

## Power Management IC for Automotive ADAS Platform

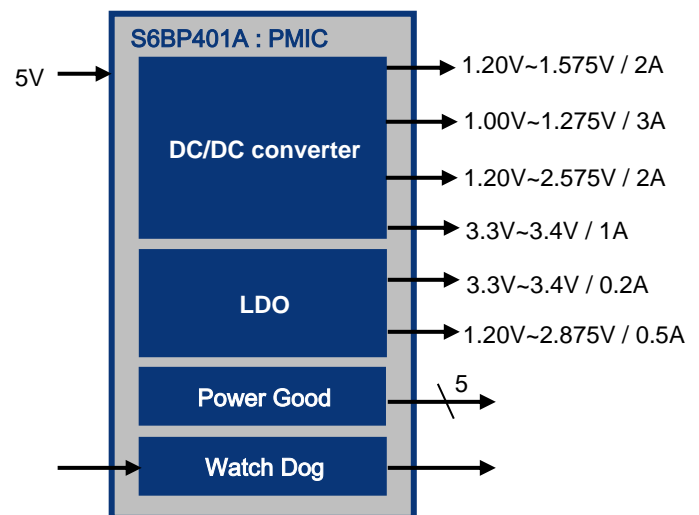
### Quad Buck 2.1 MHz DC/DC Converter and Dual LDO with Watchdog Timer

S6BP401A is a power management IC, consists of quad buck 2.1 MHz DC/DC converter with built-in switching FETs, dual Low Drop-out regulator (LDOs) and a digital windowed watchdog timer. Having the switching FETs built-in, S6BP401A realizes high power conversion efficiency and high switching frequency up to 2.4 MHz. The internal FETs are capable to handle up to 3A load. As S6BP401A employs the current mode architecture, it has fast load transient response. Built-in output voltage setting resistors and compensation circuits reduce BOM cost and component area.

### Features

- Quad Buck DC/DC Converter (DD1 to DD4)
  - VIN Input Range: 4.5V to 5.5V
  - Switching Frequency
  - External clock mode: 1.8 MHz to 2.4 MHz
  - Internal clock mode: 2.0 MHz to 2.2 MHz
  - Built-in Switching FETs up to 3A
  - Built-in Output Voltage Setting Resistors
  - Built-in Compensation Circuits
- Dual LDO (LD1, LD2)
  - VIN Input Voltage Range: 2.97V to 5.5V
  - Built-in Output Voltage Setting resistors
- Power Good Monitor Output for each DC/DC Converters, LDOs
- Built-in Windowed Watchdog Timer (WDT)
- Under Voltage Lockout (UVLO)
- Thermal Shutdown (TSD)
- Over Current Protection (OCP)
- Over Voltage Protection (OVP)
- Independent Enabling for each DC/DC Converters and LDOs
- Load-independent Soft-Start
- Built-in Discharge Resistors
- Small 6 mm x 6 mm QFN-40 Package
- AEC-Q100 compliant (Grade-1)

### Block Diagram



### Applications

- Automotive Applications
- Advanced Driver Assistance Systems (ADAS)
- Camera Systems such as Security Camera
- Industrial Applications

## More Information

Cypress provides a wealth of data at [www.cypress.com/pmic](http://www.cypress.com/pmic) to help you to select the right PMIC device for your design, and to help you to quickly and effectively integrate the device into your design. Following is an abbreviated list for S6BP401A:

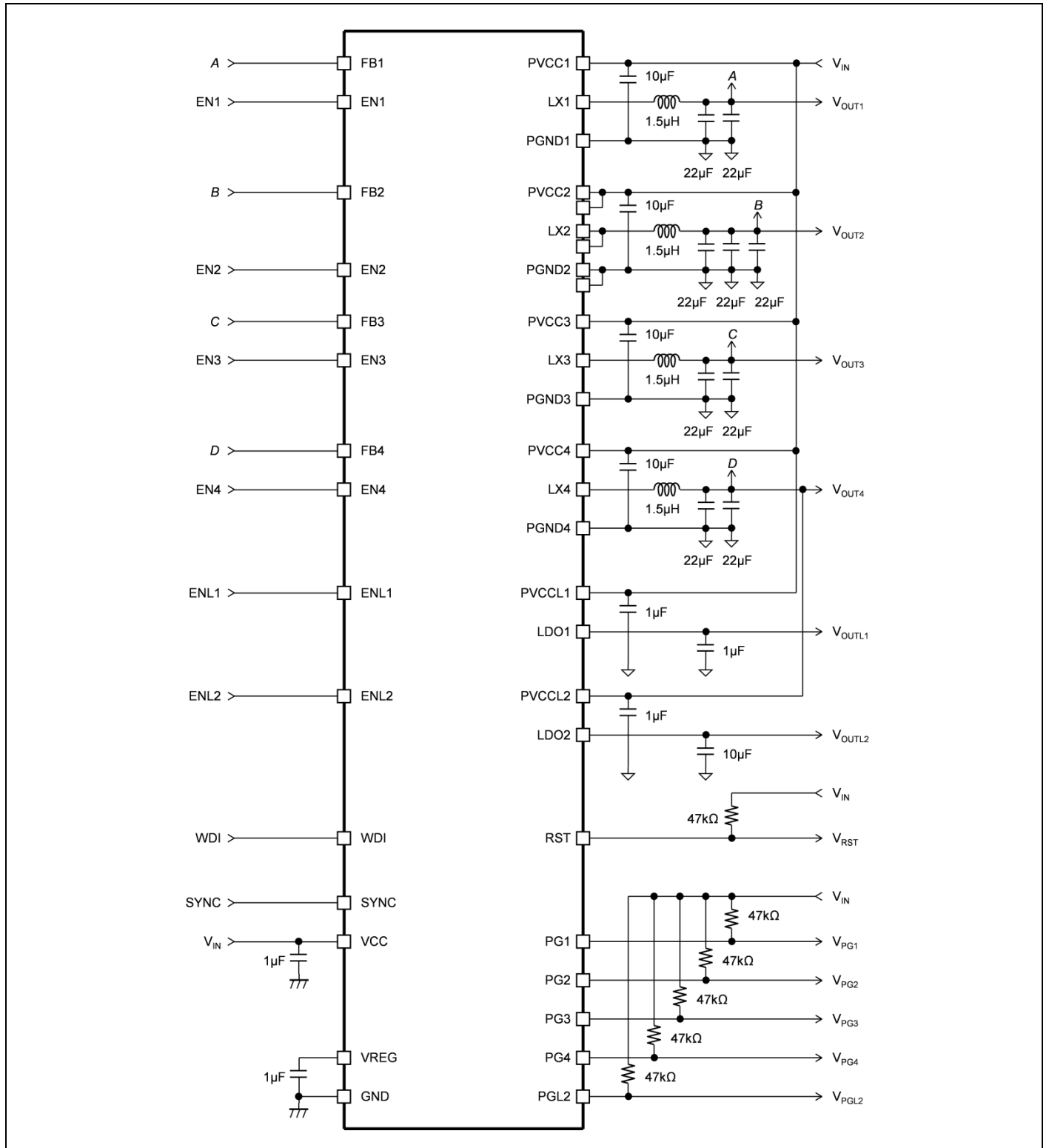
- Overview: [Automotive PMIC Portfolio](#), [Automotive PMIC Roadmap](#)
- Product Selector:
  - [S6BP401A](#): 6ch Automotive PMIC for ADAS
- Application Notes: Cypress offers S6BP401A application notes. Recommended application notes for getting started with S6BP401A are:
  - [AN98649](#): How to Design a Power Management System
  - [AN201006](#): Thermal Considerations and Parameters
- Evaluation Kit Operation Manual:
  - [S6SBP401AM2SA1001](#): Power block for automotive ADAS platform
- Related Products:
  - [S6BP201A](#), [S6BP202A](#), [S6BP203A](#): 1ch Buck-Boost Automotive PMIC
  - [S6BP501A](#), [S6BP502A](#): 3ch Automotive PMIC for Instrument Cluster

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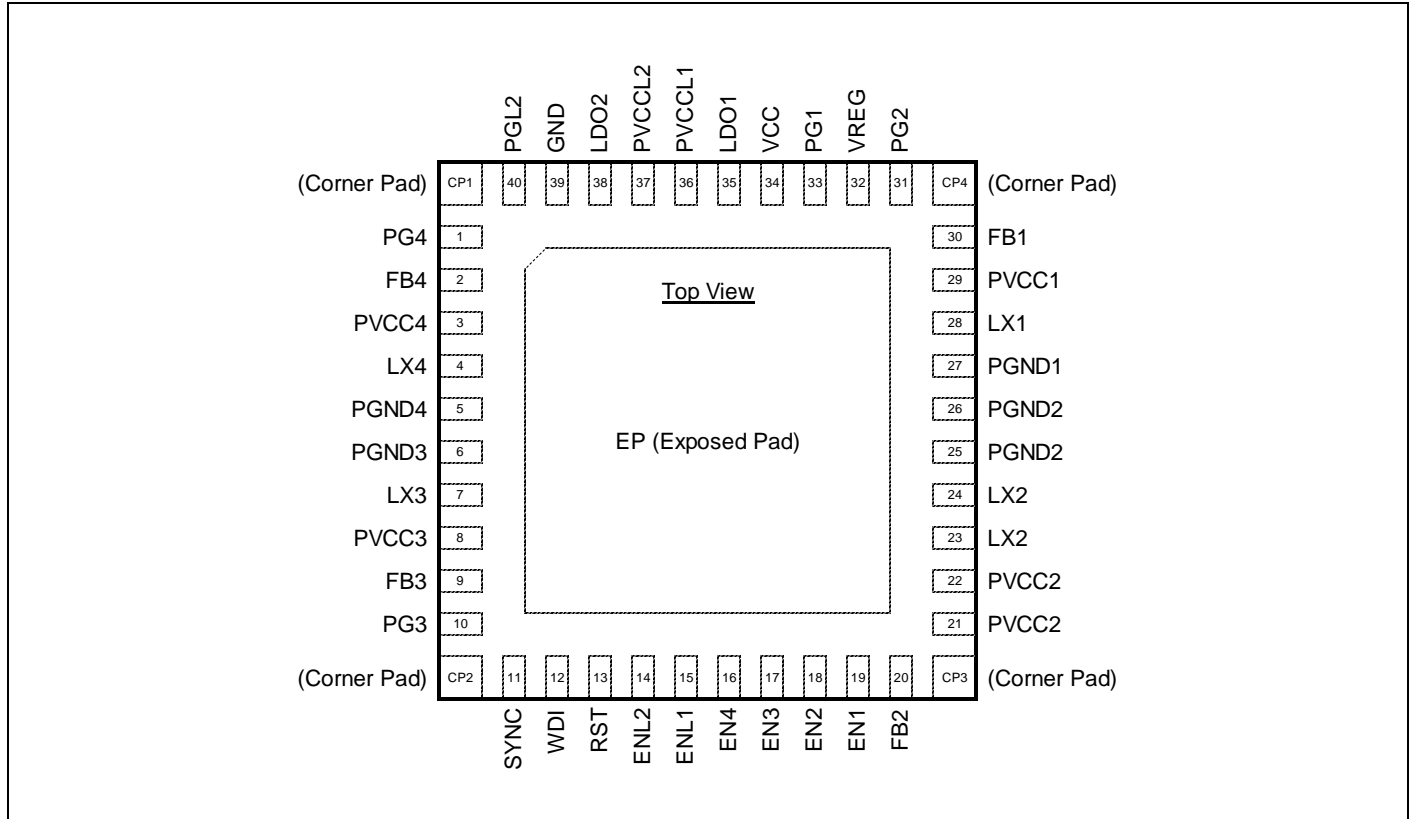
# 1. Typical Application

Figure 1-1 Typical Application



## 2. Pin Configuration

Figure 2-1 Pin Configuration



### 3. Pin Functions

**Table 3-1 Pin Functions**

| Functional Block | Pin Number         | Pin Name | I/O | Description  | Pin Setting When Not Being Used |
|------------------|--------------------|----------|-----|--|---------------------------------|
| DD1              | 19                 | EN1      | I   | Enable input terminal of DD1.  | Ground                          |
|                  | 30                 | FB1      | I   | Output voltage feedback terminal of DD1.   | Ground                          |
|                  | 33                 | PG1      | O   | Power good output terminal of DD1.   | Ground                          |
|                  | 29                 | PVCC1    | -   | Power supply terminal of DD1.  | VCC                             |
|                  | 28                 | LX1      | O   | Inductor connect terminal of DD1.  | Leave pin open                  |
|                  | 27                 | PGND1    | -   | Power ground terminal of DD1.  | Ground                          |
| DD2              | 18                 | EN2      | I   | Enable input terminal of DD2.  | Ground                          |
|                  | 20                 | FB2      | I   | Output voltage feedback terminal of DD2.   | Ground                          |
|                  | 31                 | PG2      | O   | Power good output terminal of DD2.   | Ground                          |
|                  | 21, 22             | PVCC2    | -   | Power supply terminal of DD2.  | VCC                             |
|                  | 23, 24             | LX2      | O   | Inductor connect terminal of DD2.  | Leave pin open                  |
|                  | 25, 26             | PGND2    | -   | Power ground terminal of DD2.  | Ground                          |
| DD3              | 17                 | EN3      | I   | Enable input terminal of DD3.  | Ground                          |
|                  | 9                  | FB3      | I   | Output voltage feedback terminal of DD3.   | Ground                          |
|                  | 10                 | PG3      | O   | Power good output terminal of DD3.   | Ground                          |
|                  | 8                  | PVCC3    | -   | Power supply terminal of DD3.  | VCC                             |
|                  | 7                  | LX3      | O   | Inductor connect terminal of DD3.  | Leave pin open                  |
|                  | 6                  | PGND3    | -   | Power ground terminal of DD3.  | Ground                          |
| DD4              | 16                 | EN4      | I   | Enable input terminal of DD4.  | Ground                          |
|                  | 2                  | FB4      | I   | Output voltage feedback terminal of DD4.   | Ground                          |
|                  | 1                  | PG4      | O   | Power good output terminal of DD4.   | Ground                          |
|                  | 3                  | PVCC4    | -   | Power supply terminal of DD4.  | VCC                             |
|                  | 4                  | LX4      | O   | Inductor connect terminal of DD4.  | Leave pin open                  |
|                  | 5                  | PGND4    | -   | Power ground terminal of DD4.  | Ground                          |
| LD1              | 15                 | ENL1     | I   | Enable input terminal of LD1.  | Ground                          |
|                  | 36                 | PVCC1    | -   | Power supply terminal of LD1.  | VCC                             |
|                  | 35                 | LDO1     | O   | Output terminal of LD1.  | Leave pin open                  |
| LD2              | 14                 | ENL2     | I   | Enable input of LD2.   | Ground                          |
|                  | 40                 | PGL2     | O   | Power good output terminal of LD2.   | Ground                          |
|                  | 37                 | PVCC2    | -   | Power supply terminal of LD2.  | VCC                             |
|                  | 38                 | LDO2     | O   | Output terminal of LD2.  | Leave pin open                  |
| WDT              | 12                 | WDI      | I   | Trigger input terminal of WDT.   | Ground                          |
|                  | 13                 | RST      | O   | Reset input terminal of WDT.   | Ground                          |
| SYNC             | 11                 | SYNC     | I   | External clock input terminal.   | Ground                          |
| -                | 34                 | VCC      | -   | Power supply terminal for analog controller.   | -                               |
| -                | 32                 | VREG     | O   | Internal 1.8V supply voltage capacitor terminal. Do NOT supply or load this terminal externally. | -                               |
| -                | 39                 | GND      | -   | Ground terminal for analog controller.   | -                               |
| -                | EP                 | EP       | -   | Exposed pad. Connect to ground plane.  | -                               |
| -                | CP1, CP2, CP3, CP4 | CP       | -   | Corner pad for reinforcing attachment to a board. Connect to ground plane.                       | -                               |

### 4. Preset Output Voltage

Table 4-1 Preset Output Voltage (Buck DC/DC Converter)

| Channel | Preset Output Voltage [V] | Soft-start Time [ms] | Maximum Output Current [mA] | Under Voltage Threshold [%] | Over Voltage Threshold [%] |
|---------|---------------------------|----------------------|-----------------------------|-----------------------------|----------------------------|
| DD1     | 1.200                     | 1.200                | 2000                        | 94.0                        | 106.0                      |
|         | 1.225                     | 1.225                |                             |                             |                            |
|         | 1.250                     | 1.250                |                             |                             |                            |
|         | 1.275                     | 1.275                |                             |                             |                            |
|         | 1.300                     | 1.300                |                             |                             |                            |
|         | 1.325                     | 1.325                |                             |                             |                            |
|         | 1.500                     | 1.500                |                             |                             |                            |
|         | 1.525                     | 1.525                |                             |                             |                            |
|         | 1.550                     | 1.550                |                             |                             |                            |
|         | 1.575                     | 1.575                |                             |                             |                            |
| DD2     | 1.000                     | 1.000                | 3000                        | 94.0                        | 106.0                      |
|         | 1.025                     | 1.025                |                             |                             |                            |
|         | 1.050                     | 1.050                |                             |                             |                            |
|         | 1.075                     | 1.075                |                             |                             |                            |
|         | 1.100                     | 1.100                |                             |                             |                            |
|         | 1.125                     | 1.125                |                             |                             |                            |
|         | 1.150                     | 1.150                |                             |                             |                            |
|         | 1.175                     | 1.175                |                             |                             |                            |
|         | 1.200                     | 1.200                |                             |                             |                            |
|         | 1.225                     | 1.225                |                             |                             |                            |
|         | 1.250                     | 1.250                |                             |                             |                            |
|         | 1.275                     | 1.275                |                             |                             |                            |
|         | DD3                       | 1.200                |                             |                             |                            |
| 1.225   |                           | 1.225                |                             |                             |                            |
| 1.250   |                           | 1.250                |                             |                             |                            |
| 1.275   |                           | 1.275                |                             |                             |                            |
| 1.500   |                           | 1.500                |                             |                             |                            |
| 1.525   |                           | 1.525                |                             |                             |                            |
| 1.550   |                           | 1.550                |                             |                             |                            |
| 1.575   |                           | 1.575                |                             |                             |                            |
| 1.800   |                           | 1.800                |                             |                             |                            |
| 1.825   |                           | 1.825                |                             |                             |                            |
| 1.850   |                           | 1.850                |                             |                             |                            |
| 1.875   |                           | 1.875                |                             |                             |                            |
| 2.500   |                           | 2.500                |                             |                             |                            |
| 2.525   |                           | 2.525                |                             |                             |                            |
| 2.550   |                           | 2.550                |                             |                             |                            |
| 2.575   | 2.575                     |                      |                             |                             |                            |
| DD4     | 3.300                     | 3.300                | 1000                        | 95.5                        | 106.0                      |
|         | 3.325                     | 3.325                |                             |                             |                            |
|         | 3.350                     | 3.350                |                             |                             |                            |
|         | 3.375                     | 3.375                |                             |                             |                            |
|         | 3.400                     | 3.400                |                             |                             |                            |

**Notes:**

- Soft-start time values are at  $f_{osc} = 2.1 \text{ MHz}$
- Refer to Chapter 8 for the minimum or maximum values of output voltage, under voltage threshold and over voltage threshold.

**Table 4-2 Preset Output Voltage (LDO)**

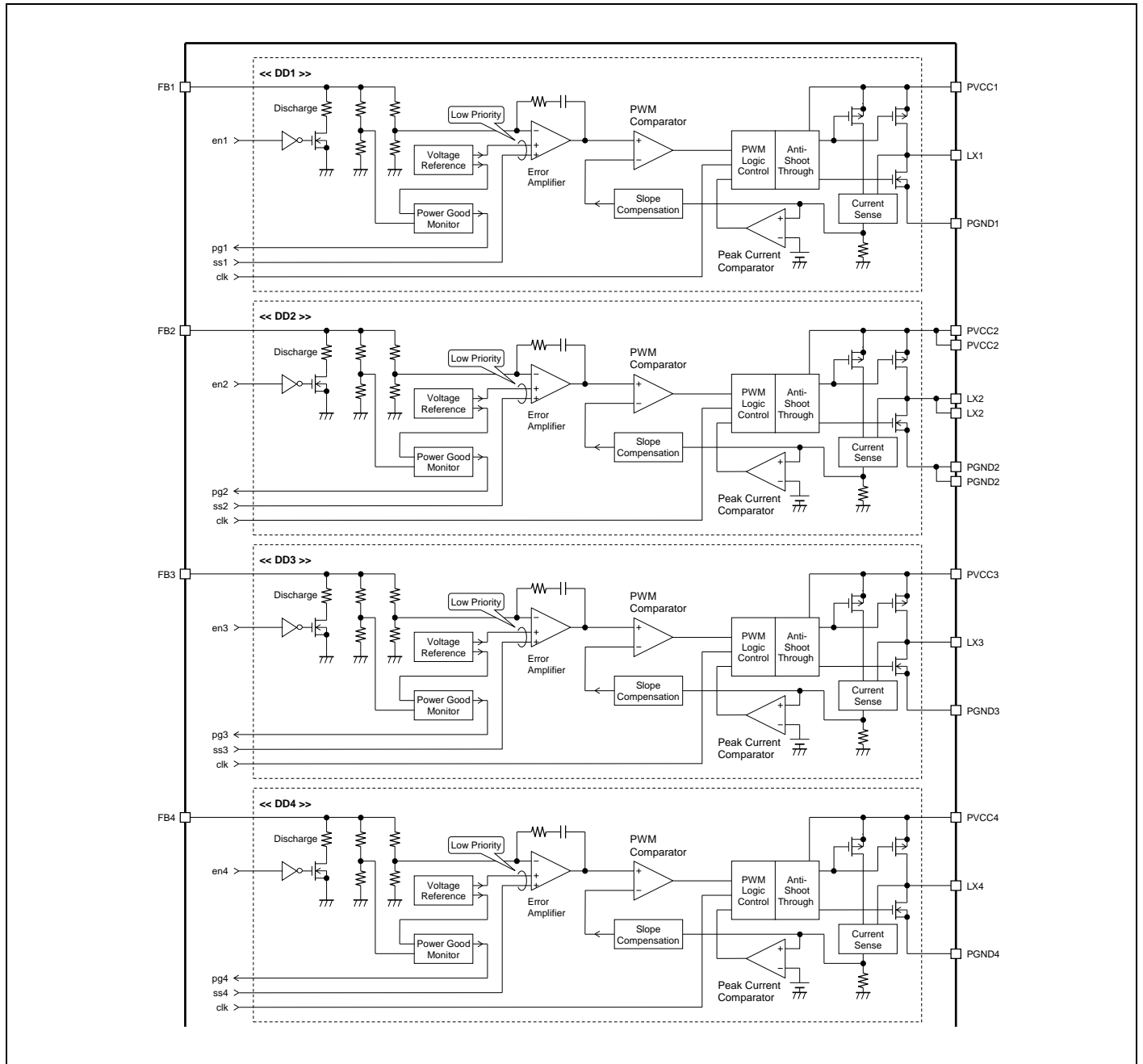
| Channel | Preset Output Voltage [V] | Soft-start Time [ms] | Maximum Output Current [mA] | Under Voltage Threshold [%] | Over Voltage Threshold [%] |
|---------|---------------------------|----------------------|-----------------------------|-----------------------------|----------------------------|
| LD1     | 3.300                     | 3.300                | 200                         | 94.0                        | 106.0                      |
|         | 3.325                     | 3.325                |                             |                             |                            |
|         | 3.350                     | 3.350                |                             |                             |                            |
|         | 3.375                     | 3.375                |                             |                             |                            |
|         | 3.400                     | 3.400                |                             |                             |                            |
| LD2     | 1.200                     | 1.200                | 500                         | 94.0                        | 106.0                      |
|         | 1.225                     | 1.225                |                             |                             |                            |
|         | 1.250                     | 1.250                |                             |                             |                            |
|         | 1.275                     | 1.275                |                             |                             |                            |
|         | 1.800                     | 1.800                |                             |                             |                            |
|         | 1.825                     | 1.825                |                             |                             |                            |
|         | 1.850                     | 1.850                |                             |                             |                            |
|         | 1.875                     | 1.875                |                             |                             |                            |
|         | 2.800                     | 2.800                |                             |                             |                            |
|         | 2.825                     | 2.825                |                             |                             |                            |
|         | 2.850                     | 2.850                |                             |                             |                            |
|         | 2.875                     | 2.875                |                             |                             |                            |

**Notes:**

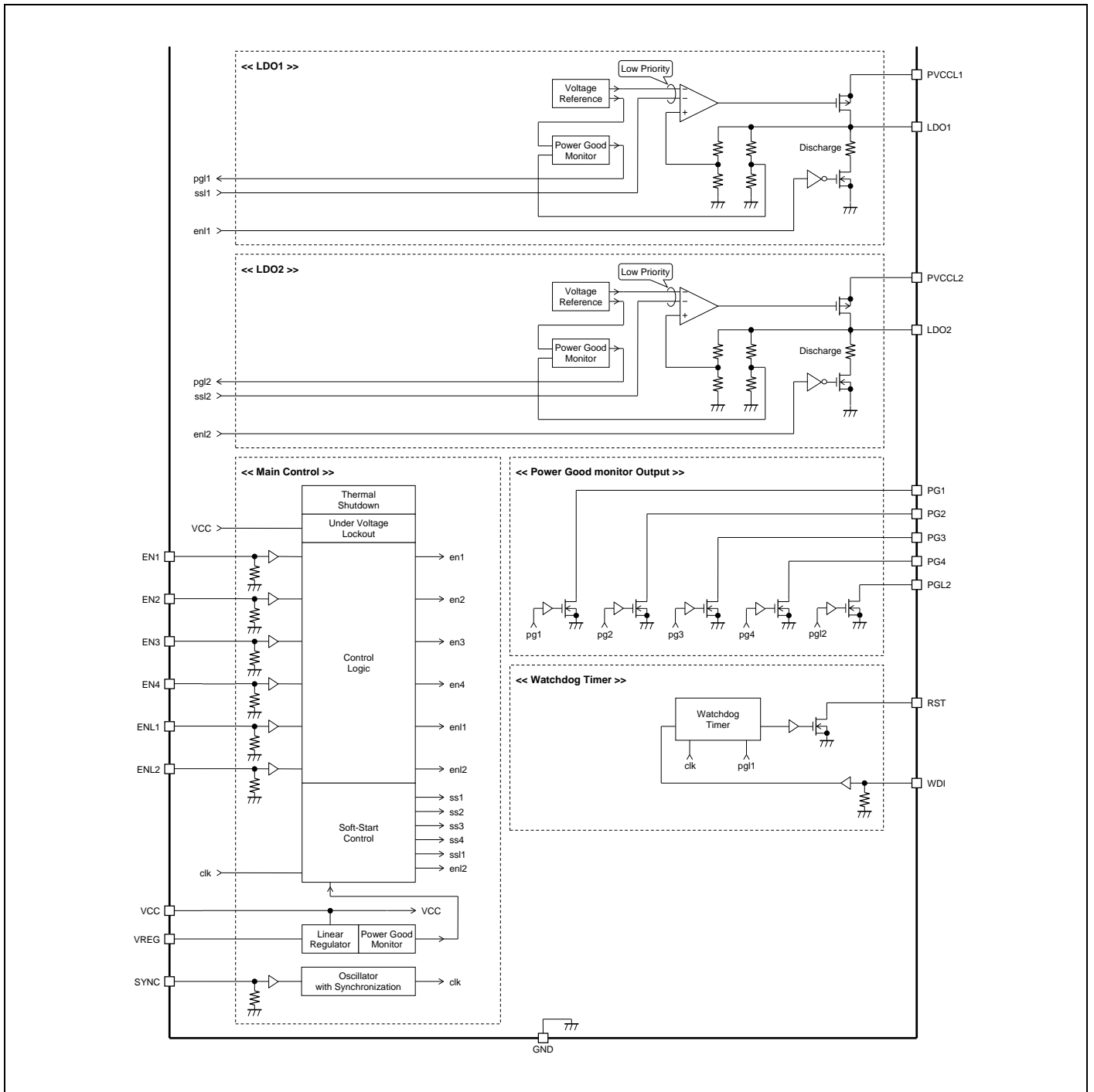
- Soft-start time values are at  $f_{OSC} = 2.1 \text{ MHz}$
- Refer to Chapter 8 for the minimum or maximum values of output voltage, under voltage threshold and over voltage threshold.

## 5. Architecture Block Diagram

Figure 5-1 Architecture Block Diagram







## 6. Absolute Maximum Ratings

Table 6-1 Absolute Maximum Ratings

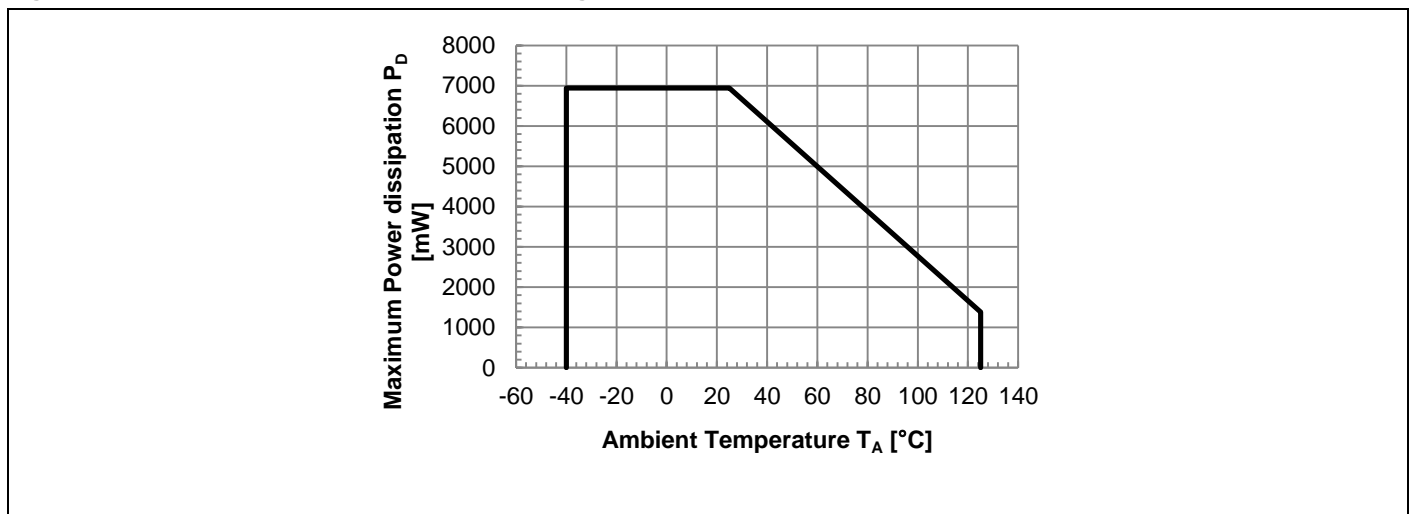
| Parameter            | Symbol                 | Condition   | Rating |      | Unit |
|----------------------|------------------------|---|--------|------|------|
|                      |                        |   | Min    | Max  |      |
| Power supply voltage | V <sub>VCC</sub>       | VCC   | -0.3   | +6.9 | V    |
|                      | V <sub>PVCC</sub>      | PVCC1, PVCC2, PVCC3, PVCC4  | -0.3   | +6.9 | V    |
|                      | V <sub>PVCCCL</sub>    | PVCCCL1, PVCCCL2  | -0.3   | +6.9 | V    |
| Input voltage        | V <sub>EN</sub>        | EN1, EN2, EN3, EN4, ENL1, ENL2  | -0.3   | +6.9 | V    |
|                      | V <sub>WDI</sub>       | WDI   | -0.3   | +6.9 | V    |
|                      | V <sub>SYNC</sub>      | SYNC  | -0.3   | +6.9 | V    |
|                      | V <sub>FB</sub>        | FB1, FB2, FB3, FB4  | -0.3   | +6.9 | V    |
|                      | V <sub>PG</sub>        | PG1, PG2, PG3, PG4, PGL2  | -0.3   | +6.9 | V    |
|                      | V <sub>RST</sub>       | RST   | -0.3   | +6.9 | V    |
| LX voltage           | V <sub>LX</sub>        | LX1, LX2, LX3, LX4  | -0.3   | +6.9 | V    |
| Voltage difference   | V <sub>PVCC-VCC</sub>  | PVCC1 -VCC, PVCC2-VCC, PVCC3-VCC, PVCC4-VCC   | -0.3   | +0.3 | V    |
|                      | V <sub>PGND-GND</sub>  | PGND1-GND, PGND2-GND, PGND3-GND, PGND4-GND  | -0.3   | +0.3 | V    |
|                      | V <sub>PVCC-LX</sub>   | PVCC1-LX1, PVCC2-LX2, PVCC3-LX3, PVCC4-LX4  | -0.3   | +6.9 | V    |
|                      | V <sub>VCC-INPUT</sub> | VCC-EN1, VCC-EN2, VCC-EN3, VCC-EN4, VCC-EN1L, VCC-EN2L, VCC-WDI, VCC-SYNC, VCC-FB1, VCC-FB2, VCC-FB3, VCC-FB4 | -0.3   | +6.9 | V    |
| Power dissipation    | P <sub>D</sub>         | T <sub>A</sub> ≤ +25°C,<br>Thermal resistance (θ <sub>JA</sub> ): 18°C/W (*1)                                 | -      | 6940 | mW   |
| Junction temperature | T <sub>J</sub>         | -   | -40    | +150 | °C   |
| Storage temperature  | T <sub>STG</sub>       | -   | -55    | +150 | °C   |

\*1: When the IC is mounted on 76.2 mm x 114.3 mm four-layer epoxy board. IC is mounted on a four-layer epoxy board, which terminal bias, and the IC's thermal pad is connected to the epoxy board.

### WARNING

- Semiconductor devices may be permanently damaged by application of stress (including, without limitation, voltage, current or temperature) in excess of absolute maximum ratings. Do not exceed any of these ratings.

Figure 6-1 Maximum Power Dissipation - Operating Ambient Temperature Characteristics



## 7. Recommended Operating Conditions

**Table 7-1 Recommended Operating Conditions**

| Parameter                     | Symbol              | Condition                      | Value |                  |                  | Unit |
|-------------------------------|---------------------|--------------------------------|-------|------------------|------------------|------|
|                               |                     |                                | Min   | Typ              | Max              |      |
| Power supply voltage          | V <sub>VCC</sub>    | VCC                            | +4.5  | +5.0             | +5.5             | V    |
|                               | V <sub>PVCC</sub>   | PVCC1, PVCC2, PVCC3, PVCC4     | -     | V <sub>VCC</sub> | -                | V    |
|                               | V <sub>PVCCCL</sub> | PVCCL1, PVCCL2                 | +2.97 | +5.0             | V <sub>VCC</sub> | V    |
| Input voltage                 | V <sub>EN</sub>     | EN1, EN2, EN3, EN4, ENL1, ENL2 | 0     | -                | V <sub>VCC</sub> | V    |
|                               | V <sub>WDI</sub>    | WDI                            | 0     | -                | V <sub>VCC</sub> | V    |
|                               | V <sub>SYNC</sub>   | SYNC                           | 0     | -                | V <sub>VCC</sub> | V    |
|                               | V <sub>FB</sub>     | FB1, FB2, FB3, FB4             | 0     | -                | V <sub>VCC</sub> | V    |
|                               | V <sub>PG</sub>     | PG1, PG2, PG3, PG4, PGL2       | 0     | -                | +5.5             | V    |
|                               | V <sub>RST</sub>    | RST                            | 0     | -                | +5.5             | V    |
| Operating ambient temperature | T <sub>A</sub>      | -                              | -40   | +25              | +125             | °C   |

**WARNING:**

1. The recommended operating conditions are required in order to ensure the normal operation of the semiconductor device. All of the device's electrical characteristics are warranted when the device is operated under these conditions.
2. Any use of semiconductor devices will be under their recommended operating condition.
3. Operation under any conditions other than these conditions may adversely affect reliability of device and could result in device failure.
4. No warranty is made with respect to any use, operating conditions or combinations not represented on this data sheet. If you are considering application under any conditions other than listed herein, please contact sales representatives beforehand.

## 8. Electrical Characteristics

$V_{VCC} = V_{PVCC} = 5.0V$ ,  $V_{PVCCCL} = 5.0V$ ,  $T_A = T_J = -40$  to  $+125$  °C, unless otherwise noted. Typical values are at  $T_A = +25$  °C.

**Table 8-1 Electrical Characteristics**

| Parameter   | Symbol         | Condition   | Value |            |           | Unit       |
|---|----------------|---|-------|------------|-----------|------------|
|   |                |   | Min   | Typ        | Max       |            |
| <b>Supply Current</b>                                 |                |   |       |            |           |            |
| Shutdown current                                      | $I_{VCCS}$     | VCC PIN,<br>$V_{EN1} = V_{EN2} = V_{EN3} = V_{EN4} = V_{ENL1} =$<br>$V_{ENL2} = 0V$ | -     | 1          | 10        | $\mu A$    |
| <b>UVLO: Under Voltage Lockout (VCC)</b>              |                |   |       |            |           |            |
| Threshold voltage                                     | $V_{UVLOF}$    | $V_{VCC}$ falling, UVLO stop voltage  | 3.80  | 3.95       | 4.10      | V          |
| Hysteresis  | $V_{UVHYS}$    | -   | 0.27  | 0.30       | 0.33      | V          |
| <b>TSD: Thermal Shutdown</b>                          |                |   |       |            |           |            |
| Shutdown temperature                                  | $T_{TSD}$      | Temperature rising  | -     | 165 (*1)   | -         | °C         |
| Hysteresis  | $T_{TSDHYS}$   | -   | -     | 10 (*1)    | -         | °C         |
| <b>Enable Inputs (EN1, EN2, EN3, EN4, ENL1, ENL2)</b> |                |   |       |            |           |            |
| Input high voltage                                    | $V_{IHEN}$     | -   | 2.0   | -          | $V_{VCC}$ | V          |
| Input low voltage                                     | $V_{ILEN}$     | -   | 0     | -          | 0.4       | V          |
| Input current   | $I_{IHEN}$     | $V_{EN} = 5.0V$   | 33    | 50         | 100       | $\mu A$    |
| Pull down resistance                                  | $R_{PDEN}$     | -   | 50    | 100        | 150       | k $\Omega$ |
| <b>Internal Linear Regulator Output (VREG)</b>        |                |   |       |            |           |            |
| Output voltage  | $V_{VREG}$     | $V_{VCC} = 5.0V$  | 1.74  | 1.80       | 1.86      | V          |
| Maximum output current                                | $I_{VREG}$     | $V_{VCC} = 5.0V$  | 5     | -          | -         | mA         |
| Over voltage lockout threshold                        | $V_{VREGOV R}$ | $V_{VREG}$ rising, Power fail   | 1.86  | 1.92       | 1.98      | V          |
|   | $V_{VREGOV F}$ | $V_{VREG}$ falling, Power good  | 1.81  | 1.87       | 1.93      | V          |
| Under voltage lockout threshold                       | $V_{VREGUV R}$ | $V_{VREG}$ rising, Power good   | 1.67  | 1.73       | 1.79      | V          |
|   | $V_{VREGUV F}$ | $V_{VREG}$ falling, Power fail  | 1.62  | 1.68       | 1.74      | V          |
| <b>Oscillator</b>                                     |                |   |       |            |           |            |
| Switching frequency                                   | $f_{OSC}$      | -   | 2.0   | 2.1        | 2.2       | MHz        |
| <b>Synchronization Input (SYNC)</b>                   |                |   |       |            |           |            |
| Input high voltage                                    | $V_{IH SYNC}$  | -   | 2.0   | -          | $V_{VCC}$ | V          |
| Input Low voltage                                     | $V_{IL SYNC}$  | -   | 0     | -          | 0.4       | V          |
| Input current   | $I_{IH SYNC}$  | $V_{EN} = 5.0V$   | 33    | 50         | 100       | $\mu A$    |
| Pull down resistance                                  | $R_{PD SYNC}$  | -   | 50    | 100        | 150       | k $\Omega$ |
| Input frequency                                       | $f_{SYNC}$     | -   | 1.8   | 2.1        | 2.4       | MHz        |
| Switching frequency                                   | $f_{OSC}$      | -   | -     | $f_{SYNC}$ | -         | MHz        |

| Parameter                                  | Symbol               | Condition  | Value |        |        | Unit |
|--|----------------------|--|-------|--------|--------|------|
|  |                      |  | Min   | Typ    | Max    |      |
| <b>Power Good Monitor (PG1, PG2, PGL2)</b> |                      |  |       |        |        |      |
| Over voltage threshold                     | V <sub>PGOV</sub>    | Ratio of power fail threshold to V <sub>OUT1</sub> , V <sub>OUT2</sub> , V <sub>OUTL2</sub> rising | 104.5 | 106.0  | 107.5  | %    |
| Over voltage hysteresis                    | V <sub>PGOVHYS</sub> | -  | 0.5   | 1.0    | 1.5    | %    |
| Under voltage threshold                    | V <sub>PGUV</sub>    | Ratio of power fail threshold to V <sub>OUT1</sub> , V <sub>OUT2</sub> , V <sub>OUT3</sub> falling | 92.5  | 94.0   | 95.5   | %    |
| Under voltage hysteresis                   | V <sub>PGUVHYS</sub> | -  | 0.5   | 1.0    | 1.5    | %    |
| Leakage current                            | I <sub>LEAKPG</sub>  | V <sub>PG</sub> = 5.0V   | -     | -      | 1      | μA   |
| Output low voltage                         | V <sub>OLPG</sub>    | I <sub>PG</sub> = 3 mA   | -     | 0.15   | 0.30   | V    |
| Propagation time                           | T <sub>PPG</sub>     | 5% outside of the threshold, Power fail  | -     | 4 (*1) | 8 (*1) | μs   |
| Power-on reset time                        | T <sub>RPG</sub>     | Power good   | 8     | 10     | 12     | ms   |
| <b>Power Good Monitor (PG3)</b>            |                      |  |       |        |        |      |
| Over voltage threshold                     | V <sub>PGOV</sub>    | Ratio of power fail threshold to V <sub>OUT3</sub> rising  | 104.5 | 106.0  | 107.5  | %    |
| Over voltage hysteresis                    | V <sub>PGOVHYS</sub> | -  | 0.5   | 1.0    | 1.5    | %    |
| Under voltage threshold                    | V <sub>PGUV</sub>    | Ratio of power fail threshold to V <sub>OUT3</sub> falling   | 93.7  | 95.2   | 96.7   | %    |
| Under voltage hysteresis                   | V <sub>PGUVHYS</sub> | -  | 0.5   | 1.0    | 1.5    | %    |
| Leakage current                            | I <sub>LEAKPG</sub>  | V <sub>PG</sub> = 5.0V   | -     | -      | 1      | μA   |
| Output low voltage                         | V <sub>OLPG</sub>    | I <sub>PG</sub> = 3 mA   | -     | 0.15   | 0.30   | V    |
| Propagation time                           | T <sub>PPG</sub>     | 5% outside of the threshold, Power fail  | -     | 4 (*1) | 8 (*1) | μs   |
| Power-on reset time                        | T <sub>RPG</sub>     | Power good   | 8     | 10     | 12     | ms   |
| <b>Power Good Monitor (PG4)</b>            |                      |  |       |        |        |      |
| Over voltage threshold                     | V <sub>PGOV</sub>    | Ratio of power fail threshold to V <sub>OUT4</sub> rising  | 104.5 | 106.0  | 107.5  | %    |
| Over voltage hysteresis                    | V <sub>PGOVHYS</sub> | -  | 0.5   | 1.0    | 1.5    | %    |
| Under voltage threshold                    | V <sub>PGUV</sub>    | Ratio of power fail threshold to V <sub>OUT4</sub> falling   | 94.0  | 95.5   | 97.0   | %    |
| Under voltage hysteresis                   | V <sub>PGUVHYS</sub> | -  | 0.5   | 1.0    | 1.5    | %    |
| Leakage current                            | I <sub>LEAKPG</sub>  | V <sub>PG</sub> = 5.0V   | -     | -      | 1      | μA   |
| Output low voltage                         | V <sub>OLPG</sub>    | I <sub>PG</sub> = 3 mA   | -     | 0.15   | 0.30   | V    |
| Propagation time                           | T <sub>PPG</sub>     | 5% outside of the threshold, Power fail  | -     | 4 (*1) | 8 (*1) | μs   |
| Power-on reset time                        | T <sub>RPG</sub>     | Power good   | 8     | 10     | 12     | ms   |
| <b>Reset (RST)</b>                         |                      |  |       |        |        |      |
| Over voltage threshold                     | V <sub>RSOV</sub>    | Ratio of power fail threshold to V <sub>OUTL1</sub> rising   | 104.5 | 106.0  | 107.5  | %    |
| Over voltage hysteresis                    | V <sub>RSOVHYS</sub> | -  | 0.5   | 1.0    | 1.5    | %    |
| Under voltage threshold                    | V <sub>RSUV</sub>    | Ratio of power fail threshold to V <sub>OUTL1</sub> falling  | 92.5  | 94.0   | 95.5   | %    |
| Under voltage hysteresis                   | V <sub>RSUVHYS</sub> | -  | 0.5   | 1.0    | 1.5    | %    |
| Leakage current                            | I <sub>LEAKRST</sub> | V <sub>RST</sub> = 5.0V  | -     | -      | 1      | μA   |
| Output low voltage                         | V <sub>OLRST</sub>   | I <sub>PG</sub> = 3 mA   | -     | 0.15   | 0.30   | V    |
| Propagation time                           | T <sub>PRST</sub>    | 5% outside of the threshold, Power fail  | -     | 4 (*1) | 8 (*1) | μs   |
| Power-on reset time                        | T <sub>RD</sub>      | Power good   | 25.6  | 32.0   | 38.4   | ms   |

| Parameter                          | Symbol        | Condition   | Value    |       |           | Unit       |
|------------------------------------|---------------|---|----------|-------|-----------|------------|
|                                    |               |   | Min      | Typ   | Max       |            |
| <b>Watchdog Timer (WDI)</b>        |               |   |          |       |           |            |
| Watchdog sampling time             | $T_{SAM}$     | -   | 0.40     | 0.50  | 0.60      | ms         |
| Ignore window time                 | $T_{IW}$      | -   | 25.6     | 32.0  | 38.4      | ms         |
| Open window time                   | $T_{OW}$      | -   | 25.6     | 32.0  | 38.4      | ms         |
| Long open window time              | $T_{LOW}$     | -   | 102.4    | 128.0 | 153.6     | ms         |
| Closed window time                 | $T_{CW}$      | -   | 25.6     | 32.0  | 38.4      | ms         |
| Window watchdog trigger time       | $T_{WD}$      | -   | 38.4     | 48    | 51.2      | ms         |
| Input high voltage                 | $V_{IHWDI}$   | -   | 2.0      | -     | $V_{VCC}$ | V          |
| Input low voltage                  | $V_{ILWDI}$   | -   | 0        | -     | 0.4       | V          |
| Input current                      | $I_{IHWDI}$   | $V_{WDI} = 5.0V$  | 33       | 50    | 100       | $\mu A$    |
| Pull down resistance               | $R_{PDWDI}$   | -   | 50       | 100   | 150       | k $\Omega$ |
| <b>DD1: Buck DC/DC Converter</b>   |               |   |          |       |           |            |
| Output voltage accuracy            | $V_{OUT1}$    | $V_{VCC} = 5.0V$ ,<br>$I_{OUT1} = 10 mA$                        | -1.8     | 0     | +1.8      | %          |
| DC regulation                      | $V_{REG1}$    | $V_{VCC} = V_{PVCC1} = 4.5 to 5.5V$ ,<br>$I_{OUT1} = 0 to 2.0A$ | -15 (*1) | 0     | +5 (*1)   | mV         |
| FB1 input resistance               | $R_{FB1}$     | $V_{FB1} = 2.0V$  | 95       | 190   | 285       | k $\Omega$ |
| Switching FET ON resistance        | $R_{ONHS1}$   | $I_{LX1} = 20 mA (PVCC1 to LX1)$                                | -        | 100   | 190       | m $\Omega$ |
|                                    | $R_{ONLS1}$   | $I_{LX1} = -20 mA (LX1 to PGND1)$                               | -        | 65    | 125       | m $\Omega$ |
| Switching FET leakage current      | $I_{LEAK1}$   | $I_{PVCC1} = 5.0V$  | -        | 1     | 10        | $\mu A$    |
| Maximum output current             | $I_{OUT1}$    | $L = 1.5 \mu H$   | 2 (*1)   | -     | -         | A          |
| LX1 peak current limit             | $I_{LIMIT1}$  | $L = 1.5 \mu H$   | 2.5 (*1) | -     | -         | A          |
| Over voltage protection threshold  | $V_{OVP1}$    | $V_{OUT1}$ rising, Switching termination threshold              | 125.0    | 130.0 | 135.0     | %          |
| Over voltage protection hysteresis | $V_{OVPHYS1}$ | -   | 2.0      | 5.0   | 8.0       | %          |
| FB1 discharge resistance           | $R_{DIS1}$    | -   | 160      | 400   | 640       | $\Omega$   |
| Soft-start time coefficient        | $T_{COESS1}$  | $T_{SS1} = V_{OUT1} \times T_{COESS1}$                          | 0.9      | 1.0   | 1.1       | ms/V       |
| <b>DD2: Buck DC/DC Converter</b>   |               |   |          |       |           |            |
| Output voltage accuracy            | $V_{OUT2}$    | $V_{VCC} = 5.0V$ ,<br>$I_{OUT2} = 10 mA$                        | -1.8     | 0     | +1.8      | %          |
| DC regulation                      | $V_{REG2}$    | $V_{VCC} = V_{PVCC2} = 4.5 to 5.5V$ ,<br>$I_{OUT2} = 0 to 3.0A$ | -15 (*1) | 0     | +5 (*1)   | mV         |
| FB2 input resistance               | $R_{FB2}$     | $V_{FB2} = 2.0V$  | 95       | 190   | 285       | k $\Omega$ |
| Switching FET ON resistance        | $R_{ONHS2}$   | $I_{LX2} = 20 mA (PVCC2 to LX2)$                                | -        | 85    | 165       | m $\Omega$ |
|                                    | $R_{ONLS2}$   | $I_{LX2} = -20 mA (LX2 to PGND2)$                               | -        | 55    | 105       | m $\Omega$ |
| Switching FET leakage current      | $I_{LEAK2}$   | $I_{PVCC2} = 5.0V$  | -        | 1     | 10        | $\mu A$    |
| Maximum output current             | $I_{OUT2}$    | $L = 1.5 \mu H$   | 3 (*1)   | -     | -         | A          |
| LX2 peak current limit             | $I_{LIMIT2}$  | $L = 1.5 \mu H$   | 3.5 (*1) | -     | -         | A          |
| Over voltage protection threshold  | $V_{OVP2}$    | $V_{OUT2}$ rising, Switching termination threshold              | 125.0    | 130.0 | 135.0     | %          |
| Over voltage protection hysteresis | $V_{OVPHYS2}$ | -   | 2.0      | 5.0   | 8.0       | %          |
| FB2 discharge resistance           | $R_{DIS2}$    | -   | 160      | 400   | 640       | $\Omega$   |
| Soft-start time coefficient        | $T_{COESS2}$  | $T_{SS2} = V_{OUT2} \times T_{COESS2}$                          | 0.9      | 1.0   | 1.1       | ms/V       |

| Parameter                          | Symbol        | Condition   | Value    |       |         | Unit       |
|------------------------------------|---------------|---|----------|-------|---------|------------|
|                                    |               |   | Min      | Typ   | Max     |            |
| <b>DD3: Buck DC/DC Converter</b>   |               |   |          |       |         |            |
| Output voltage accuracy            | $V_{OUT3}$    | $V_{VCC} = 5.0V$ ,<br>$I_{OUT3} = 10\text{ mA}$                               | -1.8     | 0     | +1.8    | %          |
| DC regulation                      | $V_{REG3}$    | $V_{VCC} = V_{PVCC3} = 4.5\text{ to }5.5V$ ,<br>$I_{OUT3} = 0\text{ to }2.0A$ | -15 (*1) | 0     | +5 (*1) | mV         |
| FB3 input resistance               | $R_{FB3}$     | $V_{FB3} = 2.0V$  | 95       | 190   | 285     | k $\Omega$ |
| Switching FET ON resistance        | $R_{ONHS3}$   | $I_{LX3} = 20\text{ mA}$ (PVCC3 to LX3)                                       | -        | 100   | 190     | m $\Omega$ |
|                                    | $R_{ONLS3}$   | $I_{LX3} = -20\text{ mA}$ (LX3 to PGND3)                                      | -        | 65    | 125     | m $\Omega$ |
| Switching FET leakage current      | $I_{LEAK3}$   | $I_{PVCC3} = 5.0V$  | -        | 1     | 10      | $\mu A$    |
| Maximum output current             | $I_{OUT3}$    | $L = 1.5\ \mu H$  | 2 (*1)   | -     | -       | A          |
| LX3 peak current limit             | $I_{LIMIT3}$  | $L = 1.5\ \mu H$  | 2.5 (*1) | -     | -       | A          |
| Over voltage protection threshold  | $V_{OVP3}$    | $V_{OUT3}$ rising, Switching termination threshold                            | 125.0    | 130.0 | 135.0   | %          |
| Over voltage protection hysteresis | $V_{OVPHYS3}$ | -   | 2.0      | 5.0   | 8.0     | %          |
| FB3 discharge resistance           | $R_{DIS3}$    | -   | 160      | 400   | 640     | $\Omega$   |
| Soft-start time coefficient        | $T_{COESS3}$  | $T_{SS3} = V_{OUT3} \times T_{COESS3}$  | 0.9      | 1.0   | 1.1     | ms/V       |
| <b>DD4: Buck DC/DC Converter</b>   |               |   |          |       |         |            |
| Output voltage accuracy            | $V_{OUT4}$    | $V_{VCC} = 5.0V$ ,<br>$I_{OUT4} = 10\text{ mA}$                               | -1.8     | 0     | +1.8    | %          |
| DC regulation                      | $V_{REG4}$    | $V_{VCC} = V_{PVCC4} = 4.5\text{ to }5.5V$ ,<br>$I_{OUT4} = 0\text{ to }1.0A$ | -15 (*1) | 0     | +5 (*1) | mV         |
| FB4 input resistance               | $R_{FB4}$     | $V_{FB4} = 2.0V$  | 95       | 190   | 285     | k $\Omega$ |
| Switching FET ON resistance        | $R_{ONHS4}$   | $I_{LX4} = 20\text{ mA}$ (PVCC4 to LX4)                                       | -        | 100   | 190     | m $\Omega$ |
|                                    | $R_{ONLS4}$   | $I_{LX4} = -20\text{ mA}$ (LX4 to PGND4)                                      | -        | 65    | 125     | m $\Omega$ |
| Switching FET leakage current      | $I_{LEAK4}$   | $I_{PVCC4} = 5.0V$  | -        | 1     | 10      | $\mu A$    |
| Maximum output current             | $I_{OUT4}$    | $L = 1.5\ \mu H$  | 1 (*1)   | -     | -       | A          |
| LX4 peak current limit             | $I_{LIMIT4}$  | $L = 1.5\ \mu H$  | 1.5 (*1) | -     | -       | A          |
| Over voltage protection threshold  | $V_{OVP4}$    | $V_{OUT4}$ rising, Switching termination threshold                            | 125.0    | 130.0 | 135.0   | %          |
| Over voltage protection hysteresis | $V_{OVPHYS4}$ | -   | 2.0      | 5.0   | 8.0     | %          |
| FB4 discharge resistance           | $R_{DIS4}$    | -   | 160      | 400   | 640     | $\Omega$   |
| Soft-start time coefficient        | $T_{COESS4}$  | $T_{SS4} = V_{OUT4} \times T_{COESS4}$  | 0.9      | 1.0   | 1.1     | ms/V       |

| Parameter                   | Symbol        | Condition  | Value    |     |         | Unit     |
|-----------------------------|---------------|--|----------|-----|---------|----------|
|                             |               |  | Min      | Typ | Max     |          |
| <b>LD1: LDO Regulator</b>   |               |  |          |     |         |          |
| Output voltage accuracy     | $V_{OUTL1}$   | $V_{VCC} = 5.0V$ ,<br>$I_{OUTL1} = 10\text{ mA}$   | -1.8     | 0   | +1.8    | %        |
| DC regulation               | $V_{REGL1}$   | $V_{VCC} = 4.5\text{ to }5.5V$ , $V_{PVCC1} = 2.97\text{ to }V_{VCC}$<br>$I_{OUTL1} = 0\text{ to }I_{OUTL1}$ | -15 (*1) | 0   | +5 (*1) | mV       |
| Output FET leakage current  | $I_{LEAKL1}$  | $I_{PVCC1}=5.0V$   | -        | 1   | 10      | $\mu A$  |
| Maximum output current      | $I_{OUTL1}$   | $V_{PVCC1} - V_{OUTL1} \geq 1.6V$  | 200 (*1) | -   | -       | mA       |
|                             |               | $0.17V \leq V_{PVCC1} - V_{OUTL1} < 1.6V$  | 100 (*1) | -   | -       | mA       |
| Output current limit        | $I_{LIMIT1}$  | $V_{PVCC1} - V_{OUTL1} \geq 1.6V$  | 210 (*1) | -   | -       | mA       |
|                             |               | $0.17V \leq V_{PVCC1} - V_{OUTL1} < 1.6V$  | 105 (*1) | -   | -       | mA       |
| LDO1 discharge resistance   | $R_{DISL1}$   | -  | 160      | 400 | 640     | $\Omega$ |
| Soft-start time coefficient | $T_{COESSL1}$ | $T_{SSL1} = V_{OUTL1} \times T_{COESSL1}$  | 0.9      | 1.0 | 1.1     | ms/V     |
| <b>LD2: LDO Regulator</b>   |               |  |          |     |         |          |
| Output voltage accuracy     | $V_{OUTL2}$   | $V_{VCC} = 5.0V$ ,<br>$I_{OUTL2} = 10\text{ mA}$   | -1.8     | 0   | +1.8    | %        |
| DC regulation               | $V_{REGL2}$   | $V_{VCC} = 4.5\text{ to }5.5V$ , $V_{PVCC2} = 2.97\text{ to }V_{VCC}$<br>$I_{OUTL2} = 0\text{ to }I_{OUTL2}$ | -15 (*1) | 0   | +5 (*1) | mV       |
| Output FET leakage current  | $I_{LEAKL2}$  | $I_{PVCC2}=5.0V$   | -        | 1   | 10      | $\mu A$  |
| Maximum output current      | $I_{OUTL2}$   | $V_{PVCC2} - V_{OUTL2} \geq 1.6V$  | 500 (*1) | -   | -       | mA       |
|                             |               | $0.17V \leq V_{PVCC2} - V_{OUTL2} < 1.6V$  | 400 (*1) | -   | -       | mA       |
| Output current limit        | $I_{LIMIT2}$  | $V_{PVCC2} - V_{OUTL2} \geq 1.6V$  | 525 (*1) | -   | -       | mA       |
|                             |               | $0.17V \leq V_{PVCC2} - V_{OUTL2} < 1.6V$  | 420 (*1) | -   | -       | mA       |
| LDO2 discharge resistance   | $R_{DISL2}$   | -  | 160      | 400 | 640     | $\Omega$ |
| Soft-start time coefficient | $T_{COESSL2}$ | $T_{SSL2} = V_{OUTL2} \times T_{COESSL2}$  | 0.9      | 1.0 | 1.1     | ms/V     |

\*1: The electrical characteristic is ensured by statistical characterization and indirect tests.



## 9. Operating Mode List

Table 9-1 shows the operation list of S6BP401A.

**Table 9-1 Operation Mode List**

| Condition          |        |      |                                      |                 | Operating Block |                                  |                |     |                                     |
|--------------------|--------|------|--------------------------------------|-----------------|-----------------|----------------------------------|----------------|-----|-------------------------------------|
| T <sub>J</sub>     | SYNC   | ENL1 | EN1/<br>EN2/<br>EN3/<br>EN4/<br>ENL2 | Chip<br>Control | VREG LDO        | Watch-<br>dog Trigger<br>Monitor | Freq.<br>Sync. | LD1 | DD1/<br>DD2/<br>DD3/<br>DD4/<br>LD2 |
| < T <sub>TSD</sub> | L or H | L    | L                                    | OFF             | OFF             | OFF                              | OFF            | OFF | OFF                                 |
| < T <sub>TSD</sub> | L or H | L    | H                                    | ON              | ON              | OFF                              | OFF            | OFF | ON                                  |
| < T <sub>TSD</sub> | L or H | H    | L                                    | ON              | ON              | ON                               | OFF            | ON  | OFF                                 |
| < T <sub>TSD</sub> | L or H | H    | H                                    | ON              | ON              | ON                               | OFF            | ON  | ON                                  |
| < T <sub>TSD</sub> | clock  | L    | L                                    | OFF             | OFF             | OFF                              | OFF            | OFF | OFF                                 |
| < T <sub>TSD</sub> | clock  | L    | H                                    | ON              | ON              | OFF                              | ON             | OFF | ON                                  |
| < T <sub>TSD</sub> | clock  | H    | L                                    | ON              | ON              | ON                               | ON             | ON  | OFF                                 |
| < T <sub>TSD</sub> | clock  | H    | H                                    | ON              | ON              | ON                               | ON             | ON  | ON                                  |
| ≥ T <sub>TSD</sub> | L or H | L    | L                                    | OFF             | OFF             | OFF                              | OFF            | OFF | OFF                                 |
| ≥ T <sub>TSD</sub> | L or H | L    | H                                    | ON              | ON              | OFF                              | OFF            | OFF | OFF                                 |
| ≥ T <sub>TSD</sub> | L or H | H    | L                                    | ON              | ON              | OFF                              | OFF            | OFF | OFF                                 |
| ≥ T <sub>TSD</sub> | L or H | H    | H                                    | ON              | ON              | OFF                              | OFF            | OFF | OFF                                 |
| ≥ T <sub>TSD</sub> | clock  | L    | L                                    | OFF             | OFF             | OFF                              | OFF            | OFF | OFF                                 |
| ≥ T <sub>TSD</sub> | clock  | L    | H                                    | ON              | ON              | OFF                              | OFF            | OFF | OFF                                 |
| ≥ T <sub>TSD</sub> | clock  | H    | L                                    | ON              | ON              | OFF                              | OFF            | OFF | OFF                                 |
| ≥ T <sub>TSD</sub> | clock  | H    | H                                    | ON              | ON              | OFF                              | OFF            | OFF | OFF                                 |

## 10. Function

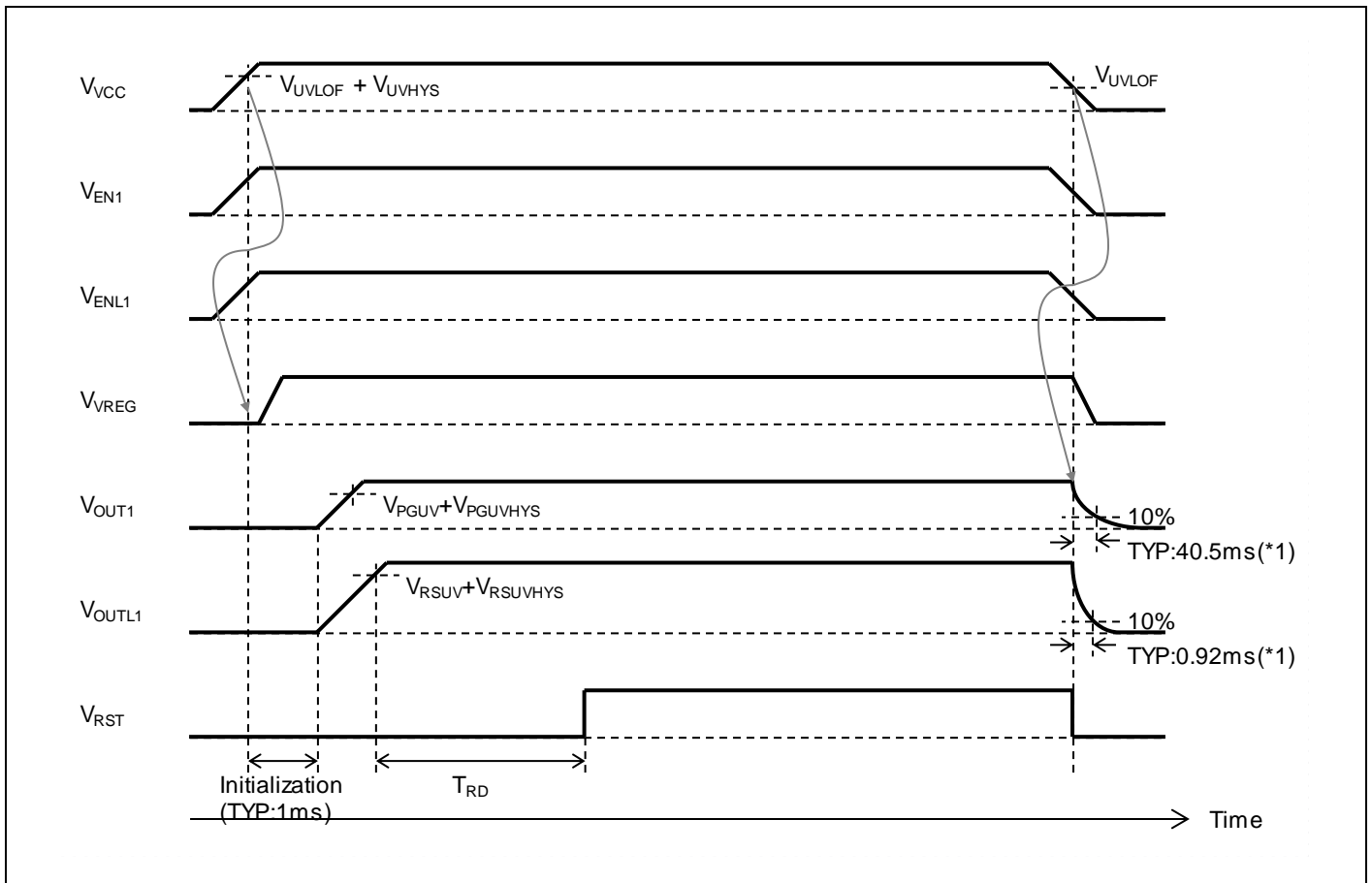
### 10.1 Turning ON and OFF Sequence

When all of the enable input terminals (EN1, EN2, EN3, EN4, ENL1 and ENL2) are “Low”, the device is in shutdown state. When any one or more than one of them go “High,” the device is initialized, then the internal linear regulator (VREG) starts generating 1.8V internal supply voltage. After that, each DC/DC converters and LDOs state is transitioned to the state which can be started.

In order for the device to start, the VCC terminal voltage must be higher than the under-voltage lockout threshold ( $V_{UVLOF} + V_{UVHYS}$ ).

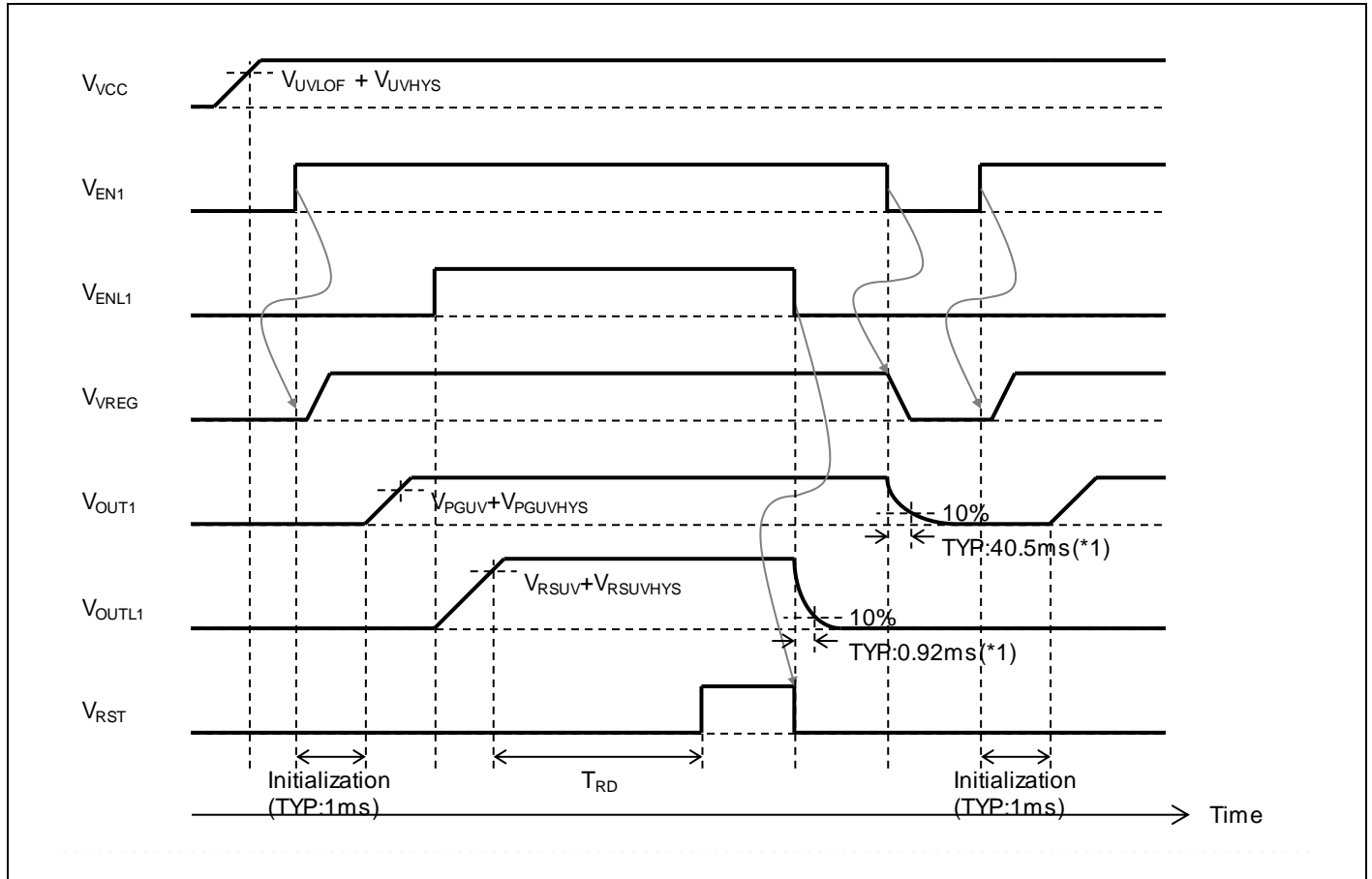
Figure 10-1 depicts the turning-on and off sequence where the enable signals are connected to VCC. Figure 10-2 depicts that where the enable signals are respectively controlled after the IC is powered.

**Figure 10-1 Turning ON and OFF Sequence (where EN1 and ENL1 are Connected to VCC)**



\*1: Given that the system employs the same external parts with those specified in “11. Application Circuit Example”.

Figure 10-2 Turning ON and OFF Sequence (where EN1 and ENL1 are Respectively Controlled)



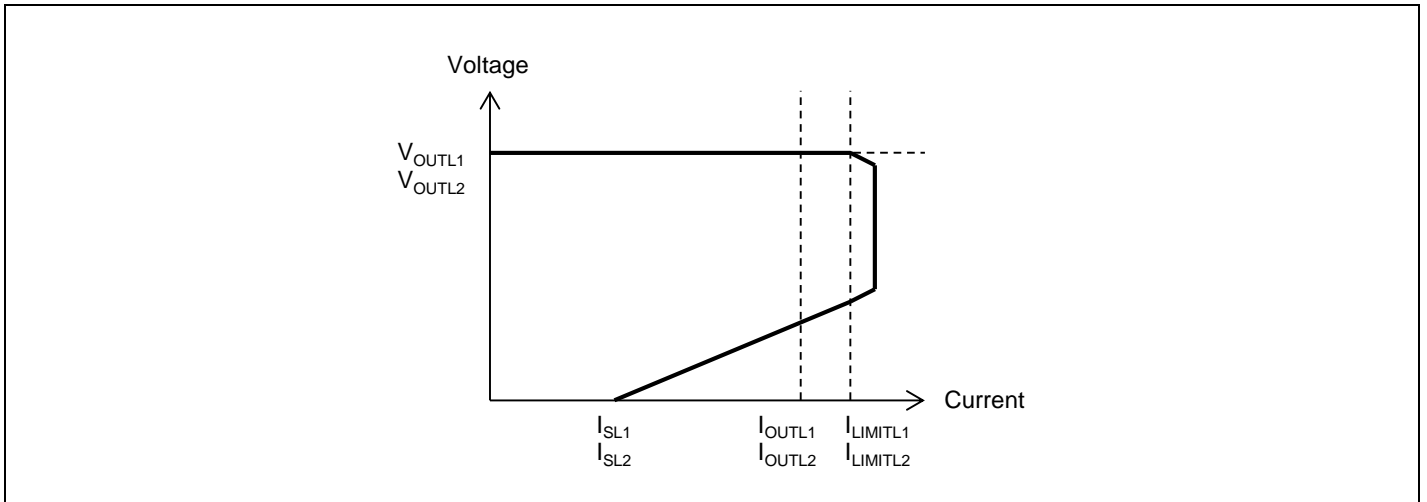
\*1: Given that the system employs the same external parts with those specified in "11. Application Circuit Example".

### 10.2 Over Current Protection

The over current protection of the DC/DC converters detects the inductor peak current with on-resistance of Internal high side switching FET. If the DC/DC converter is over current state, the corresponding output voltage is decreased. If the device returns from over current state, the output voltage is target voltage.

Each LDOs equips foldback current limiter in order to prevent the IC itself from being damaged or destroyed. The curve of output current and output voltage in over current state is shown in the Figure 10-3.

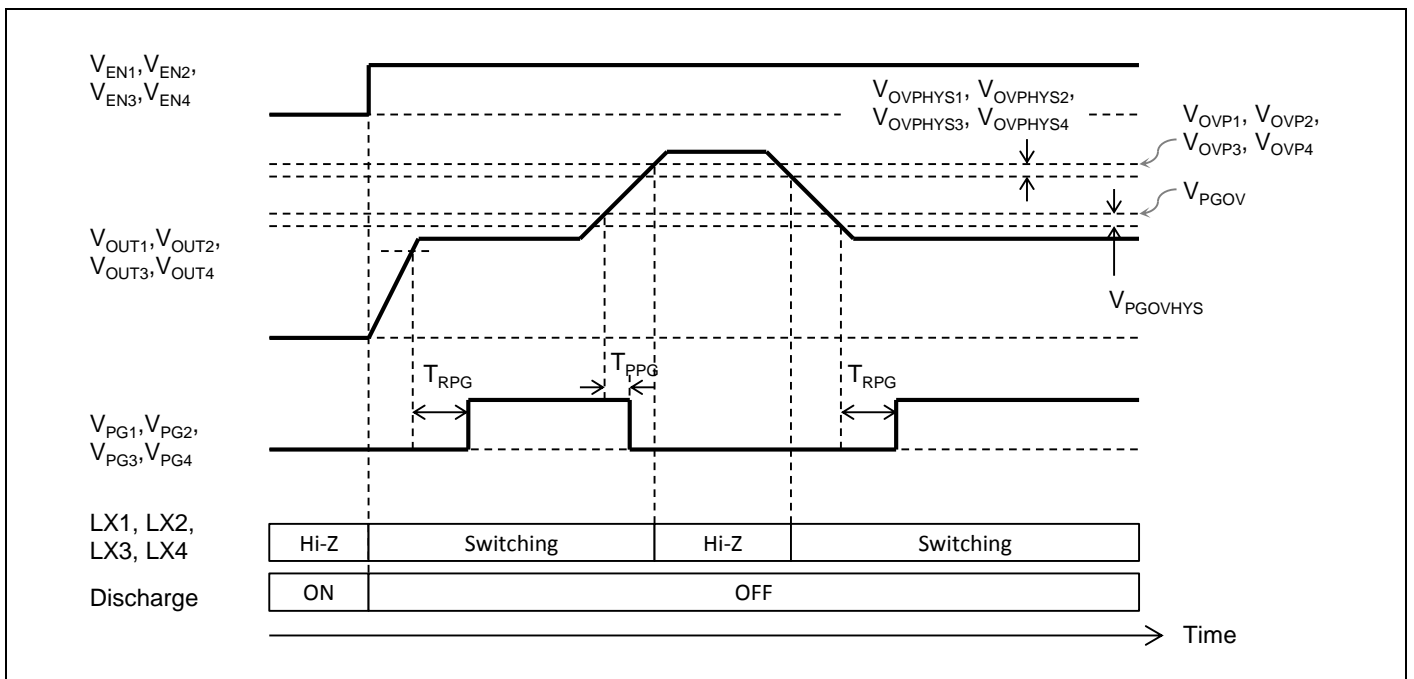
**Figure 10-3 LDO Foldback Over Current Protection Characteristic**



### 10.3 Over Voltage Protection

The over voltage protection of the DC/DC converters detects the output voltage. If the DC/DC converter is over voltage state, the corresponding channel stops switching and inductor connecting terminal (LX1, LX2, LX3, LX4) is held at high impedance. If the device returns from over voltage state, the channel returns switching automatically.

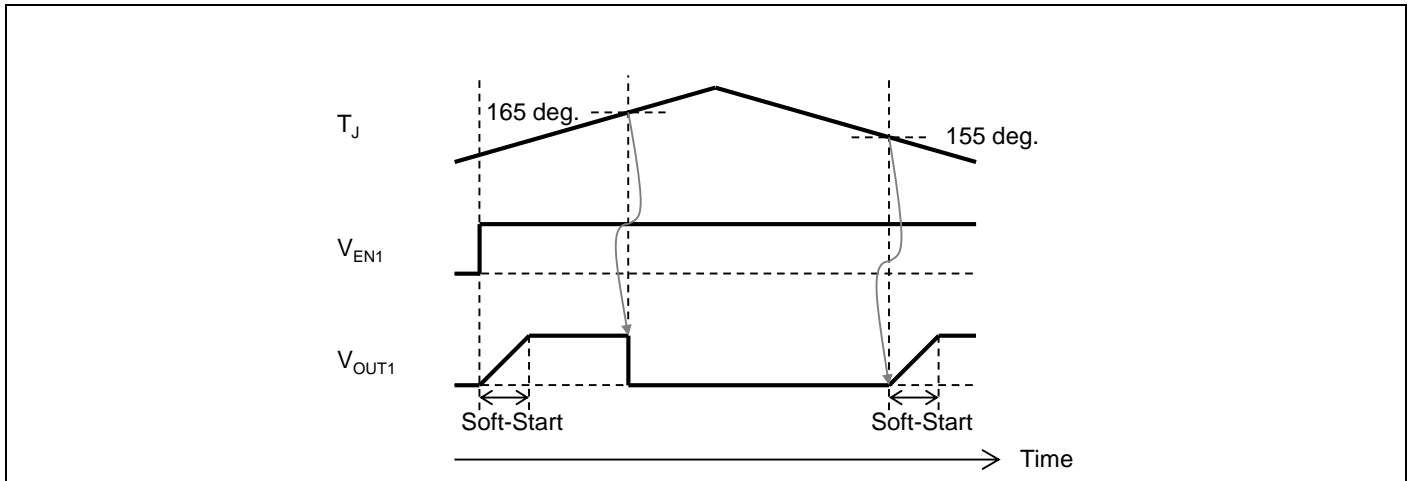
**Figure 10-4 Over Voltage Protection Timing Chart**



**10.4 Thermal Shutdown (TSD)**

If the junction temperature reaches +165°C, all DC/DC converters and LDOs stop outputting voltage. Then the discharge operation is carried out to discharge the output capacitor (The discharge operation continues until the state of the thermal shutdown released.) When the junction temperature drops below +155°C, the soft-starters activate regulators and start generating voltage gradually if the enable is "High."

**Figure 10-5 Thermal Shutdown Timing Chart**



**10.5 Under Voltage Lockout (UVLO)**

If the VCC terminal voltage ( $V_{VCC}$ ) drops below the lower UVLO threshold ( $V_{UVLOF}$ ), all DC/DC converters (DD1, DD2, DD3, DD4), LDOs (LD1, LD2), windowed watchdog timer (WDT) and the internal linear regulator (VREG) stop working. When the VCC terminal voltage ( $V_{VCC}$ ) is raised higher than the higher UVLO threshold ( $V_{UVLOF} + V_{UVHYS}$ ), the device returns automatically.

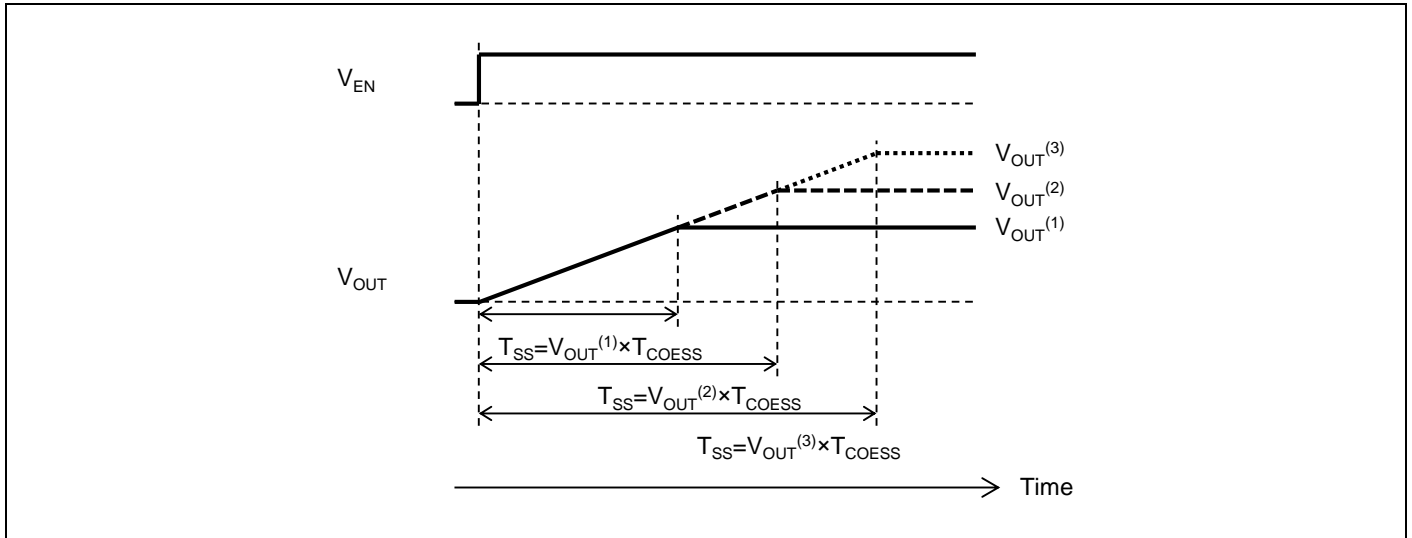
**10.6 Soft-Start Operation**

S6BP401A equips load-independent soft-start function in order to prevent the DC/DC converters and LDOs from having rush current at the start-up. The soft-start timing is shown in the Figure 10-6, and is given by the following equation;

$$T_{SS} = V_{OUT} \times T_{COESS}, \text{ where}$$

- $T_{SS}$  [ms] : Soft-start time
- $V_{OUT}$  [V] : Output voltage ( $V_{OUT1}$ ,  $V_{OUT2}$ ,  $V_{OUT3}$ ,  $V_{OUT4}$ ,  $V_{OUTL1}$ ,  $V_{OUTL2}$ )
- $T_{COESS}$  [ms/V] : Soft-start time coefficient ( $T_{COESS1}$ ,  $T_{COESS2}$ ,  $T_{COESS3}$ ,  $T_{COESS4}$ ,  $T_{COESSL1}$ ,  $T_{COESSL2}$ )

Figure 10-6 Soft-Start Operation Timing Chart



**10.7 Discharge Operation**

When an enable signal goes “Low”, the corresponding output capacitor is discharged by the internal discharge resistor and the output voltage is decreased gradually. Note that the discharge time is not consistent: it depends on the output load current.

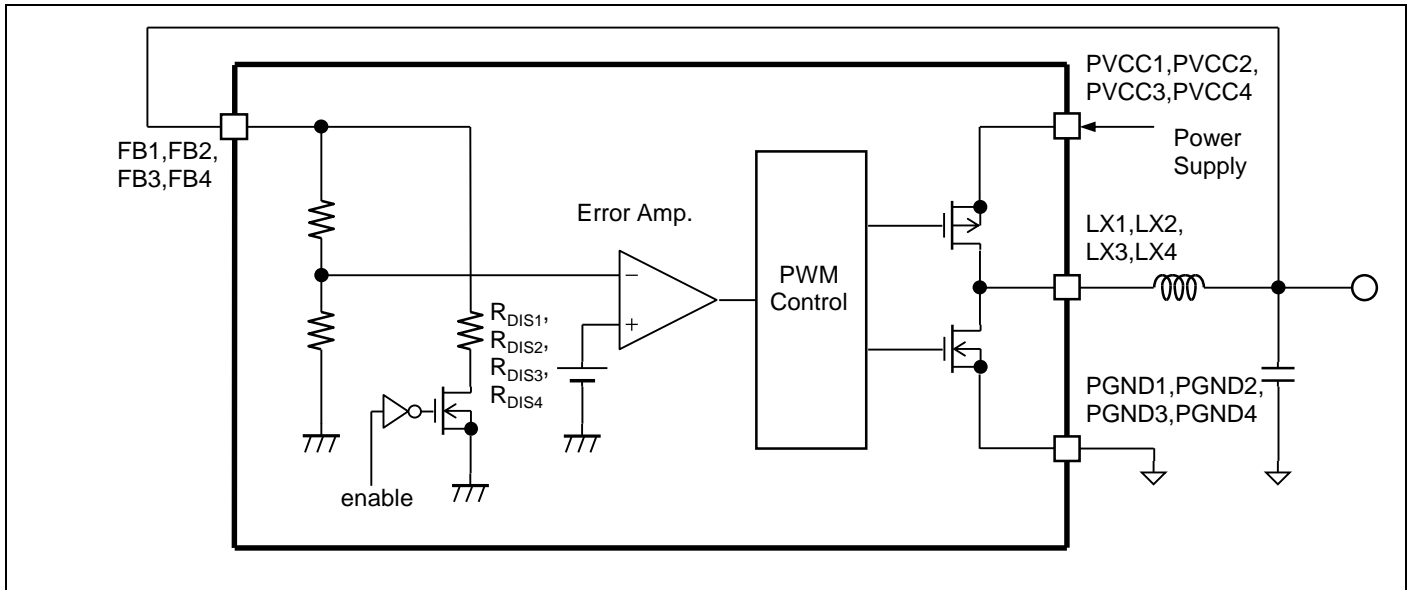
As for a DC/DC converter, the output capacitor is discharged from FB1, FB2, FB3 and FB4 terminal to PGND1, PGND2, PGND3 and PGND4 terminal respectively. As for a LDO, the output capacitor is dis-charged from LDO1, LDO2 terminal to GND terminal.

The discharge time required to decrease the output voltage by 90% without any explicit load given by the following equation;

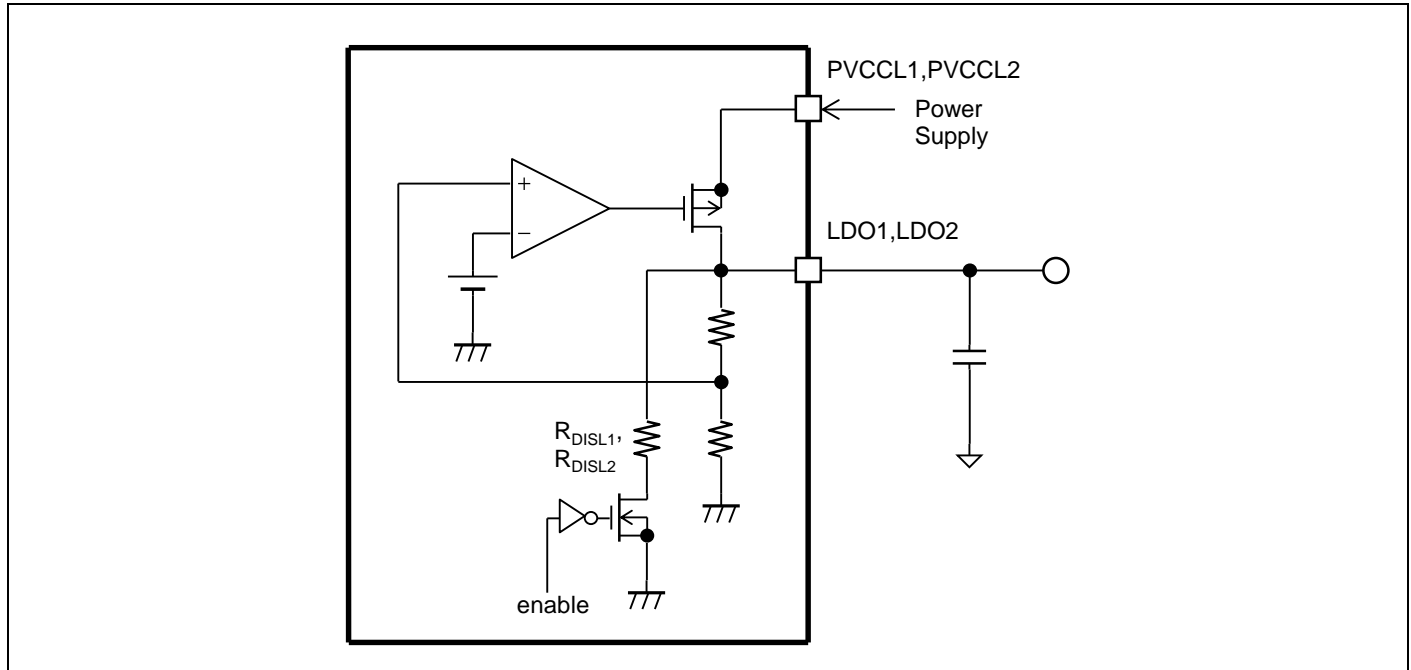
$$T_{DIS} = 2.3 \times R_{DIS} \times C_{OUT}, \text{ where}$$

- T<sub>DIS</sub> [ms] : Discharge time
- R<sub>DIS</sub> [kΩ] : Discharge resistance (R<sub>DIS1</sub>, R<sub>DIS2</sub>, R<sub>DIS3</sub>, R<sub>DIS4</sub>, R<sub>DISL1</sub>, R<sub>DISL2</sub>)
- C<sub>OUT</sub> [μF] : Output capacitor

Figure 10-7 Discharge Diagram (DC/DC Converter)



**Figure 10-8 Discharge Diagram (LDO)**



**10.8 Power Good Monitor and Reset Function**

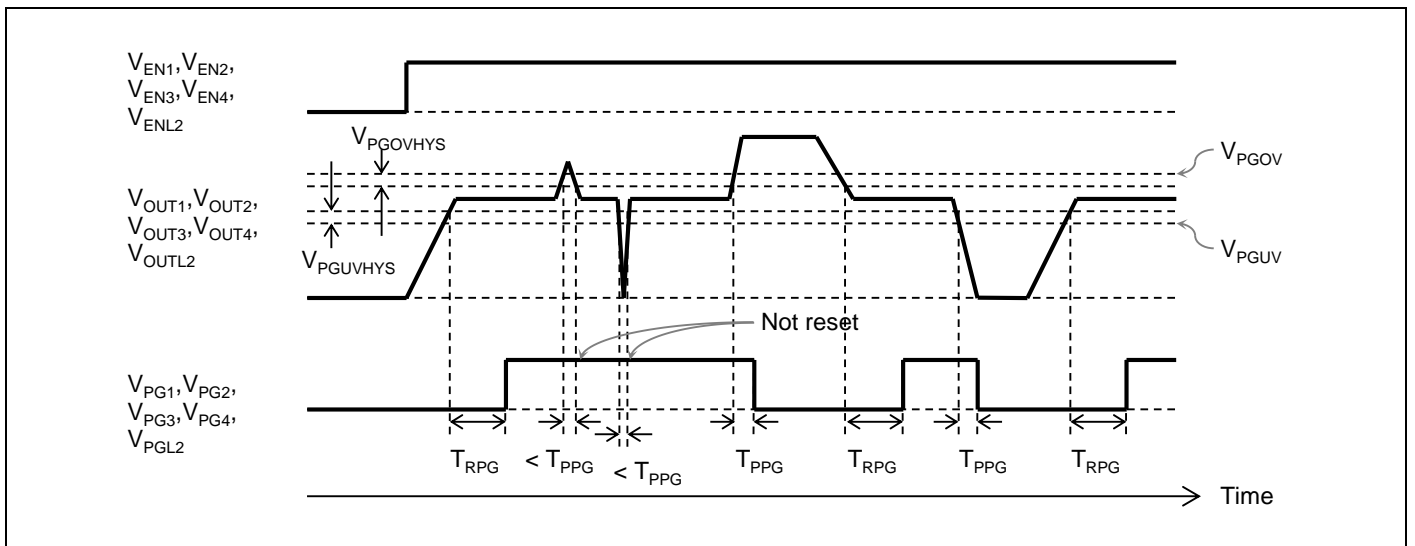
Each DC/DC converters and LDOs has power good function to indicate whether the output voltage is in the expected range. The Table 10-1 describes the power good pin names and their functions of each DC/DC converters and LDOs. The Figure 10-9 and Figure 10-10 depict power-good timing chart.

**Table 10-1 Power Good Monitor and Reset Function Pin List**

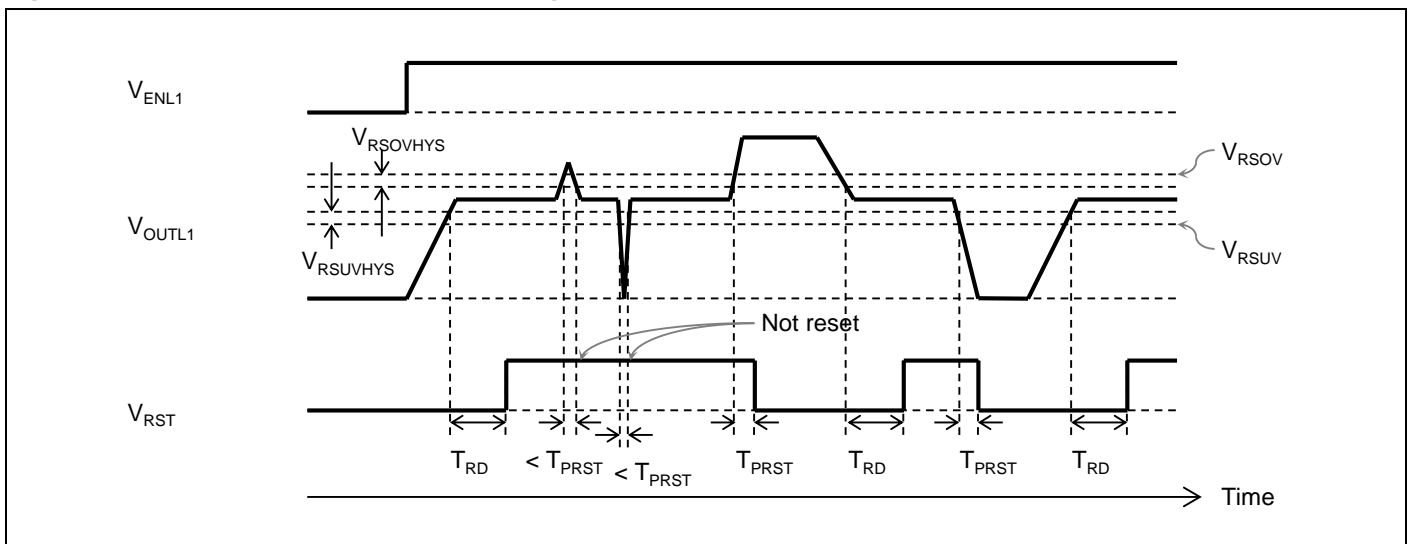
| Channel | Pin Name | Description  |
|---------|----------|--|
| DD1     | PG1      | Enabling DD1 is followed by rising of the DD1 output voltage ( $V_{OUT1}$ ). Once $V_{OUT1}$ reaches within the power good range ( $V_{PGUV} + V_{PGUVHYS} < V_{OUT1} < V_{PGOV} - V_{PGOVHYS}$ ), the power good monitor output (PG1 terminal) changes its state from “Low” to “Open” after a power-on-reset time ( $T_{RPG}$ ). When $V_{OUT1}$ is out of the power good range ( $V_{OUT1} \leq V_{PGUV}$ or $V_{OUT1} \geq V_{PGOV}$ ), PG1 terminal changes its state from “Open” to “Low” after the propagation delay ( $T_{PPG}$ ). The glitch within $T_{PPG}$ does not affect the power good monitor output. |
| DD2     | PG2      | Enabling DD2 is followed by rising of the DD2 output voltage ( $V_{OUT2}$ ). Once $V_{OUT2}$ reaches within the power good range ( $V_{PGUV} + V_{PGUVHYS} < V_{OUT2} < V_{PGOV} - V_{PGOVHYS}$ ), the power good monitor output (PG2 terminal) changes its state from “Low” to “Open” after a power-on-reset time ( $T_{RPG}$ ). When $V_{OUT2}$ is out of the power good range ( $V_{OUT2} \leq V_{PGUV}$ or $V_{OUT2} \geq V_{PGOV}$ ), PG2 terminal changes its state from “Open” to “Low” after the propagation delay ( $T_{PPG}$ ). The glitch within $T_{PPG}$ does not affect the power good monitor output. |
| DD3     | PG3      | Enabling DD3 is followed by rising of the DD3 output voltage ( $V_{OUT3}$ ). Once $V_{OUT3}$ reaches within the power good range ( $V_{PGUV} + V_{PGUVHYS} < V_{OUT3} < V_{PGOV} - V_{PGOVHYS}$ ), the power good monitor output (PG3 terminal) changes its state from “Low” to “Open” after a power-on-reset time ( $T_{RPG}$ ). When $V_{OUT3}$ is out of the power good range ( $V_{OUT3} \leq V_{PGUV}$ or $V_{OUT3} \geq V_{PGOV}$ ), PG3 terminal changes its state from “Open” to “Low” after the propagation delay ( $T_{PPG}$ ). The glitch within $T_{PPG}$ does not affect the power good monitor output. |
| DD4     | PG4      | Enabling DD4 is followed by rising of the DD4 output voltage ( $V_{OUT4}$ ). Once $V_{OUT4}$ reaches within the power good range ( $V_{PGUV} + V_{PGUVHYS} < V_{OUT4} < V_{PGOV} - V_{PGOVHYS}$ ), the power good monitor output (PG4 terminal) changes its state from “Low” to “Open” after a power-on-reset time ( $T_{RPG}$ ). When $V_{OUT4}$ is out of the power good range ( $V_{OUT4} \leq V_{PGUV}$ or $V_{OUT4} \geq V_{PGOV}$ ), PG4 terminal changes its state from “Open” to “Low” after the propagation delay ( $T_{PPG}$ ). The glitch within $T_{PPG}$ does not affect the power good monitor output. |

| Channel | Pin Name | Description   |
|---------|----------|---|
| LD1     | RST      | Enabling LD1 is followed by rising of the LD1 output voltage ( $V_{OUTL1}$ ). Once $V_{OUTL1}$ reaches within the power good range ( $V_{RSUV} + V_{RSUVHYS} < V_{OUTL1} < V_{RSOV} - V_{RSOVHYS}$ ), the RST terminal changes its state from “Low” to “Open” after a power-on-reset time ( $T_{RD}$ ). When $V_{OUTL1}$ is out of the power good range ( $V_{OUTL1} \leq V_{RSUV}$ or $V_{OUTL1} \geq V_{RSOV}$ ), RST terminal changes “Open” to “Low” after the propagation delay ( $T_{PRST}$ ). The glitch within $T_{PRST}$ does not affect the power good monitor output.                                  |
| LD2     | PGL2     | Enabling LD2 is followed by rising of the LD2 output voltage ( $V_{OUTL2}$ ). Once $V_{OUTL2}$ reaches within the power good range ( $V_{PGUV} + V_{PGUVHYS} < V_{OUTL2} < V_{PGOV} - V_{PGOVHYS}$ ), the power good monitor output (PGL2 terminal) changes its state from “Low” to “Open” through the power-on-reset time ( $T_{RPG}$ ). When $V_{OUTL2}$ is out of the power good range ( $V_{OUTL2} \leq V_{PGUV}$ or $V_{OUTL2} \geq V_{PGOV}$ ), PGL2 terminal changes “Open” to “Low” after the propagation delay ( $T_{PPG}$ ). The glitch within $T_{PPG}$ does not affect the power good monitor output. |

**Figure 10-9 Power-Good Monitor Output Timing Chart (PG1, PG2, PG3, PG4, PGL2)**



**Figure 10-10 Power-Good Monitor Output Timing Chart (RST)**





### 10.9 Watchdog Timer

S6BP401A employs a digital windowed watchdog timer. The digital windowed watchdog timer starts monitoring trigger signal, when the LD1 output voltage ( $V_{OUTL1}$ ) reaches the power good level after enabling LD1.

Figure 10-11 shows the state diagram of the digital watchdog timer. There are six states in the diagram. In the normal operation, the state is expected to move back and forth between “CW” and “OW”,

At first, as described in the section 10.8, enabling LD1 brings “RESET” state, and the “RESET” state is kept for the “Reset Time ( $T_{RD}$ )” outputting “Low” from RST terminal.

In the second, after  $T_{RD}$  in the “RESET” state, the state will transition to “Ignore Window (IW)”, and let RST terminal be “Open”. The “IW” state will be elapsed in the “Ignore Window Time ( $T_{IW}$ )”.

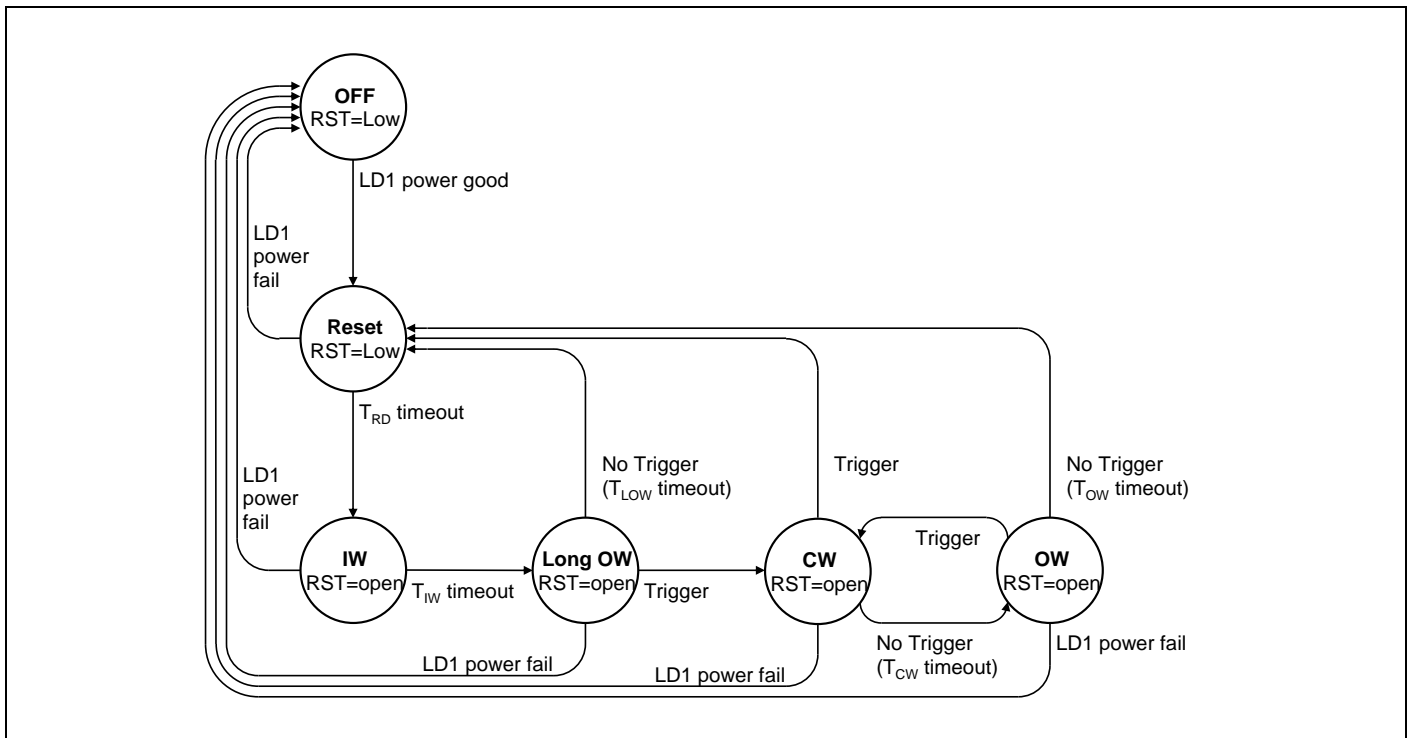
In the third, after elapsing, the state will transition will transition to “Long Open Window (LOW)” state, and let RST terminal be “Open.” In this state, a trigger signal is expected to be input: if an input trigger arrives, the state will immediately transition to the “Closed Window (CW)” state. Without an input trigger in the “Long Open Window Time ( $T_{LOW}$ )” the state will be elapsed and will transition to “RESET” state.

In the “CW” state, a trigger signal is expected NOT to be input: if an input trigger arrives, the state will immediately transition to the “RESET” state. Without an input trigger in the “Closed Window Time ( $T_{CW}$ )” the state will be elapsed and will transition to “Open Window (OW)” state.

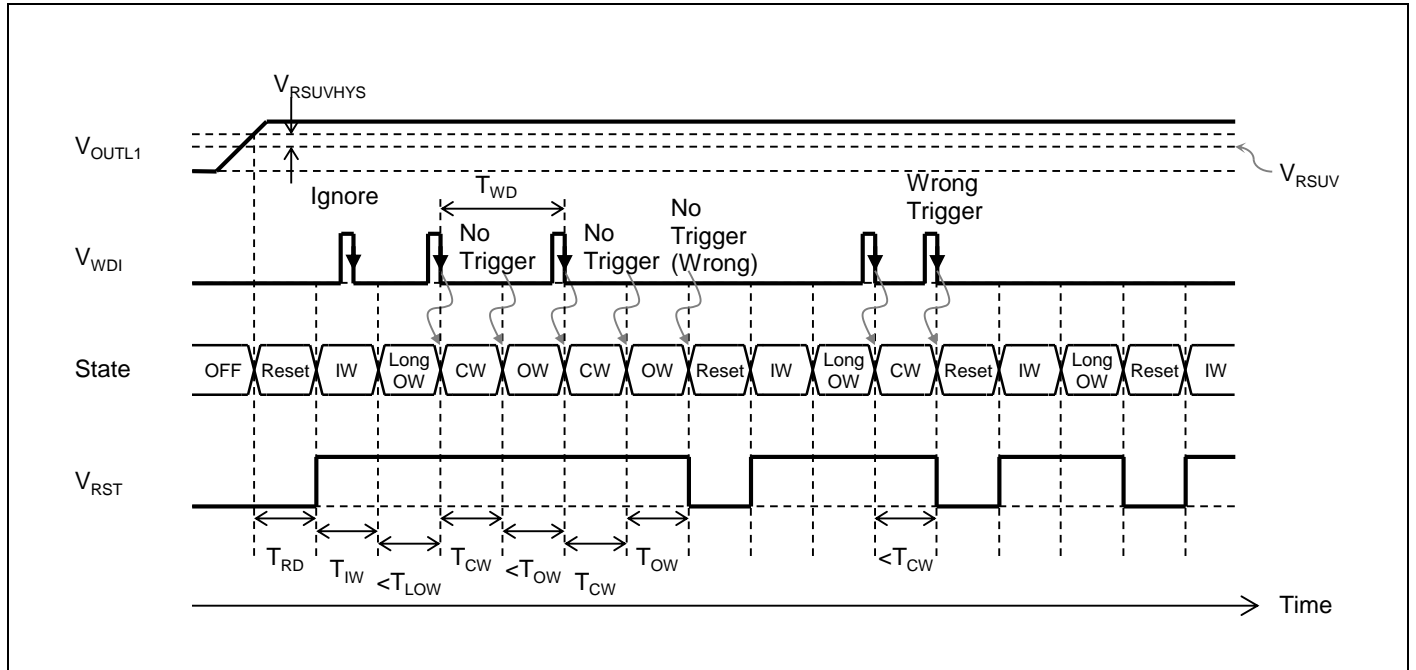
In the “OW” state, a trigger signal is expected NOT to be input: if an input trigger arrives, the state will immediately transition to the “RESET” state. Without an input trigger in the “Open Window Time ( $T_{OW}$ )” the state will be elapsed and will transition to “Closed Window (CW)” state.

In any states above, a power failure of LD1 will cause a transition to “OFF” state, and output “Low” from RST terminal until LD1 goes well.

Figure 10-11 Watchdog Timer State Diagram



**Figure 10-12 Window Watchdog Timing Chart (WDI)**



**Figure 10-13 Window Watchdog Timing Chart (LD1)**

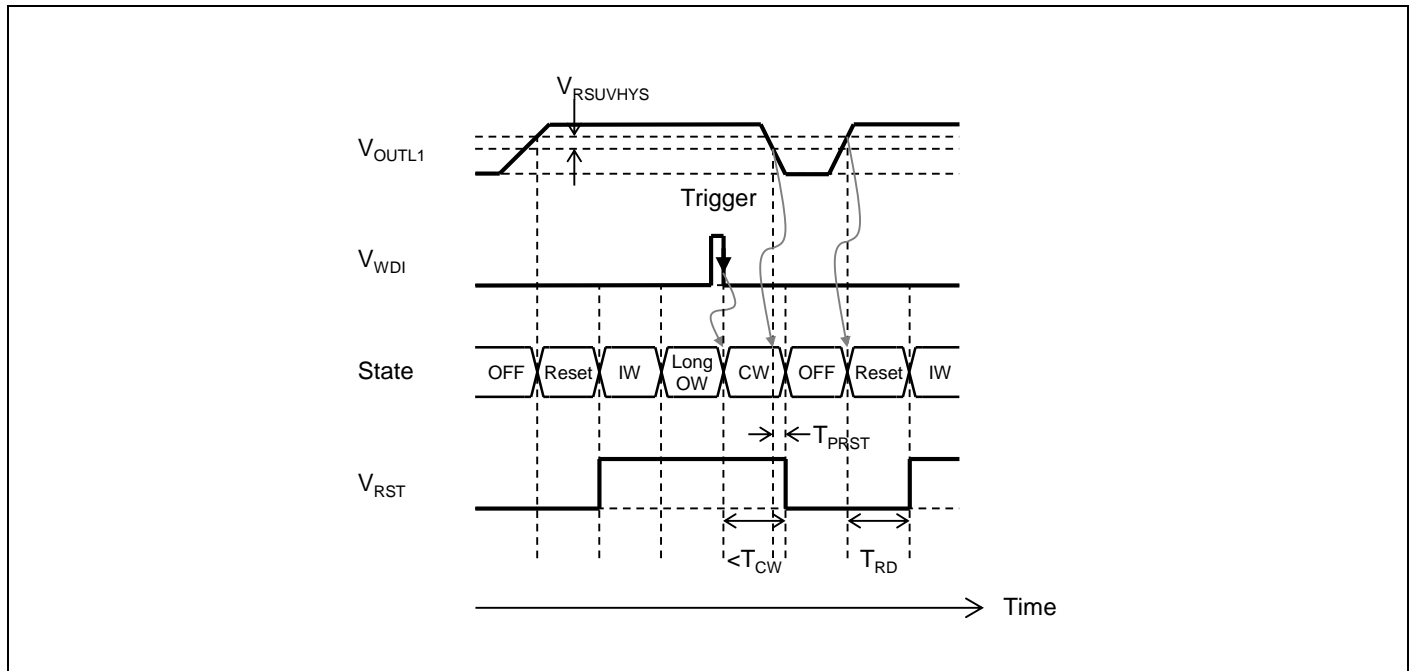
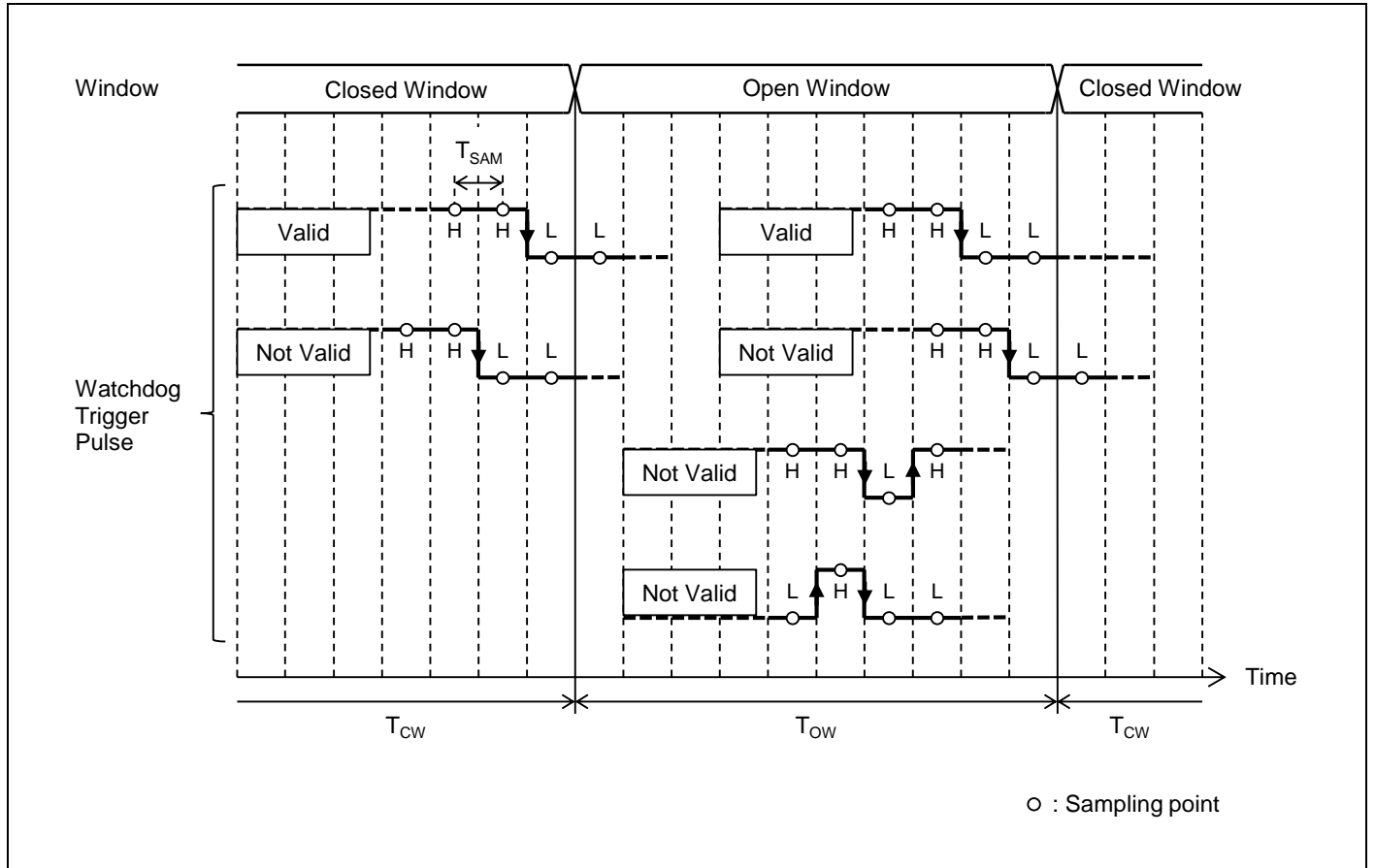


Figure 10-14 De-glint of Window Watchdog Trigger Pulse

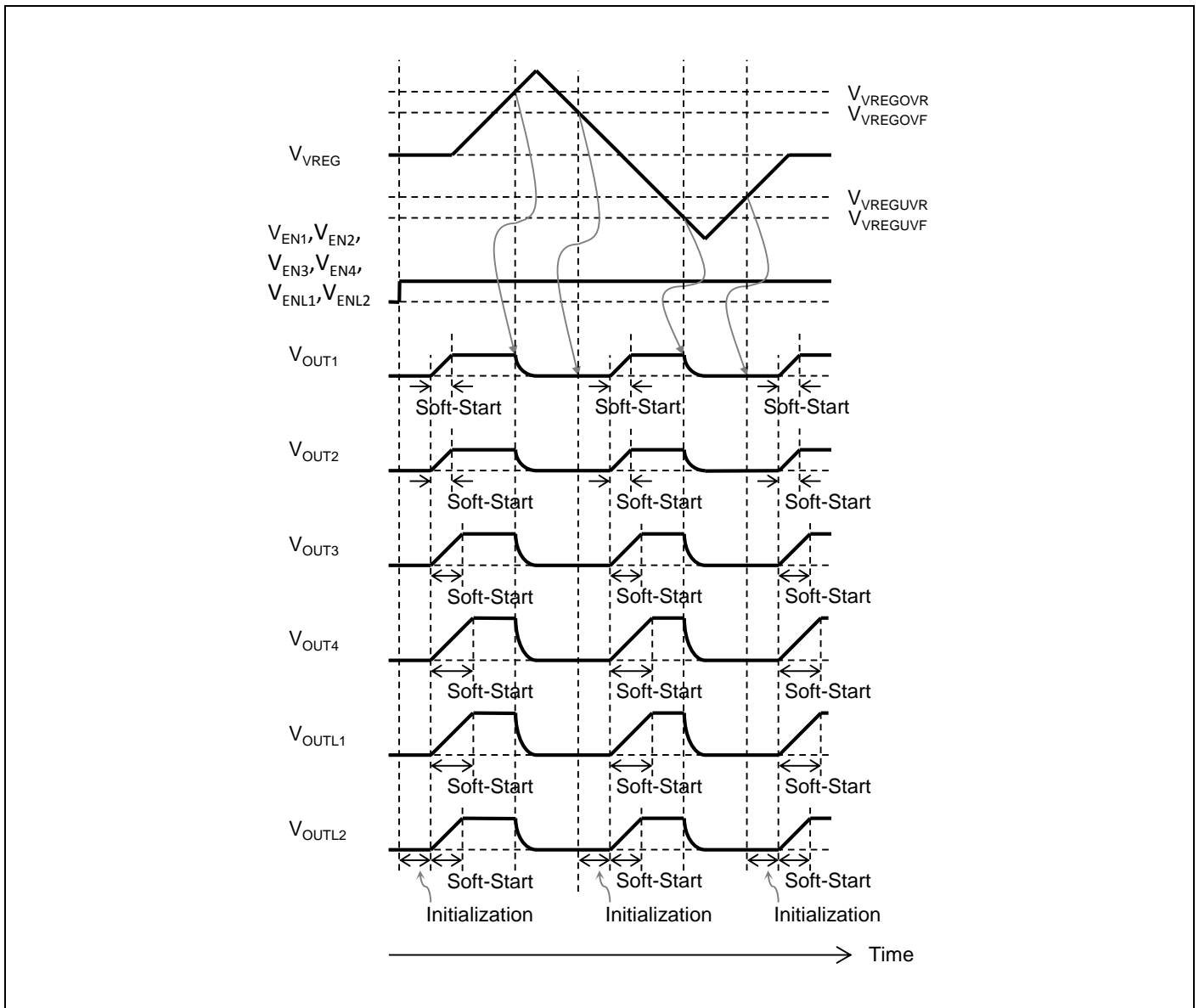


**10.10 Internal Linear Regulator Output (VREG)**

S6BP401A equips a 1.8V linear regulator as the power source for its internal circuit. A low ESR 1.0μF ceramic capacitor should be connected from VREG pin to GND. VREG is not designed to supply to external load.

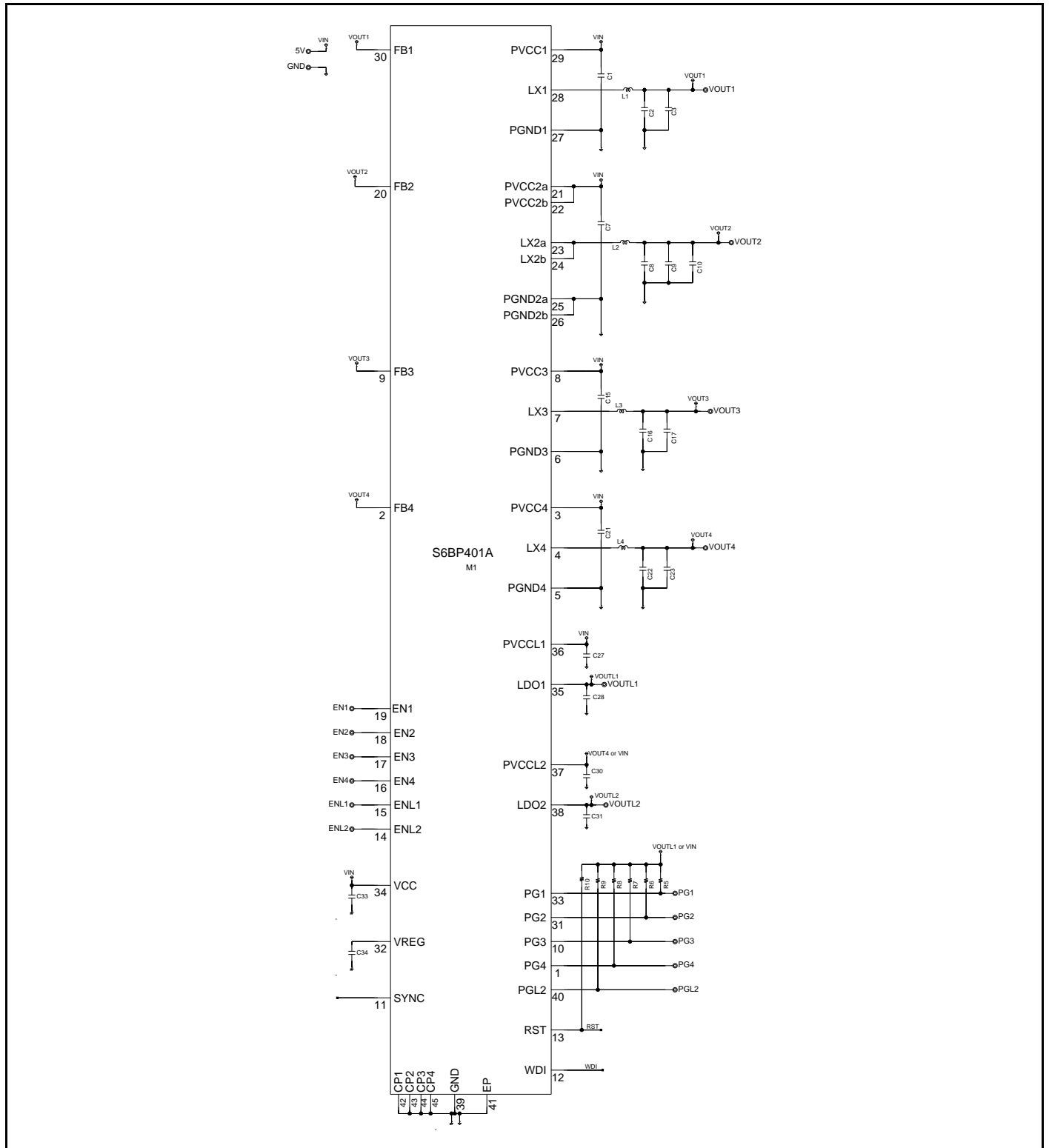
Unless the VREG terminal voltage is in the range between the over voltage lockout level  $V_{VREGOVR}$  and the under voltage lockout level  $V_{VREGUVF}$ , S6BP401A considers it abnormal and halts all DC/DC converters, LDOs and windowed watchdog timer. When the VREG terminal voltage returns to the power good voltage range ( $V_{VREGUVR} \leq V_{VREG} \leq V_{VREGOVF}$ ), S6BP401A returns the DC/DC converters, LDOs and window watchdog timer to the normal mode. Soft-start circuits of each regulator gradually generates supply voltage as described in the section 10.6.

**Figure 10-15 VREG OVLO/UVLO Timing Chart**



## 11. Application Circuit Example

Figure 11-1 Application Circuit Example



**Table 11-1 Parts list**

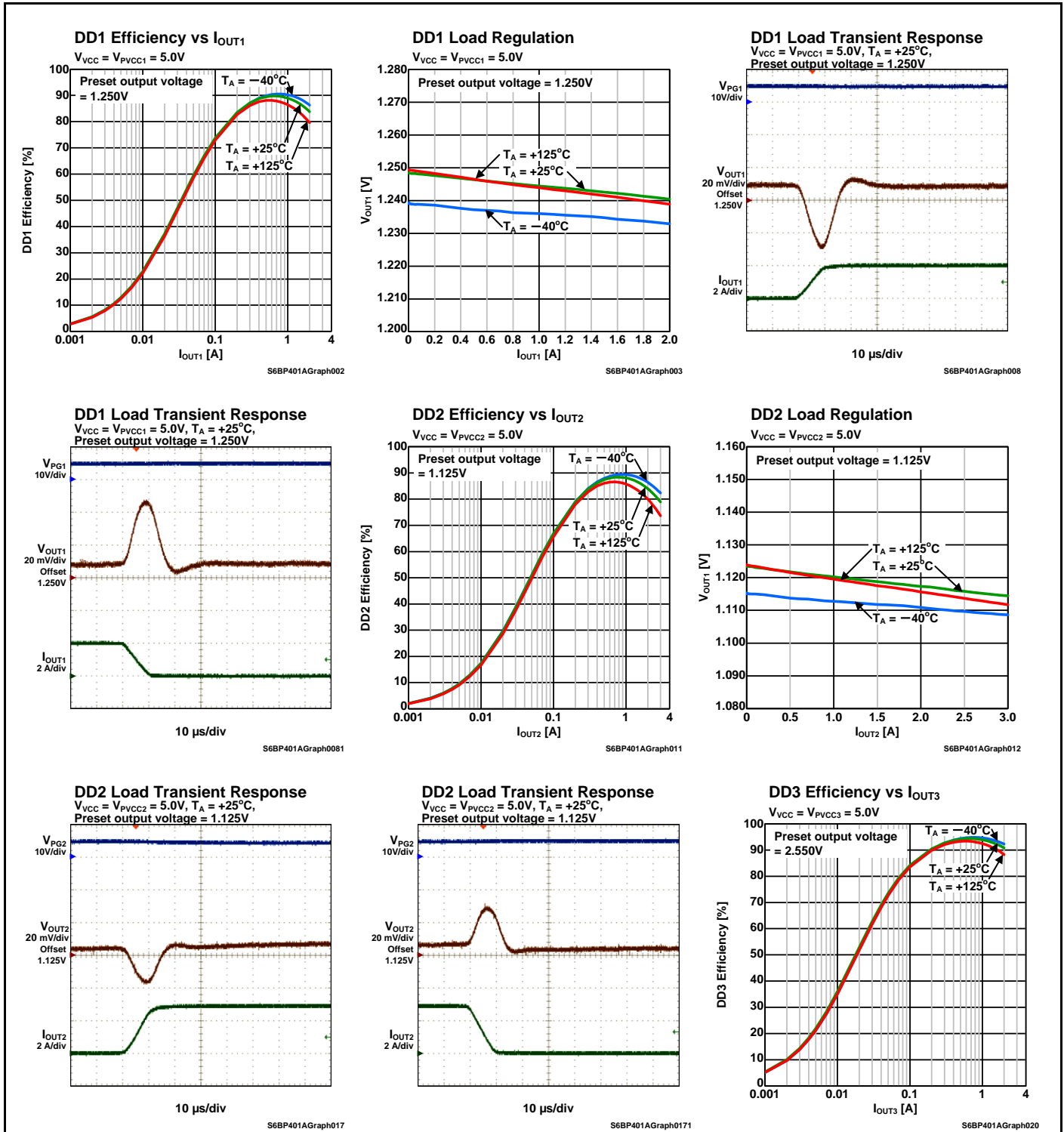
| Symbol | Parts             | Part number          | Specifications | Vendor |
|--------|-------------------|----------------------|----------------|--------|
| C1     | Ceramic Capacitor | CGA5L1X7R1C106K160AC | 10 $\mu$ F     | TDK    |
| C2     | Ceramic Capacitor | CGA6P1X7R1C226M250AC | 22 $\mu$ F     | TDK    |
| C3     | Ceramic Capacitor | CGA6P1X7R1C226M250AC | 22 $\mu$ F     | TDK    |
| C7     | Ceramic Capacitor | CGA5L1X7R1C106K160AC | 10 $\mu$ F     | TDK    |
| C8     | Ceramic Capacitor | CGA6P1X7R1C226M250AC | 22 $\mu$ F     | TDK    |
| C9     | Ceramic Capacitor | CGA6P1X7R1C226M250AC | 22 $\mu$ F     | TDK    |
| C10    | Ceramic Capacitor | CGA6P1X7R1C226M250AC | 22 $\mu$ F     | TDK    |
| C15    | Ceramic Capacitor | CGA5L1X7R1C106K160AC | 10 $\mu$ F     | TDK    |
| C16    | Ceramic Capacitor | CGA6P1X7R1C226M250AC | 22 $\mu$ F     | TDK    |
| C17    | Ceramic Capacitor | CGA6P1X7R1C226M250AC | 22 $\mu$ F     | TDK    |
| C21    | Ceramic Capacitor | CGA5L1X7R1C106K160AC | 10 $\mu$ F     | TDK    |
| C22    | Ceramic Capacitor | CGA6P1X7R1C226M250AC | 22 $\mu$ F     | TDK    |
| C23    | Ceramic Capacitor | CGA6P1X7R1C226M250AC | 22 $\mu$ F     | TDK    |
| C27    | Ceramic Capacitor | CGA3E1X7R1C105M080AC | 1 $\mu$ F      | TDK    |
| C28    | Ceramic Capacitor | CGA3E1X7R1C105M080AC | 1 $\mu$ F      | TDK    |
| C30    | Ceramic Capacitor | CGA3E1X7R1C105M080AC | 1 $\mu$ F      | TDK    |
| C31    | Ceramic Capacitor | CGA5L1X7R1C106K160AC | 10 $\mu$ F     | TDK    |
| C33    | Ceramic Capacitor | CGA3E1X7R1C105M080AC | 1 $\mu$ F      | TDK    |
| C34    | Ceramic Capacitor | CGA3E1X7R1C105M080AC | 1 $\mu$ F      | TDK    |
| L1     | Inductor          | CLF6045T-1R5N-D      | 1.5 $\mu$ H    | TDK    |
| L2     | Inductor          | CLF6045T-1R5N-D      | 1.5 $\mu$ H    | TDK    |
| L3     | Inductor          | CLF6045T-1R5N-D      | 1.5 $\mu$ H    | TDK    |
| L4     | Inductor          | CLF6045T-1R5N-D      | 1.5 $\mu$ H    | TDK    |
| R5     | Resistor          | RG1608P-473-B        | 47 k $\Omega$  | SSM    |
| R6     | Resistor          | RG1608P-473-B        | 47 k $\Omega$  | SSM    |
| R7     | Resistor          | RG1608P-473-B        | 47 k $\Omega$  | SSM    |
| R8     | Resistor          | RG1608P-473-B        | 47 k $\Omega$  | SSM    |
| R9     | Resistor          | RG1608P-473-B        | 47 k $\Omega$  | SSM    |
| R10    | Resistor          | RG1608P-473-B        | 47 k $\Omega$  | SSM    |

TDK : TDK Corporation  
 SSM : SUSUMU CO., LTD.

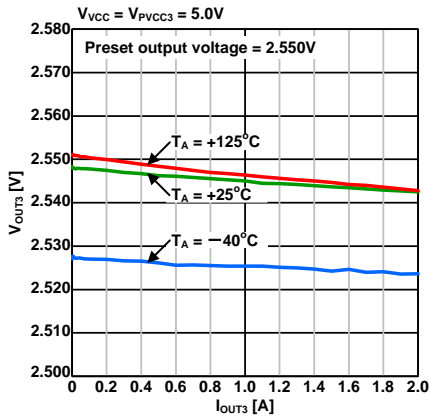
## 12. Reference Data

The followings are the reference data measured under the conditions shown in "11. Application Circuit Example".

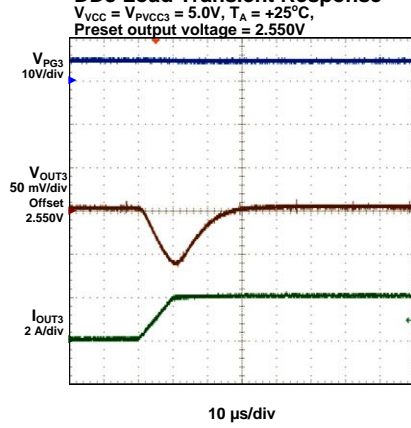
Figure 12-1 DC/DC Converter



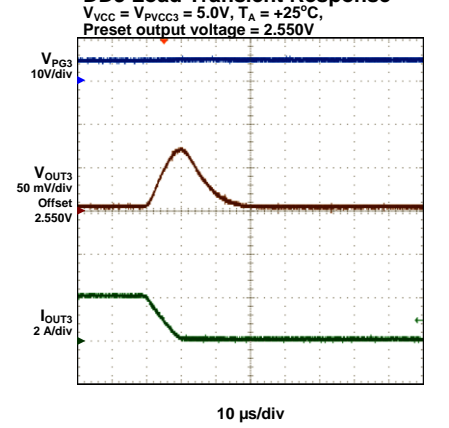
**DD3 Load Regulation**



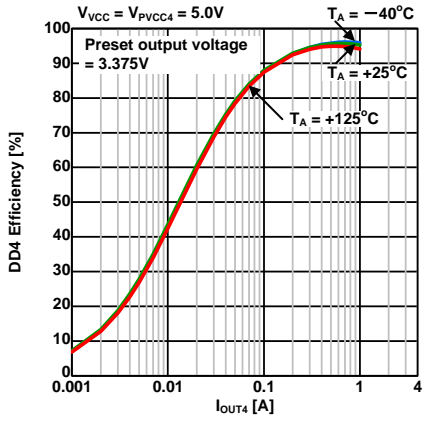
**DD3 Load Transient Response**



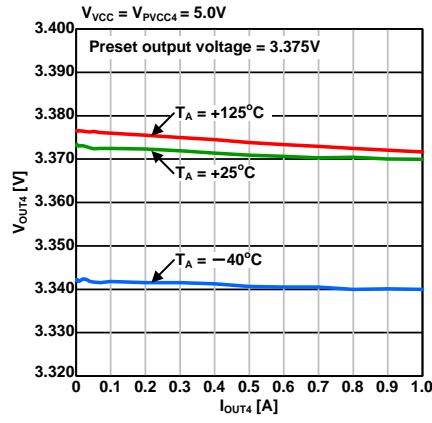
**DD3 Load Transient Response**



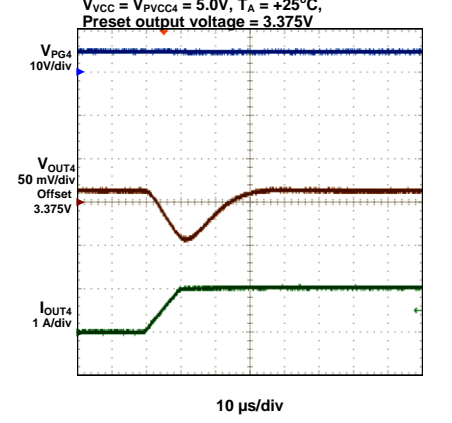
**DD4 Efficiency vs IOUT4**



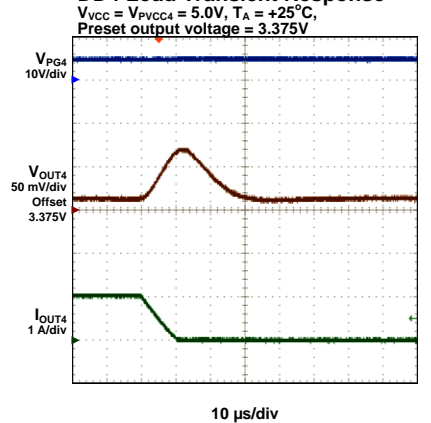
**DD4 Load Regulation**



**DD4 Load Transient Response**



**DD4 Load Transient Response**



**fosc vs VVCC**

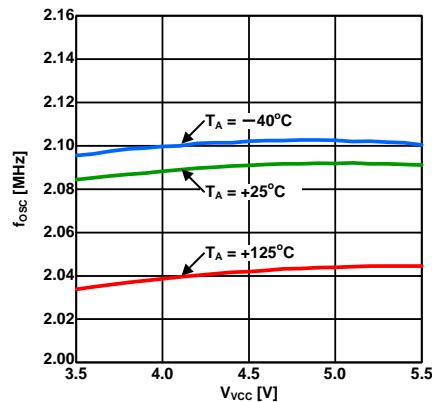
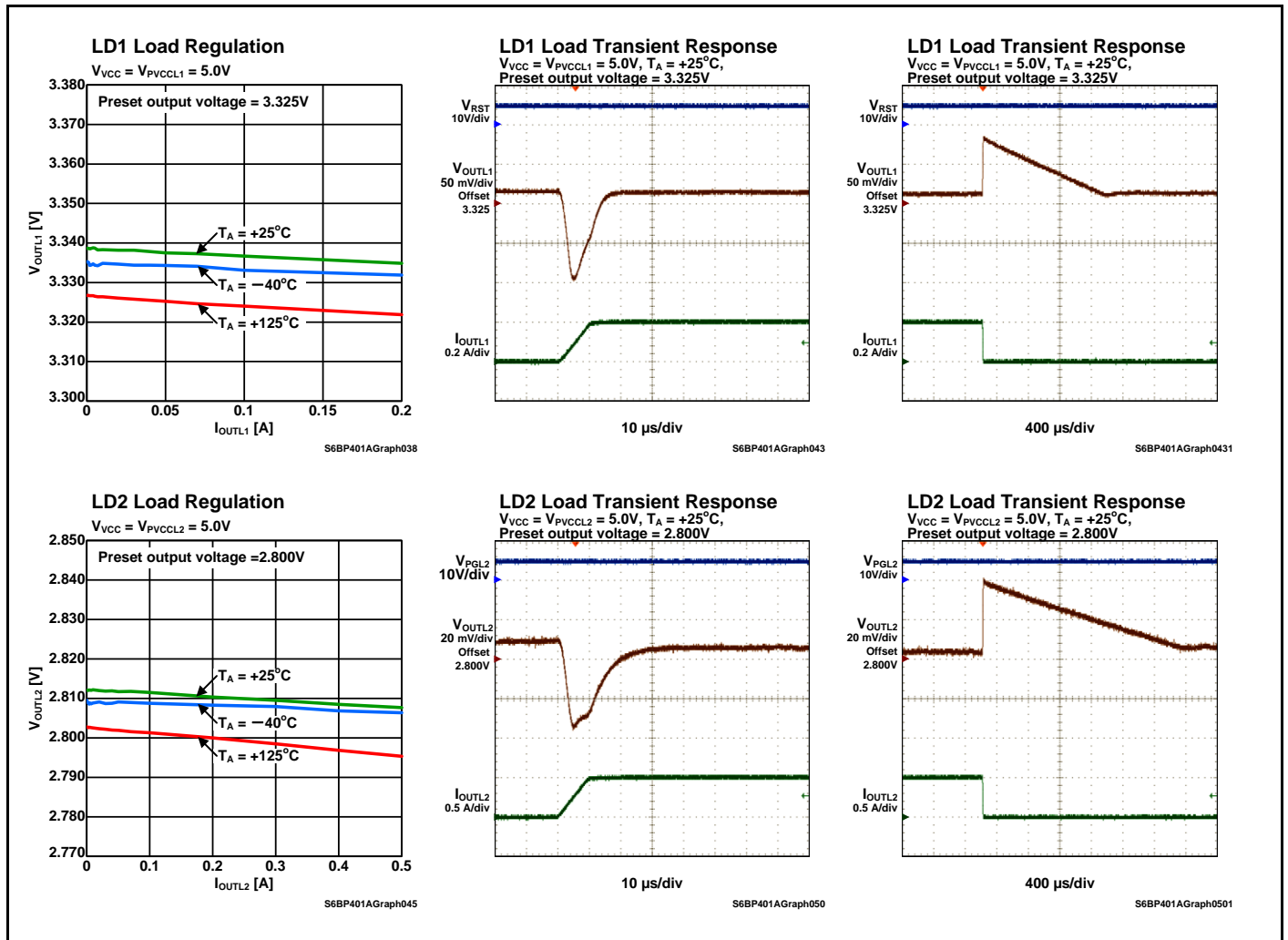




Figure 12-2 LDO regulator



### 13. Ordering Information

**Table 13-1** Ordering information

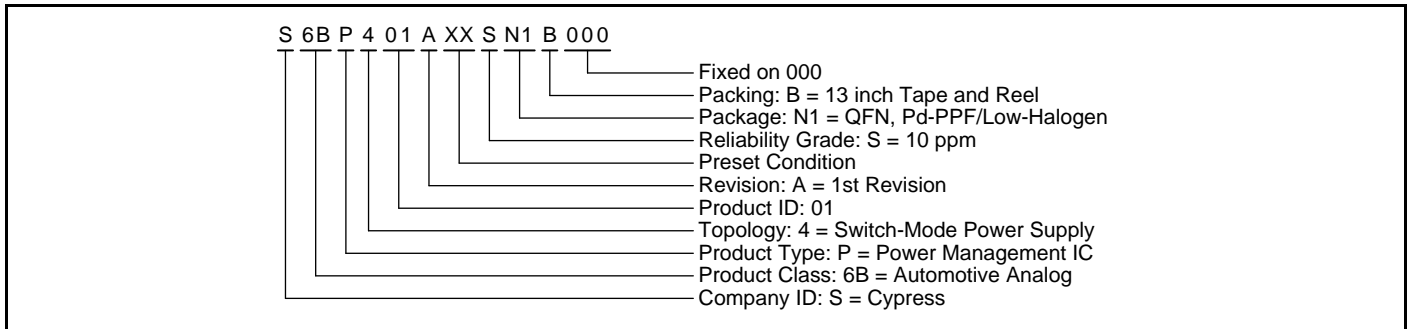
| Part Number (MPN) (*1) | Output Voltage [V] |       |       |       |       |       | Package  |
|------------------------|--------------------|-------|-------|-------|-------|-------|--|
|                        | DD1                | DD2   | DD3   | DD4   | LD1   | LD2   |  |
| S6BP401AB1SN1B000      | 1.250              | 1.250 | 1.250 | 3.375 | 3.325 | 1.850 | Plastic, QFN (0.50 mm pitch),<br>40-pin (VND040) |
| S6BP401AE0SN1B000      | 1.200              | 1.000 | 1.500 | 3.300 | 3.300 | 1.800 |  |
| S6BP401AE1SN1B000      | 1.200              | 1.100 | 1.500 | 3.300 | 3.300 | 1.800 |  |
| S6BP401AJ0SN1B000      | 1.250              | 1.250 | 1.850 | 3.375 | 3.300 | 2.800 |  |
| S6BP401AJ1SN1B000      | 1.200              | 1.000 | 1.800 | 3.300 | 3.300 | 2.800 |  |
| S6BP401AJ2SN1B000      | 1.200              | 1.100 | 1.800 | 3.300 | 3.300 | 2.800 |  |
| S6BP401AL0SN1B000      | 1.200              | 1.000 | 2.500 | 3.300 | 3.300 | 1.800 |  |
| S6BP401AL1SN1B000      | 1.200              | 1.100 | 2.500 | 3.300 | 3.300 | 1.800 |  |
| S6BP401AL2SN1B000      | 1.250              | 1.125 | 2.550 | 3.375 | 3.325 | 1.850 |  |
| S6BP401AM2SN1B000      | 1.250              | 1.125 | 2.550 | 3.375 | 3.325 | 2.800 |  |
| S6BP401AW0SN1B000      | 1.500              | 1.100 | 1.800 | 3.300 | 3.300 | 2.800 |  |
| S6BP401AY0SN1B000      | 1.500              | 1.000 | 2.500 | 3.300 | 3.300 | 1.800 |  |
| S6BP401AY1SN1B000      | 1.500              | 1.100 | 2.500 | 3.300 | 3.300 | 1.800 |  |
| S6BP401AY2SN1B000      | 1.500              | 1.200 | 2.500 | 3.300 | 3.300 | 1.800 |  |

MPN: Marketing Part Number

\*1: Please contact our sales division for the output voltage combination not mentioned in this table.

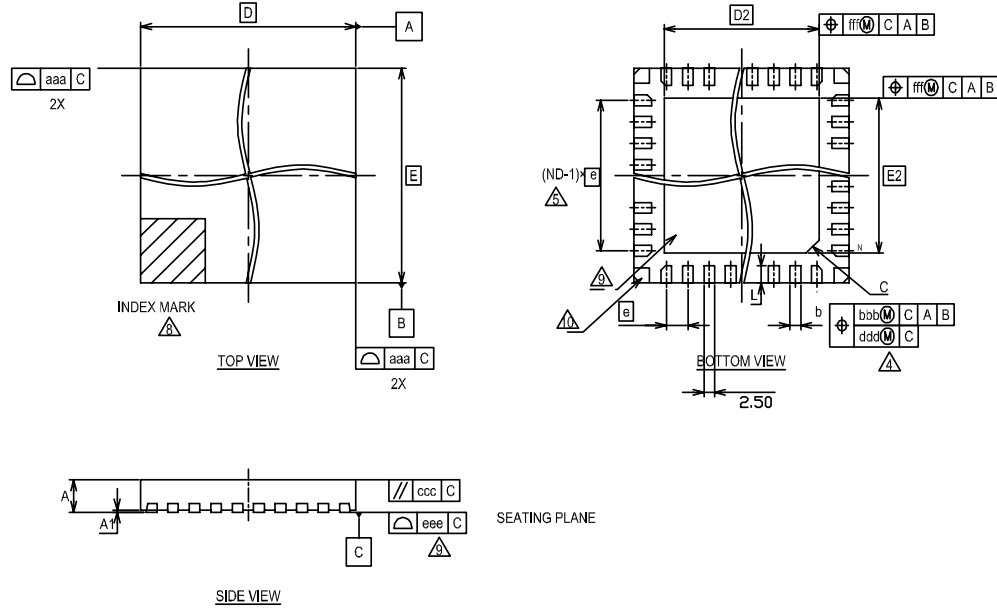
#### Part Numbering Conventions

These ICs follow the part numbering convention described in the following table. Each single-character is alphanumeric (0, 1, 2, ..., 9, A, B, ..., Z) unless stated otherwise. The part numbers are defined as follows.



14. Package Dimensions

VERY THIN PLASTIC QUAD FLAT NO LEAD PACKAGES (VND040)



| SYMBOL | MILLIMETER |      |      | NOTE                |
|--------|------------|------|------|---------------------|
|        | MIN.       | NOM. | MAX. |                     |
| A      | —          | —    | 0.90 | PROFILE             |
| A1     | 0.00       | —    | 0.05 | TERMINAL HEIGHT     |
| D      | 6.00 BSC.  |      |      | BODY SIZE           |
| E      | 6.00 BSC.  |      |      | BODY SIZE           |
| b      | 0.20       | 0.25 | 0.30 | TERMINAL WIDTH      |
| D2     | 4.20 BSC.  |      |      | EXPOSED PAD SIZE    |
| E2     | 4.20 BSC.  |      |      | EXPOSED PAD SIZE    |
| e      | 0.50 BSC.  |      |      | TERMINAL PITCH      |
| N      | 40         |      |      | TERMINAL COUNT      |
| L      | 0.30       | 0.40 | 0.50 | TERMINAL LENGTH     |
| C      | C0.50      |      |      | EXPOSED PAD CHAMFER |
| aaa    | 0.2        |      |      |                     |
| bbb    | 0.05       |      |      |                     |
| ccc    | 0.2        |      |      |                     |
| ddd    | -          |      |      |                     |
| eee    | 0.05       |      |      |                     |
| fff    | -          |      |      |                     |

1. DIMENSIONING AND TOLERANCING CONFORMS TO ASME Y14.5-1994.
2. ALL DIMENSIONS ARE IN MILLIMETERS.
3. N IS THE TOTAL NUMBER OF TERMINALS.
- △ DIMENSION "b" APPLIES TO METALIZED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.30mm FROM TERMINAL TIP. IF THE TERMINAL HAS THE OPTIONAL RADIUS ON THE OTHER END OF THE TERMINAL, THE DIMENSION "b" SHOULD NOT BE MEASURED IN THAT RADIUS AREA.
- △ ND REFER TO THE NUMBER OF TERMINALS ON D OR E SIDE.
6. MAX. PACKAGE WARPAGE IS 0.05mm.
7. MAXIMUM ALLOWABLE BURRS IS 0.076mm IN ALL DIRECTIONS.
- △ PIN #1 ID ON TOP WILL BE LOCATED WITHIN INDICATED ZONE.
- △ BILATERAL COPLANARITY ZONE APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.
- △ Reinforcement Land size 0.35mm SQ.

**15. Major Changes**

Spancion Publication Number: S6BP401A\_DS405-00024

| Page                             | Section | Change Results  |
|----------------------------------|---------|-----------------|
| Revision 0.1 (February 19, 2015) |         |                 |
| -                                | -       | Initial release |

**NOTE: Please see "Document History" about later revised information.**

**Document History**

**Document Title: S6BP401A Power Management IC for Automotive ADAS Platform**

**Document Number: 002-03341**

| Revision | ECN     | Orig. of Change | Submission Date | Description of Change  |
|----------|---------|-----------------|-----------------|--|
| **       | 4922113 | YMAE            | 09/16/2015      | New Spec.<br>Updated Ordering Information  |
| *A       | 5085035 | HIXT            | 01/14/2016      | Updated "3. Pin Functions"<br>Updated "6. Absolute Maximum Ratings"<br>Updated "7. Recommended Operating Conditions"<br>Added "Development Support"<br>Added "12. Reference Data"<br>Updated "13. Ordering Information"  |
| *B       | 5160391 | HIXT            | 03/04/2016      | Added "AEC-Q100 compliant (Grade-1)" in "Features"<br>Added the following values in "8. Electrical Characteristics"<br>Supply Current<br>I <sub>VCCS</sub> : Max value<br>UVLO: Under Voltage Lockout (VCC)<br>V <sub>UVHYS</sub> : Min and Max values<br>Enable Inputs (EN1, EN2, EN3, EN4, ENL1, ENL2)<br>I <sub>IHEN</sub> : Min and Max values<br>Synchronization Input (SYNC)<br>I <sub>IHSYNC</sub> : Min and Max values<br>Power Good Monitor (PG1, PG2, PG3, PG4, PGL2, RST)<br>V <sub>PGOVHYS</sub> : Min and Max values<br>V <sub>PGUVHYS</sub> : Min and Max values<br>Watchdog Timer (WDI)<br>T <sub>WD</sub> : Min and Max values<br>I <sub>IHWDI</sub> : Min and Max values<br>DD1: Buck DC/DC Converter<br>R <sub>FB1</sub> : Min and Max values<br>R <sub>ONHS1</sub> : Max values<br>R <sub>ONLS1</sub> : Max values<br>I <sub>LEAK1</sub> : Max value<br>V <sub>OVPHYS1</sub> : Min and Max values<br>R <sub>DIS1</sub> : Min and Max values<br>T <sub>COESS1</sub> : Min and Max values<br>DD2: Buck DC/DC Converter<br>R <sub>FB2</sub> : Min and Max values<br>R <sub>ONHS2</sub> : Max values<br>R <sub>ONLS2</sub> : Max values |

| Revision | ECN     | Orig. of Change | Submission Date | Description of Change   |
|----------|---------|-----------------|-----------------|---|
| *B       | 5160391 | HIXT            | 03/04/2016      | <p>           I<sub>LEAK2</sub>: Max value<br/>           V<sub>OVPHYS2</sub>: Min and Max values<br/>           R<sub>DIS2</sub>: Min and Max values<br/>           T<sub>COESS2</sub>: Min and Max values<br/>           DD3: Buck DC/DC Converter<br/>           R<sub>FB3</sub>: Min and Max values<br/>           R<sub>ONHS3</sub>: Max values<br/>           R<sub>ONLS3</sub>: Max values<br/>           I<sub>LEAK3</sub>: Max value<br/>           V<sub>OVPHYS3</sub>: Min and Max values<br/>           R<sub>DIS3</sub>: Min and Max values<br/>           T<sub>COESS3</sub>: Min and Max values<br/>           DD4: Buck DC/DC Converter<br/>           R<sub>FB4</sub>: Min and Max values<br/>           R<sub>ONHS4</sub>: Max values<br/>           R<sub>ONLS4</sub>: Max values<br/>           I<sub>LEAK4</sub>: Max value<br/>           V<sub>OVPHYS4</sub>: Min and Max values<br/>           R<sub>DIS4</sub>: Min and Max values<br/>           T<sub>COESS4</sub>: Min and Max values<br/>           LD1: LDO Regulator<br/>           I<sub>LEAKL1</sub>: Max value<br/>           R<sub>DISL1</sub>: Min and Max values<br/>           T<sub>COESSL1</sub>: Min and Max values<br/>           LD2: LDO Regulator<br/>           I<sub>LEAKL2</sub>: Max value<br/>           R<sub>DISL2</sub>: Min and Max values<br/>           T<sub>COESSL2</sub>: Min and Max values<br/>           Updated the following values in "8. Electrical Characteristics"<br/>           DD1: Buck DC/DC Converter<br/>               R<sub>ONHS1</sub>: Typ value<br/>               R<sub>ONLS1</sub>: Typ value<br/>           DD2: Buck DC/DC Converter<br/>               R<sub>ONHS2</sub>: Typ value<br/>               R<sub>ONLS2</sub>: Typ value<br/>           DD3: Buck DC/DC Converter<br/>               R<sub>ONHS3</sub>: Typ value<br/>               R<sub>ONLS3</sub>: Typ value<br/>           DD4: Buck DC/DC Converter<br/>               R<sub>ONHS4</sub>: Typ value<br/>               R<sub>ONLS4</sub>: Typ value<br/>           Delete the following values in "8. Electrical Characteristics"<br/>           Updated "Figure 10-1" and "Figure 10-2"<br/>           Updated "10.5 Under Voltage Lockout (UVLO)"<br/>           Added a part number, S6BP401AL2SN1B000, in "Table 13-1".<br/>           Corrected an error in "Table 13-1".<br/>               from S6BP401AW1SN1B000 to S6BP401AW0SN1B000         </p> |
| *C       | 5396389 | HIXT            | 08/09/2016      | <p>           Deleted "Development Support" and added "More Information"<br/>           Added "S6BP401AY2SN1B000" to "Table 13-1 Ordering information"         </p>   |

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