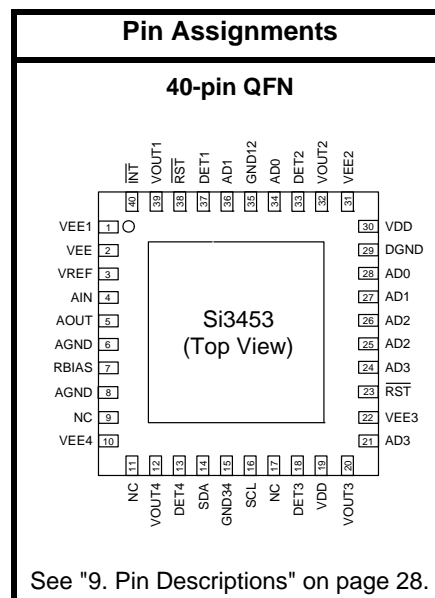
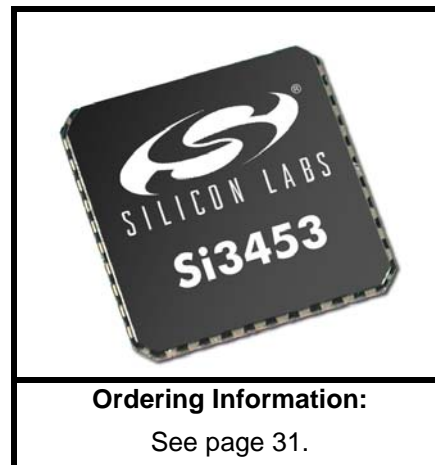




## QUAD HIGH-VOLTAGE PORT CONTROLLER FOR PoE AND PoE+ PSEs

### Features

- Each Si3453 high-voltage port controller supports four PSE power interfaces
- Programmable current limits for PoE (15.4 W), PoE+ (30 W), and proprietary systems (up to 40 W) per port
- I<sup>2</sup>C interface requires no external MCU for easy, low-cost management of 4 to 48 ports by the host system
- Unique mixed-signal IC high-voltage component integration simplifies design, lowers power dissipation, minimizes external BOM, and reduces PCB footprint
  - Internal low-R<sub>ON</sub> power FETs with current-sense circuitry
  - Integrated transient voltage surge suppressors
  - DC disconnect sensing method
- Programmable architecture supports IEEE 802.3af (PoE) and IEEE 802.3at (PoE+) PSEs
  - Programmable current limits for PoE (350 mA) and PoE+ (600 mA), and custom limits to 850 mA
  - Per-port current and voltage monitoring for sophisticated power management and control
  - Power policing mode
  - Robust multi-point detection
  - Supports 1-Event and 2-Event classification algorithms
- Comprehensive, robust, fault-protection circuitry
  - Supply undervoltage lockout (UVLO)
  - Output current limit and short-circuit protection
  - Foldback current limiting
  - Dual-threshold thermal overload protection
  - Fault source reporting for intelligent port management
- Industrial (-40 to 85 °C) operating temperature
- Compact, 6x6 mm<sup>2</sup>, 40-pin QFN RoHS-compliant package



### Applications

- Power over Ethernet Endpoint switches and Midspans for IEEE Std 802.3af and 802.3at
- Supports high-power PDs, such as:
  - Pan/Tilt/Zoom security cameras
  - 802.11n WAPs
  - Multi-band, multi-radio WAPs
- Security and RFID systems
- Industrial automation systems
- Networked audio
- IP Phone Systems and iPBXs
- Metropolitan area networked WAPs, cameras, and sensors
- WiMAX ASN/BTS and CPE/ODU systems

# Si3453

## Description

When connected directly to the host system or configured in Auto mode, each Si3453 high-voltage port controller provides all of the critical circuitry and sophisticated power measurement functionality for the high-voltage interfaces of four complete PSE ports. The Si3453 fully integrates robust, low- $R_{ON}$  ( $0.3\ \Omega$  typical) power MOSFET switches, low-power dissipation current sensing circuitry, and transient voltage surge suppression devices.

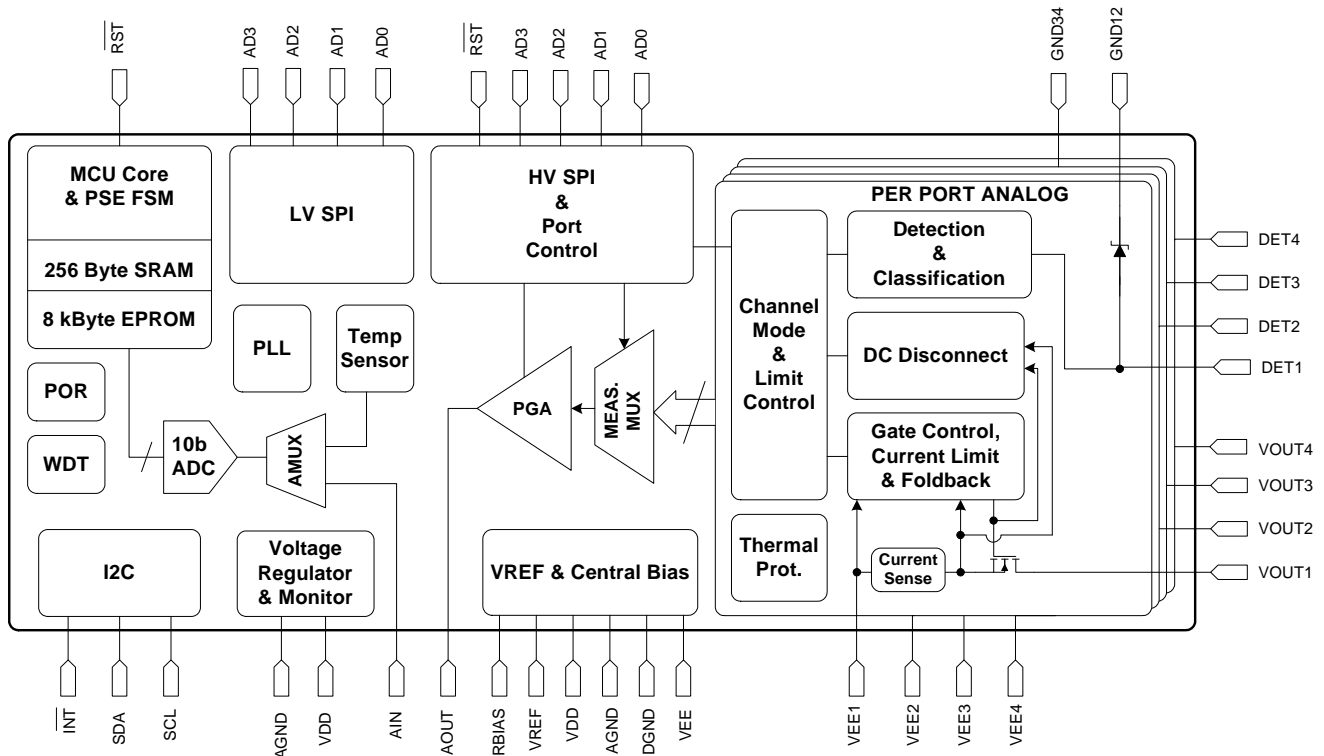
The on-chip current sense circuitry and power MOSFETs provide programmable scaling of current limits to match either PoE (350 mA, 15.4 W), PoE+ (600 mA, 30 W), and extended (800 mA, 40 W) power requirements on a per-port basis. Designed for use in Endpoint PSE (e.g., Ethernet switches) or Midspan PSE (e.g., inline power injectors) applications, each Si3453 also performs the IEEE-required powered device (PD) detection, classification, and disconnect functionality.

The flexible architecture enables powered device disconnect detection using a dc disconnect sensing algorithm. Also provided are multi-point detection algorithms and per-port current and voltage monitoring.

Intelligent protection circuitry includes power supply undervoltage lockout (UVLO), port output current limiting and short-circuit protection, thermal overload sensing and port shutdown, and transient voltage surge suppressors capable of protecting the Si3453 from a variety of harsh surge events seen on the RJ-45 interface.

To maximize system design flexibility and minimize cost, each Si3453 connects directly to a system host controller through an I<sup>2</sup>C serial interface, eliminating the need for an external MCU. The Si3453 can be set to one of 12 unique addresses, allowing control of up to 48 ports on a single I<sup>2</sup>C bus.

## Functional Block Diagram



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**TABLE OF CONTENTS**


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| <b><u>Section</u></b>   | <b><u>Page</u></b> |
|---|--------------------|
| <b>1. Electrical Specifications</b> .....                     | <b>4</b>           |
| <b>2. PSE System-Level Diagrams</b> .....                     | <b>11</b>          |
| <b>3. PSE Application Diagrams</b> .....                      | <b>11</b>          |
| <b>4. Functional Description</b> .....                        | <b>12</b>          |
| 4.1. Detection .....  | 12                 |
| 4.2. Classification .....                                     | 13                 |
| 4.3. Port Turn-On and Power FETs .....                        | 13                 |
| 4.4. Disconnect Detection .....                               | 14                 |
| 4.5. Transient Voltage Surge Suppression .....                | 14                 |
| 4.6. Temperature Sense .....                                  | 14                 |
| 4.7. Port Measurement and Monitoring .....                    | 14                 |
| 4.8. SMBus/I <sup>2</sup> C Interface Description .....       | 15                 |
| <b>5. Register Interface</b> .....                            | <b>17</b>          |
| 5.1. Interrupt (Registers 0x00–0x01) .....                    | 17                 |
| 5.2. Port Event (Registers 0x02–0x05) .....                   | 17                 |
| 5.3. Port Status (Registers 0x06–0x09) .....                  | 17                 |
| 5.4. Port Configuration (Registers 0x0A–0x11) .....           | 18                 |
| 5.5. Command and Return Registers (Registers 0x12–0x1C) ..... | 19                 |
| 5.6. Device Status Register (0x1D) .....                      | 19                 |
| <b>6. Operational Notes</b> .....                             | <b>25</b>          |
| 6.1. Port Turn On .....                                       | 25                 |
| 6.2. Changing the Interrupt Mask .....                        | 25                 |
| 6.3. Port Voltage and Current Measurements .....              | 25                 |
| <b>7. PCB Layout Guidelines</b> .....                         | <b>26</b>          |
| <b>8. Firmware Release Notes</b> .....                        | <b>27</b>          |
| 8.1. I <sup>2</sup> C Address ACK .....                       | 27                 |
| <b>9. Pin Descriptions</b> .....                              | <b>28</b>          |
| <b>10. Package Outline: 40-Pin QFN</b> .....                  | <b>31</b>          |
| <b>11. Recommended PCB Footprint</b> .....                    | <b>32</b>          |
| <b>12. Ordering Guide</b> .....                               | <b>34</b>          |
| 12.1. Evaluation Kits and Reference Designs .....             | 34                 |
| <b>13. Device Marking Diagram</b> .....                       | <b>35</b>          |
| <b>Document Change List</b> .....                             | <b>36</b>          |
| <b>Contact Information</b> .....                              | <b>38</b>          |

## 1. Electrical Specifications

Unless noted otherwise, specifications apply over the operating temperature range with VDD = +3.3 V and VEE = -48 V relative to GND.

VDD pins should be electrically shorted. AGND pins, DGND, GND12, and GND34 should be electrically shorted ("GND"). VEE, VEE1, VEE2, VEE3, and VEE4 should be electrically shorted ("VEE").

VPort for any port is measured from GND to the respective VOUTn.

**Table 1. Absolute Maximum Ratings<sup>1</sup>**

| Type  | Description  | Rating                     | Unit |
|---|--|----------------------------|------|
| Supply Voltages   | VEE to GND   | -62 to +0.3                | V    |
|   | VDD to GND   | -0.3 to +3.6               | V    |
|   | VDD1 to VDD2   | -0.3 to +0.3               | V    |
|   | Any VEE to any other VEE   | -0.3 to +0.3               | V    |
|   | Any GND to any other GND   | -0.3 to +0.3               | V    |
| Voltage on Digital Pins   | SDA, SCL, ADn, $\overline{\text{RST}}$ , $\overline{\text{INT}}$ | (GND - 0.3) to (VDD + 0.3) | V    |
| Voltage on Analog Pins  | VREF, AIN, AOUT, RBIAS, OSC                                      | (GND - 0.3) to (VDD + 0.3) | V    |
|   | VOUTn, DETn  | (VEE - 0.3) to (GND + 0.3) | V    |
| DETn Peak Currents During Surge Events <sup>2</sup>   |  | ±5                         | A    |
| Maximum Continuous Power Dissipation <sup>3</sup>   |  | 1.2                        | W    |
| Maximum Junction Temperature  |  | 125                        | °C   |
| Ambient Storage Temperature   |  | -55 to 150                 | °C   |
| Lead Temperature (Soldering, 10 seconds Maximum)  |  | 260                        | °C   |
| <b>Notes:</b> <ol style="list-style-type: none"> <li>Functional operation should be restricted to those conditions specified in Table 2. Functional operation or specification compliance is not implied at these conditions. Stresses beyond those listed in absolute maximum ratings may cause permanent damage to the device.</li> <li>See IEEE Std 802.3-2005, clause 33.4, for a description of surge events.</li> <li>If all ports are on with 600 mA load, the power dissipation is &lt;1.2 W. At 85 °C ambient with the expected 32 °C/W thermal impedance, the junction temperature would be 123.4 °C, which is within the 125 °C maximum rating.</li> </ol> |  |                            |      |

Table 2. Recommended Operating Conditions

| Description  | Symbol        | Test Conditions                       | Min | Typ | Max | Unit |
|--|---------------|---------------------------------------|-----|-----|-----|------|
| Ambient Operating Temperature  | $T_A$         |                                       | -40 | —   | 85  | °C   |
| Thermal Impedance*   | $\theta_{JA}$ | No airflow                            | —   | 32  | —   | °C/W |
|  |               | 1 m/s airflow                         | —   | 28  | —   |      |
| <b>Power Supply Voltages</b>   |               |                                       |     |     |     |      |
| $V_{EE}$ Supply Voltage  | $V_{EE}$      | For IEEE 802.3af (15.4 W) apps.       | -57 | -48 | -45 | V    |
|  |               | For IEEE 802.3at (30 W) apps.         | -57 | -54 | -51 | V    |
| $V_{DD}$ Supply Voltage  | $V_{DD}$      |                                       | 3.0 | 3.3 | 3.6 | V    |
| <b>Power Supply Currents</b>   |               |                                       |     |     |     |      |
| $V_{EE}$ Supply Current  | $I_{EE}$      | All ports on, excluding load current. | —   | 3.7 | 6.0 | mA   |
|  |               | All ports in shutdown mode            | —   | 1   | 2   |      |
| $V_{DD}$ Supply Current  | $I_{DD}$      |                                       | —   | 8   | 14  | mA   |
| *Note: Modeled with six parts evenly spaced on a 30 x 120 mm <sup>2</sup> , four-layer board with 25 thermal vias to a Vneg plane on the back. |               |                                       |     |     |     |      |

Table 3. UVLO, and Reset Specifications

| Description   | Symbol       | Test Conditions   | Min                 | Typ  | Max | Unit |
|---|--------------|---|---------------------|------|-----|------|
| $V_{DD}$ Reset Threshold  | $V_{RST}$    |   | —                   | 1.75 | —   | V    |
| $V_{DD}$ Power-On Ramp*   |              | Ramp from 0 V to 3.0 V  | —                   | —    | 1   | ms   |
| $\overline{RST}$ Input High Voltage   |              |   | $0.7 \times V_{DD}$ | —    | —   | V    |
| $\overline{RST}$ Input Low Voltage  |              |   | —                   | —    | 0.8 | V    |
| $\overline{RST}$ Input Leakage  |              | $\overline{RST} = 0\text{ V}$   | —                   | —    | 40  | μA   |
| Reset Time Delay  | $T_{RSTDLY}$ | Time between end of reset and beginning of normal operation               | —                   | —    | 100 | ms   |
| Reset Assertion Time  | $T_{RST}$    | $\overline{RST}$ low time to generate system reset                        | 15                  | —    | —   | μs   |
| $V_{EE}$ Monitor Accuracy   | $V_{EEMON}$  | Measured $V_{EE}$ relative to actual $V_{EE}$ for $V_{EE}$ (-44 to -57 V) | -4                  | —    | 4   | %    |
| $V_{EE}$ UVLO Threshold   | $V_{UVLO}$   | Point at which VEE UVLO is declared.                                      | -38                 | -36  | —   | V    |
|   |              | VEE going negative<br>VEE going positive                                  | —                   | -33  | -31 |      |
| *Note: If VDD ramp time is slower than 1 ms, hold the reset pins low until VDD is above 3.0 V to insure proper reset operation. |              |   |                     |      |     |      |

Table 4. Detection Specifications

| Description   | Symbol                                 | Test Conditions                   | Min             | Typ                  | Max               | Unit       |
|---|--|-----------------------------------|-----------------|----------------------|-------------------|------------|
| Detection Current Limit                               | $I_{LIM\_DET}$                         | Measured with DETn shorted to GND | —               | 3                    | 5                 | mA         |
| Detection Voltage, when $R_{DET} = 25\text{ k}\Omega$ | $V_{DET1}$<br>$V_{DET2}$<br>$V_{DET3}$ |                                   | —<br>-10.0<br>— | -4.0<br>-8.0<br>-4.0 | -2.8<br>—<br>-2.8 | V          |
| Detection Slew Rate                                   |  |                                   | —               | —                    | 0.1               | V/ $\mu$ s |
| Detection Probe Duration                              | $T_{PROBE}$                            |                                   | 10              | —                    | 30                | ms         |
| Detection Probe Cycle Time                            | $T_{DET}$                              |                                   | —               | —                    | 500               | ms         |
| Minimum Valid Signature Resistance                    | $R_{DET\_MIN}$                         |                                   | 15              | —                    | 19                | k $\Omega$ |
| Maximum Valid Signature Resistance                    | $R_{DET\_MAX}$                         |                                   | 26.5            | —                    | 33                | k $\Omega$ |
| Resistance at which Open Circuit is Declared          | $R_{OPEN}$                             |                                   | 100             | —                    | 400               | k $\Omega$ |
| Resistance at which Short Circuit is Declared         | $R_{SHORT}$                            |                                   | 150             | —                    | 400               | W          |
| Valid Detect Capacitance                              | $C_{DET\_VALID}$                       |                                   | —               | —                    | 150               | nF         |
| Invalid Detect Capacitance                            | $C_{DET\_INVALID}$                     |                                   | 10              | —                    | —                 | $\mu$ F    |

Table 5. Classification Specifications

| Description                    | Symbol           | Test Conditions  | Min                            | Typ                        | Max                            | Unit |
|--------------------------------|------------------|--|--------------------------------|----------------------------|--------------------------------|------|
| Class Event Voltage            | $V_{CLASS}$      | $0\text{ mA} < I_{Port} < 45\text{ mA}$                                | -20.5                          | —                          | -15.5                          | V    |
| Mark Event Voltage             | $V_{MARK}$       | $0\text{ mA} < I_{Port} < 5\text{ mA}$                                 | -7                             | —                          | -10                            | V    |
| Classification Current Limit   | $I_{LIM\_CLASS}$ | Measured with DETn shorted to GND                                      | 51                             | —                          | 100                            | mA   |
| Classification Current Regions |                  | Class 0<br>Class 1<br>Class 2<br>Class 3<br>Class 4<br>Overcurrent     | 0<br>8<br>16<br>25<br>35<br>51 | —<br>—<br>—<br>—<br>—<br>— | 5<br>13<br>21<br>31<br>45<br>— | mA   |
| Classification Delay           | $T_{CLASS\_DLY}$ | Time from end of valid detect cycle to classification begin            | —                              | 5                          | —                              | ms   |
| Classification Event Time      | $T_{CLE}$        | Width of valid $V_{CLASS}$ probe for 1-Event or 2-Event classification | 10                             | —                          | 30                             | ms   |
| Mark Event Time                | $T_{ME}$         | Width of mark between classification events                            | —                              | 8                          | —                              | ms   |

Table 6. VOUT Drive and Power-on Specifications

| Description   | Symbol           | Test Conditions  | Min                            | Typ                   | Max                   | Unit          |
|---|------------------|--|--------------------------------|-----------------------|-----------------------|---------------|
| Max Output Resistance (Port On)   | $R_{ON}$         | $I_{Port} \leq 720 \text{ mA}$   | —                              | 0.3                   | 0.6                   | $\Omega$      |
| Current Limit   | $I_{LIM}$        | 1x mode, $V_{port} = V_{EE} + 1 \text{ V}$   | 400                            | 425                   | 450                   | mA            |
| Change in Current Limit   | $\Delta I_{LIM}$ | 1x mode, $V_{port} = V_{EE} + 1 \text{ V}$ to $-30 \text{ V}^1$  | -2                             | —                     | 2                     | %             |
| Current Limit   | $I_{LIM}$        | 2x mode, $V_{port} = V_{EE} + 1 \text{ V}$   | 800                            | 860                   | 920                   | mA            |
| Change in Current Limit   | $\Delta I_{LIM}$ | 2x mode, $V_{port} = V_{EE} + 1 \text{ V}$ to $-40 \text{ V}^2$  | -2                             | —                     | 2                     | %             |
| Current Limit   | $I_{LIM}$        | 1x mode or 2x mode, $V_{port} = -10 \text{ V}$   | 60                             | —                     | —                     | mA            |
| Overload Current Threshold  | $I_{CUT}$        | Class 0<br>Class 1 (class policing enabled) <sup>3</sup><br>Class 2 (class policing enabled) <sup>3</sup><br>Class 3<br>Class 4 <sup>4</sup> | 350<br>91<br>160<br>350<br>600 | —<br>—<br>—<br>—<br>— | —<br>—<br>—<br>—<br>— | mA            |
| Over Current Time Limit <sup>5</sup>  | $T_{OVL D}$      | Load current $\geq I_{CUT}$ or $I_{LIM}$   | 50                             | —                     | 75                    | ms            |
| VOUTn Turn-on Slew  | $T_{RISE}$       | 10% to 90%   | 15                             | 70                    | —                     | $\mu\text{s}$ |
| Power Turn On Timing  | $T_{PON}$        | Time from end of valid detect to power on  | —                              | —                     | 400                   | ms            |
| VOUTn Leakage Current   | $I_{OUT\_LEAK}$  | Port in shutdown   | —                              | —                     | 10                    | $\mu\text{A}$ |
| <b>Notes:</b>   |                  |  |                                |                       |                       |               |
| 1. $T_J > 25 \text{ }^\circ\text{C}$ , $-35 \text{ V}$ over the full temperature range.   |                  |  |                                |                       |                       |               |
| 2. 1x mode current limit is enforced during the 60 ms $T_{START}$ time.   |                  |  |                                |                       |                       |               |
| 3. In auto mode, class policing is automatically enabled. In manual mode, $I_{CUT}$ must be programmed manually. See "5.4. Port Configuration (Registers 0x0A–0x11)" on page 18 for more information. |                  |  |                                |                       |                       |               |
| 4. 600 mA is consistent with the IEEE 802.3at draft standard. $I_{CUT}$ is user-programmable in 3.2 mA increments to over 800 mA for non-standard applications.                                       |                  |  |                                |                       |                       |               |
| 5. For 2x mode and extreme overload or short-circuit events, $T_{OVL D}$ will dynamically decrease to prevent excessive FET heating. This is consistent with the 802.3at draft.                       |                  |  |                                |                       |                       |               |

Table 7. DC Disconnect Specifications

| Description                          | Symbol          | Test Conditions                                   | Min | Typ | Max | Unit |
|--------------------------------------|-----------------|---|-----|-----|-----|------|
| Load Current to Prevent Disconnect   | $I_{ON}$        |   | 10  | —   | —   | mA   |
| Load Current to Guarantee Disconnect | $I_{OFF}$       | dc disconnect                                     | —   | —   | 5   | mA   |
| Disconnect Delay                     | $T_{DCDV\_DLY}$ | Time from $I_{OFF}$ load current to port turn off | 300 | —   | 400 | ms   |

**Table 8. Port Measurement and Monitoring Specifications**

| Description                        | Symbol              | Test Conditions  | Min | Typ | Max | Unit |
|------------------------------------|---------------------|--|-----|-----|-----|------|
| Port Current Measurement Offset    | $I_{\text{OFFSET}}$ | 20 mA $\leq$ $I_{\text{PORT}} \leq$ $I_{\text{CUT}}$ . For final $I_{\text{PORT}}$ reading, add offset to% of reading tolerance. | -5  | —   | 5   | mA   |
| Port Current Measurement Tolerance | %TOL                |  | -4  | —   | 4   | %    |

**Table 9. SMBus (I<sup>2</sup>C) Electrical Specifications**

VDD = 3.0 to 3.6 V

| Description           | Symbol          | Test Conditions                      | Min | Typ | Max  | Unit    |
|-----------------------|-----------------|--------------------------------------|-----|-----|------|---------|
| Input Low Voltage     | $V_{\text{IL}}$ | SCL, SDA pins                        | —   | —   | 0.8* | V       |
| Input High Voltage    | $V_{\text{IH}}$ | SCL, SDA pins                        | 2.2 | —   | —    | V       |
| Output Low Voltage    | $V_{\text{OL}}$ | SCL, SDA pins, driving $\leq$ 8.5 mA | —   | —   | 0.6  | V       |
| Input Leakage Current | $I_{\text{L}}$  | SCL, SDA pins                        | —   | —   | 40   | $\mu$ A |

**\*Note:** 0.85 V for  $T_j \geq -10$  °C. This ensures compatibility with Si840x isolators with 3 k $\Omega$  pull up. For isolator compatibility over the full temperature range, use Si860x isolators.

**Table 10. Address Pin Electrical Specifications\***

VDD = 3.0 to 3.6 V

| Description           | Symbol                       | Test Conditions         | Min                        | Typ | Max | Unit    |
|-----------------------|------------------------------|-------------------------|----------------------------|-----|-----|---------|
| Input Low Voltage     | $V_{\text{IL}}$              | AD0, AD1, AD2, AD3 pins | —                          | —   | 0.8 | V       |
| Input High Voltage    | $V_{\text{IH}}$              | AD0, AD1, AD2, AD3 pins | $0.7 \times V_{\text{DD}}$ | —   | —   | V       |
| Input Leakage Current | $I_{\text{H}}, I_{\text{L}}$ | AD0, AD1, AD2, AD3 pins | -10                        | —   | 10  | $\mu$ A |

**\*Note:** At power-up, these pins are logic inputs. A 10 k $\Omega$  pull up or pull down resistor is used for address selection. After address recognition, the pins are used for internal communications.

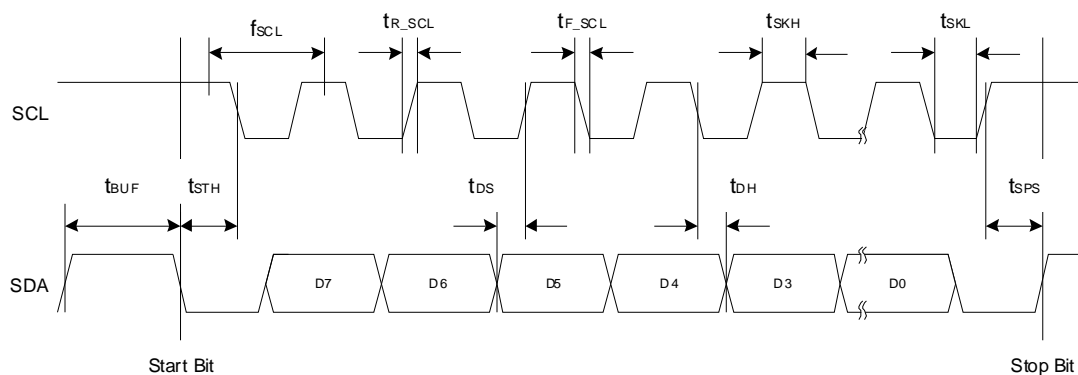
**Table 11. SMBus (I<sup>2</sup>C) Timing Specifications (see Figure 1)**

VDD = 3.0 to 3.6 V

| Description  | Symbol       | Test Conditions                       | Min | Typ | Max | Unit    |
|--|--------------|---------------------------------------|-----|-----|-----|---------|
| Serial Bus Clock Frequency   | $f_{SCL}$    |                                       | 0   | —   | 400 | kHz     |
| SCL High Time  | $t_{SKH}$    |                                       | 600 | —   | —   | ns      |
| SCL Low Time   | $t_{SKL}$    |                                       | 1.3 | —   | —   | $\mu$ s |
| SCL, SDA Rise Time   | $t_{R\_SCL}$ |                                       | 20  | —   | 300 | ns      |
| SCL, SDA Fall Time   | $t_{F\_SCL}$ |                                       | 20  | —   | 150 | ns      |
| Bus Free Time  | $t_{BUF}$    | Between START and STOP conditions.    | 1.3 | —   | —   | $\mu$ s |
| Start Hold Time  | $t_{STH}$    | Between START and first low SCL.      | 600 | —   | —   | ns      |
| Start Setup Time   | $t_{STS}$    | Between SCL high and START condition. | 600 | —   | —   | ns      |
| Stop Setup Time  | $t_{SPS}$    | Between SCL high and STOP condition.  | 600 | —   | —   | ns      |
| Data Hold Time   | $t_{DH}$     |                                       | 200 | —   | —   | ns      |
| Data Setup Time  | $t_{DS}$     |                                       | 200 | —   | —   | ns      |
| Time from Hardware or Software Reset until Start of I <sup>2</sup> C Traffic | $t_{RESET}$  | Reset to start condition              | —   | —   | 100 | ms      |
| Delay from Event to INT Pin Low or from Clear-On-Read to INT Pin High        | $t_{INT}$    |                                       | —   | —   | 5   | ms      |

**Notes:**

1. Not production tested (guaranteed by design).
2. All timing references measured at  $V_{IL}$  and  $V_{IH}$ .
3. The Si3453 will stretch (pull down on) SCK during the ACK time period if required. The maximum SCL stretching is 10  $\mu$ sec; so, SCL only needs to be bidirectional for I<sup>2</sup>C bus speeds over 50 kHz.

**Figure 1. I<sup>2</sup>C Timing Diagram**

**Table 12. Interrupt ( $\overline{\text{INT}}$ ) Specifications**

| Description        | Symbol   | Test Conditions                                   | Min | Typ | Max | Unit |
|--------------------|----------|---|-----|-----|-----|------|
| Output Low Voltage | $V_{OL}$ | $\overline{\text{INT}}$ pin driving $\leq 8.5$ mA | —   | —   | 0.6 | V    |

**Table 13. Input Voltage Reference Specifications**

| Description         | Symbol | Test Conditions | Min | Typ | Max | Unit          |
|---------------------|--------|-----------------|-----|-----|-----|---------------|
| Nominal VREF Input  |        |                 | —   | 1.1 | —   | V             |
| Reference Tolerance |        |                 | —   | —   | 1   | %             |
| VREF Loading        |        | Input current   | -10 | —   | +10 | $\mu\text{A}$ |

## 2. PSE System-Level Diagrams

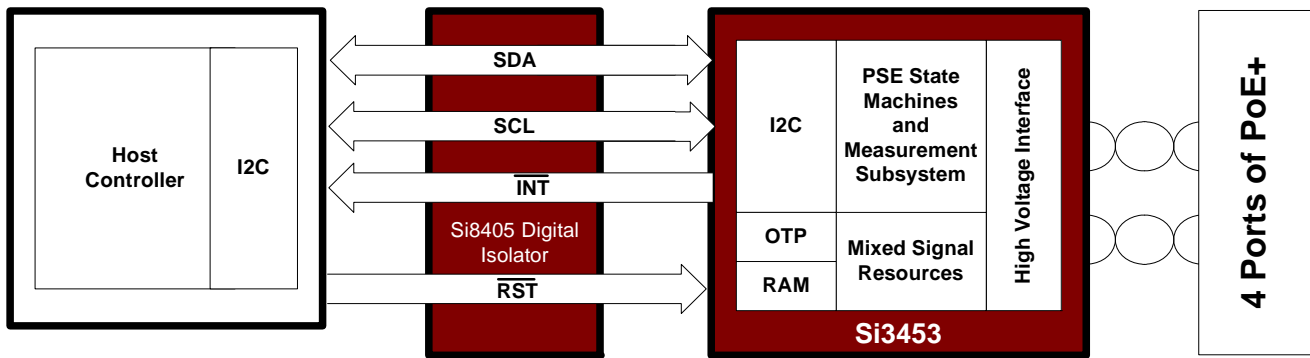


Figure 2. 4-Port System with Direct Host Connection

## 3. PSE Application Diagrams

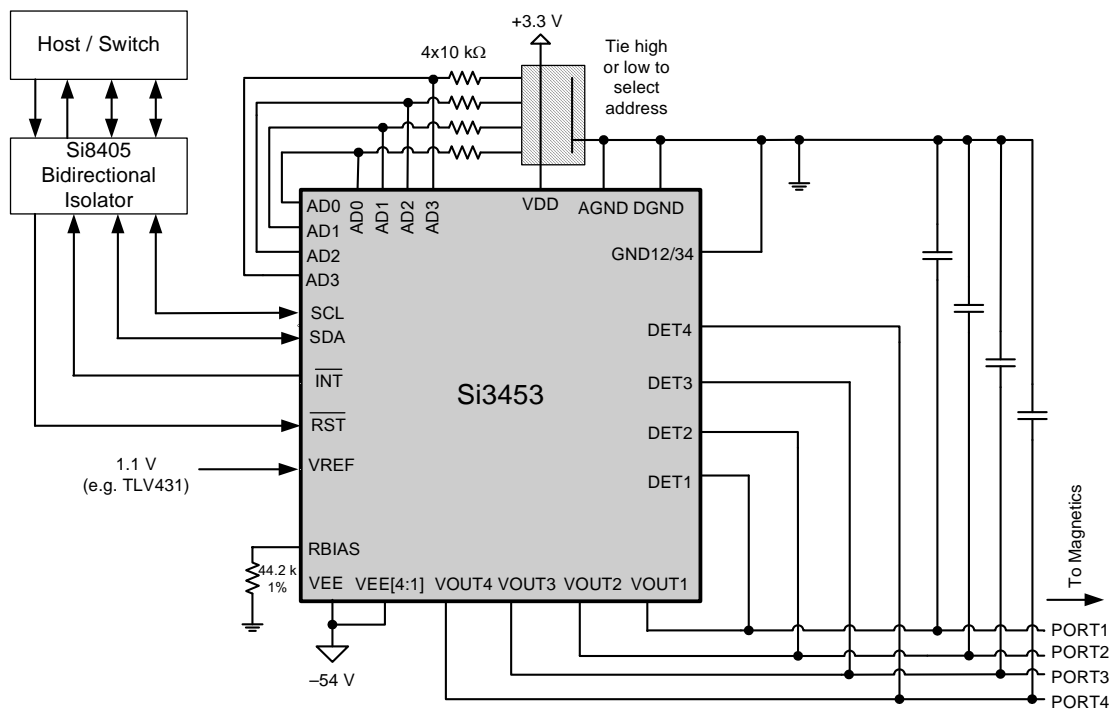


Figure 3. 4-Port Application Diagram Using DC Disconnect and I<sup>2</sup>C Host Interface

## 4. Functional Description

Integrating four independent high-voltage PSE port interfaces, the Si3453 high-voltage port controller enables extremely flexible solutions for virtually any PoE or PoE+ PSE application. The Si3453 provides all of the high-voltage Power over Ethernet PSE functions.

Each port of the Si3453 integrates all high-voltage PSE controller functions needed for a quad-port PoE design, including the power MOSFET, efficient current-sensing circuitry, transient voltage surge suppressor, and multiple detect and disconnect circuits. When the dc disconnect sensing method is selected, the external BOM is typically only a single filter capacitor on each high-voltage port.

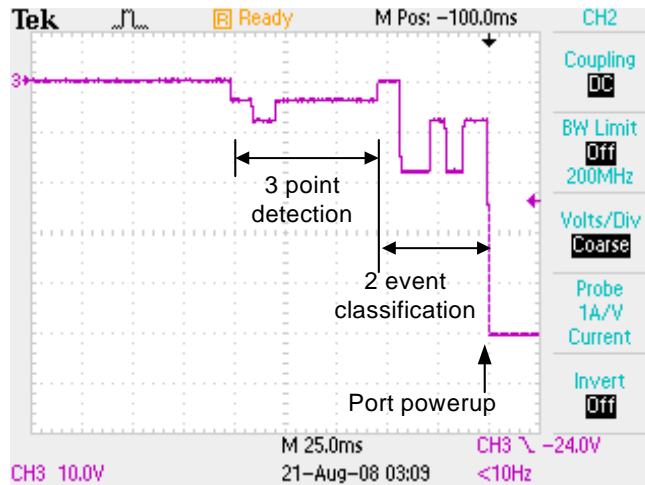
When a PD device has been properly detected and classified, the port is powered by a  $-54\text{ V}$  nominal supply with continuous monitoring of voltage and current for feedback to the host system.

In addition to the required IEEE features, the Si3453 includes many additional features:

- Per port current / voltage monitoring and measurement
- Support for 1-Event and 2-Event classification algorithms
- Start up in shutdown or auto mode
- Alternative A (typically used for endpoint systems) or Alternative B (typically used for midspan systems) detection timing

### 4.1. Detection

The Si3453 has per-port signature detection that satisfies the IEEE Std 802.3™-2005 specifications. However, by utilizing a 3-point voltage-forced detection method, the Si3453 yields robust recognition of valid and invalid powered device (PD) signatures, properly identifying signatures often mischaracterized by other detection techniques.



**Figure 4. PSE Sequencing (3-Point Detection followed by 2-Event Classification and Powerup) Vport Relative to GND**

The detection circuitry performs the function of setting the output voltage on any channel to the proper value for detection or classification and then measuring the resulting line current.

A typical detection cycle consists of applying 4 V, then 8 V, then 4 V again with the current limit set to 3 mA. The current is measured after an appropriate settling time. For a valid PD, the detection signature must be compliant with the detection voltage both increasing and decreasing.

## 4.2. Classification

Following a successful PD detection, the classification phase will be automatically initiated in all operational modes. During this phase, a single measurement will be made at 18 V to determine how much power the PD device will draw under maximum loads per the IEEE 802.3af and 802.3at standards. The current limit during this test mode is 60 mA nominal.

The Si3453 supports 1-Event and 2-Event classification. When operating in PoE ( $\leq 15.4$  W) mode, 1-Event classification is used. Operation in PoE+ ( $>15.4$  W) mode results in 2-Event classification probes. The 1-Event classification is compliant to IEEE standard 802.3-2005. 2-Event classification is compliant to draft IEEE P802.3at.

## 4.3. Port Turn-On and Power FETs

The FET is turned on with a gate drive that results in a very low-noise turn-on waveform with a slew rate of less than 1 V/ $\mu$ sec (See Figure 5).

The power FET switch on each port has been sized to have a typical ON resistance of approximately 0.3  $\Omega$ . The shunt resistor for current measurement has also been set to 0.1  $\Omega$ . Including interconnection and process variation, the total resistance to VEE for a port that is on is 0.6  $\Omega$  (max). This limits the maximum power dissipation per channel to < 250 mW when the operating current is 600 mA, the maximum current allowed by the IEEE 802.3at PoE+ standard.

The FET has a programmable operating current limit. Each channel can be set to support output currents of 400 mA or 800 mA minimum.

In addition to the normal current limit, there is a short circuit current shutdown approximately 25% greater than the nominal current limit. If there is a transient current surge where the current ramps up faster than the programmed current limit can respond, the gate drive voltage is clamped immediately to VEE. The clamp is enabled for at least 10  $\mu$ s, which allows the normal current circuitry to respond.

Another important protection feature is foldback current limiting. When VOUT is near VEE, the current limit is at maximum. As the VDS of the driver switch increases (and VOUT is closer to ground), the current limit goes to its lowest level. The amount of the foldback current is scaled proportionally with the programmed current limit.

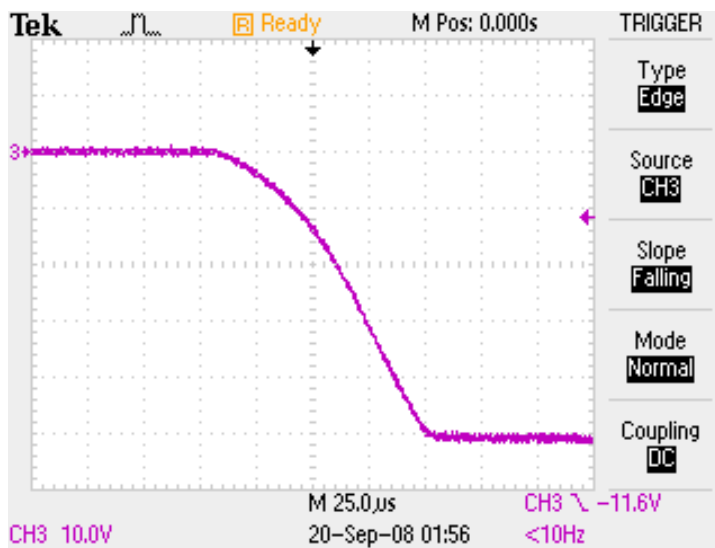


Figure 5. Turn-On Waveform—Vport Relative to GND

## 4.4. Disconnect Detection

The port current is continuously monitored by the Si3453. The Si3453 can dynamically change the measurement scale to achieve accuracy over a wide range of currents.

As defined in the IEEE 802.3 PoE standard, the PSE should disconnect if the port current is less than a nominal 7.5 mA for more than 350 ms.

## 4.5. Transient Voltage Surge Suppression

The Si3453 features robust on-chip surge protectors on each port; this is an industry first. This unique protection circuitry acts as an active device that can withstand lightning-induced transients as well as large ESD transient events. When the port voltage exceeds its protection limit and the current reaches a triggering threshold, current is shunted from the port to the ground pins.

Internal circuitry is provided to protect the line outputs from externally-coupled fault currents. These are transient currents of up to 5 A peak.

The operation of the protection circuits depends on the operating mode of the channel switch and the direction of the fault current. The clamping operation is performed on the detect pin.

The switch itself will also be protected by the current limit. If the transient lasts long enough to heat up the die, then the temperature sense circuit will shut off the switch, and all the fault current will flow through the clamp diode.

## 4.6. Temperature Sense

A temperature sense signal is used in conjunction with the current limit status signals from the gate drive blocks. Any channel that is generating excess heat is assumed to be operating in current limit mode, with both high voltage drop and high current.

If the port is in PoE mode, an overload will generally not result in thermal shutdown before the 60 ms  $I_{CUT}$  period. If the port is in PoE+ mode, an overload may cause the port to shut down prior to the 60 ms  $I_{CUT}$  period. In either case, the event is reported as  $I_{CUT}$ . The faster shutdown in PoE+ mode is consistent with and specifically allowed by the 802.3at draft and provides much more robust overload protection than is possible with external FETs.

In addition, there is a thermal shutdown if the package temperature exceeds 120 °C. If this threshold is reached, all output drivers are turned off and detection modes are disabled. This secondary threshold limit guards against the possibility that the overheating is not caused by a driver operating in current limit.

## 4.7. Port Measurement and Monitoring

VEE monitoring in conjunction with port current monitoring allows measurement of port power. Port power monitoring, dynamic power allocation via LLDP\*, and port power policing allow efficient power supply sizing.

The Si3453 is factory-calibrated and temperature-compensated for the following measurements:

- Port current measurement. These measurements are auto-ranged and scaled to a 16 bit number at 100  $\mu$ A per bit. Port current accuracy is  $\pm 4\% \pm 2$  mA.
- $V_{EE}$  is measured with a scale of 64 V. The measurement is reported as a 16-bit number scaled at 1 mV per bit.  $V_{EE}$  measurement accuracy is  $\pm 4\%$  over the valid  $V_{EE}$  range.

\***Note:** LLDP = Link Layer Discovery Protocol. Refer to IEEE 802.3at (draft) and IEEE 802.1AB for more information.

## 4.8. SMBus/I<sup>2</sup>C Interface Description

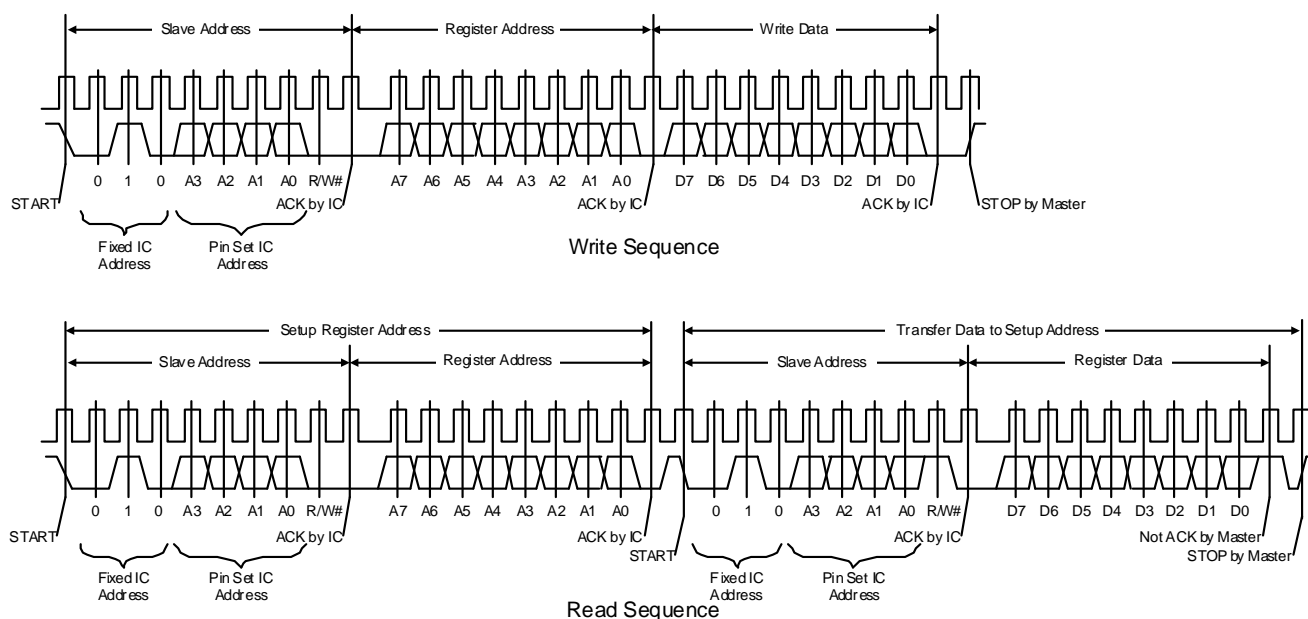
The I<sup>2</sup>C interface is a two-wire, bidirectional serial bus. The I<sup>2</sup>C is compliant with the System Management Bus Specification (SMBus), version 1.1 and compatible with the I<sup>2</sup>C serial bus. Reads and writes to the interface by the system controller are byte-oriented with the I<sup>2</sup>C interface autonomously controlling the serial transfer of the data. A method of extending the clock-low duration is available to accommodate devices with different speed capabilities on the same bus. The I<sup>2</sup>C provides control of SDA (serial data), SCL (serial clock) generation and synchronization, arbitration logic, and START/STOP control and generation.

A typical I<sup>2</sup>C transaction consists of a START condition followed by an address byte (Bits7–1: 7-bit slave address; Bit0: R/W direction bit), one or more bytes of data, and a STOP condition. Each byte that is received (by a master or slave) must be acknowledged (ACK) with a low SDA during a high SCL (see Figure 6). If the receiving device does not ACK, the transmitting device will read a NACK (not acknowledge), which is a high SDA during a high SCL.

The direction bit (R/W) occupies the least-significant bit position of the address byte. The direction bit is set to logic 1 to indicate a “READ” operation and cleared to logic 0 to indicate a “WRITE” operation. All transactions are initiated by a master, with one or more addressed slave devices as the target. The master generates the START condition and then transmits the slave address and direction bit. If the transaction is a WRITE operation from the master to the slave, the master transmits the data one byte at a time, waiting for an ACK from the slave at the end of each byte.

For READ operations, the slave transmits the data waiting for an ACK from the master at the end of each byte. At the end of the data transfer, the master generates a STOP condition to terminate the transaction and free the bus. Figure 6 illustrates a typical SMBus/I<sup>2</sup>C transaction.

Silicon Laboratories recommends the use of bidirectional digital isolators, such as the Si840x, to isolate the I<sup>2</sup>C communications interface between the Si3453 high-voltage port controllers and the system host controller.



**Figure 6. Typical I<sup>2</sup>C Bus Transactions**

The Si3453 does not support the alert response address (ARA) protocol. Polling is used to determine which controller is interrupting in an interrupt-driven system.

## 4.8.1. Address Pins

**Table 14. Address Pin Assignments**

| Pin # | Pin Name |
|-------|----------|
| 21    | AD3      |
| 24    | AD3      |
| 25    | AD2      |
| 26    | AD2      |
| 27    | AD1      |
| 28    | AD0      |
| 34    | AD0      |
| 36    | AD1      |

Pins with the same name must be externally connected and then tied high or low via a weak (10 kΩ) pull up or pull down to establish the device address at power up. The Si3453 powers up in either Auto mode or Shutdown mode depending on the ordering part number. For more information, see "12. Ordering Guide" on page 34.

## 4.8.2. Address Format

The address byte of the I<sup>2</sup>C communication protocol has the following format:

**Table 15. I<sup>2</sup>C Address Byte Protocol**

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| 0     | 1     | 0     | AD3   | AD2   | AD1   | AD0   | R/W   |

AD3, AD2, AD1, and AD0 are the pin-selected address bits (pull up = 1; pull down = 0). For the R/W bit, see Figure 6. The device will also respond to the global address, 0x30. The Si3453 does not support bus arbitration; so, a global read command will generally give an invalid result. Global writes can be useful for initialization as well as for shutting down low-priority ports. Table 16 lists the valid device addresses:

**Table 16. Address Selection**

| AD3 | AD2 | AD1 | AD0 | Address | Valid |
|-----|-----|-----|-----|---------|-------|
| 0   | 0   | 0   | 0   | 0x20    | Y     |
| 0   | 0   | 0   | 1   | 0x21    | Y     |
| 0   | 0   | 1   | 0   | —       | N     |
| 0   | 0   | 1   | 1   | —       | N     |
| 0   | 1   | 0   | 0   | 0x24    | Y     |
| 0   | 1   | 0   | 1   | 0x25    | Y     |
| 0   | 1   | 1   | 0   | —       | N     |
| 0   | 1   | 1   | 1   | —       | N     |
| 1   | 0   | 0   | 0   | 0x28    | Y     |
| 1   | 0   | 0   | 1   | 0x29    | Y     |
| 1   | 0   | 1   | 0   | 0x2A    | Y     |
| 1   | 0   | 1   | 1   | 0x2B    | Y     |
| 1   | 1   | 0   | 0   | 0x2C    | Y     |
| 1   | 1   | 0   | 1   | 0x2D    | Y     |
| 1   | 1   | 1   | 0   | 0x2E    | Y     |
| 1   | 1   | 1   | 1   | 0x2F    | Y     |

## 5. Register Interface

The registers types are described in the following sections.

### 5.1. Interrupt (Registers 0x00–0x01)

An interrupt ( $\overline{\text{INT}}$  pin low) is generated if any bit of the Interrupt register (register 0x00) is true. The Interrupt register contains the information about which port is generating the interrupt or if the interrupt is due to a global event.

The port interrupt is generated by the port event register masked by the interrupt mask register.

Port event = ( $t_{\text{START}}$  Event AND  $t_{\text{START}}$  mask) OR ( $t_{\text{CUT}}$  Event AND  $t_{\text{CUT}}$  mask) OR (Rgood\_CLS\_event AND Rgood\_CLS\_mask) OR (DET\_COMPL\_EVENT AND DET\_COMPL\_MASK) OR (PwrGood\_change AND Pwrgood\_change\_MASK) OR (Penable\_event AND Penable\_mask)

The device event bit of the interrupt register is set if there is a change in the  $V_{\text{EE}}$  or temperature status in register 0x1D. Reading 0x1D clears the event.

### 5.2. Port Event (Registers 0x02–0x05)

This register contains bits that become true if the event has occurred. The registers are Clear On Read (COR) so that reading these registers will clear the  $\overline{\text{INT}}$  pin if the  $\overline{\text{INT}}$  pin is being held low due to a port event.

- **$t_{\text{START}}$**  is an event bit indicating an overload occurred for all but 5 ms of the initial 60 ms start up time.
- **$t_{\text{CUT}}$**  is an event bit indicating that an overload condition has existed for greater than 60 ms after the first 60 ms.  $t_{\text{CUT}}$  has a 16:1 up/down counter so that, if the overload is present at less than a 6.66% cycle, the port will not shut down. Overload is defined as  $I > I_{\text{CUT}}$  or port voltage not within 2 V of  $V_{\text{EE}}$ . The port is turned off on this event. A  $t_{\text{CUT}}$  event is also generated if the port is shutdown due to an overload or due to the protection clamp turning on. If the port is set to auto mode, it will attempt to re-power after >750 ms if there is a good detection signature.
- **Rgood CLS** indicates classification has been completed. Classification is only attempted after an Rgood; so, if this bit is set, it indicates that detection gave an Rgood and classification is complete.
- **DET compl** indicates the completion of a detection cycle. Normally, this bit will be masked. The DET complete bit is used for legacy detection via modified link pulses. If the link pulse is returned indicating a PD is present, then, normally, a detection is done, and the port is powered only if the result is not a short. In some cases, it may be desirable to deny power to a port where an overload has been detected until the port is unplugged. In this case, the Ropen result will be used to indicate the port has been unplugged and detection and classification can resume.
- **Disconnect event** indicates a disconnect has occurred. DC power was removed due to the dc disconnect. Overload conditions or loss of  $V_{\text{EE}}$  turns off ports but does not generate a disconnect event.
- **Pgood** indicates the port has been turned on and did not shut down during the Tstart time.
- **Penable** indicates a port has been turned on.

### 5.3. Port Status (Registers 0x06–0x09)

These registers specify the port status. They are read-only registers.

- **Pwr good** indicates that the port has been turned on and the port voltage is within 2 V of  $V_{\text{EE}}$ .
- **Pwr Enable** indicates the port has been turned on.

The three class status bits indicate the last classification result for that port. If a classification has not been done or if the port is shut down with no new classification result, the class status is reported as unknown.

The three detect status bits indicate the last detection result for that port. If a detection has not been done or if the port is shut down with no new detection result, the detection status is reported as unknown.

## 5.4. Port Configuration (Registers 0x0A–0x11)

These registers indicate the port configuration and are read/write registers.

The port priority bit is set if the port is not high priority. Low-priority ports are shut down when the shutdown low-priority ports command is issued.

The “PoE+” bit specifies the dc current limit at either 425 mA or 850 mA nominal\*.

**\*Note:** The PoE+ mode should be set correctly according to the electrical design of the PSE circuit (transformer and conductor current carrying capacity). The PoE+ port mode can safely be changed prior to port turn-on, but changes after port turn-on do not have an immediate effect and are not recommended.

“Disconnect enable” must be set for power to be removed if there is a disconnect.

“Port mode” is set according to Table 17.

**Table 17. Port Mode Selection**

| Port Mode Setting<br>B1, B0 | Mode     | Description  |
|-----------------------------|----------|--|
| 00b                         | Shutdown | The power is shut down with no detection pulses. A command to manually power the port is ignored.  |
| 01b                         | Manual   | The port can be powered by the manual power command.   |
| 10b                         | Semiauto | Detection is done and classification is done for Rgood, but the port does not power.   |
| 11b                         | Auto     | Detection classification and port powering are all automatic with no host intervention required. $I_{CUT}$ and $I_{LIM}$ are automatically set according to the PoE+ mode and classification result. |

$I_{CUT}$  is the nominal current level at which the port will automatically power down if  $I_{CUT}$  is exceeded for 60 ms. It can be set with 3.2 mA resolution. The accuracy of current measurement is approximately 5%; so,  $I_{CUT}$  is normally set 7% higher than the supported current level.  $I_{CUT}$  is automatically set based on the classification result and PoE+ mode. The automatically-set  $I_{CUT}$  level is appropriate for a 45 V minimum system power supply for classes 0–3 and for a 51 V minimum power supply for PoE+ mode. This feature is classification policing.

If the Si3453 is in the semi-auto mode,  $I_{CUT}$  will not be updated according to the classification result. This means that if it is desired to set  $I_{CUT}$  at port turn-on, this should be done before the port is turned on.

Once a port is turned on,  $I_{CUT}$  can be changed dynamically. It is often undesirable to use a low value of  $I_{CUT}$  during port turn-on because inrush can trigger the  $I_{CUT}$  event. For this reason, it is normal to allow the port to turn on with the automatic  $I_{CUT}$  setting and then later change this value after port current has stabilized and also if the PD and PSE have negotiated for a different  $I_{CUT}$  value based on the PoE L2 power negotiation protocol (LLDP).

The Si3453 supports 2-Event classification as defined in the IEEE 802.3at draft. 2-event classification is an alternative to L2 power management where the PSE advertises it is capable of PoE powering by generating two classification pulses. 2-Event classification is only supported for auto mode. If the Si3453 is in auto mode and the first event classification result is Class 4, the mark, second event, and second mark are performed. Power is applied only if the second event is also Class 4. If the second event is not Class 4, the classification error is reported, and the port will not power. If the port is in manual mode, classification is done prior to turning on the port.

## 5.5. Command and Return Registers (Registers 0x12–0x1C)

The global command register enables manual port turn-on or turn-off, chip reset, port reset, and measurement of port current and  $V_{EE}$ . Register 0x12 is a Write only register. See Table 24 on page 24 for a list of all available commands.

If the command results in a numerical return value, that value is stored in the measurement registers, which are read-only. Each of the five possible measurements results in a 2 byte return value, and that value is stored in a unique register.  $V_{EE}$  is encoded in mV units; so, the full scale is 65.535 V. Iport is encoded in 100  $\mu$ A units; so, the full scale is 6.5535 A.

The output data is updated by the proper command register write operation (see Table 23). This means that the numerical value of the port current or  $V_{EE}$  voltage in the measurement register will be the value at the time the command was issued. If the port turns off due to an overload or disconnect, the port current register contents will not be set to zero. If a command to read port current is issued and the port is off, the return value will be zero.

## 5.6. Device Status Register (0x1D)

The device event bits are listed in Table 18.

**Table 18. Device Status Bits**

| Bit               | Description  |
|-------------------|--|
| B6—OverTemp       | The Si3453 has per-port thermal shutdown sensors as well a global thermal shutdown at a slightly higher temperature. The global thermal shutdown bit of the device event register is set if this occurs. |
| B5— $V_{EE}$ UVLO | $V_{EE}$ UVLO. The part is put in its reset state if $V_{EE}$ is not in a valid range.   |

The Device status register is RO. The  $V_{EE}$ , UVLO, and overtemp bits reflect the device status. They are set if  $V_{EE}$  or temperature is out of range and reset if the  $V_{EE}$  or temperature is in range. Bit 6 of the Interrupt register is set if there is a change in the overtemp status (bit 6 of 0x1D), and bit 5 of the Interrupt register is set if there is a change in the  $V_{EE}$  UVLO status (bit 5 of 0x1D). Reading register 0x1D clears these bits of the Interrupt register but does not clear the device status register.

In addition, bit B0 indicates whether or not detection back-off is used. For PSEs that are wired as Alternative B (power on the spare pair—typically used for midspans), the time between detection pulses is increased to slightly over two seconds to avoid interference with Alternative A (power on the data pair—typically used for endpoints). Bit B0 can be toggled using the 0x10 command code.

Table 19. Si3453 Register Map

| Address   | Register Name    | Type | B7                 | B6                       | B5                          | B4             | B3             | B2              | B1             | B0           | Register Content at Powerup |
|---|------------------|------|--------------------|--------------------------|-----------------------------|----------------|----------------|-----------------|----------------|--------------|-----------------------------|
| <b>Interrupts</b>   |                  |      |                    |                          |                             |                |                |                 |                |              |                             |
| 0x00  | Interrupt Reg 1  | RO   |                    | Overtemp change          | V <sub>EE</sub> UVLO change |                | Port 4 event   | Port 3 event    | Port 2 event   | Port 1 event | 0x00                        |
| 0x01  | Interrupt Mask 1 | RW   | Device status mask | t <sub>START</sub> mask  | t <sub>CUT</sub> mask       | Rgood CLS mask | DET compl mask | Disconnect mask | PwrGood mask   | PwrEn mask   | 0x85                        |
| <b>Port Events</b>  |                  |      |                    |                          |                             |                |                |                 |                |              |                             |
| 0x02  | Port 1 Events    | COR  |                    | t <sub>START</sub> Event | t <sub>CUT</sub> Event      | Rgood CLS      | DET compl      | Disconnect Ev   | PwrGood Change | PwrEn Change | 0x00                        |
| 0x03  | Port 2 Events    | COR  |                    | t <sub>START</sub> Event | t <sub>CUT</sub> Event      | Rgood CLS      | DET compl      | Disconnect Ev   | PwrGood Change | PwrEn Change | 0x00                        |
| 0x04  | Port 3 Events    | COR  |                    | t <sub>START</sub> Event | t <sub>CUT</sub> Event      | Rgood CLS      | DET compl      | Disconnect Ev   | PwrGood Change | PwrEn Change | 0x00                        |
| 0x05  | Port 4 Events    | COR  |                    | t <sub>START</sub> Event | t <sub>CUT</sub> Event      | Rgood CLS      | DET compl      | Disconnect Ev   | PwrGood Change | PwrEn Change | 0x00                        |
| <b>Status</b>   |                  |      |                    |                          |                             |                |                |                 |                |              |                             |
| 0x06  | Port 1 Status    | RO   | PwrGood Status     | PwrEnable Status         | CLS Stat B2                 | CLS Stat B1    | CLS Stat B0    | DET Stat B2     | DET Stat B1    | DET Stat B0  | 0x00                        |
| 0x07  | Port 2 Status    | RO   | PwrGood Status     | PwrEnable Status         | CLS Stat B2                 | CLS Stat B1    | CLS Stat B0    | DET Stat B2     | DET Stat B1    | DET Stat B0  | 0x00                        |
| 0x08  | Port 3 Status    | RO   | PwrGood Status     | PwrEnable Status         | CLS Stat B2                 | CLS Stat B1    | CLS Stat B0    | DET Stat B2     | DET Stat B1    | DET Stat B0  | 0x00                        |
| 0x09  | Port 4 Status    | RO   | PwrGood Status     | PwrEnable Status         | CLS Stat B2                 | CLS Stat B1    | CLS Stat B0    | DET Stat B2     | DET Stat B1    | DET Stat B0  | 0x00                        |
| <b>Configuration<sup>1</sup></b>  |                  |      |                    |                          |                             |                |                |                 |                |              |                             |
| 0x0A  | Port 1 Config    | RW   |                    |                          |                             | Port priority  | PoE+           | Discon En       | Port Mode B1   | Port Mode B0 | 00000100b                   |
| 0x0B  | Port 2 Config    | RW   |                    |                          |                             | Port priority  | PoE+           | Discon En       | Port Mode B1   | Port Mode B0 | 00000100b                   |
| 0x0C  | Port 3 Config    | RW   |                    |                          |                             | Port priority  | PoE+           | Discon En       | Port Mode B1   | Port Mode B0 | 00000100b                   |
| 0x0D  | Port 4 Config    | RW   |                    |                          |                             | Port priority  | PoE+           | Discon En       | Port Mode B1   | Port Mode B0 | 00000100b                   |
| <b>Notes:</b>   |                  |      |                    |                          |                             |                |                |                 |                |              |                             |
| 1. Register content at Power Up is shown for the Si3453 Shutdown Mode part. Refer to "12. Ordering Guide" on page 34 to order Auto Mode parts with different default settings. This register can be changed via the host. Refer to Table 17 on page 18 for register variations. |                  |      |                    |                          |                             |                |                |                 |                |              |                             |
| 2. B0 Alternative B timing is set to 0x01 if using Alternative B detect timing. Refer to "5.6. Device Status Register (0x1D)" on page 19 and "12. Ordering Guide" on page 34.   |                  |      |                    |                          |                             |                |                |                 |                |              |                             |

Table 19. Si3453 Register Map (Continued)

| Address   | Register Name              | Type | B7 | B6       | B5                   | B4          | B3          | B2          | B1           | B0                   | Register Content at Powerup |
|---|----------------------------|------|----|----------|----------------------|-------------|-------------|-------------|--------------|----------------------|-----------------------------|
| 0x0E  | Port 1 I <sub>CUT</sub>    | RW   | B7 | B6       | B5                   | B4          | B3          | B2          | B1           | B0                   | 0x75                        |
| 0x0F  | Port 2 I <sub>CUT</sub>    | RW   | B7 | B6       | B5                   | B4          | B3          | B2          | B1           | B0                   | 0x75                        |
| 0x10  | Port 3 I <sub>CUT</sub>    | RW   | B7 | B6       | B5                   | B4          | B3          | B2          | B1           | B0                   | 0x75                        |
| 0x11  | Port 4 I <sub>CUT</sub>    | RW   | B7 | B6       | B5                   | B4          | B3          | B2          | B1           | B0                   | 0x75                        |
| <b>Global Device</b>  |                            |      |    |          |                      |             |             |             |              |                      |                             |
| 0x12  | Command Register           | WO   |    |          | CMD Code B5          | CMD Code B4 | CMD Code B3 | CMD Code B2 | CMD Param B1 | CMD Param B0         | 0x00                        |
| 0x13  | V <sub>EE</sub> MSB        | RO   |    |          |                      |             |             |             |              |                      | 0x00                        |
| 0x14  | V <sub>EE</sub> LSB        | RO   |    |          |                      |             |             |             |              |                      | 0x00                        |
| 0x15  | Current P1 MSB             | RO   |    |          |                      |             |             |             |              |                      | 0x00                        |
| 0x16  | Current P1 LSB             | RO   |    |          |                      |             |             |             |              |                      | 0x00                        |
| 0x17  | Current P2 MSB             | RO   |    |          |                      |             |             |             |              |                      | 0x00                        |
| 0x18  | Current P2 LSB             | RO   |    |          |                      |             |             |             |              |                      | 0x00                        |
| 0x19  | Current P3 MSB             | RO   |    |          |                      |             |             |             |              |                      | 0x00                        |
| 0x1A  | Current P3 LSB             | RO   |    |          |                      |             |             |             |              |                      | 0x00                        |
| 0x1B  | Current P4 MSB             | RO   |    |          |                      |             |             |             |              |                      | 0x00                        |
| 0x1C  | Current P4 LSB             | RO   |    |          |                      |             |             |             |              |                      | 0x00                        |
| 0x1D  | Device Status <sup>2</sup> | RO   |    | OverTemp | V <sub>EE</sub> UVLO |             |             |             |              | Alternative B Timing | 0x00                        |
| <b>Revision</b>   |                            |      |    |          |                      |             |             |             |              |                      |                             |
| 0x60  | Hardware Revision          | RO   |    |          |                      |             |             |             |              |                      |                             |
| 0x61  | Firmware Revision          | RO   |    |          |                      |             |             |             |              |                      |                             |
| <b>Notes:</b>   |                            |      |    |          |                      |             |             |             |              |                      |                             |
| 1. Register content at Power Up is shown for the Si3453 Shutdown Mode part. Refer to "12. Ordering Guide" on page 34 to order Auto Mode parts with different default settings. This register can be changed via the host. Refer to Table 17 on page 18 for register variations. |                            |      |    |          |                      |             |             |             |              |                      |                             |
| 2. B0 Alternative B timing is set to 0x01 if using Alternative B detect timing. Refer to "5.6. Device Status Register (0x1D)" on page 19 and "12. Ordering Guide" on page 34.   |                            |      |    |          |                      |             |             |             |              |                      |                             |

Table 19. Si3453 Register Map (Continued)

| Address | Register Name     | Type | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | Register Content at Powerup |
|---------|-------------------|------|----|----|----|----|----|----|----|----|-----------------------------|
| 0x62    | Firmware Revision | RO   |    |    |    |    |    |    |    |    |                             |
| 0x63    | Firmware Revision | RO   |    |    |    |    |    |    |    |    |                             |

**Notes:**

1. Register content at Power Up is shown for the Si3453 Shutdown Mode part. Refer to "12. Ordering Guide" on page 34 to order Auto Mode parts with different default settings. This register can be changed via the host. Refer to Table 17 on page 18 for register variations.
2. B0 Alternative B timing is set to 0x01 if using Alternative B detect timing. Refer to "5.6. Device Status Register (0x1D)" on page 19 and "12. Ordering Guide" on page 34.

**Table 20. Si3453 Detect Encoding**

| Value | Condition |
|-------|-----------|
| 000b  | Unknown   |
| 001b  | Short     |
| 010b  | Reserved  |
| 011b  | Rlow      |
| 100b  | Good      |
| 101b  | Rhigh     |
| 110b  | Ropen     |
| 111b  | Reserved  |

**Table 21. Si3453 Class Encoding**

| Value | Condition        |
|-------|------------------|
| 000b  | Unknown          |
| 001b  | Class 1          |
| 010b  | Class 2          |
| 011b  | Class 3          |
| 100b  | Class 4          |
| 101b  | Probes Not Equal |
| 110b  | Class 0          |
| 111b  | Class Overload   |

**Table 22. Si3453 Port Mode Encoding**

| Value | Condition |
|-------|-----------|
| 00b   | Shutdown  |
| 01b   | Manual    |
| 10b   | Semiauto  |
| 11b   | Auto      |

**Table 23. Si3453 Port Configuration**

| PoE+ bit          | Class | Auto Mode Setting of I <sub>CUT</sub> Register | I <sub>CUT</sub> Nominal | Ilim Nominal* |
|-------------------|-------|--|--------------------------|---------------|
| 0 or 1 don't care | 1     | 0x1E   | 97 mA                    | 425 mA        |
| 0 or 1 don't care | 2     | 0x35   | 170 mA                   | 425 mA        |
| 0 or 1 don't care | 0/3   | 0x75   | 375 mA                   | 425 mA        |
| 0                 | 4     | 0x75   | 375 mA                   | 425 mA        |
| 1                 | 4     | 0xC9   | 640 mA                   | 850 mA        |

**\*Note:** During initial port turn-on (T<sub>START</sub> time of 60 ms), the current limit is set to 425 mA, even in PoE+ mode.

**Table 24. Si3453 Command Codes**

| Command                                       | CMD Register   | [B5..B2] | [B1..B0] Command Parameter     | 2 Byte Return Value          |
|---|----------------|----------|--------------------------------|------------------------------|
| Power on port                                 | 0x04   port no | 0001b    | 2 bit port number <sup>1</sup> | —                            |
| Power off port                                | 0x08   port no | 0010b    | 2 bit port number              | —                            |
| Reset port                                    | 0x0C   port no | 0011b    | 2 bit port number              | —                            |
| Toggle detection back-off timing <sup>2</sup> | 0x10           | 0100b    | NA                             | —                            |
| Reset chip                                    | 0x14           | 0101b    | NA                             | —                            |
| Get V <sub>EE</sub>                           | 0x18           | 0110b    | NA                             | V <sub>EE</sub> in mV units  |
| Read port current                             | 0x1C   port no | 0111b    | 2 bit port number              | Port current in 100 μA units |
| Shut down low-priority ports                  | 0x20           | 1000b    | NA                             | —                            |

**Notes:**

- Port 1 has 2 bit port number 0x00; port 2 is 0x01, etc.
- This command toggles bit 0 of Register 0x1D. When bit zero is set, the detection back-off of 2 seconds is implemented (alternative B or “midspan” mode).

## 6. Operational Notes

### 6.1. Port Turn On

If the port is turned on by putting it in auto mode, the Si3453 will take care of all specified timing, and it will take care of the two-event classification if the first event result is Class 4 and PoE+ mode is enabled. However, if automatic mode operation is not desired after port turn-on, the port should be set to semi-auto or manual mode once it has powered. In automatic mode,  $I_{CUT}$  is set according to the classification result.

The port turn-on command is used to turn on a port in semi-auto or manual mode. If the port is turned on in semi-auto mode, turn-on is delayed until the next detection and classification. If the detection or classification result is not valid, the port will not power. If the classification is Class 4 and PoE+ mode is enabled, a 2-event classification is given.  $I_{CUT}$  setting is not automatic for port turn-on in semi-auto or manual mode.

If the port is turned on by putting it in manual mode, the normal sequence is to start with the port in semi-auto mode and interrupt on a classification complete, which indicates that there is a valid PD signature and that a classification result is available. Based on the classification result, the host can make a decision to apply power or not. The IEEE standard requires that a port be powered within 400 ms of a valid detect complete. It is also desirable to power the port prior to the start of the next detection pulse, which can occur in as little as 300 ms. Therefore, it is recommended that ports be powered in under 250 ms from the class complete interrupt when using the manual mode turn-on command.

Using manual mode turn-on, detection is not done prior to port turn on, but classification is always performed just prior to port turn on. Ports are turned on in manual mode regardless of the classification result. 2-event classification is performed if the first event result is Class 4 and the port is enabled for PoE+ mode. The manual mode classification step does not generate a classification complete flag because it is assumed that the classification was already done in semi-auto mode and the host has already made the decision to grant power.

During the initial 60 ms ( $T_{start}$ ) time of port turn-on, 1x current limit and  $I_{CUT} = 375$  mA (nominal) is enforced. After  $T_{start}$ , if the port is not overloaded,  $P_{good}$  is set to true, and  $I_{CUT}$  and 1x or 2x current limit will follow the  $I^2C$  register settings. In auto mode, the  $I^2C$  registers are set according to the classification result, but, if desired, they can be overwritten after  $P_{good}$  becomes true. After  $T_{start}$ , 2x current limit is always allowed if PoE+ mode is enabled.

### 6.2. Changing the Interrupt Mask

The INT register and  $\overline{INT}$  pin are always synchronized. However, there can be up to a 5 ms delay between an event that causes or clears an interrupt and the update of the register and pin.

Thus, if the INT mask register is changed to clear an interrupt or to block an interrupt source, there can be up to a 5 ms delay between the change of the INT mask register and the resultant change in the INT register and  $\overline{INT}$  pin.

Generally, use of the mask register to clear interrupts is not recommended; it is better to clear an interrupt by reading the appropriate COR register.

### 6.3. Port Voltage and Current Measurements

Port current voltage and current are reported as of the time the measurement command is written to register 0x12. Spikes of current or other momentary current changes are not filtered. It may be desirable to add a ~1 second averaging filter to reported current when using port current information for power management decisions.

## 7. PCB Layout Guidelines

Following are some PCB layout considerations. See also "12.1. Evaluation Kits and Reference Designs" on page 34 for reference design information. Please visit the Silicon Labs technical support web page at [www.silabs.com/support/pages/contacttechnicalsupport.aspx](http://www.silabs.com/support/pages/contacttechnicalsupport.aspx) and register to request support for your design, particularly if you are not closely following the recommended reference design.

Due to the high current of up to 800 mA per port, the following board layout guidelines apply. In addition, contact Silicon Laboratories for access to complete PSE reference design databases including recommended layouts.

The VEE1, VEE2, VEE3, and VEE4 pins can carry up to 800 mA and are connected to a  $V_{EE}$  bus. The  $V_{EE}$  bus for a 24 port PCB layout can thus carry as much as 20 A current. With 2 oz. copper on an outer layer, a bus of 0.4 inches is needed. For an inner layer, this increases to a 1 inch wide bus. Use of large or multiple vias is required for properly supporting the 800 mA per channel operating current. The VEE pin does not carry high current and can be connected directly to the bus as well. The best practice is to devote an entire inner layer for  $V_{EE}$  power routing.

Similarly, GND1/2 and GND3/4 pins can carry up to 1.6 A per pin, and the GND return bus should be at least as wide as the  $V_{EE}$  bus described above. The best practice is to devote an entire inner layer for ground power routing. The ground power plane does not generally have a high frequency content (other than external faults); so, it is generally acceptable to use the ground power plane as a ground signal plane and tie AGND and GND12, GND34 to this plane as well.

The VOUTn pins carry up to 800 mA dc and up to 5 A in faults; so, a 20 mil trace with wide or multiple vias is also recommended. The VDETn pins also carry fault current; so, this pin connection to VOUTn needs to use 20 mil traces and wide or multiple vias where needed.

The VDD currents are not large; so, it is acceptable to route the VDD nodes on one of the outer layers.

If care is taken to avoid disruption of the high current paths, VDD can be globally routed on one of the power planes and then locally routed on an inner or outer layer.

To avoid coupling between surge events and logic signals, it is recommended that VOUTn traces be routed on the side opposite the I<sup>2</sup>C interface pins.

The thermal pad of the Si3453 is connected to VEE. At full IEEE 802.3at current of 600 mA on each port, the dissipation of the Si3453 is up to 1.2 W; so, multiple vias are required to conduct the heat from the thermal pad to the VEE plane. As many as 36 small vias provide the best thermal conduction.

## 8. Firmware Release Notes

Devices marked with firmware revision 02 (see "13. Device Marking Diagram" on page 35) have the firmware revision registers set as 0x61 = 0x00; 0x62 = 0x02, and 0x63 = 0x51 (0.2.81).

The following is a known issue, which may be addressed with a future firmware revision:

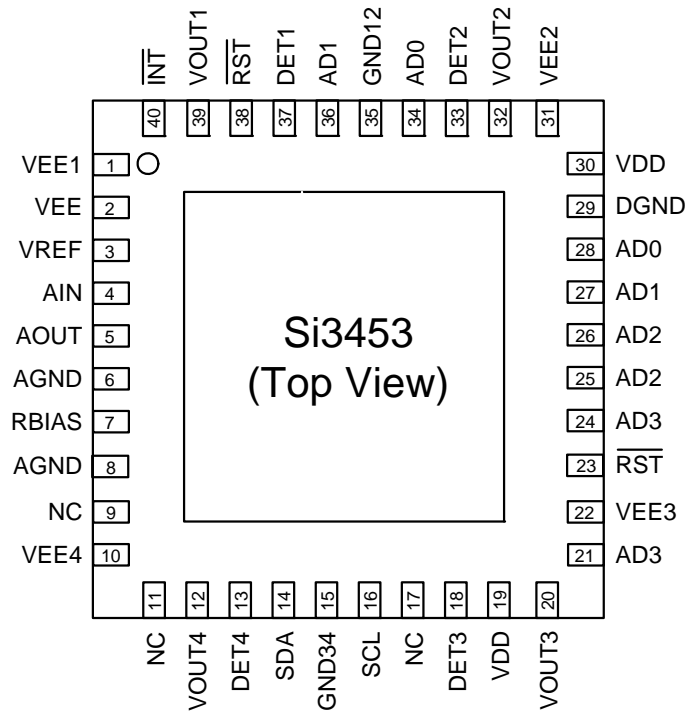
### 8.1. I<sup>2</sup>C Address ACK

**Issue:** Very rarely, the Si3453 may not ACK the I<sup>2</sup>C address byte.

**Impact:** This is allowed in the I<sup>2</sup>C specification.

**Workaround:** Retransmit the address byte if there is an ACK failure.

## 9. Pin Descriptions



**Table 25. Si3453 Pin Descriptions**

| Pin # | Name  | Type          | Description   |
|-------|-------|---------------|---|
| 1     | VEE1  | Supply        | Driver 1 VEE supply. Short to VEE, VEE2/3/4.  |
| 2     | VEE   | Supply        | Global PoE (–48 V nom.) or PoE+ (–54 V nom.) supply. Short to VEE1/2/3/4.                             |
| 3     | VREF  | Analog input  | 1.1 V nom. voltage reference from reference generator (for example, TLV431 or power management unit). |
| 4     | AIN   | Analog input  | Measurement data converter input. Short to AOUT.  |
| 5     | AOUT  | Analog output | Measurement multiplexer subsystem output. Short to AIN.   |
| 6     | AGND  | Ground        | Analog ground reference. Short to AGND pin 8, GND12/34, DGND.   |
| 7     | RBIAS | Analog input  | External 44.2 k $\Omega$ ( $\pm 1\%$ ) resistor to ground sets internal bias currents.                |
| 8     | AGND  | Ground        | Analog ground reference. Short to AGND pin 6, GND12/34, DGND.   |
| 9     | NC    | No connect    | Do not connect (float).   |
| 10    | VEE4  | Supply        | Driver 4 VEE supply. Short to VEE, VEE1/2/3.  |
| 11    | NC    | No connect    | Do not connect (float).   |
| 12    | VOUT4 | Analog I/O    | Port 4 power FET switch output. When on, provides a low impedance path to VEE4.                       |

Table 25. Si3453 Pin Descriptions (Continued)

| Pin # | Name  | Type          | Description   |
|-------|-------|---------------|---|
| 13    | DET4  | Analog I/O    | Connection for port 4 detection, classification, and transient surge protection. This pin is tied to VOUT4.   |
| 14    | SDA   | Digital I/O   | I <sup>2</sup> C data pin   |
| 15    | GND34 | Ground        | Ground supply for protection clamps. Short to AGND, GND12, DGND.  |
| 16    | SCL   | Digital I/O   | I <sup>2</sup> C clock pin  |
| 17    | NC    | No connect    | Do not connect (float).   |
| 18    | DET3  | Analog I/O    | Connection for port 3 detection and classification. See DET4 for detailed description.  |
| 19    | VDD   | Supply        | +3.3 V ( $\pm 10\%$ ) isolated supply. Short to VDD pin 30.   |
| 20    | VOUT3 | Analog I/O    | Port 3 power FET switch output. When on, provides a low impedance path to VEE3.   |
| 21    | AD3   | Digital I/O   | Chip address bit 3 pin, read after reset. Address set with defined resistor dividers. Pin also used for internal communications. Short to AD3 pin 24.                 |
| 22    | VEE3  | Supply        | Driver 3 VEE supply. Short to VEE, VEE1/2/4.  |
| 23    | RST   | Digital input | Active low digital reset. Short to $\overline{\text{RST}}$ pin 38.  |
| 24    | AD3   | Digital I/O   | Chip address bit 3 pin, read after reset. Address set with a 10 k $\Omega$ pull-up or pull-down resistor. Also used for internal communications. Short to AD3 pin 21. |
| 25    | AD2   | Digital I/O   | Chip address bit 2 pin, read after reset. Address set with a 10 k $\Omega$ pull-up or pull-down resistor. Also used for internal communications. Short to AD2 pin 26. |
| 26    | AD2   | Digital I/O   | Chip address bit 2 pin, read after reset. Address set with a 10 k $\Omega$ pull-up or pull-down resistor. Also used for internal communications. Short to AD2 pin 25. |
| 27    | AD1   | Digital I/O   | Chip address bit 1 pin, read after reset. Address set with a 10 k $\Omega$ pull-up or pull-down resistor. Also used for internal communications. Short to AD1 pin 36. |
| 28    | AD0   | Digital I/O   | Chip address bit 0 pin, read after reset. Address set with a 10 k $\Omega$ pull-up or pull-down resistor. Also used for internal communications. Short to AD0 pin 34. |
| 29    | DGND  | Ground        | Digital ground reference. Short to AGND, GND12/34   |
| 30    | VDD   | Supply        | +3.3 V isolated supply. Short to VDD pin 19.  |
| 31    | VEE2  | Supply        | Driver 2 VEE supply. Short to VEE, VEE1/3/4.  |
| 32    | VOUT2 | Analog I/O    | Port 2 power FET switch output. When on, provides a low impedance path to VEE2.   |

**Table 25. Si3453 Pin Descriptions (Continued)**

| Pin # | Name  | Type           | Description  |
|-------|-------|----------------|--|
| 33    | DET2  | Analog I/O     | Connection for port 2 detection and classification. See DET4 for detailed description.   |
| 34    | AD0   | Digital I/O    | Chip address bit 0 pin. See description for- and short to AD0 pin 28.  |
| 35    | GND12 | Ground         | Ground supply for protection clamps. Short to AGND, GND34, DGND.   |
| 36    | AD1   | Digital I/O    | Chip address bit 1 pin. See description for- and short to AD1 pin 27.  |
| 37    | DET1  | Analog I/O     | Connection for port 1 detection and classification. See DET4 for detailed description.   |
| 38    | RST   | Digital input  | Active low digital reset. Short to $\overline{\text{RST}}$ pin 23.   |
| 39    | VOUT1 | Analog I/O     | Port 1 power FET switch output. When on, provides a low impedance path to VEE1.  |
| 40    | INT   | Digital output | Active low interrupt output pin.   |
| ePAD  | Vee   | Supply         | Connect the thermal pad to a plane which connects to Vee. For best results, use a 5 x 5 or larger via array for best thermal conductivity with 1 square inch or larger of plane area per device. |

## 10. Package Outline: 40-Pin QFN

The Si3453 is packaged in an industry-standard, RoHS compliant 6 x 6 mm<sup>2</sup>, 40-pin QFN package.

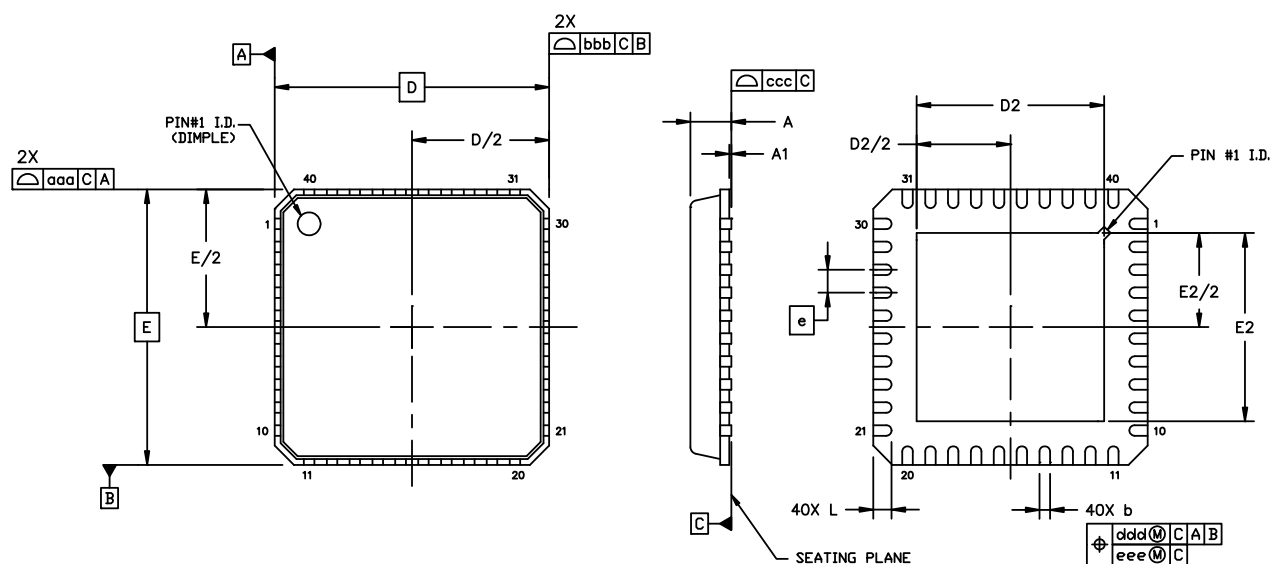


Figure 7. 40-Pin QFN Mechanical Diagram

Table 26. Package Diagram Dimensions

| Dimension  | Min       | Nom  | Max  |
|--|-----------|------|------|
| A  | 0.80      | 0.85 | 0.90 |
| A1   | 0.00      | 0.02 | 0.05 |
| b  | 0.18      | 0.25 | 0.30 |
| D  | 6.00 BSC. |      |      |
| D2   | 3.95      | 4.10 | 4.25 |
| e  | 0.50 BSC. |      |      |
| E  | 6.00 BSC. |      |      |
| E2   | 3.95      | 4.10 | 4.25 |
| L  | 0.30      | 0.40 | 0.50 |
| aaa  | 0.10      |      |      |
| bbb  | 0.10      |      |      |
| ccc  | 0.08      |      |      |
| ddd  | 0.10      |      |      |
| eee  | 0.05      |      |      |
| <b>Notes:</b>  |           |      |      |
| 1. All dimensions shown are in millimeters (mm) unless otherwise noted.                                    |           |      |      |
| 2. Dimensioning and Tolerancing per ANSI Y14.5M-1994.  |           |      |      |
| 3. This drawing conforms to JEDEC outline MO-220, Variation VJJD-2   |           |      |      |
| 4. Recommended card reflow profile is per the JEDEC/IPC J-STD-020 specification for Small Body Components. |           |      |      |

## 11. Recommended PCB Footprint

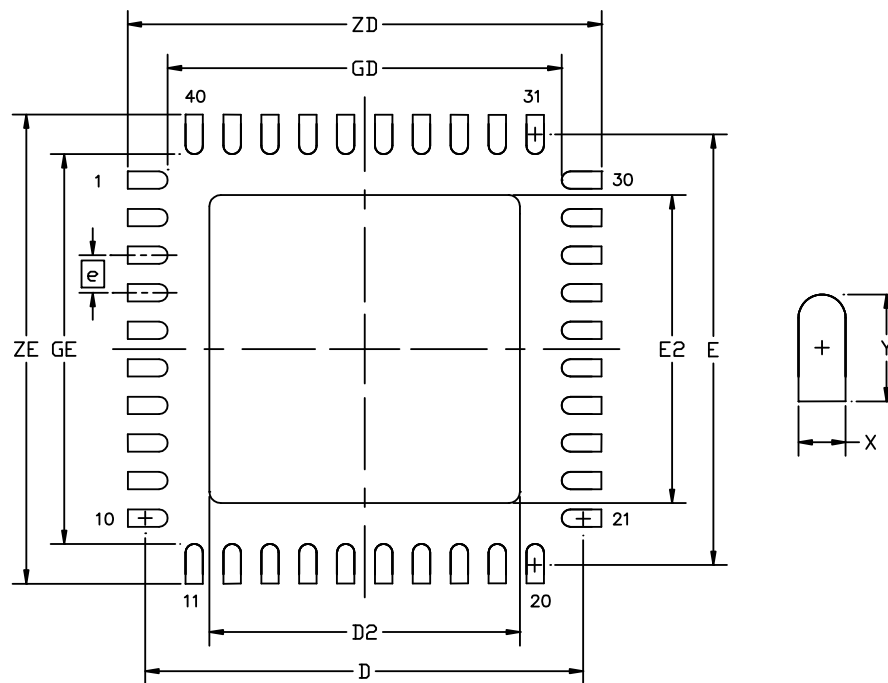


Figure 8. PCB Land Pattern

Table 27. PCB Land Pattern Dimensions

| Dimension | Min      | Max  |
|-----------|----------|------|
| e         | 0.50 BSC |      |
| E         | 5.42 REF |      |
| D         | 5.42 REF |      |
| E2        | 4.00     | 4.20 |
| D2        | 4.00     | 4.20 |
| GE        | 4.53     | —    |
| GD        | 4.53     | —    |
| X         | —        | 0.28 |
| Y         | 0.89 REF |      |
| ZE        | —        | 6.31 |
| ZD        | —        | 6.31 |

**Notes:****General**

1. All dimensions shown are in millimeters (mm) unless otherwise noted.
2. Dimensioning and Tolerancing is per the ANSI Y14.5M-1994 specification.
3. This Land Pattern Design is based on IPC-SM-782 guidelines.
4. All dimensions shown are at Maximum Material Condition (MMC). Least Material Condition (LMC) is calculated based on a Fabrication Allowance of 0.05 mm.

**Solder Mask Design**

5. All metal pads are to be non-solder mask defined (NSMD). Clearance between the solder mask and the metal pad is to be 60  $\mu\text{m}$  minimum, all the way around the pad.

**Stencil Design**

6. A stainless steel, laser-cut and electro-polished stencil with trapezoidal walls should be used to assure good solder paste release.
7. The stencil thickness should be 0.125 mm (5 mils).
8. The ratio of stencil aperture to land pad size should be 1:1 for the perimeter pads.
9. A 4x4 array of 0.80 mm square openings on 1.05 mm pitch should be used for the center Vee pad.

**Card Assembly**

10. A No-Clean, Type-3 solder paste is recommended.
11. The recommended card reflow profile is per the JEDEC/IPC J-STD-020 specification for Small Body Components.

## 12. Ordering Guide

| Ordering Part Number <sup>1</sup> | Detect Timing <sup>2</sup> | Powerup Mode <sup>2,3,4,5</sup> |          | Firmware Revision | Package <sup>6</sup> Temp. Range |
|-----------------------------------|----------------------------|---------------------------------|----------|-------------------|----------------------------------|
| Si3453-B02-GM                     | Alt A                      | PoE <sup>7</sup>                | Shutdown | 0.2.81            | -40 to 85 °C ambient             |
| Si3453A-B02-GM                    | Alt A                      | PoE (15.4 W)                    | Auto     |                   |                                  |
| Si3453B-B02-GM                    | Alt B                      |                                 |          |                   |                                  |
| Si3453C-B02-GM                    | Alt A                      | PoE+ (30 W)                     |          |                   |                                  |
| Si3453D-B02-GM                    | Alt B                      |                                 |          |                   |                                  |

**Notes:**

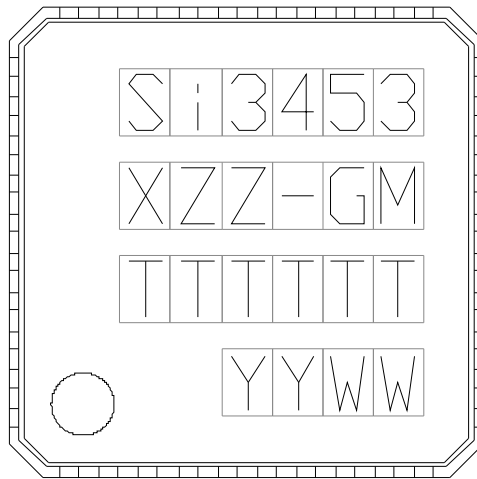
1. Add "R" to the end of the ordering part number to denote tape-and-reel option. E.g., Si3452-B02-GMR.
2. For alternative A, power is applied to wire pairs 1,2 and 3,6. For alternative B, power is applied to wire pairs 4,5 and 7,8 (the spare pairs in the case of 10/100 Ethernet). Conventionally, alternative B is used for midspan power injectors. For alternative B, detection is done with over 2 seconds between detection pulses so as to avoid interfering with end-point equipment trying to provide power using alternative A.
3. Devices powering up into shutdown mode are intended for use with a system host that provides run-time configuration or power-management.
4. The maximum PoE or PoE+ power applies to all ports on Auto mode devices.
5. Detect Timing and Powerup Modes (PoE vs. PoE+, Shutdown vs. Auto) are pre-configured in firmware but can be reconfigured at any time via a host connection.
6. All devices are packaged in RoHS-compliant, 40-pin, 6x6 mm QFN.
7. The Si3453-B02-GM is PoE+ capable. The part defaults to PoE mode at powerup but can be reconfigured to PoE+ via register settings.

### 12.1. Evaluation Kits and Reference Designs

| Part Number   | Populated Device | Description  | Related Ethernet Chipset    | Type             |
|---------------|------------------|--|-----------------------------|------------------|
| Si3452MS8-KIT | Si3453-B02-GM    | PoE+ 8-port Midspan PSE evaluation kit. Includes PC-control interface, PD loads, and cables. | None                        | Evaluation Kit   |
| Si3452V1-RD*  | Si3453-B02-GM    | PoE/PoE+ 24-port daughter-card   | Vitesse E-StaX (VSC7407)    | Reference Design |
| Si3452V2-RD*  | Si3453-B02-GM    | PoE+ 8-port Gb-Ethernet switch   | Vitesse SparX-G8e (VSC7398) | Reference Design |
| Si3452M1-RD*  | Si3453-B02-GM    | PoE/PoE+ 24-port daughter-card   | Marvell Prestera-DX, xCAT   | Reference Design |

**\*Note:** Due to unique high-voltage and high-power design considerations, Silicon Laboratories recommends that the reference designs be followed very closely for both bill of materials and layout. Please visit the Silicon Labs technical support web page at [www.silabs.com/support/pages/contacttechnicalsupport.aspx](http://www.silabs.com/support/pages/contacttechnicalsupport.aspx) and register to request support for your design, particularly if you are not closely following the recommended reference design.

### 13. Device Marking Diagram



**Figure 9. Device Marking Diagram**

**Table 28. Device Marking Table**

| Line # | Text Value | Description   |
|--------|------------|---|
| 1      | Si3453     | Base part number. This is not the "Ordering Part Number" since it does not contain a specific revision. Refer to "12. Ordering Guide" on page 34 for complete ordering information. |
| 2      | XZZ        | X = Device revision.<br>ZZ = Firmware revision.   |
| 2      | GM         | G = Industrial temperature range.<br>M = QFN package.   |
| 3      | TTTTTT     | Trace code (assigned by the assembly subcontractor).  |
| 4      | O          | Pin 1 identifier.   |
|        | YY         | Assembly year.  |
|        | WW         | Assembly week.  |

## DOCUMENT CHANGE LIST

### Revision 1.1 to Revision 1.2

- Removed references to Si3452.
- Updated Figure 9, "Device Marking Diagram," on page 35.
- Updated typical VDD reset threshold in Table 3, "UVLO, and Reset Specifications," on page 5.
- Clarified notes in Table 19, "Si3453 Register Map," on page 20.
- Updated Table 28, "Device Marking Table," on page 35.
- Clarified notes in "12. Ordering Guide" on page 34.

### Revision 1.2 to Revision 1.3

- Updated "8. Firmware Release Notes" on page 27.
- Updated "12. Ordering Guide" on page 34.
- Updated "12.1. Evaluation Kits and Reference Designs" on page 34.

NOTES:

## CONTACT INFORMATION

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