



# Si3404 Data Sheet

## Fully-Integrated IEEE 802.3 Type 1-Compliant POE PD Interface and High-Efficiency Switching Regulator with Compact Footprint

The Si3404 integrates the power management and control functions required in a Power-over-Ethernet (PoE) powered device (PD) application. These devices convert the high voltage supplied over the 10/100/1000BASE-T Ethernet connection to a regulated, low-voltage output supply. The optimized architecture of this device minimizes the solution footprint and external BOM cost and enables the use of low-cost external components while maintaining high performance. The Si3404 integrates a transient surge suppressor. The switching power FET and associated functions are also integrated. The integrated, current mode controlled switching regulator supports isolated or non-isolated flyback and buck converter topologies. The switching frequency for the regulator is tunable with a simple external resistor value to help avoid unwanted harmonics for better emissions control.

This device fully supports the IEEE 802.3at specification for Type 1, single-event classification. Standard external resistors provide the proper IEEE 802.3 signatures for the detection function and programming of the classification mode, and internal startup circuits ensure well-controlled soft-start initial operation of both the hotswap switch and the voltage regulator.

The Si3404 is available in a low-profile, 20-pin, 4 x 4 mm QFN package.

### KEY FEATURES

- Type 1 (PoE) power
- IEEE 802.3at Type 1 compliance
- Current mode dc-dc converter
- Tunable switching frequency
- Transformer bias winding support
- Auxiliary adapter capability
- Integrated hotswap FET and switching FET
- 120 V Absolute Max voltage performance
- Extended -40 to +85 °C temperature
- Compact ROHS-compliant 4 mm x 4 mm QFN Package

### APPLICATIONS

- Voice over IP telephones
- Wireless access points
- Security and surveillance IP cameras
- Point-of-sale terminals
- Internet appliances
- Network devices

## 1. Ordering Guide

**Table 1.1. Si3404 Ordering Guide**

| Ordering Part Number | Package                                    | Temperature Range (Ambient) | Applications |
|----------------------|--------------------------------------------|-----------------------------|--------------|
| Si3404-A-GM          | 4 x 4 mm 20-QFN<br>Pb-free, RoHS-compliant | –40 to 85 °C Extended       | All Purposes |

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## 2. System Overview

The following Block Diagrams will give the designer a sense for the internal arrangement of functional blocks, plus their relationships to external pins. The Block Diagrams are followed by a description of the features of these integrated circuits.

### 2.1 Block Diagram

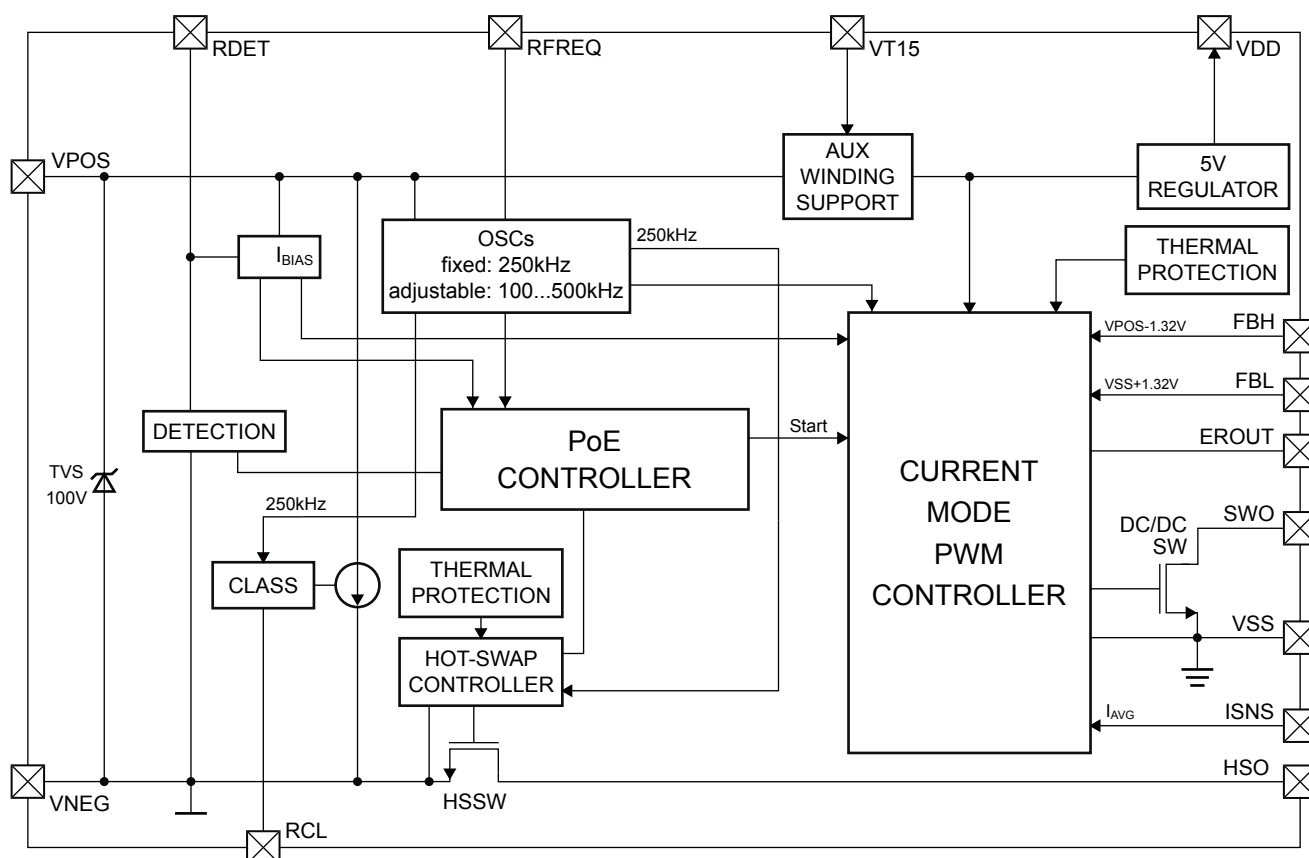


Figure 2.1. Si3404 Block Diagram

### 2.2 Power over Ethernet (PoE) Line-Side Interface

The PoE line interface consists of external diode bridges, internal surge protection, and protocol interface support for detection and classification.

The chip features active protection against surge transients and accidentally applied telephony voltages.

#### 2.2.1 Surge Protection

The surge protection circuit is activated if the VPOS-VNEG voltage exceeds  $V_{\text{PROT}}$  and the hotswap switch is off (dc-dc is not powered). If the hotswap switch is on, the surge power is sunk in the dc-dc's input capacitance.

The internal surge protection can be overridden with an external TVS if higher than specified surge conditions need be tolerated. The external surge device must be connected in parallel to the internal one; therefore, the designer must ensure that the external surge protection will activate prior to the internal surge protection.

#### 2.2.2 Telephony Protection

The Si3404 provides protection against telephony ringing voltage. The telephony ringing is much longer than the surge pulse but it has less energy, therefore, the Si3404 has a switch parallel with the supply (between VPOS and VNEG). When the protection circuit is activated, it turns ON the protection switch; the ringing energy then dissipates on this switch and ringing generator resistance ( $> 400 \Omega$ ).

### 2.2.3 Detection and Classification

When the Si3404 is connected via Ethernet cable to a PSE-enabled Ethernet switch, it has to provide a characteristic resistance (~25 k $\Omega$ ) to the PSE in a given voltage range (2.7–10.1 V). This is called detection. After the PSE detects the PD, the PSE increases the voltage above the classification threshold 14.5 V. Then, the PD provides the classification current to inform the PSE about its required power class (Class 1, 2, 3, or 4). Type 1 PSEs cannot provide enough power for a Class 4 PD. Type 2 PSEs have additional voltage steps before switching on the PD. After an initial classification voltage pulse, the Type 2 PSE reduces the voltage below the mark threshold level (10 V) then raises it up again to the Class event range. Last, before switching ON the dc-dc, it reduces the voltage again.

The Si3404 is a Type 1 PD. The following figure represents the typical turning ON procedure of the PD, which includes detection, classification and PD turn ON.

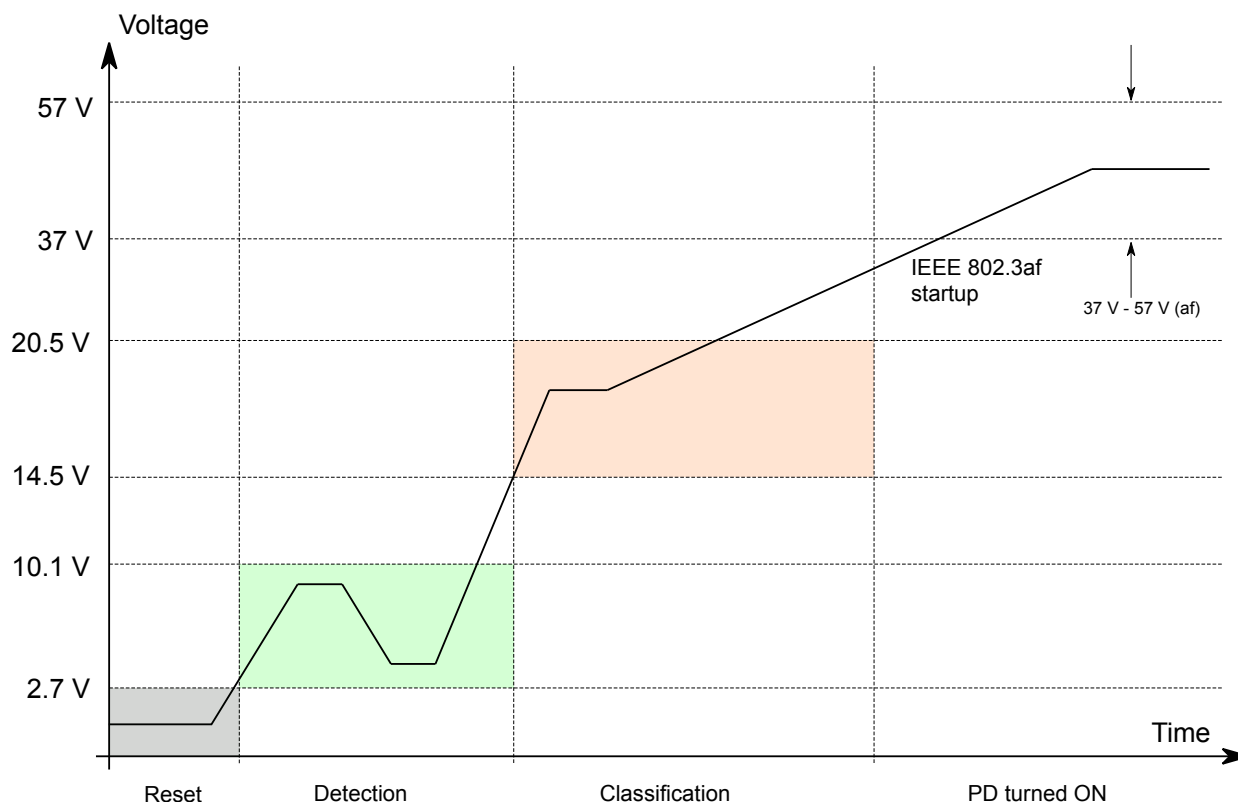


Figure 2.2. Powered Device Voltages

### 2.3 Hotswap Switch

The hotswap switch is a high voltage switch which separates the PoE interface from the dc-dc converter domain. The internal hotswap switch (HSSW) is turned on (conducting) when the PoE interface voltage goes above  $V_{UVLO\_R}$ . It provides limited inrush current until the dc-dc side capacitor is charged. The hotswap switch turns off (open) if voltage on the HSSW switch is greater than  $V_{HSSW\_OFF}$ .

In overload, the hotswap switch goes into current-limiting mode with a current limit of  $I_{OVL}$ . It will turn back ON after  $T_{WAITHSSW}$  elapses and the dc-dc input capacitor is recharged, meaning the HSO-VNEG voltage is less than  $V_{HSSW\_ON}$ .

## 2.4 HSSW State Machine

The HSSW operates as simple 4-state state machine:

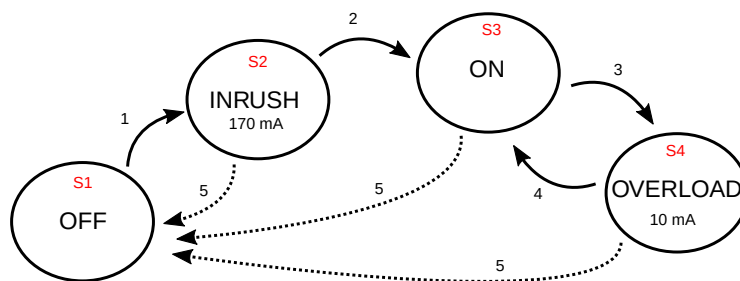


Figure 2.3. Hotswap Switch 4-State Machine

### Transitions

1. UVLO released.
2. Input capacitor charged; PWM starts with Soft-Start protection.
3. Overcurrent detected; going to Overload state.
4. Overcurrent not present; going back to ON state.
5. Turning OFF the PD.

### OFF State

HSSW turn-on is controlled by UVLO, the undervoltage lockout feature. When UVLO is engaged, the HSSW is OFF. In this state, the HSSW is in idle mode, VNEG and HSO pins are disconnected. In normal operation, a complete detect/classification procedure precedes the HSSW turn-on, and the control of this sequence is implemented in the state machine logic of the chip.

### INRUSH State

After the controller enables the HSSW, the block starts operation in the INRUSH state. In this state the switch itself is not directly turned on, but operating in a closed-loop current limit mode to avoid high current peaks during the charging of the input capacitor of the dc-dc converter.

If the  $V_{HSSW}$  voltage drops below 380 mV (meaning the bypass cap is 99% charged), the HSSW will change state to ON.

### ON State

In ON state, the HSSW switch is completely turned on. The HSSW circuit continuously monitors  $V_{HSSW}$ . HSSW will change to OVERLOAD state if  $V_{HSSW}$  voltage increases over 3.5 V.

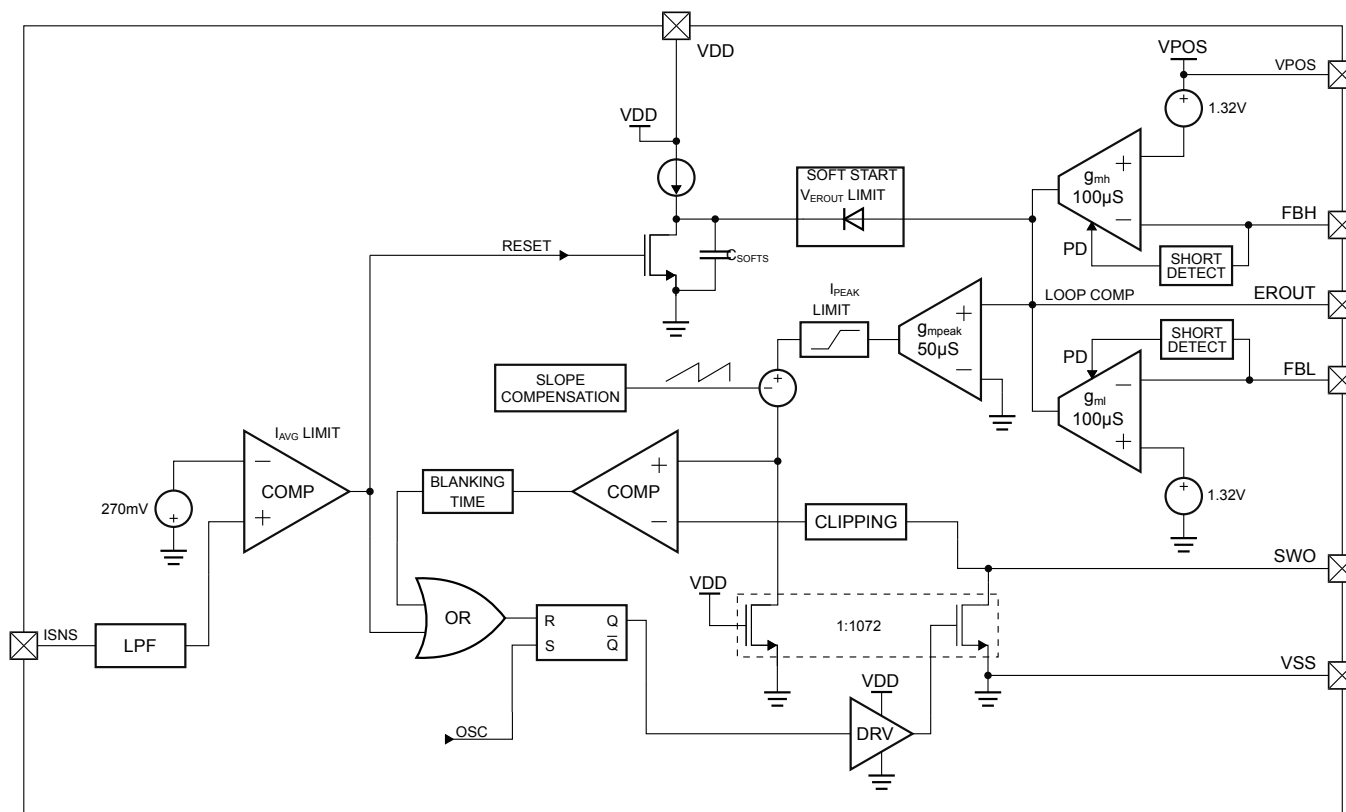
### OVERLOAD State

In OVERLOAD state the HSSW operates in closed-loop low current limit mode. If the  $V_{HSSW}$  voltage drops below 380 mV again, and the HSSW has been in the OVERLOAD state for at least  $T_{WAITHSSW}$ , the HSSW will change back to the ON state.

## 2.5 DC-DC Converter

The dc-dc converter is current-controlled for easier compensation and more robust protection of circuit magnetics. The controller has the following features:

- High- and low-side error amplifier (supports Buck and Flyback topologies).
- $<1\ \Omega$  internal switching FET
- Overcurrent detection
- Cycle skipping at low current and short circuit conditions



**Figure 2.4. Si3404 DC-DC Converter Block Diagram**

Feedback to the dc-dc converter can be provided in three ways:

- High side, referenced to VPOS, connected to FBH pin (Buck converter)
- Low side, referenced to VSS, connected to FBL pin (nonisolated Flyback)
- Directly to EROUT pin by a voltage to current converter (isolated Flyback)

The EROUT pin provides current output (if FBL or FBH is used) and voltage input. Also, the loop compensation impedance is connected to EROUT. The active voltage range is  $V_{EROUT}$ , which is proportional to the converter peak current.

The converter startup is not configurable; soft start is accomplished by internal circuitry. Soft start time is  $T_{SOFTSTART}$ . The intelligent soft start circuit dynamically adjusts the soft start time depending on the connected load.

### 2.5.1 Average Current Sensing, Overcurrent, Low-Current Detection, and Output Short Protection

The application average current is sensed by an external resistor ( $R_{SENSE}$ ) connected between VSS and ISNS. Overcurrent is detected and triggered when the voltage on the sense resistor exceeds  $V_{ISNS\_OVC}$ . Sizing the resistor allows the designer to set the overcurrent limit according to application needs. When overcurrent is triggered, the dc-dc controller goes into reset until the overcurrent resolves. When the overcurrent is no longer present, the controller starts up again with softstart.

The Si3404 integrates an output short protection. If the output is shorted for more than 1 ms, the controller will detect a high EROUT signal for more than 1 ms, which will reset the dc-dc controller. A new startup cycle with soft-start turn ON will follow.

## 2.6 Tunable Oscillator

The dc-dc frequency can be fixed to 250 kHz or tunable by an external resistor.

The tuning resistor must be connected between the  $R_{FREQ}$  pin and VPOS. If  $R_{FREQ}$  is shorted to VPOS, the fixed frequency oscillator will provide the clock,  $F_{OSCINT}$ , to the dc-dc converter; otherwise, the resistor will determine the frequency as shown in the curve below.

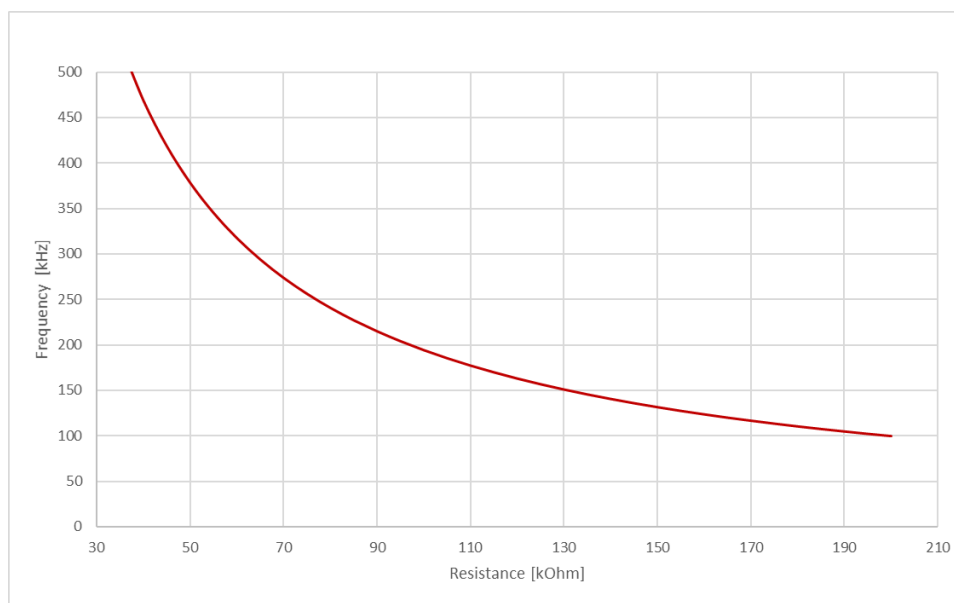


Figure 2.5.  $R_{FREQ}$  Frequency Selector Diagram

## 2.7 Regulators

The chip provides a 5 V output to power LEDs or optocouplers. This is a closed-loop regulator, which ensures accurate output voltage. The 5 V regulator is supplied by an internal 11 V open loop regulator. The 11 V regulator is supplied by a coarse regulator, which is also open-loop. With the Si3404, the VT15 pin can be used to supply this regulator from an optional auxiliary transformer bias winding. The advantage of doing so is additional power saving. The application must be designed to ensure that the absolute maximum rating voltage for the VT15 pin is not exceeded.

## 2.8 External Wall Adapter Support

The Si3404 allows the use of a range of external wall adapters as a primary or secondary supply. For details on adapter connection, please refer to "AN1130: Using the Si3406/Si34061/Si34062 PoE+ and Si3404 PoE PD Controller In Isolated and Non-Isolated Designs".



### 3. Application Examples

The following diagrams demonstrate the ease of use and straightforward BOM of the Si3404 Powered Device IC. Detailed reference designs are available in Evaluation KIT User Guides. Also refer to "AN1130: Using the Si3406/Si34061/Si34062 PoE+ and Si3404 PoE PD Controller In Isolated and Non-Isolated Designs".

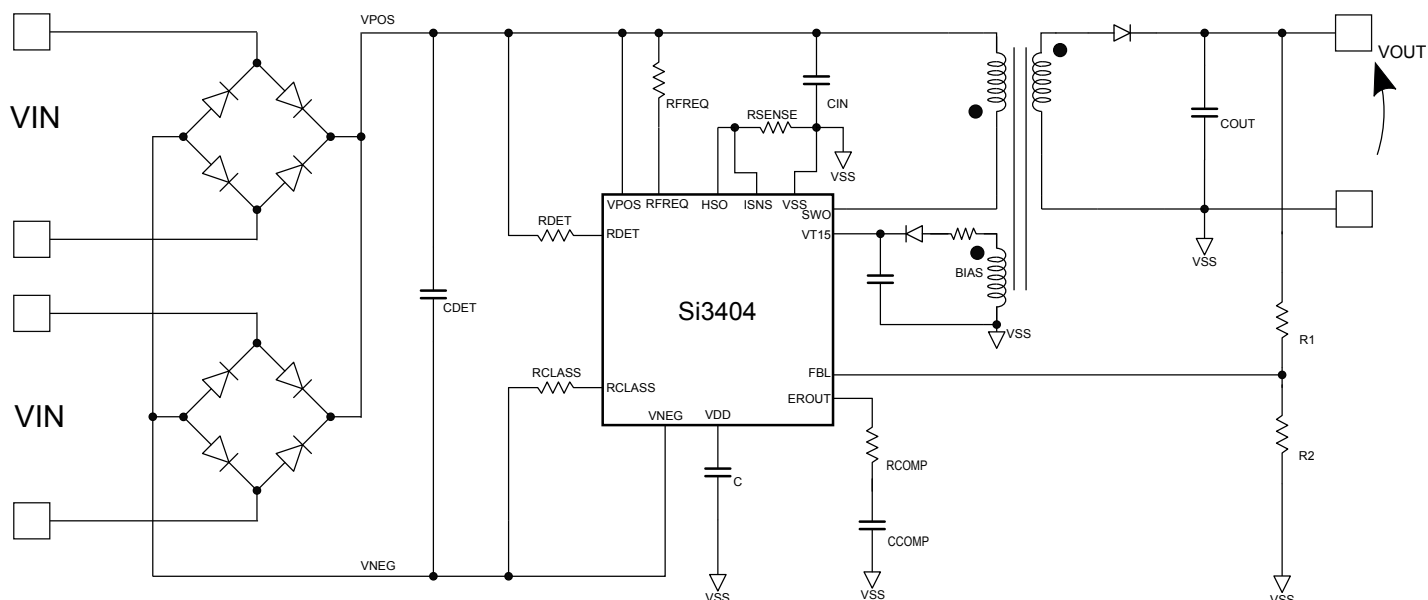


Figure 3.1. Si3404 Non-ISO Flyback Application Diagram

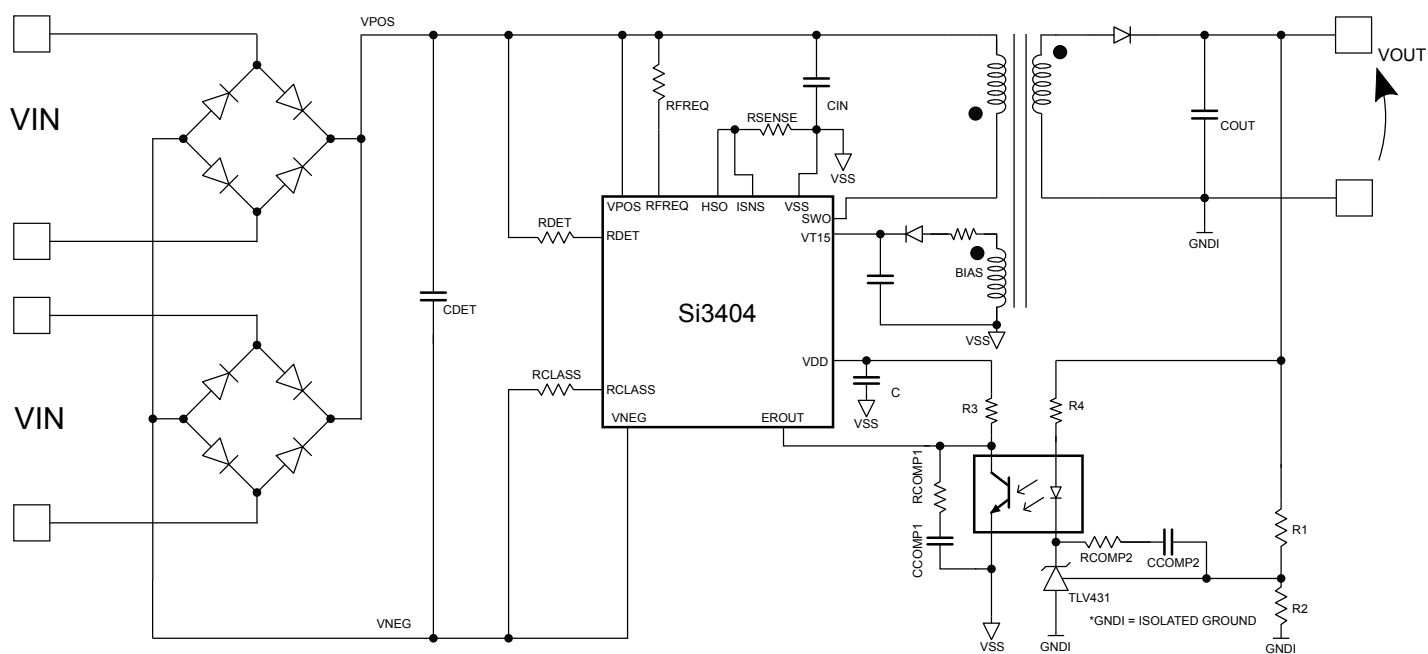


Figure 3.2. Si3404 Isolated Flyback Application Diagram

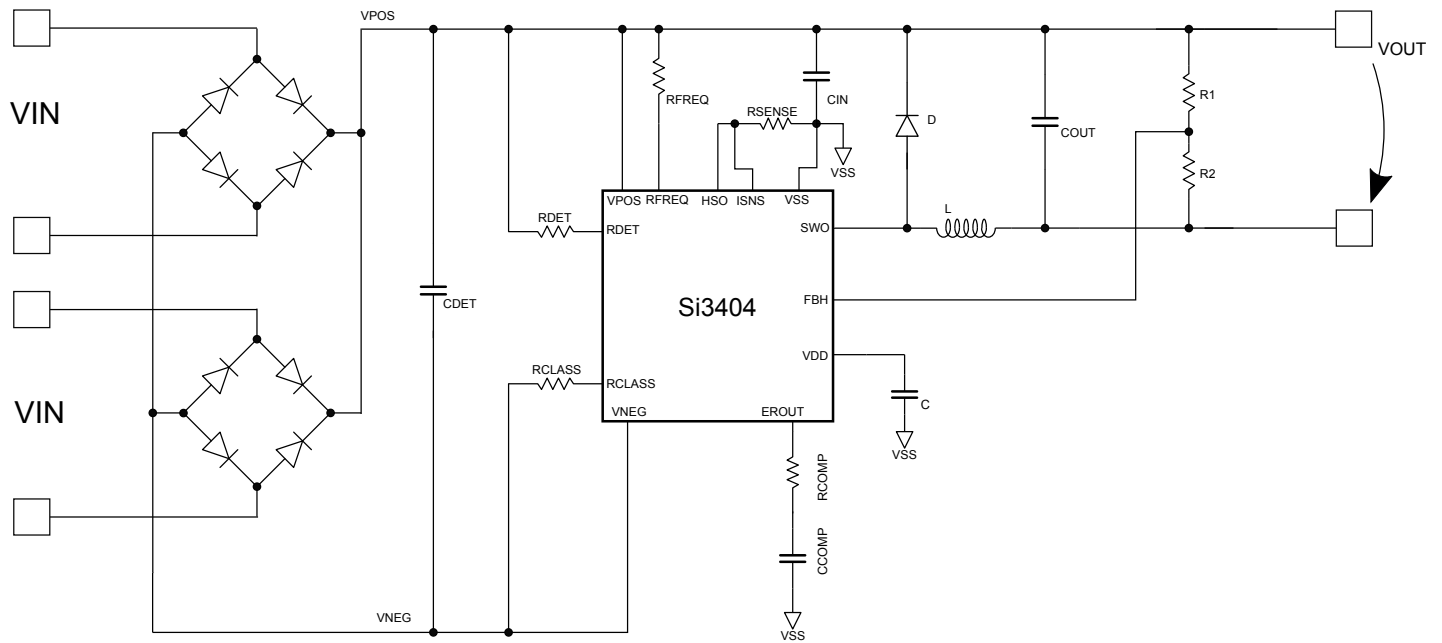


Figure 3.3. Si3404 Buck Application Diagram

## 4. Electrical Specifications

**Table 4.1. Absolute Maximum Ratings<sup>1</sup>**

| Type         | Description                                                                            | Min  | Max | Units |
|--------------|----------------------------------------------------------------------------------------|------|-----|-------|
| Voltage      | VNEG-VSS, VPOS- VNEG, HSO <sup>2</sup> , RDET <sup>3</sup>                             | −0.7 | 100 | V     |
|              | SWO-VSS                                                                                | −0.7 | 120 | V     |
|              | ISNS                                                                                   | −1   | 1   | V     |
|              | Low Voltage pins: FBH <sup>3</sup> , EROUT, FBL, RCL <sup>2</sup> , RFREQ <sup>3</sup> | −0.7 | 6   | V     |
|              | Mid Voltage pins: VT15                                                                 | −0.7 | 18  | V     |
| Peak Current | VPOS <sup>4</sup>                                                                      | −5   | 5   | A     |
| Temperature  | Storage Temperature                                                                    | −65  | 150 | °C    |
|              | Ambient Operating Temperature                                                          | −40  | 85  |       |

**Note:**

1. Unless otherwise noted, all voltages referenced to VSS. Permanent device damage may occur if the maximum ratings are exceeded. Functional operation should be restricted to those conditions specified in the operational sections of this data sheet. Exposure to absolute maximum rating conditions for extended periods may adversely affect device reliability.
2. Voltage referenced to VNEG.
3. Voltage referenced to VPOS.
4. Si340x provides internal protection from certain transient surge voltages on these pins. For more information, refer to "AN1130: Using the Si3406/Si34061/Si34062 PoE+ and Si3404 PoE PD Controller in Isolated and Non-Isolated Designs".

**Table 4.2. Recommended Operating Conditions**

| Symbol               | Parameter (Condition)                                                                                                     | Min  | Typ  | Max  | Unit |
|----------------------|---------------------------------------------------------------------------------------------------------------------------|------|------|------|------|
| V <sub>PORT</sub>    | V <sub>PORT</sub> = V <sub>POS</sub> – V <sub>NEG</sub>                                                                   | 1.5  | —    | 57   | V    |
| V <sub>HV_OP</sub>   | V <sub>NEG</sub> -V <sub>SS</sub> , V <sub>NEG</sub> -H <sub>SO</sub> , V <sub>POS</sub> -V <sub>SS</sub>                 | 1.5  | —    | 57   | V    |
| V <sub>LV_OP</sub>   | V <sub>POS</sub> referred low voltage pins: RFREQ, RDET, FBH                                                              | –5.5 | —    | 0    | V    |
| V <sub>LV_OP</sub>   | V <sub>SS</sub> referred low voltage pins: VDD, FBL, EROUT                                                                | 0    | —    | 5.5  | V    |
| V <sub>ISNS_OP</sub> | V <sub>SS</sub> referred current sensing pin: ISNS                                                                        | –0.5 | —    | 0.5  | V    |
| V <sub>LV_OP</sub>   | V <sub>NEG</sub> referred low voltage pins: RCL                                                                           | 0    | —    | 5.5  | V    |
| V <sub>MV_VT15</sub> | V <sub>SS</sub> referred medium voltage pin VT15 <sup>1</sup>                                                             | 12   | 14.5 | 16.5 | V    |
| I <sub>AVG</sub>     | Allowable continuous current on V <sub>POS</sub> , S <sub>WO</sub> , V <sub>SS</sub> , H <sub>SO</sub> , V <sub>NEG</sub> | —    | —    | 600  | mA   |
| I <sub>MAX</sub>     | Max current on H <sub>SO</sub> , V <sub>NEG</sub> , V <sub>POS</sub><br>Max 75 ms 5% Duty Cycle                           | —    | —    | 683  | mA   |

**Note:**

1. V<sub>MV\_VT15</sub> is relevant for Si3404 only when an external auxiliary bias winding from the primary side of the transformer is being used to improve power conversion efficiency. This can be left undriven, in which case an internal regulator will be used.

Table 4.3. Electrical Characteristics

| Symbol                                                  | Parameter (Condition)                                       | Min   | Typ  | Max   | Unit       |
|---------------------------------------------------------|-------------------------------------------------------------|-------|------|-------|------------|
| <b>PoE PROTOCOL</b>                                     |                                                             |       |      |       |            |
| <b>Detection</b>                                        |                                                             |       |      |       |            |
| $V_{DET}$                                               | Signature Range (at $V_{PORT}$ )                            | 1.5   | —    | 10.1  | V          |
|                                                         | Signature Resistance (at $V_{PORT}$ )                       | 23.75 | —    | 26.25 | k $\Omega$ |
| <b>Classification</b>                                   |                                                             |       |      |       |            |
| $V_{RESET}$                                             | Classification Reset (at $V_{PORT}$ )                       | 0     | —    | 2.81  | V          |
| $V_{CLASS}$                                             | Classification Voltage ON (at $V_{PORT}$ )                  | —     | —    | 14.5  | V          |
|                                                         | Classification Voltage OFF (at $V_{PORT}$ )                 | 20.5  | —    |       | V          |
| $I_{PortCLASS}$                                         | Class 0 ( $R_{CLASS} > 681 \Omega$ )                        | 0     | —    | 4     | mA         |
|                                                         | Class 1 ( $R_{CLASS} = 140 \Omega @ 1\%$ )                  | 9     | —    | 12    | mA         |
|                                                         | Class 2 ( $R_{CLASS} = 75 \Omega @ 1\%$ )                   | 17    | —    | 20    | mA         |
|                                                         | Class 3 ( $R_{CLASS} = 48.7 \Omega @ 1\%$ )                 | 26    | —    | 30    | mA         |
| <b>Power On and UVLO</b>                                |                                                             |       |      |       |            |
| $V_{UVLO\_R}$                                           | Hotswap closed and converter on                             | 34    | 37   | 40    | V          |
| $V_{UVLO\_F}$                                           | Hotswap open and converter off                              | 30    | 32   | 34    | V          |
| $V_{UVLO\_HYST}$                                        |                                                             | 3.5   | 4.5  | 6     | V          |
| <b>Thermal Characteristics</b>                          |                                                             |       |      |       |            |
| $T_{shd}$                                               | Thermal shutdown                                            | —     | 160  | —     | °C         |
| $T_{HYST}$                                              | Thermal shutdown hysteresis                                 | —     | 20   | —     | °C         |
| <b>On-Chip Transient Voltage Suppression/Protection</b> |                                                             |       |      |       |            |
| $V_{PROT}$                                              | TVS protection activation voltage ( $V_{POS}$ - $V_{NEG}$ ) | 100   | —    | —     | V          |
| <b>Hotswap Switch</b>                                   |                                                             |       |      |       |            |
| $I_{inrush}$                                            | Inrush current                                              | 100   | 170  | 200   | mA         |
| $I_{MAXHSSW}$                                           | Maximum continuous operating current                        | —     | —    | 600   | mA         |
| $V_{HSSW\_ON}$                                          | Switch ON voltage                                           | —     | 380  | —     | mV         |
| $V_{HSSW\_OFF}$                                         | Switch OFF voltage, HSSW goes to overload cycle             | —     | 3.5  | —     | V          |
| $I_{OVL}$                                               | Switch current limit in OVERLOAD State                      | —     | 10.5 | —     | mA         |
| $T_{WAITHSSW}$                                          | Wait time in OVERLOAD                                       | 80    | 96   | 116   | ms         |
| $R_{ONHSSW}$                                            | Internal hotswap drain-source resistance while ON           | 0.65  | 1.5  | 2.9   | $\Omega$   |
| <b>DC-DC</b>                                            |                                                             |       |      |       |            |

| Symbol                                       | Parameter (Condition)                                                  | Min  | Typ  | Max  | Unit |
|----------------------------------------------|------------------------------------------------------------------------|------|------|------|------|
| $I_{SWOPEAK}$                                | Peak current limit of internal FET (SWO pin)                           | 2.1  | —    | 2.7  | A    |
| $F_{OSCINT}$                                 | Using internal Oscillator                                              | 215  | 250  | 290  | kHz  |
| $F_{OSCEXT}$                                 | Using external Oscillator, RFREQ = 215 kΩ                              | 75   | 95   | 115  | kHz  |
|                                              | Using external Oscillator, RFREQ = 39 kΩ                               | 420  | 470  | 520  | kHz  |
| DUC                                          | Output duty cycle of PWM                                               | —    | —    | 75   | %    |
| $V_{FBREF}$                                  | FBH (referenced to VPOS) and FBL (referenced to VSS) reference voltage | 1.28 | 1.32 | 1.36 | V    |
| $V_{EROUT}$                                  | Operating voltage range of error input                                 | 1    | —    | 4    | V    |
| $T_{HICCUP}$                                 | Output short protection if EROUT is max                                | —    | 1    | —    | ms   |
| $V_{ISNS\_OVC}$                              | Overcurrent limit voltage on ISNS (ref. to VSS)                        | −305 | −270 | −255 | mV   |
| $T_{SOFTSTART}$                              | Startup time <sup>1</sup>                                              | —    | 15   | —    | ms   |
| $R_{ONDCDC}$                                 | Internal dc-dc switching FET drain-source resistance while ON          | —    | 0.9  | 1.2  | Ω    |
| <b>Regulators</b>                            |                                                                        |      |      |      |      |
| VT15                                         | Override internal regulator with transformer winding                   | 12.5 | —    | 16.5 | V    |
| VDD                                          | 5 V regulated output                                                   | 4.9  | 5.2  | 5.5  | V    |
| $VDD_{ILIM}$                                 | dc current limit of VDD                                                | 9.7  | 11.2 | —    | mA   |
| $C_{REG}$                                    | Filter capacitor on VDD                                                | 82   | 100  | 220  | nF   |
| <b>Power Dissipation</b>                     |                                                                        |      |      |      |      |
| $P_{INTMAX}$                                 | dc-dc max power internal FET                                           | —    | 0.5  | 0.9  | W    |
| $I_{PortOP}$                                 | Operating current (V <sub>PORT</sub> 57 V; 250 kHz)                    | —    | 3    | 5    | mA   |
| <b>Package Thermal Characteristics</b>       |                                                                        |      |      |      |      |
| $\theta_{JA-EFF}$                            | QFN20 <sup>2</sup>                                                     | —    | 46.8 | —    | °C/W |
| <b>Note:</b>                                 |                                                                        |      |      |      |      |
| 1. Depends on output load.                   |                                                                        |      |      |      |      |
| 2. Assumes 4-Layer PCB with adequate layout. |                                                                        |      |      |      |      |

## 5. Pin Descriptions

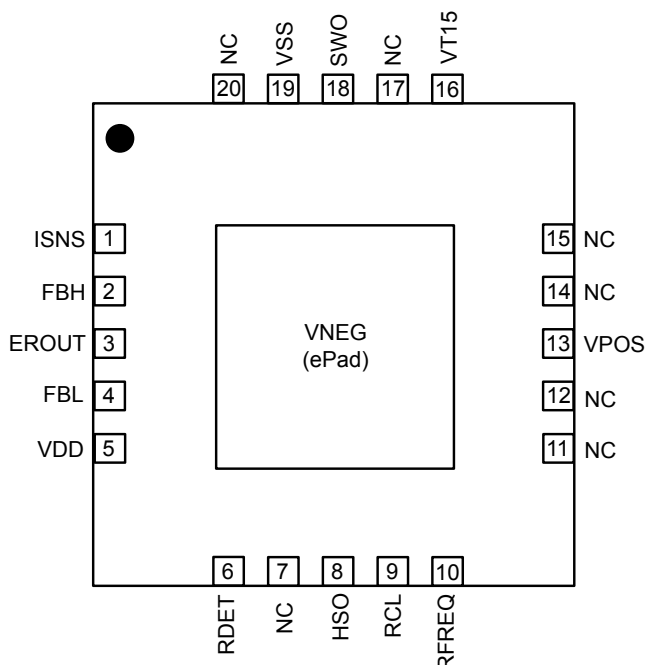


Figure 5.1. Si3404 Pinout

Table 5.1. Pin Descriptions

| Si3404 Pins               | Name  | Ref  | Dir. | Vrange    | Description                                                                   |
|---------------------------|-------|------|------|-----------|-------------------------------------------------------------------------------|
| 1                         | ISNS  | VSS  | I    | –0.5 to 0 | Chip current sense resistor input                                             |
| 2                         | FBH   | VPOS | I    | 0–5.5     | High side (VPOS referred) dc-dc feedback (Buck converter)                     |
| 3                         | EROUT | VSS  | IO   | 0–5.5     | Error amplifier current output, compensation impedance input                  |
| 4                         | FBL   | VSS  | I    | 0–5.5     | Low side (VSS referenced) dc-dc feedback (Flyback converter)                  |
| 5                         | VDD   | VSS  | O    | 0–5.5     | 5 V regulator output                                                          |
| 6                         | RDET  | VPOS | IO   | 0–100     | Detection resistor                                                            |
| 8                         | HSO   | VNEG | IO   | 0–100     | Hotswap switch output                                                         |
| 9                         | RCL   | VNEG | IO   | 0–5.5     | Classification resistor                                                       |
| 10                        | RFREQ | VPOS | IO   | 0–5.5     | Oscillator frequency tuning resistor, tie to VPOS to select default frequency |
| 13                        | VPOS  | —    | IO   | 0–100     | Rectified high-voltage supply positive rail                                   |
| 16                        | VT15  | VSS  | I    | 0–16.5    | dc-dc transformer auxiliary winding input                                     |
| 18                        | SWO   | VSS  | O    | 0–120     | Internal dc-dc switch output (NMOS drain)                                     |
| 19                        | VSS   | —    | IO   | 0         | dc-dc converter primary ground                                                |
| ePad                      | VNEG  | —    | IO   | 0         | Rectified high voltage supply ground                                          |
| 7, 11, 12, 14, 15, 17, 20 | NC    | —    | —    | —         | Connect to VNEG for better thermal performance                                |

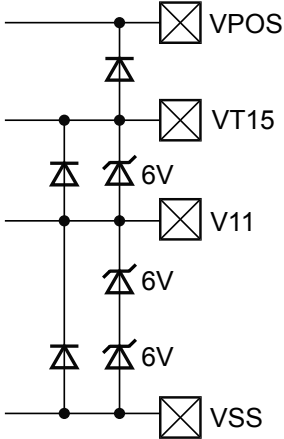
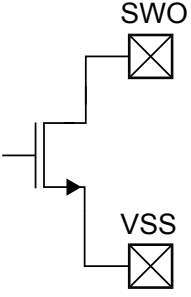
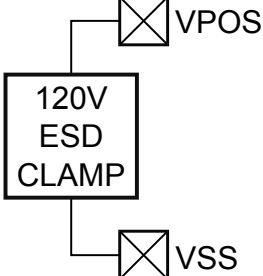
## 5.1 Detailed Pin Descriptions

Table 5.2. Circuit Equivalent and Description of Die Pads

| Pin Name | Detailed Description                                                                                                                                                                                                             | Circuit Detail |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| ISNS     | Average current sense resistor input. The resistor value will set the maximum allowed current for the application. The overcurrent threshold voltage $V_{ISNS\_OVC}$ . Note that this pin voltage goes below VSS.                |                |
| FBH      | High side dc-dc feedback input. Need to be tied to VPOS when not used. See VFBREF.                                                                                                                                               |                |
| EROUT    | dc-dc converter error output; current out, voltage sense. Loop compensating impedance should be connected here.<br>$I_{EROUT} = (V_{FBH} - V_{FBREF}) \times 50 \mu A$ or<br>$I_{EROUT} = (V_{FBL} - V_{FBREF}) \times 50 \mu A$ |                |
| FBL      | Low side dc-dc feedback input. Need to be tied to VSS when not used. See VFBREF                                                                                                                                                  |                |
| VDD      | Regulated 5 V relative to VSS. There is no foldback characteristic, reaching $VDD_{ILIM}$ the output voltage decreases.<br>The regulator needs $C_{REG}$ external capacitance.                                                   |                |

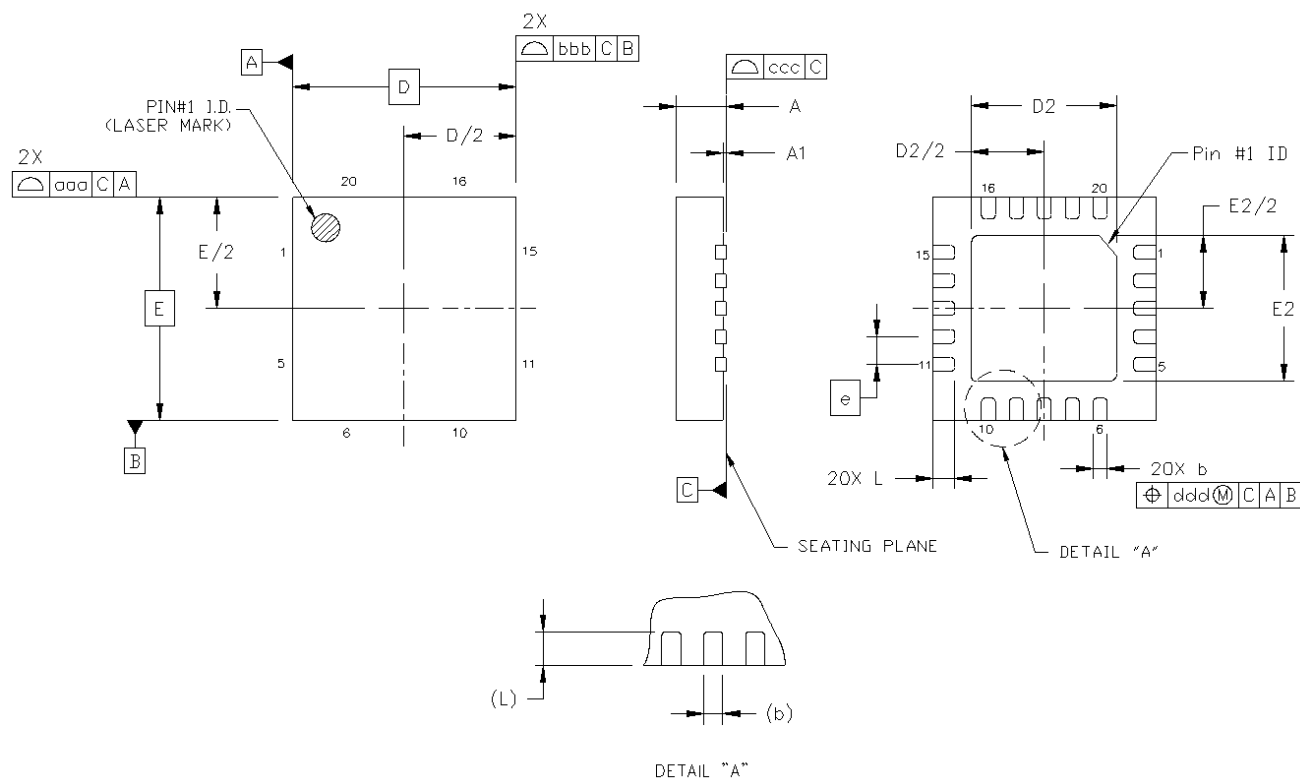


| Pin Name   | Detailed Description                                                                                                                                                                                                                                                                                | Circuit Detail |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| RCL        | Classification resistor input. For class 0 this pin can be left floating. Pin is active only at time of classification.                                                                                                                                                                             |                |
| RFREQ      | Used for adjusting the oscillator frequency.<br>The frequency is inversely proportional to the value of the connected resistor.                                                                                                                                                                     |                |
| VPOS, VNEG | Main chip input power. Note that VNEG (the ePad on the bottom of the chip) also provides thermal relief.                                                                                                                                                                                            |                |
| HSO        | Hotswap Switch Output. The switch shorts the VNEG and HSO pins, and includes several other functions. See hotswap switch section for details.                                                                                                                                                       |                |
| RDET       | The user has to tie the RDET resistor between this pin and VPOS. During detection, a high voltage switch pulls down RDET to VNEG. After detection, the reference block uses RDET as absolute chip current reference, forcing -750 mV relative to VPOS, creating 30 $\mu$ A for the internal blocks. |                |

| Pin Name | Detailed Description                                                                                                                                                                                                                                                                                                   | Circuit Detail                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| VT15     | VT15 is input for an optional 15 V supply generated by an auxiliary transformer bias winding. If the bias winding voltage is lower than VT15_MIN, the internal 15 V coarse regulator will provide the current for the 11 V regulator. V11 is not available on the Si3404 but is included to show internal connections. |  <p>The diagram shows a vertical stack of components connected to a common ground (VSS). From top to bottom: a VPOS input, a diode pointing down, a VT15 input, a diode pointing up, a 6V Zener diode, a V11 input, a 6V Zener diode, and a diode pointing down. The V11 input is shown as a square symbol with an 'X' inside, indicating it is not available on the Si3404.</p> |
| SWO      | dc-dc converter switching transistor drain output, Vmax = 120 V.                                                                                                                                                                                                                                                       |  <p>The diagram shows a switching transistor with its drain connected to SWO, its source connected to VSS, and its gate connected to an input signal.</p>                                                                                                                                                                                                                        |
| VSS      | dc-dc converter ground.                                                                                                                                                                                                                                                                                                |  <p>The diagram shows a 120V ESD CLAMP block connected between VPOS and VSS. The block is a rectangle with '120V ESD CLAMP' written inside.</p>                                                                                                                                                                                                                                 |

## 6.1 Package Outline: Si3404

The figure below illustrates the package details for the Si3404. The table lists the values for the dimensions shown in the illustration.



**Figure 6.1. 20-Pin, QFN Package**

Table 6.1. Package Diagram Dimensions

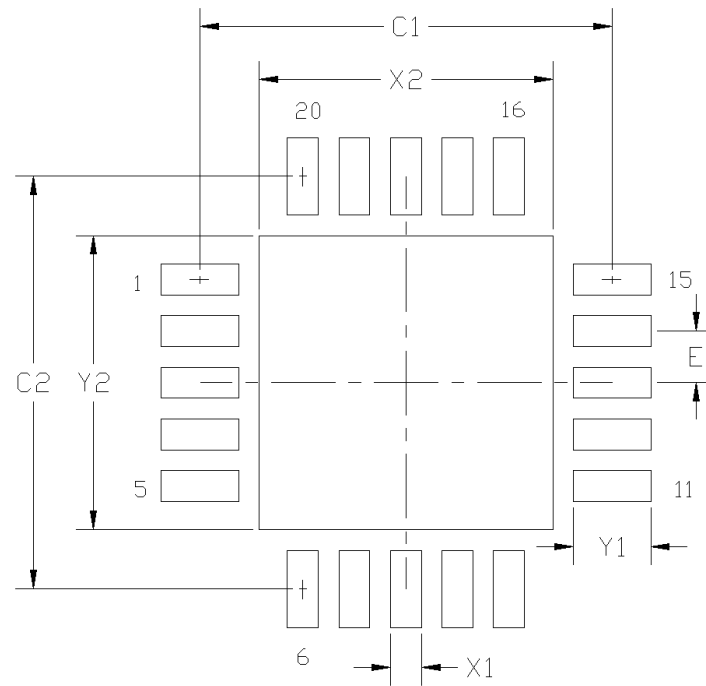
| Dimension | Min       | Nom  | Max  |
|-----------|-----------|------|------|
| A         | 0.80      | 0.85 | 0.90 |
| A1        | 0.00      | 0.02 | 0.05 |
| b         | 0.18      | 0.25 | 0.30 |
| D         | 4.00 BSC. |      |      |
| D2        | 2.55      | 2.60 | 2.65 |
| e         | 0.50 BSC. |      |      |
| E         | 4.00 BSC. |      |      |
| E2        | 2.50      | 2.60 | 2.70 |
| L         | 0.30      | 0.40 | 0.50 |
| aaa       | —         | —    | 0.10 |
| bbb       | —         | —    | 0.10 |
| ccc       | —         | —    | 0.08 |
| ddd       | —         | —    | 0.10 |
| eee       | —         | —    | 0.10 |

**Note:**

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 the JEDEC Solid State Outline MO-220, Variation VGGD-8.
4. Recommended card reflow profile is per the JEDEC/IPC J-STD-020C specification for Small Body Components.

## 6.2 Land Pattern: Si3404

The figure below illustrates the land pattern details for the Si3404. The table lists the values for the dimensions shown in the illustration.



**Figure 6.2. 20-Pin, QFN Land Pattern**

Table 6.2. Land Pattern Dimensions

| Dimension | Min      | Max  |
|-----------|----------|------|
| C1        | 3.90     | 4.00 |
| C2        | 3.90     | 4.00 |
| E         | 0.50 BSC |      |
| X1        | 0.20     | 0.30 |
| X2        | 2.55     | 2.65 |
| Y1        | 0.65     | 0.75 |
| Y2        | 2.55     | 2.65 |

**Note:****General**

1. All dimensions shown are in millimeters (mm) unless otherwise noted.
2. This land pattern design is based on the IPC-7351 guidelines.

**Solder Mask Design**

1. All metal pads are to be non-solder mask defined (NSMD). Clearance between the solder mask and the metal pad is to be 60 mm minimum, all the way around the pad.

**Stencil Design**

1. A stainless steel, laser-cut and electro-polished stencil with trapezoidal walls should be used to assure good solder paste release.
2. The stencil thickness should be 0.125 mm (5 mils).
3. The ratio of stencil aperture to land pad size should be 1:1 for all perimeter pads.
4. A 2x2 array of 1.10 mm x 1.10 mm openings on 1.30 mm pitch should be used for the center ground pad.

**Card Assembly**

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

7. Si3404 Top Marking

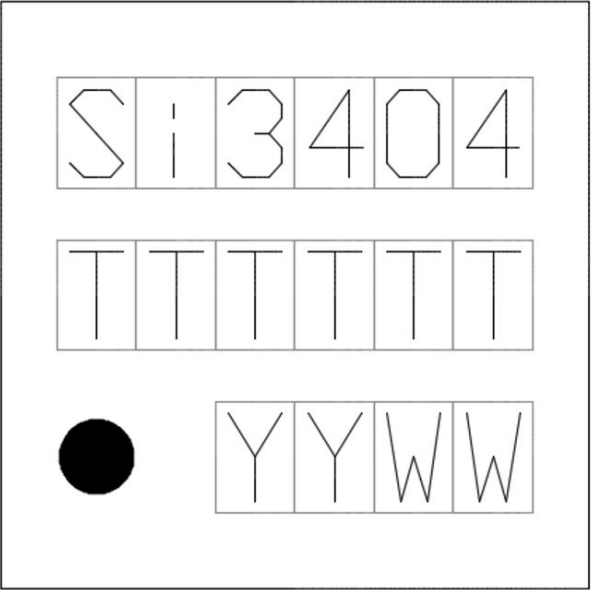


Figure 7.1. Si3404 Top Marking

Table 7.1. Si3404 Top Marking Explanation

|                     |                                               |                                                  |
|---------------------|-----------------------------------------------|--------------------------------------------------|
| Mark Method:        | Laser                                         |                                                  |
| Pin 1 Mark:         | Circle = 0.50 mm Diameter (Lower-Left Corner) |                                                  |
| Font Size:          | 0.6 Point (24 mils)                           |                                                  |
| Line 1 Mark Format: | Device Part Number                            | Si3404                                           |
| Line 2 Mark Format: | TTTTTT                                        | Trace code from the Assembly Purchase Order form |
| Line 3 Mark Format: | YY = Year<br>WW = Work Week                   | Assembly Year<br>Assembly Week                   |

## 8. Revision History

### Revision 1.0

July, 2018

- Updated [Figure 2.2 Powered Device Voltages on page 5](#).
  - Removed Type 2 signaling from diagram.
- Updated [Figure 2.3 Hotswap Switch 4-State Machine on page 6](#).
  - Clearer state transition diagram and improved transition descriptions.
- Updated [2.5.1 Average Current Sensing, Overcurrent, Low-Current Detection, and Output Short Protection](#).
  - Added information on output short protection.
- Updated [Table 4.1 Absolute Maximum Ratings<sup>1</sup> on page 11](#).
  - Added min and max current for VPOS.
  - Added note about internal surge protection.
- Updated [Table 4.2 Recommended Operating Conditions on page 12](#).
  - Added VPOS to  $I_{AVG}$  spec; changed  $I_{PEAK}$  to  $I_{MAX}$ , and removed SWO and VSS from specification.
- Updated [Table 4.3 Electrical Characteristics on page 13](#).
  - Updated  $V_{DET}$  spec to include low threshold and high threshold specs.
  - Updated classification reset max voltage ( $V_{RESET}$ ) based on final characterization data.
  - Updated classification voltage  $V_{CLASS}$  based on final characterization data.
  - Added max and min  $V_{UVLO\_R}$ ,  $V_{UVLO\_F}$ , and  $V_{UVLO\_HYST}$  max and min voltages.
  - Removed  $I_{OVL}$  max and min current.
  - Added min and max frequency to  $F_{OSCINT}$  based on final characterization data.
  - Removed “TBD” from DUC spec.
  - Added max and min  $V_{FBREF}$  voltage.
  - Added  $T_{HICCUP}$  typical spec.
  - Added max and min  $V_{ISNS\_OVC}$  voltage.
  - Updated  $T_{SOFTSTART}$  time based on application data and added note about dependence on output load.
  - Updated min VT15 based on characterization data.
  - Updated VDD min, typ, and max based on final characterization data.
  - Added VDD<sub>ILIM</sub> max voltage.
  - Added min and max  $C_{REG}$  capacitance.
  - Updated  $P_{INTMAX}$  based on final characterization data.
  - Removed  $P_{MAX}$  spec.
  - Updated  $I_{PORTOP}$  max current based on final characterization data.
- Updated [Table 5.1 Pin Descriptions on page 15](#).
  - Updated Vrange.
- Updated [Table 5.2 Circuit Equivalent and Description of Die Pads on page 16](#).
  - Added detail to VT15 pin description.

### Revision 0.5

February, 2018

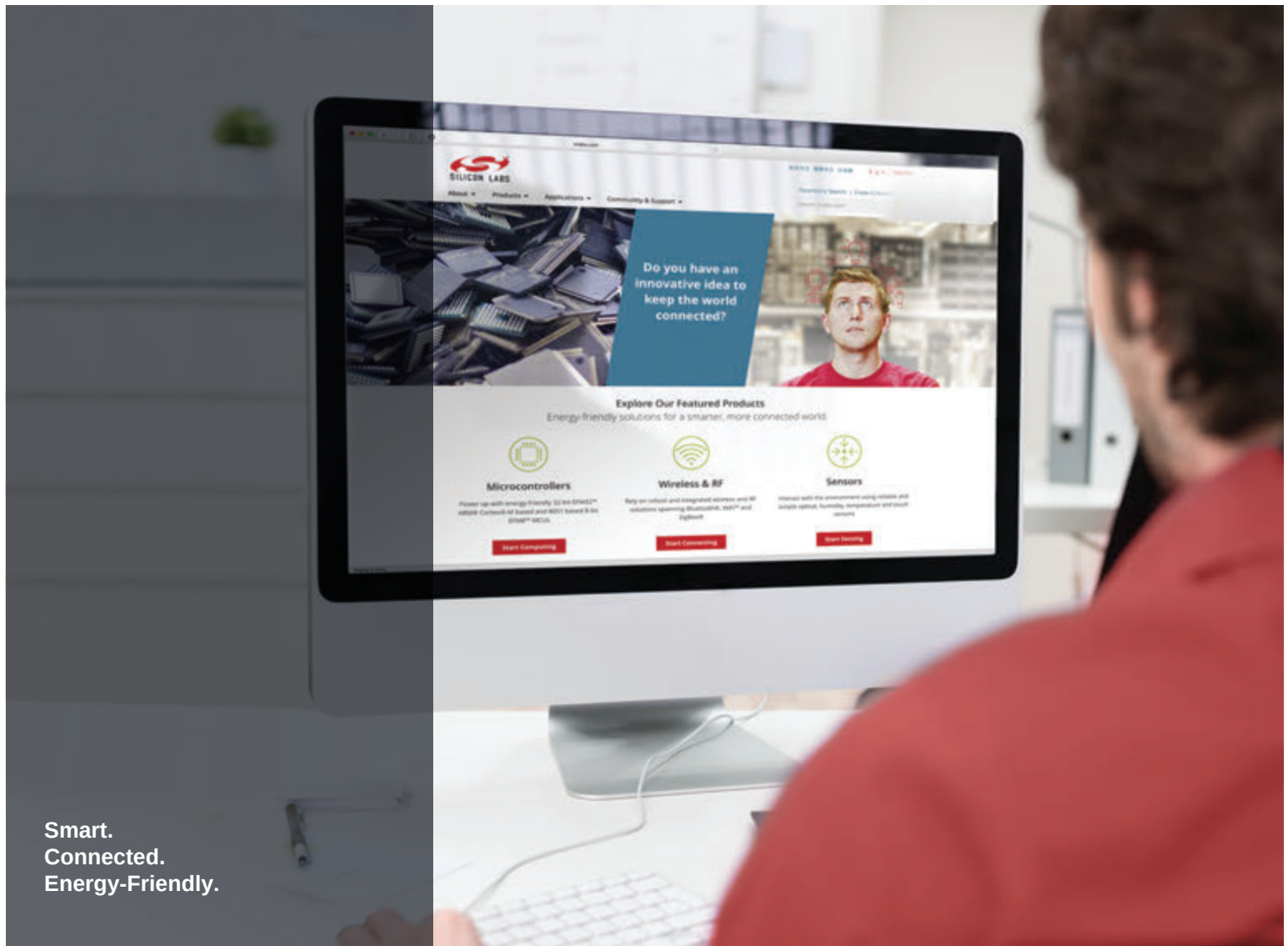
- Updated [2. System Overview](#) and [3. Application Examples](#).
  - Added theory of operation and application content.
- Updated [Table 4.1 Absolute Maximum Ratings<sup>1</sup> on page 11](#), [Table 4.2 Recommended Operating Conditions on page 12](#), and [Table 4.3 Electrical Characteristics on page 13](#).
  - Clarified multiple parameters.
- Added [5.1 Detailed Pin Descriptions](#).
- Added [6. Packaging](#) including outline and land pattern.



## Revision 0.1

March, 2017

- Initial release.

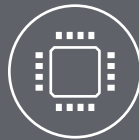


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