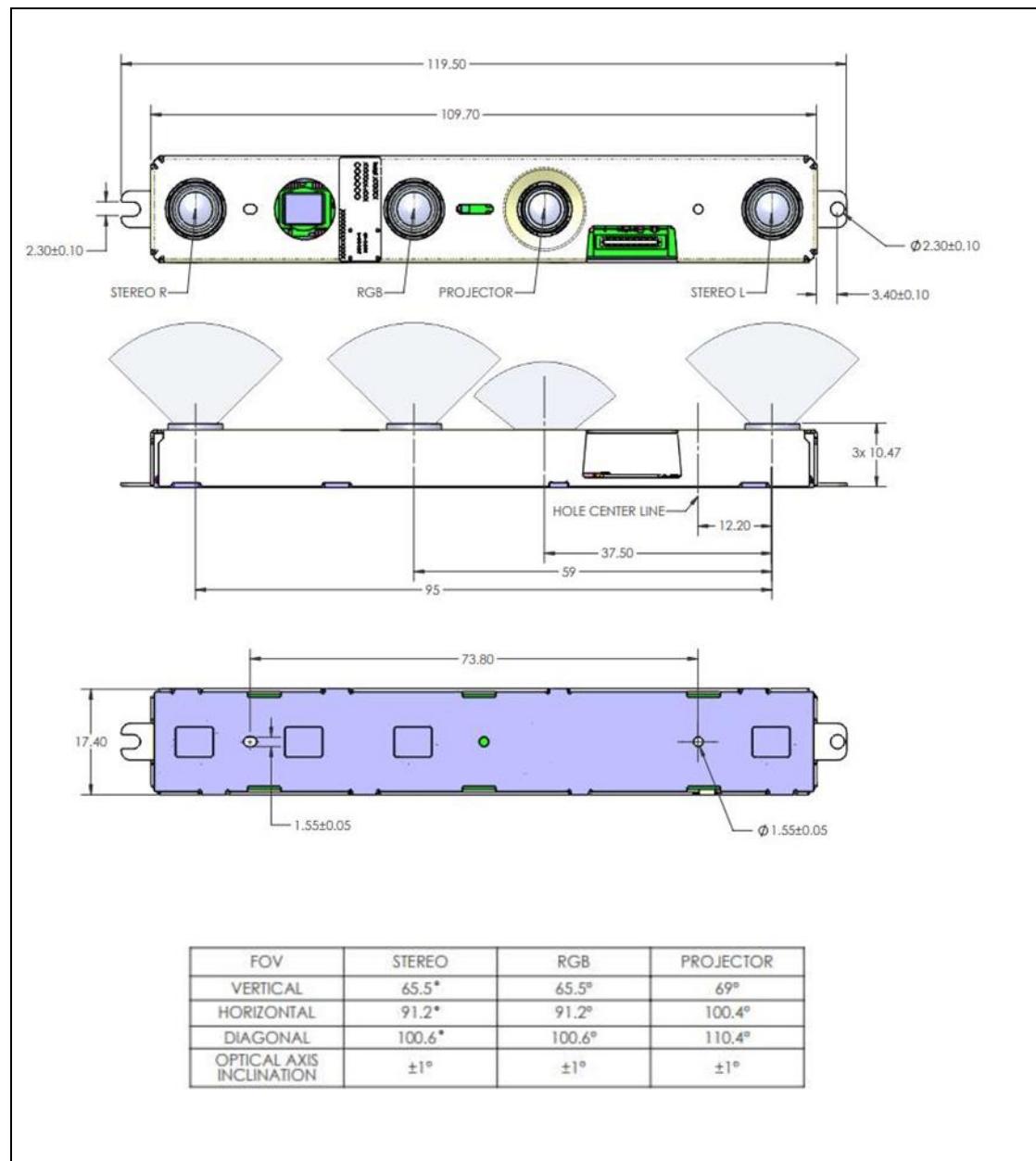
**Figure 10-2. Intel® RealSense™ Depth Module D415**



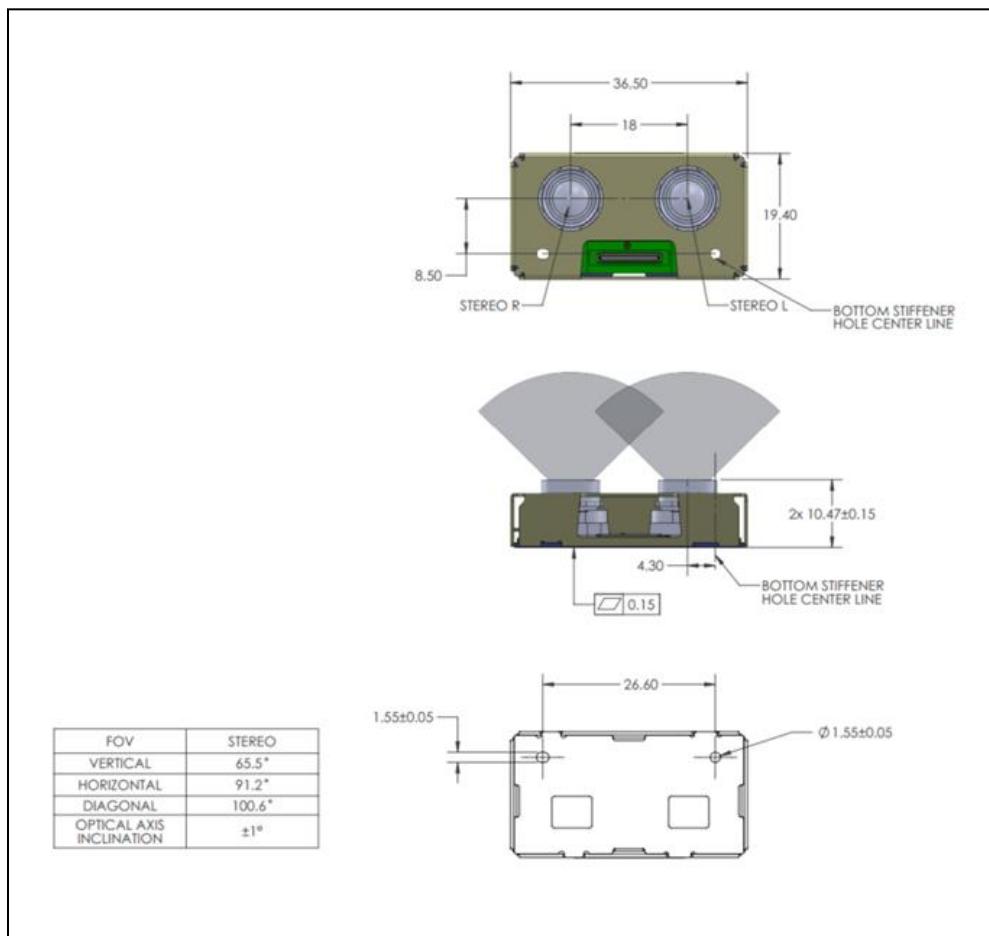
**Figure 10-3. Intel® RealSense™ Depth Module D430**



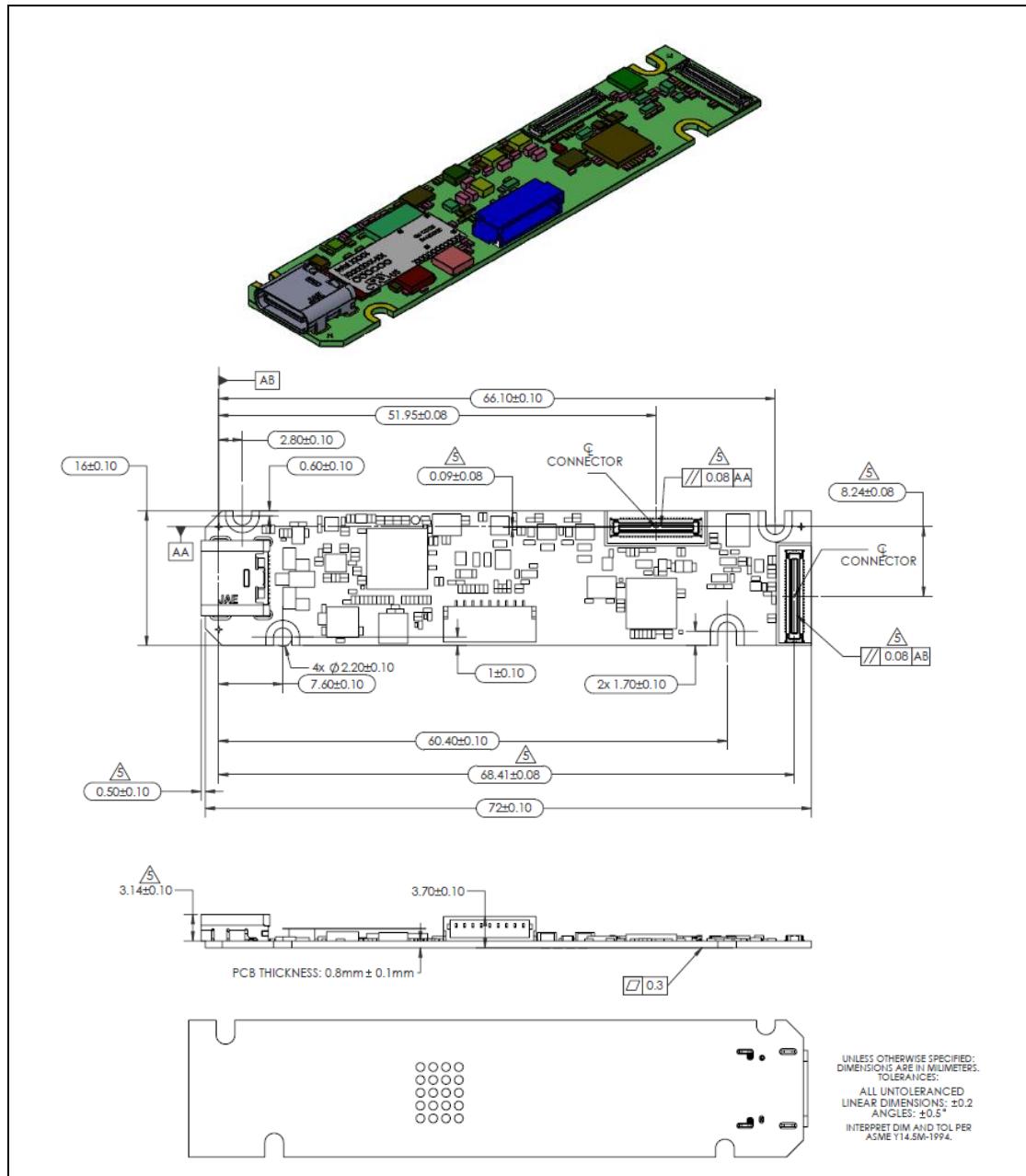
**Figure 10-4. Intel® RealSense™ Depth Module D450**



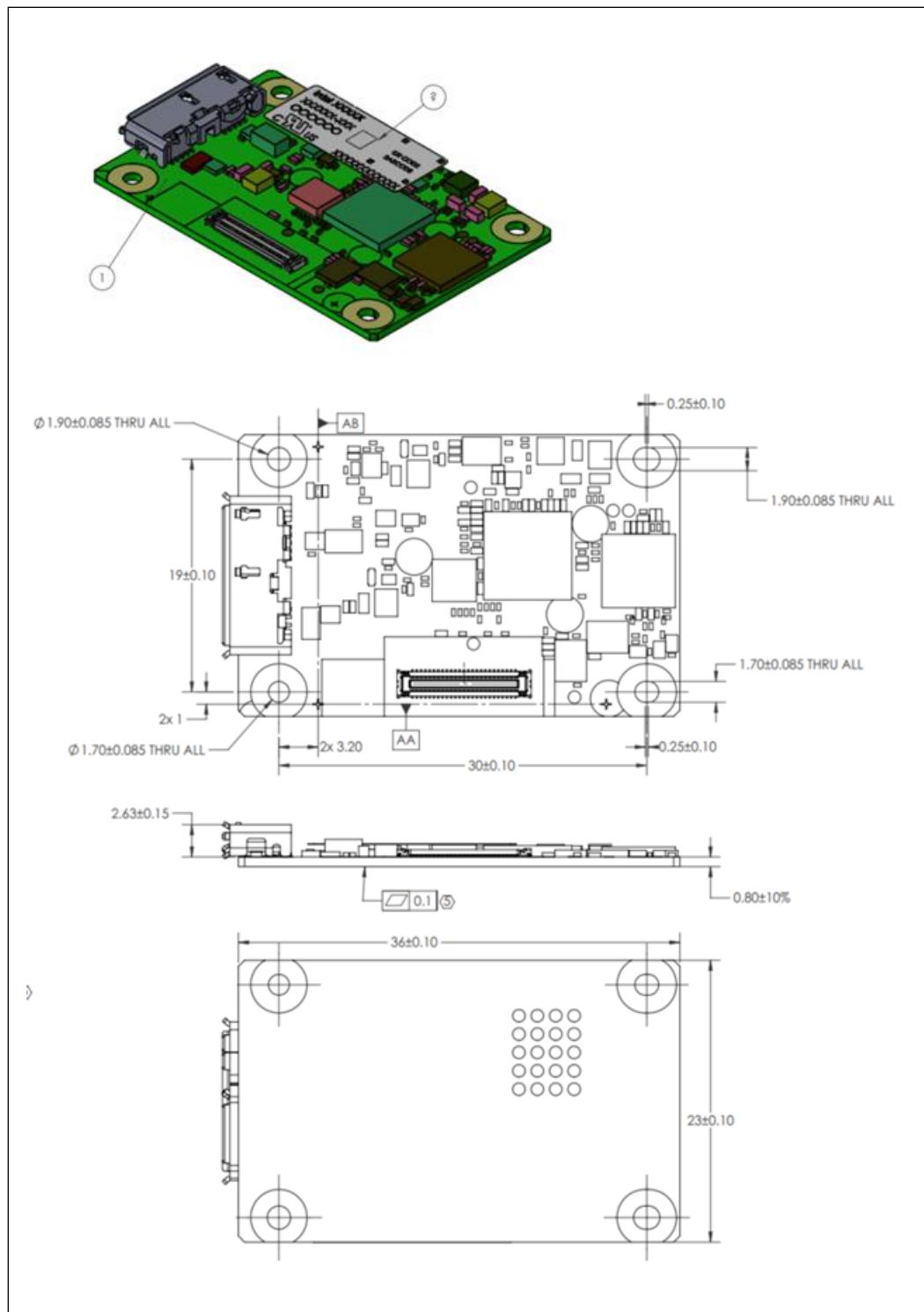
**Figure 10-5. Intel® RealSense™ Depth Module D401**



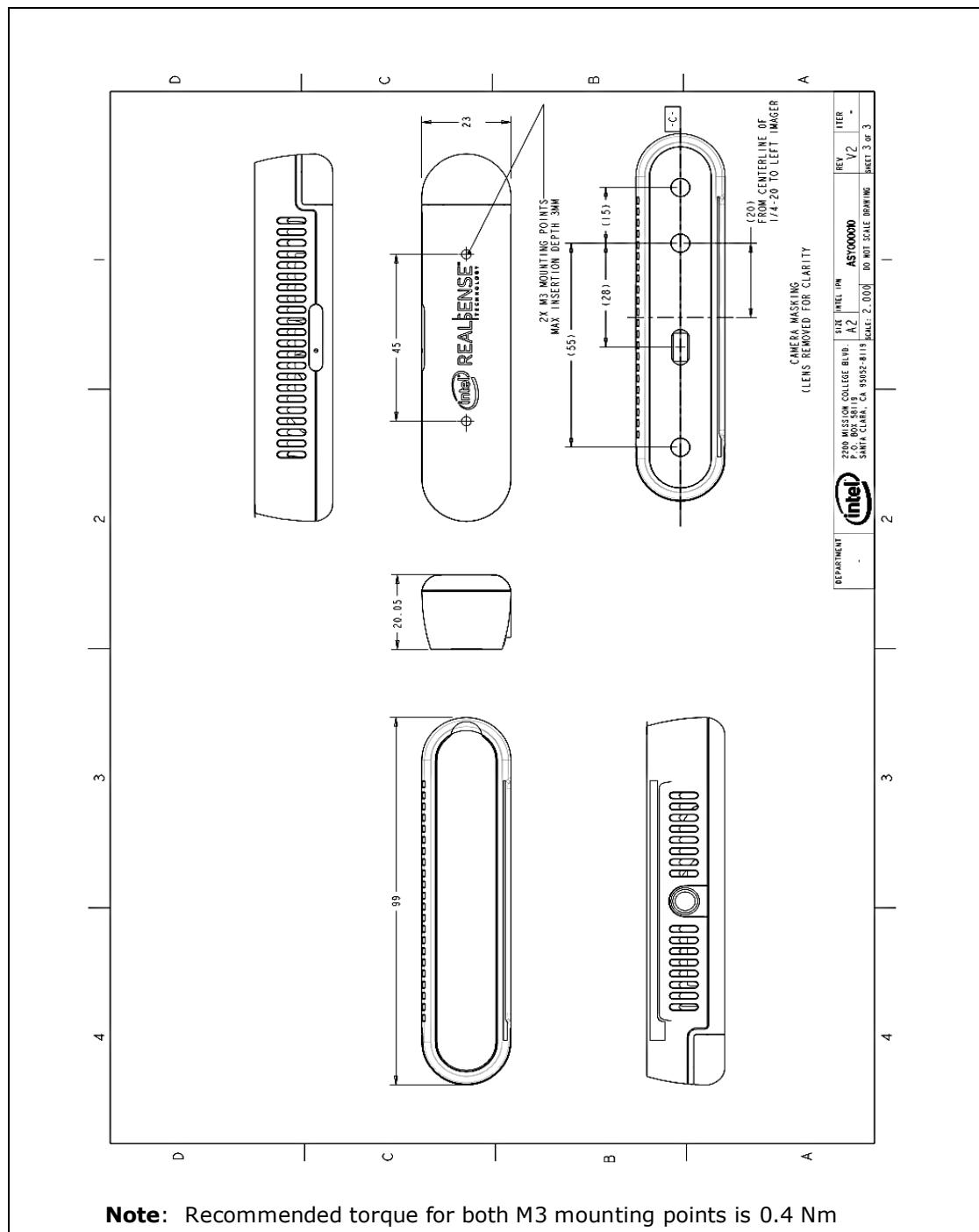
**Figure 10-6. Vision Processor D4 Board USB Type-C (Intel® RealSense™ Vision Processor D4 Board – V1 and V3)**



**Figure 10-7. Vision Processor D4 Board USB Micro-B (Intel® RealSense™ Vision Processor D4 Board – V4)**

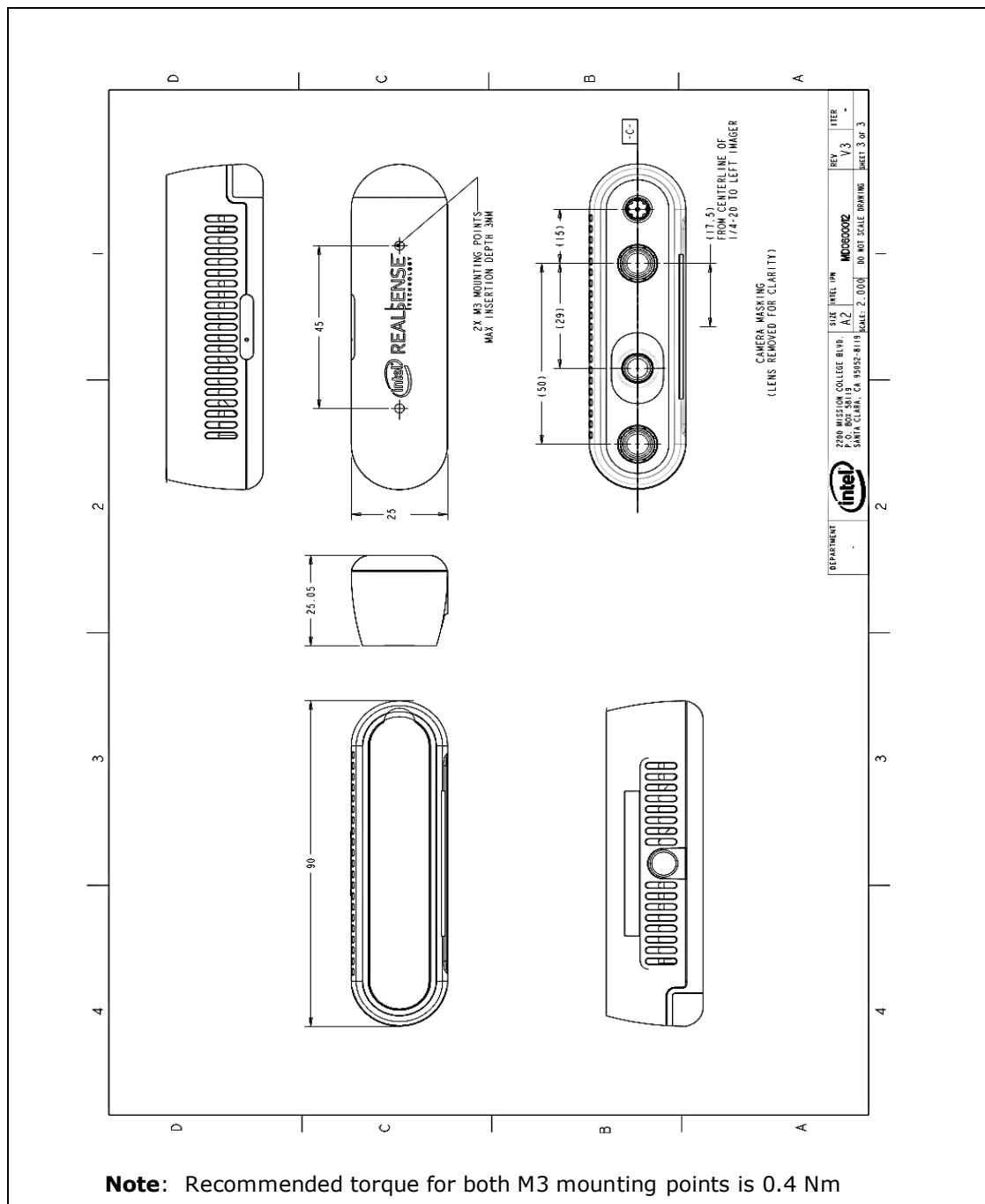


**Figure 10-8. Intel® RealSense™ Depth Camera D415**

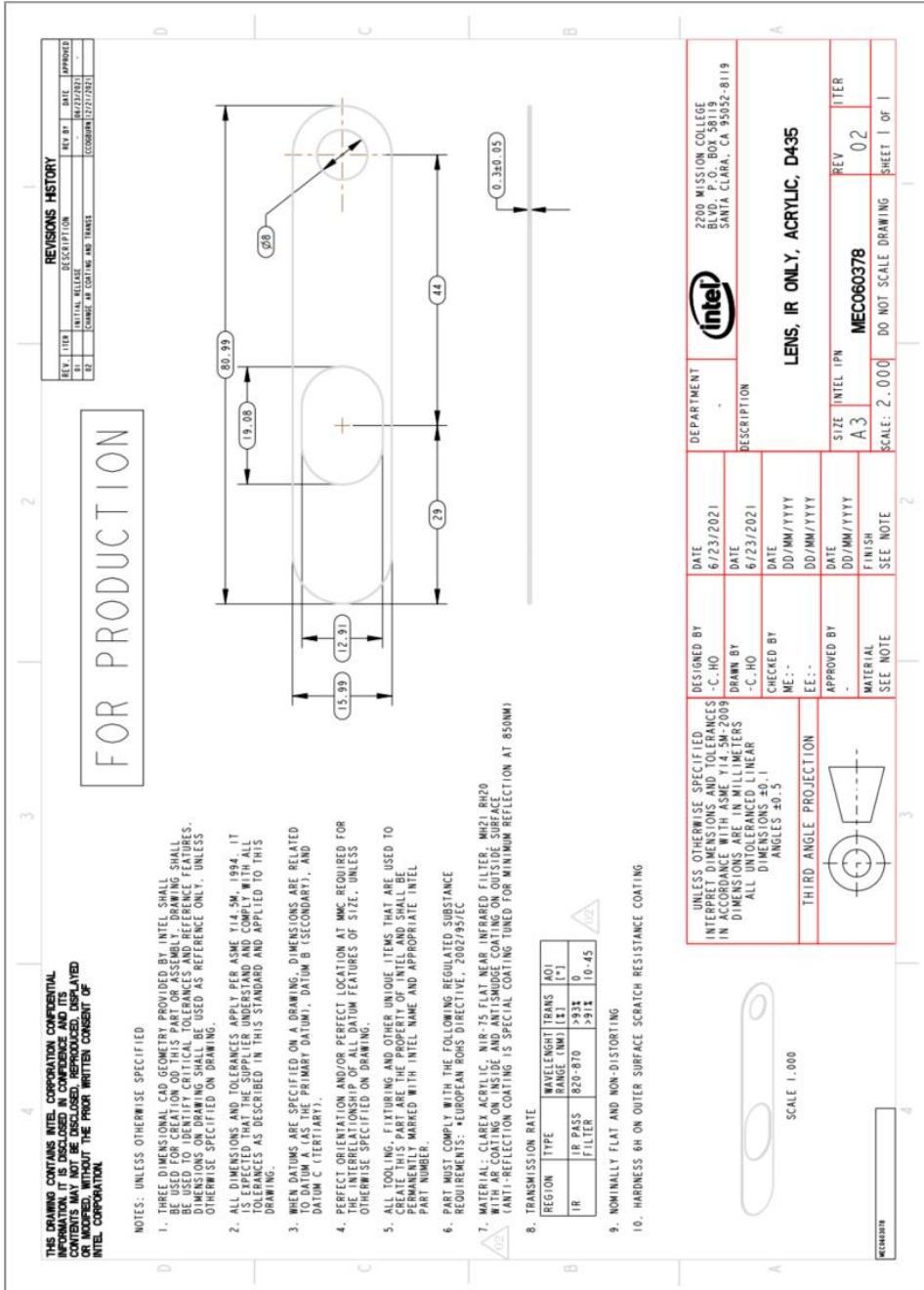


**Note:** Recommended torque for both M3 mounting points is 0.4 Nm

**Figure 10-9. Intel® RealSense™ Depth Camera D435/D435i**

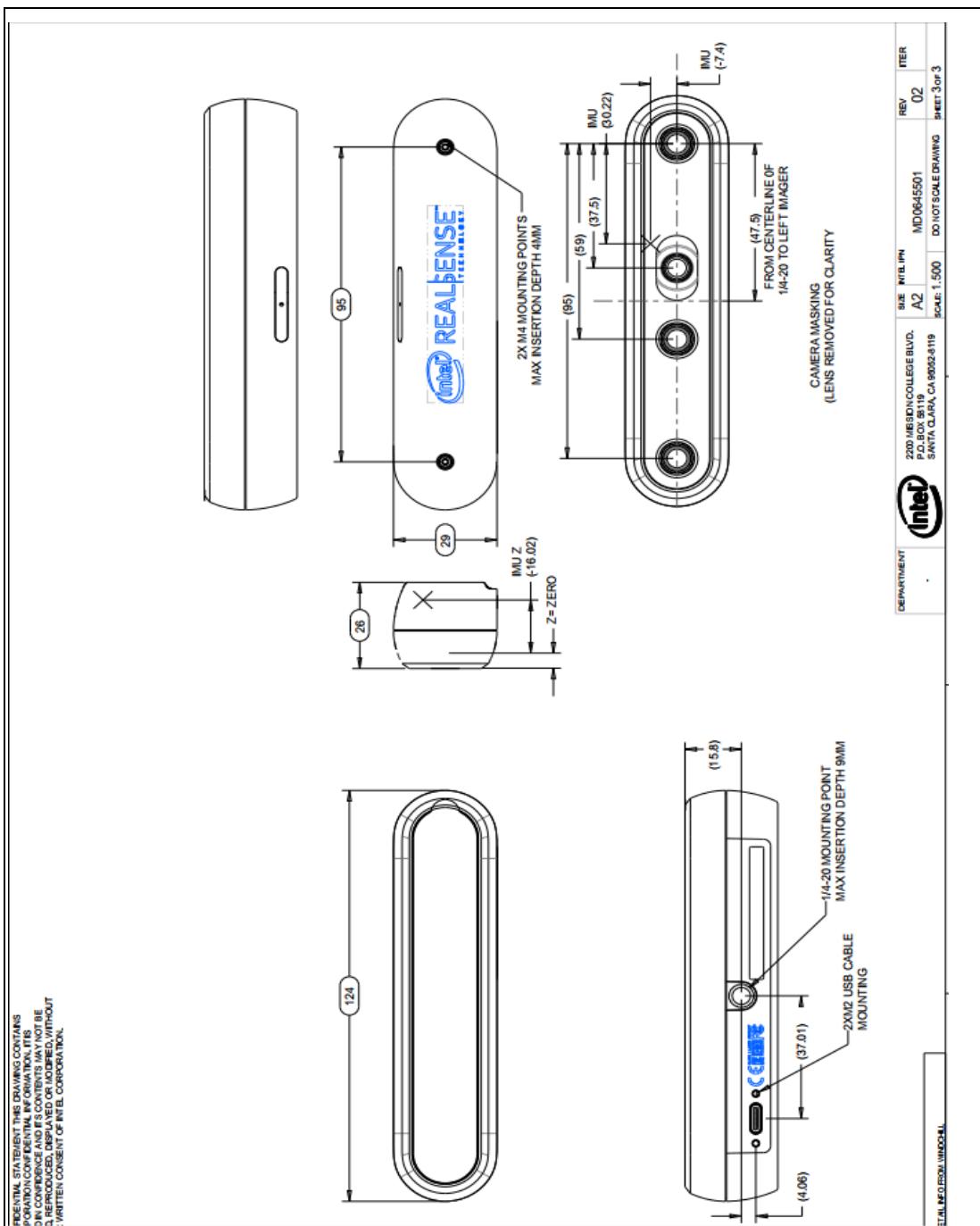


**Figure 10-10. Intel® RealSense™ Depth Camera D435f/D435if NIR Filter**

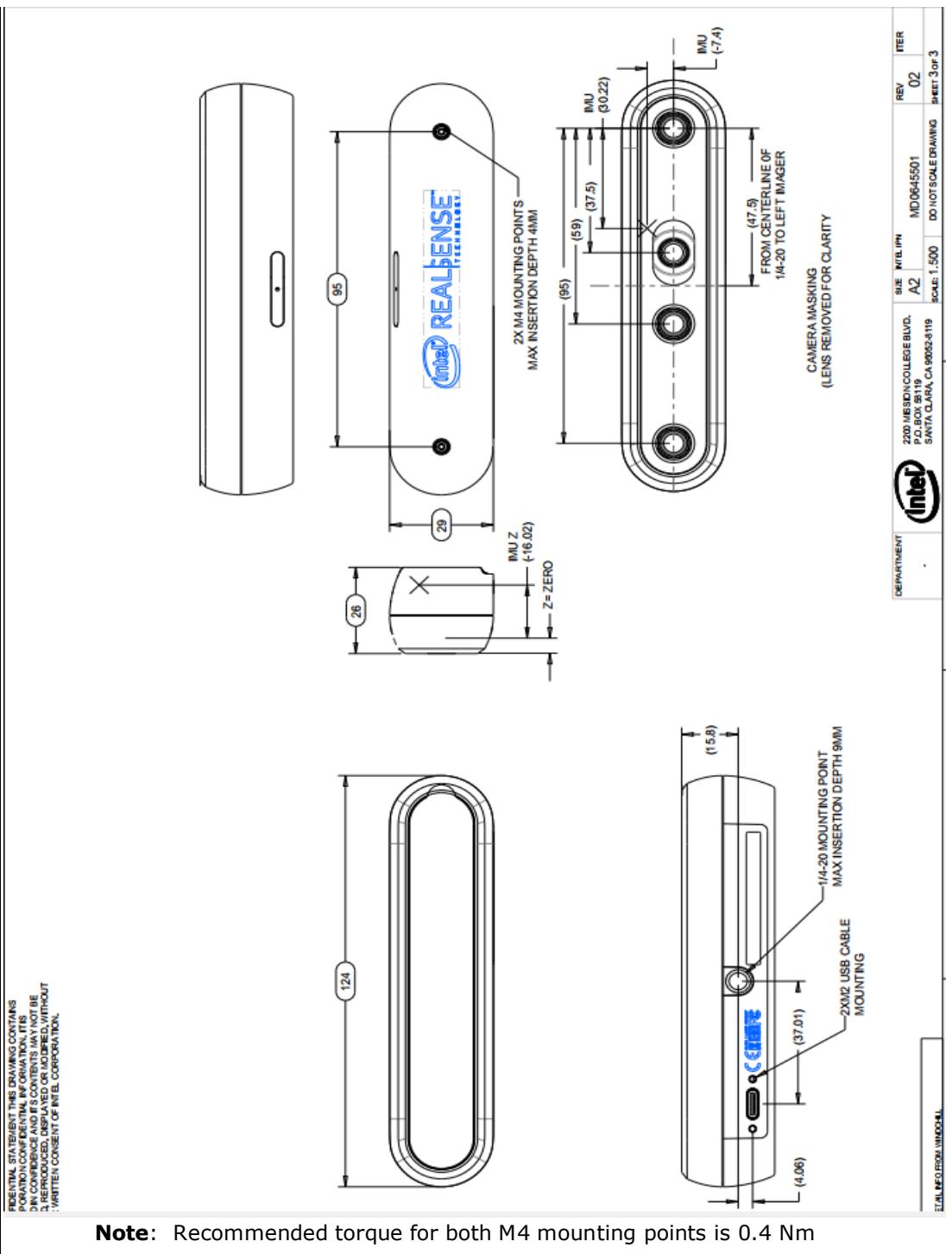


**Figure 10-11. Intel® RealSense™ Depth Camera D455**

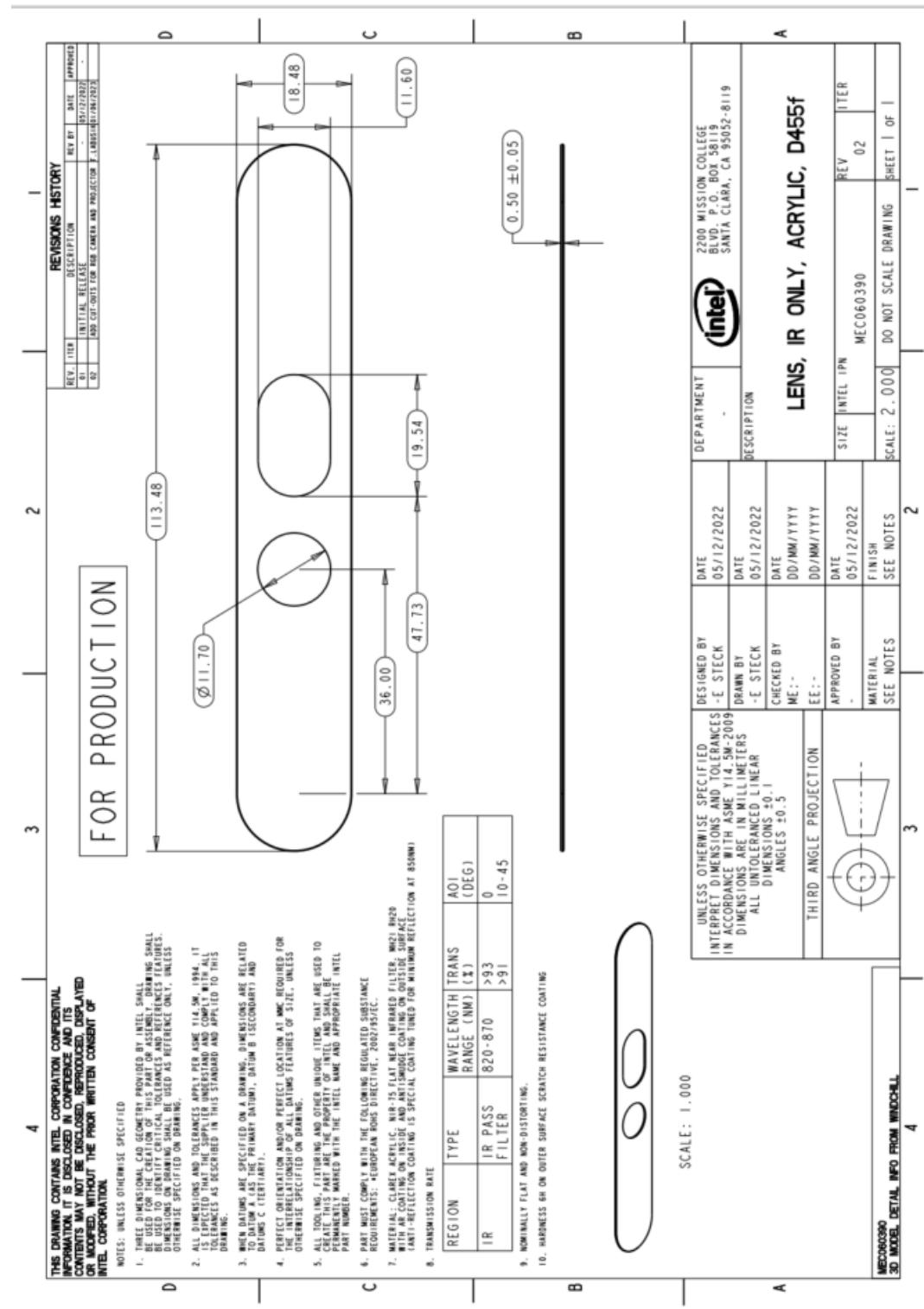
PROPRIETARY STATEMENT THIS DRAWING CONTAINS  
INFORMATION CONFIDENTIAL IN NATURE. IT IS  
INTENDED FOR INTERNAL USE ONLY AND MAY NOT BE  
REPRODUCED OR DISCLOSED WITHOUT  
WRITTEN CONSENT OF INTEL CORPORATION.



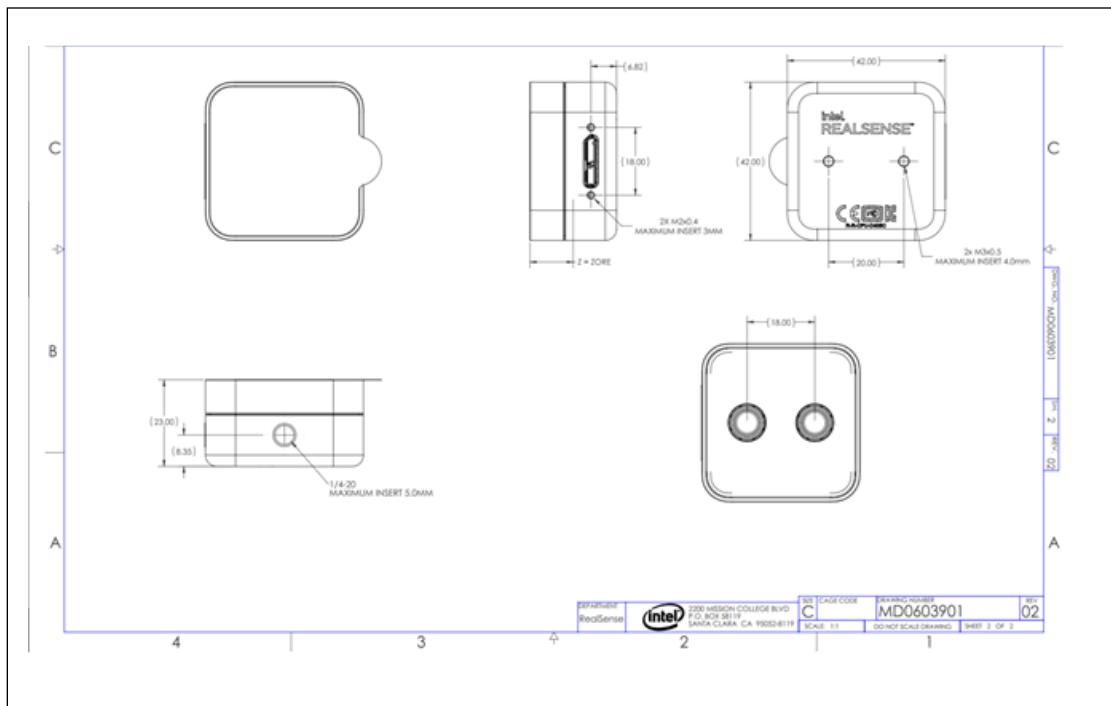
CONFIDENTIAL STATEMENT THIS DRAWING CONTAINS  
INFORMATION CONFIDENTIAL IN OPERATION. IT IS  
NOT TO BE REPRODUCED, DISPLAYED OR MODIFIED, WITHOUT  
WRITTEN CONSENT OF INTEL CORPORATION.



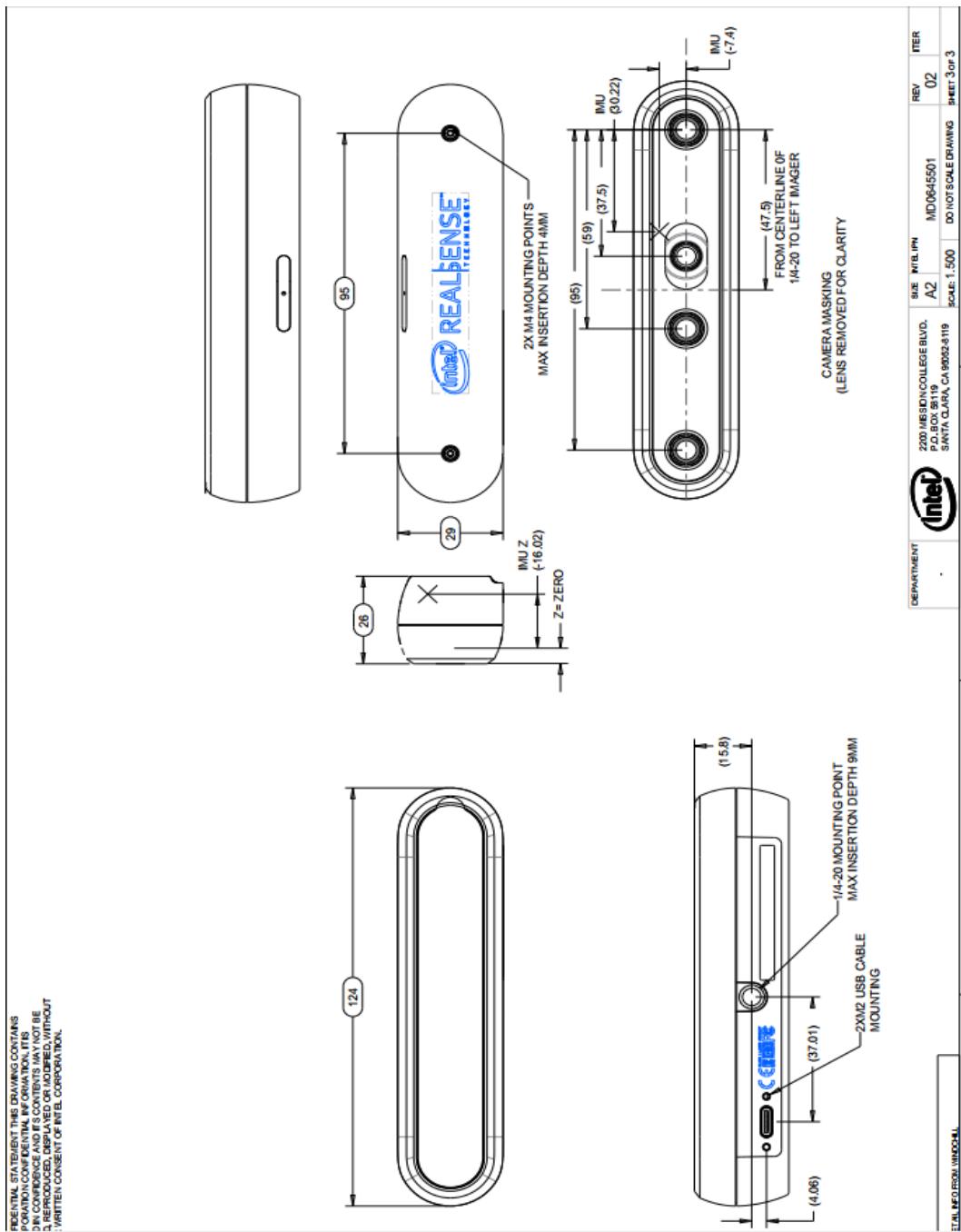
**Figure 10-12. Intel® RealSense™ Depth Camera D455f/ NIR Filter**



**Figure 10-13. Intel® RealSense™ Depth Camera D405**

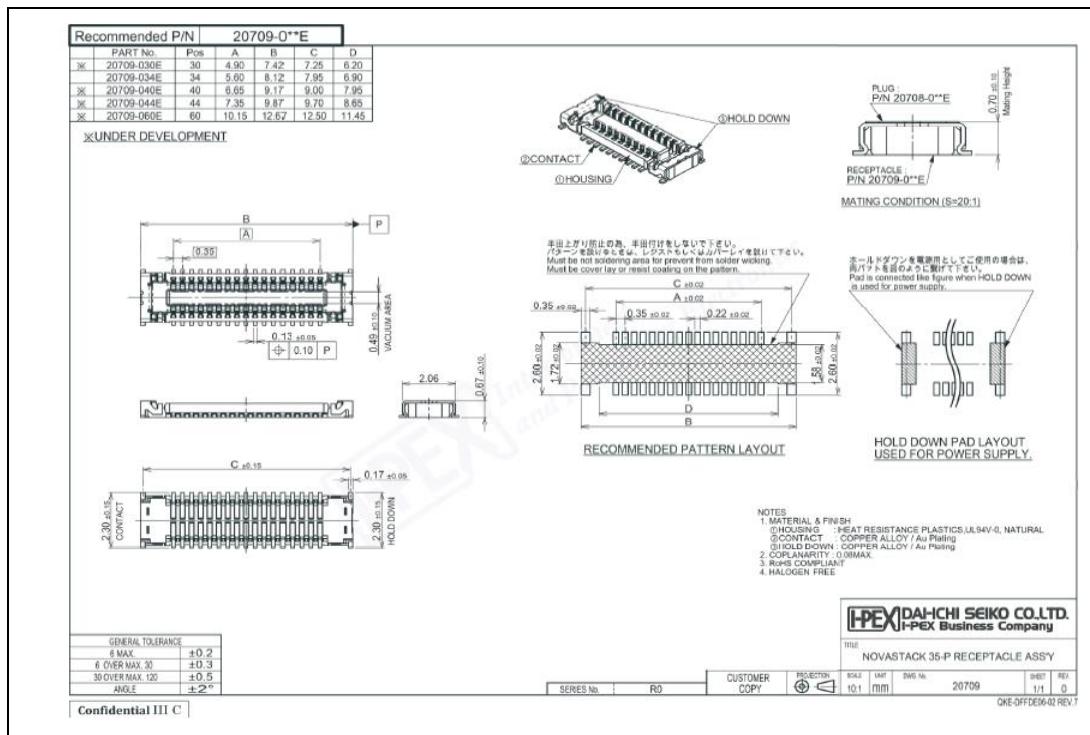


**Figure 10-14. Intel® RealSense™ Depth Camera D456**

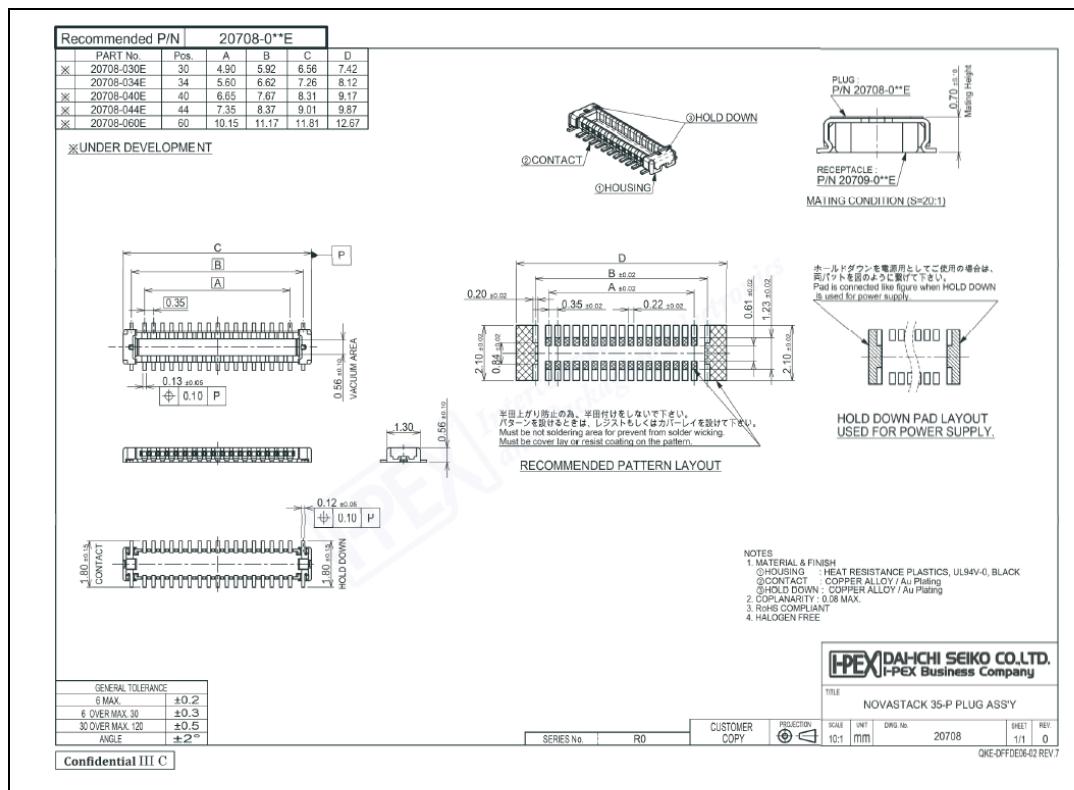


# 11 Connector Drawings

**Figure 11-1. Receptacle Mechanical Drawing (50-Pin Depth Module Receptacle)**



**Figure 11-2. Plug Mechanical Drawing (50-Pin Depth Module Plug)**



# 12 Appendix A – Vision Processor D4 on Motherboard Schematic Checklist

---

The following checklist should be compared to the D4 on motherboard design.

**Table 12-1. Vision Processor D4 on Motherboard Schematic Checklist**

**Note:**

1. Vision Processor D4 Ball Out and Signal Listing lists additional interfaces and signal pins that are not supported in current D4 camera system. These pins are called out as **RESERVED**.

**Definitions:**

- **Stuff** = Component is populated
- **No Stuff** = Component is not populated

| Signal Name   | Pad | Connection  | ✓ |
|---|-----|---|---|
| <b>HOST MIPI</b>  |     |   |   |
| H_DATAP0  | B04 | No Connect  |   |
| H_DATAN0  | A05 | No Connect  |   |
| H_DATAP1  | B05 | No Connect  |   |
| H_DATAN1  | A06 | No Connect  |   |
| H_DATAP2  | B07 | No Connect  |   |
| H_DATAN2  | A08 | No Connect  |   |
| H_DATAP3  | B08 | No Connect  |   |
| H_DATAN3  | A09 | No Connect  |   |
| H_CLKP  | B06 | No Connect  |   |
| H_CLKN  | A07 | No Connect  |   |
| H_SDA   | B03 | No Connect  |   |
| H_SCL   | A04 | No Connect  |   |
| H_REXT  | C05 | 6.04K 1% resistor pull down to GND. (This resistor should be placed as close to ASIC as possible) |   |
| <b>IMAGER A MIPI (Stereo Depth Left Imager Interface)</b> |     |   |   |
| A_DATAP0  | P03 | Routed to Stereo Depth Receptacle Pin 16  |   |

| <b>Signal Name</b>              | <b>Pad</b> | <b>Connection</b>   | <b>✓</b> |
|---------------------------------|------------|---|----------|
| A_DATANO                        | R02        | Routed to Stereo Depth Receptacle Pin 18  |          |
| A_DATAP1                        | P05        | Routed to Stereo Depth Receptacle Pin 28  |          |
| A_DATAN1                        | R04        | Routed to Stereo Depth Receptacle Pin 30  |          |
| A_CLKP                          | P04        | Routed to Stereo Depth Receptacle Pin 22  |          |
| A_CKLN                          | R03        | Routed to Stereo Depth Receptacle Pin 24  |          |
| A_SDA                           | N01        | Routed to Stereo Depth Receptacle Pin 41 with 2.2K pull up to 1.8V                                |          |
| A_SCL                           | N02        | Routed to Stereo Depth Receptacle Pin 39 with 2.2K pull up to 1.8V                                |          |
| A_RCLK                          | P02        | Routed to Stereo Depth Receptacle Pin 27  |          |
| A_PDOWN                         | N03        | No Connect  |          |
| A_VSYNC                         | M01        | Routed to Stereo Depth Receptacle Pin 23  |          |
| A_RESETN                        | P01        | Routed to Stereo Depth Receptacle Pin 31  |          |
| A_REXT                          | N04        | 6.04K 1% resistor pull down to GND. (This resistor should be placed as close to ASIC as possible) |          |
| <b>IMAGER B MIPI (Reserved)</b> |            |   |          |
| B_DATAP0                        | B11        | No Connect  |          |
| B_DATANO                        | A12        | No Connect  |          |
| B_DATAP1                        | B09        | No Connect  |          |
| B_DATAN1                        | A10        | No Connect  |          |
| B_CLKP                          | B10        | No Connect  |          |
| B_CKLN                          | A11        | No Connect  |          |
| B_SDA                           | C12        | No Connect  |          |
| B_SCL                           | B12        | No Connect  |          |
| B_RCLK                          | C07        | No Connect  |          |
| B_PDOWN                         | C09        | No Connect  |          |
| B_VSYNC                         | C08        | No Connect  |          |
| B_RESETN                        | C10        | No Connect  |          |
| B_REXT                          | C11        | 6.04K 1% resistor pull down to GND. (This resistor should be placed as close to ASIC as possible) |          |

| <b>Signal Name</b>                               | <b>Pad</b> | <b>Connection</b>   | <b>✓</b> |
|--|------------|---|----------|
| <b>IMAGER M MIPI (Stereo Depth Right Imager)</b> |            |   |          |
| M_DATAP0   | P08        | Routed to Stereo Depth Receptacle Pin 34  |          |
| M_DATAN0   | R07        | Routed to Stereo Depth Receptacle Pin 36  |          |
| M_DATAP1   | P10        | Routed to Stereo Depth Receptacle Pin 46  |          |
| M_DATAN1   | R09        | Routed to Stereo Depth Connector Pin 48   |          |
| M_CLKP   | P09        | Routed to Stereo Depth Receptacle Pin 40  |          |
| M_CKLN   | R08        | Routed to Stereo Depth Receptacle Pin 42  |          |
| M_SDA  | P06        | Routed to External Sensor Sync Connector Pin 6 through 2.2K pull up to 1.8V                       |          |
| M_SCL  | R05        | Routed to External Sensor Sync Connector Pin 7 through 2.2K pull up to 1.8V                       |          |
| M_RCLK   | R06        | Routed to Stereo Depth Receptacle Pin 37  |          |
| M_PDOWN  | P07        | No Connect  |          |
| M_VSYNC  | N06        | No Connect  |          |
| M_RESETN   | N07        | No Connect  |          |
| M_REXT   | M06        | 6.04K 1% resistor pull down to GND. (This resistor should be placed as close to ASIC as possible) |          |
| <b>IMAGER Y MIPI (Color ISP)</b>                 |            |   |          |
| Y_DATAP0   | C14        | Routed to Color ISP (Intel® Vision Processor D4 Board) or No Connect                              |          |
| Y_DATAN0   | B15        | Routed to Color ISP (Intel® Vision Processor D4 Board) or No Connect                              |          |
| Y_DATAP1   | B13        | Routed to Color ISP (Intel® Vision Processor D4 Board) or No Connect                              |          |
| Y_DATAN1   | A13        | Routed to Color ISP (Intel® Vision Processor D4 Board) or No Connect                              |          |
| Y_CLKP   | B14        | Routed to Color ISP (Intel® Vision Processor D4 Board) or No Connect                              |          |
| Y_CKLN   | A14        | Routed to Color ISP (Intel® Vision Processor D4 Board) or No Connect                              |          |
| Y_SDA  | E14        | Routed to Color ISP (Intel® Vision Processor D4 Board) or No Connect                              |          |
| Y_SCL  | D15        | Routed to Color ISP (Intel® Vision Processor D4 Board) or No Connect                              |          |
| Y_RCLK   | D14        | Routed to Color ISP (Intel® Vision Processor D4 Board) or No Connect                              |          |

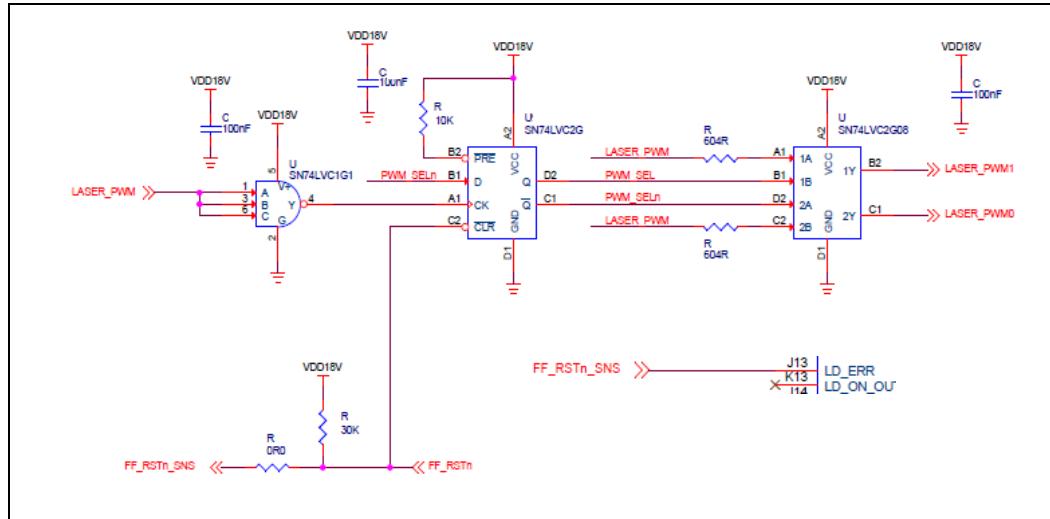
| <b>Signal Name</b>               | <b>Pad</b> | <b>Connection</b>   | <b>✓</b> |
|----------------------------------|------------|---|----------|
| Y_PDOWN                          | E13        | No Connect  |          |
| Y_VSYNC                          | F13        | Routed as RGB_FSYNC to Stereo Depth Receptacle Pin 7 through 0 ohm <b>stuff</b> resistor. Alternately also as routed as RGB_STROBE to Stereo Depth Receptacle Pin 9 through 0 ohm <b>no stuff</b> resistor. |          |
| Y_RESETN                         | F14        | Routed to Color ISP (Intel® Vision Processor D4 Board) or No Connect  |          |
| Y_RECT                           | C15        | 6.04K 1% resistor pull down to GND. (This resistor should be placed as close to ASIC as possible)   |          |
| <b>IMAGER Z MIPI (Reserved)</b>  |            |   |          |
| Z_DATAP0                         | P13        | No Connect  |          |
| Z_DATAN0                         | R12        | No Connect  |          |
| Z_DATAP1                         | P11        | No Connect  |          |
| Z_DATAN1                         | R10        | No Connect  |          |
| Z_CLKP                           | P12        | No Connect  |          |
| Z_CKLN                           | R11        | No Connect  |          |
| Z_SDA                            | N13        | No Connect  |          |
| Z_SCL                            | N12        | No Connect  |          |
| Z_RCLK                           | R13        | No Connect  |          |
| Z_PDOWN                          | N11        | No Connect  |          |
| Z_VSYNC                          | R14        | Depth VSYNC - Routed to External Sensor Sync Connector Pin 5  |          |
| Z_RESETN                         | P14        | No Connect  |          |
| Z_RECT                           | N10        | 6.04K 1% resistor pull down to GND. (This resistor should be placed as close to ASIC as possible)   |          |
| <b>SPI (SERIAL FLASH MEMORY)</b> |            |   |          |
| SPI_DI                           | N14        | Routed to 16 Mbit SERIAL FLASH MEMORY (IS25WP016 pin 5 or equivalent)   |          |
| SPI_DO                           | N15        | Routed to 16 Mbit SERIAL FLASH MEMORY (IS25WP016 pin 2 or equivalent)   |          |
| SPI_CLK                          | M14        | Routed to 16 Mbit SERIAL FLASH MEMORY (IS25WP016 pin 6 or equivalent)   |          |
| SPI_CS                           | M13        | Routed to 16 Mbit SERIAL FLASH MEMORY (IS25WP016 pin 1 or equivalent)   |          |
| SPI_WP                           | M15        | Routed to 16 Mbit SERIAL FLASH MEMORY (IS25WP016 pin 3 or equivalent)   |          |

| Signal Name | Pad | Connection  | ✓ |
|-------------|-----|---|---|
| <b>GPIO</b> |     |   |   |
| GPIO[0]     | E15 | No Connect if not used.   |   |
| GPIO[1]     | F15 | No Connect if not used.   |   |
| GPIO[2]     | G14 | LASER_PWM - Routed to Stereo Depth Receptacle pin 43 with 0 ohm <b>no stuff</b> resistor. Refer to LASER_PWM platform implementation schematic in Figure 10-1. Laser PWM0 is routed to Stereo Depth Receptacle Pin 43 through 0 ohm <b>stuff</b> resistor. Laser PWM1 is routed to Stereo Depth Receptacle Pin 47 |   |
| GPIO[3]     | H14 | GVSYNC0 - Routed to External Sensor Sync Connector Pin 1  |   |
| GPIO[4]     | G13 | GVSYNC1 - Routed to External Sensor Sync Connector pin 2 through 0 ohm <b>stuff</b> resistor with optional LASER_PWRDN through 0 ohm <b>no stuff</b> resistor or No Connect if not used.  |   |
| GPIO[5]     | G15 | GVSYNC2 - Routed to External Sensor Sync Connector pin 3 through 0 ohm <b>stuff</b> resistor with optional FLAGB through 0 ohm <b>no stuff</b> resistor or No Connect if not used.  |   |
| GPIO[6]     | H15 | GVSYNC3 - Routed to External Sensor Sync Connector pin 4 through 0 ohm <b>stuff</b> resistor with optional LASER_PWM through 0 ohm <b>no stuff</b> resistor or No Connect if not used.  |   |
| GPIO[7]     | H13 | Routed to Stereo Depth Receptacle Pin 21 or No Connect if not used.   |   |
| EGPIO[0]    | L01 | FLAGB - Routed to Stereo Depth Connector Receptacle Pin 49 with pull up option to 1.8 V with 0 ohm <b>no stuff</b> resistor   |   |
| EGPIO[1]    | E03 | Pull up option to 1.8 V with 0 ohm <b>no stuff</b> resistor   |   |
| EGPIO[2]    | K01 | Pull up option to 1.8 V with 0 ohm <b>no stuff</b> resistor   |   |
| EGPIO[3]    | L02 | LASER_PWRDN - Routed to Stereo Depth Connector Receptacle Pin 45 with pull up option to 1.8 V with 0 ohm <b>no stuff</b> resistor   |   |
| EGPIO[4]    | M02 | Pull up to 1.8 V with 4.99K resistor  |   |
| EGPIO[5]    | J02 | Pull down option to GND with 0 Ohms <b>no stuff</b> resistor  |   |
| EGPIO[6]    | D01 | Pull up option to 1.8 V with 0 ohm <b>no stuff</b> resistor   |   |
| EGPIO[7]    | E01 | Pull down to GND with 4.99K resistor  |   |
| EGPIO[8]    | F01 | ISP_FCS – Color ISP EEPROM Chip Select. Also pulled up to 1.8 V with 4.99K resistor   |   |

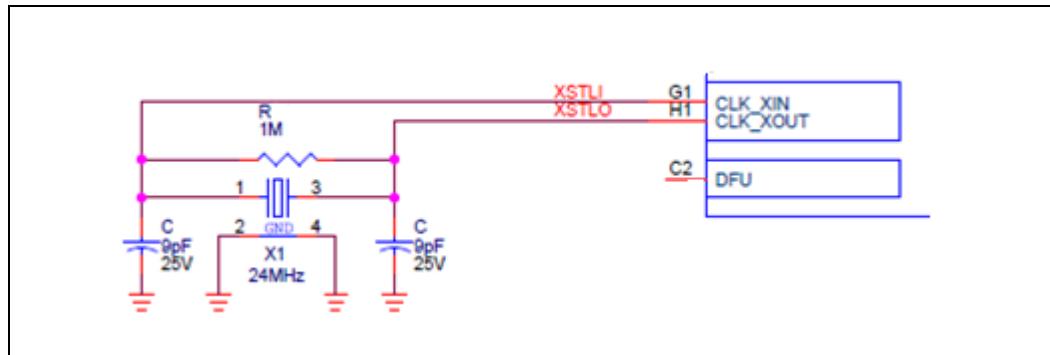
| <b>Signal Name</b>   | <b>Pad</b> | <b>Connection</b>   | <b>✓</b> |
|----------------------|------------|---|----------|
| EGPIO[9]             | E02        | Pull up option to 1.8 V with 0 ohm <b>no stuff</b> resistor   |          |
| EGPIO[10]            | J01        | Pull up option to 1.8 V with 4.99K <b>no stuff</b> resistor   |          |
| EGPIO[11]            | F03        | Pull up option to 1.8 V with 4.99K <b>no stuff</b> resistor   |          |
| EGPIO[12]            | K02        | Pull up option to 1.8 V with 4.99K <b>no stuff</b> resistor   |          |
| EGPIO[13]            | F02        | Pull up option to 1.8 V with 0 ohm <b>no stuff</b> resistor   |          |
| <b>USB</b>           |            |   |          |
| USB_RXP              | B02        | Intel® Vision Processor D4 Board supports USB Type-C connection to Host USB. Route as appropriate connection to Host USB  |          |
| USB_RXN              | A03        | Intel® Vision Processor D4 Board supports USB Type-C connection to Host USB. Route as appropriate connection to Host USB. |          |
| USB_TXP              | B01        | Intel® Vision Processor D4 Board supports USB Type-C connection to Host USB. Route as appropriate connection to Host USB. |          |
| USB_TXN              | A02        | Intel® Vision Processor D4 Board supports USB Type-C connection to Host USB. Route as appropriate connection to Host USB. |          |
| USB_DP               | D03        | Intel® Vision Processor D4 Board supports USB Type-C connection to Host USB. Route as appropriate connection to Host USB. |          |
| USB_DN               | D02        | Intel® Vision Processor D4 Board supports USB Type-C connection to Host USB. Route as appropriate connection to Host USB. |          |
| USB_ID               | E05        | Intel® Vision Processor D4 Board supports USB Type-C connection to Host USB. Route as appropriate connection to Host USB. |          |
| USB_RESREF           | E04        | 200 ohm pull down to GND. (This resistor should be placed as close to ASIC as possible)                                   |          |
| <b>MISCELLANIOUS</b> |            |   |          |
| LD_ON_OUT_XX         | K13        | (RESERVED) No Connect   |          |
| MODSTROB             | J15        | (RESERVED) No Connect   |          |
| MODSIGN              | J14        | (RESERVED) No Connect   |          |
| LD_ERR               | J13        | Connected to FF_RSTn (schematic)  |          |
| CLKXI                | G1         | 24 MHz XTAL. Refer to platform implementation schematic in Figure 10-2.   |          |
| CLKXO                | H1         | 24 MHz XTAL. Refer to platform implementation schematic in Figure 10-2.   |          |
| PRSTN                | C3         | Platform implementation specific  |          |
| CW_CSR_PRSTN         | P15        | No Connect  |          |

| <b>Signal Name</b>      | <b>Pad</b> | <b>Connection</b>   | <b>✓</b> |
|-------------------------|------------|---|----------|
| PMU_PWR_EN              | K3         | Enables VDD_PG voltage rail.  |          |
| DFU                     | C2         | Platform implementation specific  |          |
| ISP_SCL                 | M10        | (RESERVED) No Connect   |          |
| ISP_SDA                 | N9         | (RESERVED) No Connect   |          |
| VQPSQ                   | L3         | (RESERVED) No Connect   |          |
| VQPSM                   | M3         | (RESERVED) No Connect   |          |
| REFPADCLKP              | D6         | (RESERVED) No Connect   |          |
| REFPADCLKM              | E6         | (RESERVED) No Connect   |          |
| <b>JTAG</b>             |            |   |          |
| TDI                     | L13        | Routed to Test Point or pulldown resistor of 4.7 - 10K Ohm if JTAG is not used.                           |          |
| TDO                     | L14        | Routed to Test Point  |          |
| TCLK                    | K14        | Routed to Test Point or pulldown resistor of 4.7 - 10K Ohm if JTAG is not used.                           |          |
| TMS                     | K15        | Routed to Test Point or pulldown resistor of 4.7 - 10K Ohm if JTAG is not used.                           |          |
| TRSTN                   | L15        | Routed to Test Point  |          |
| <b>POWER AND GROUND</b> |            |   |          |
| VDD                     |            | 0.9 V   |          |
| VDD_PG                  |            | 0.9 V   |          |
| USB_DVDD                |            | 0.9 V   |          |
| VPTX0                   |            | 0.9 V   |          |
| VP                      |            | 0.9 V   |          |
| *_AVDD                  |            | 1.8 V   |          |
| VDDPLL                  |            | 0.9 V   |          |
| VDDTS                   |            | 1.8 V   |          |
| VDDPST18                |            | 1.8 V   |          |
| USB_VDD330              |            | 3.3 V   |          |
| VBUS0                   |            | VBUS Power Monitor Signal. VBUS0 signal level is at VBUS*(200k/(200k+30k)) using external voltage divider |          |
| VSS                     |            | Ground  |          |
| *_AGND                  |            | Ground  |          |

**Figure 12-1. Vision Processor D4 Laser PWM Reference Platform Schematic**



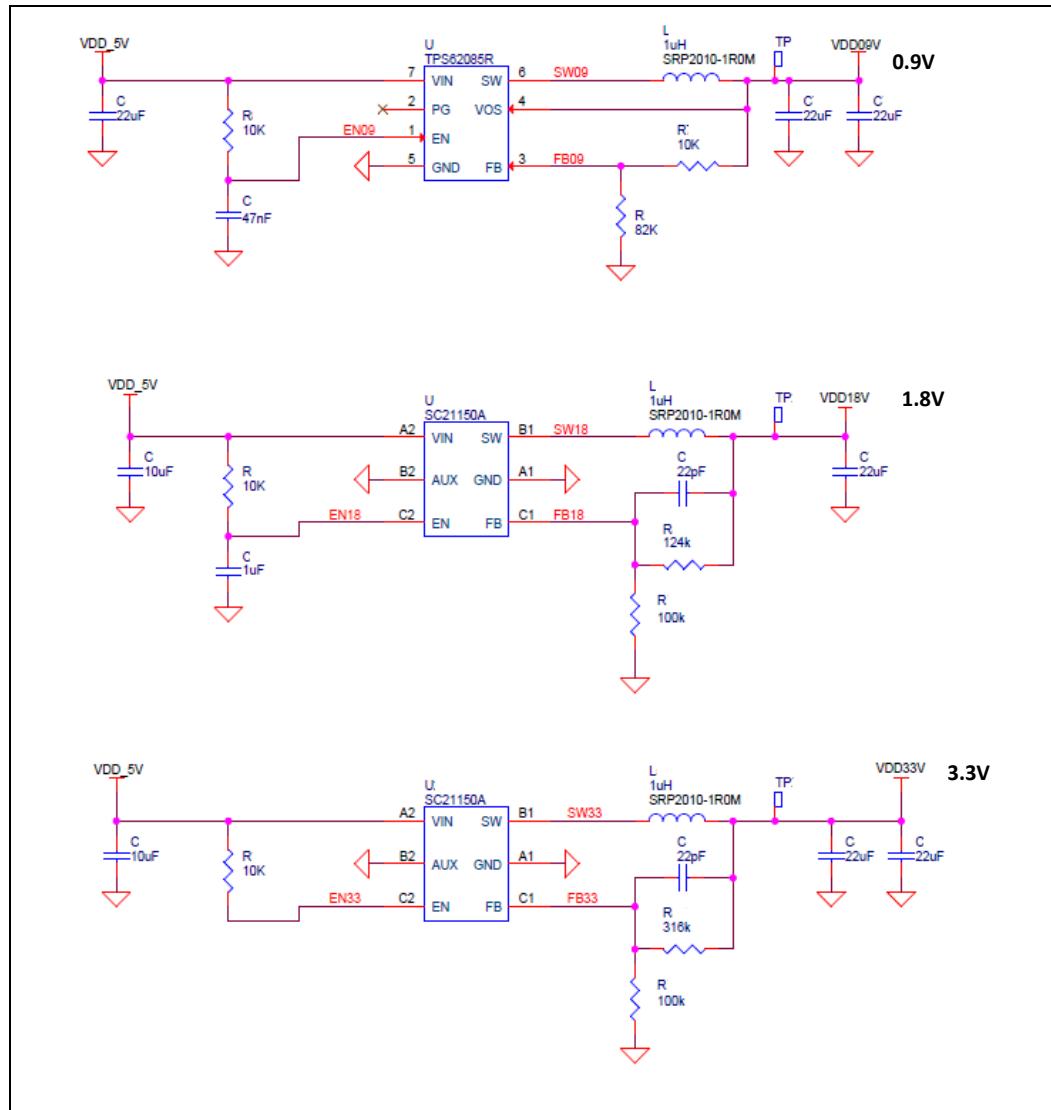
**Figure 12-2. Vision Processor D4 24 MHz Crystal Clock Reference Platform Schematic**



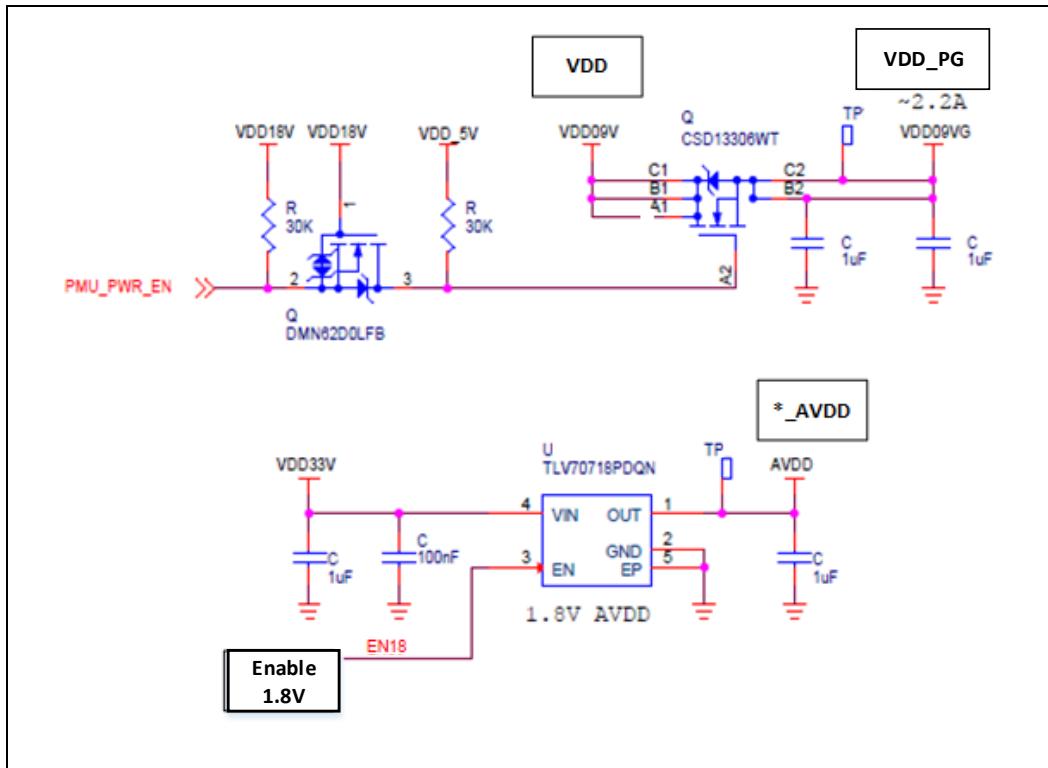
## 12.1 Power Delivery

The DC–DC power circuitry discussed in this section must be followed for Vision Processor D4 on Motherboard designs. TPS62085R DC–DC converter ([www.ti.com](http://www.ti.com)) generates 0.9 V and SC21150 ([www.semtech.com](http://www.semtech.com)) generates 1.8 V and 3.3 V voltage rails from 5 V to power Vision Processor D4, Stereo Depth Module.

**Figure 12-3. DC-DC Reference Platform Schematic (3.3 V, 1.8 V, 0.9 V)**



**Figure 12-4. Vision Processor D4 VDD\_PG and AVDD Reference Platform Schematic**



**Table 12-2. Vision Processor D4 Decoupling and Filter Requirements**

| Voltage Ball Name               | Decoupling | Filter                                  | Notes |
|---------------------------------|------------|---|-------|
| VDD                             | 4X 100 nF  |   |       |
| VDD_PG                          | 8X 100 nF  |   |       |
| USB_DVDD                        |            | 1X 100 nF                               |       |
| VPTX0                           | 2X 100 nF  | 1X FERRITE BEAD<br>120 ohm              |       |
| VP                              |            |   |       |
| *AVDD                           | 1X 100 nF  |   |       |
| VDDPLL                          | 1X 100 nF  | 1X 100 nF<br>1X FERRITE BEAD<br>120 ohm |       |
| VDDTS                           | 1X 100 nF  |   |       |
| VDDPST18<br>(Left and<br>Right) | 1X 100 nF  |   |       |
| USB_VDD330                      | 1X 100 nF  |   |       |
| VBUS0                           |            |   |       |

# 13 Appendix B – Cover Material

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Cover materials placed over the camera sensor must be carefully selected to avoid impacting software performance. The following parameters are an example of a suitable cover material. Other solutions are also acceptable but careful design and validation work should be done to verify a solution will perform adequately.

**Table 13-1. Example: Cover Material Parameters**

| Specification                                       | Recommendation  | Notes                                       |
|---|---|---|
| Hardness  | 6H  | Prevent Scratches                           |
| Flatness  | 0.05 mm   | Minimize Distortion                         |
| Air gap between the tip of the lens to cover window | 0.3 mm  | Cover Material not to exceed 1 mm thickness |
| Thickness of Cover                                  | 0.55 mm ± 0.03 mm   | Cover Material not to exceed 1 mm thickness |
| Coatings  | AR inside and outside.<br>AR coating on the whole exterior surface (non-ink side) of the cover window.        | Avoid Reflections                           |
| Transmission Wavelength Range                       | 400 to 865 nm (Visible and Infrared) @ 98% transmission rate or higher at all viewing and transmitting angles |   |
| Cover Tilt Tolerance                                | ± 1.0°  |   |