

# FAN5631 / FAN5632

## Regulated Step-Down Charge Pump DC/DC Converter

### Features

- 90% Peak Efficiency
- Low EMI
- Low Ripple
- Selectable Output Voltage: 1.2V/1.5V for FAN5631
- Efficiency Optimizer Feature for FAN5632
- Input Voltage Range: 2.2V to 5.5V
- Output Current: Up to 250mA
- $\pm 5\%$  Output Voltage Accuracy
- 30 $\mu$ A Operating Current
- $I_{CC} < 1\text{mA}$  in Shutdown Mode
- 1.5MHz Operating Frequency
- Shutdown Isolates Output from Input
- Soft-Start Limits Inrush Current
- Short-Circuit and Over-Temperature Protection
- Minimum External Component Count
- 10-Lead 3x3mm MLP Package

### Applications

- Cell Phones
- Handheld Computers
- Portable Electronic Equipment
- Core Supply to Next-Generation Processors
- Low-Voltage DC Bus
- Digital Cameras
- DSP Supplies

### Description

The FAN5631/FAN5632 is an advanced, third-generation switched capacitor step-down DC/DC converter utilizing Fairchild's proprietary ScalarPump technology. This innovative architecture utilizes scalar switch re-configuration and fractional switching techniques to produce low output ripple, lower ESR spikes, and improve efficiency over a wide load range.

The FAN5631/FAN5632 produces a fixed regulated output voltage from an input voltage of 2.2V to 5V.

To maximize efficiency, the FAN5631/5632 achieves regulation by skipping pulses. Depending on load current, the size of the switches are scaled dynamically; consequently, current spikes and EMI are minimized. An internal soft-start circuitry prevents excessive current from the supply. The device is internally protected against short-circuit and over-temperature conditions.

The FAN5631 has a dual-output voltage feature. When  $V_{SEL}$  is high,  $V_{OUT}$  is 1.5V; and when  $V_{SEL}$  is low,  $V_{OUT}$  is 1.2V.

The FAN5632 has an efficiency optimizer feature that, when enabled, changes the switch mode configuration from 2:1 to 1:1 at the lower threshold of  $V_{IN}$ . The efficiency is maintained at its peak level over a wider range of input voltages. In addition,  $V_{OUT}$  varies from 1.2V to 1.5V as a result of this efficiency optimization. If the efficiency optimizer is not enabled,  $V_{OUT}$  is regulated to 1.5V.

Both the FAN5631 and FAN5632 are available in a 10-lead 3x3mm MLP package.

### Ordering Information

| Part Number | Package                                     | Packing Method |
|-------------|---------------------------------------------|----------------|
| FAN5631MPX  | 10-Lead 3x3mm Molded Leadless Package (MLP) | Tape and Reel  |
| FAN5632MPX  | 10-Lead 3x3mm Molded Leadless Package (MLP) | Tape and Reel  |

 All packages are lead free per JEDEC: J-STD-020B standard.

## Typical Application

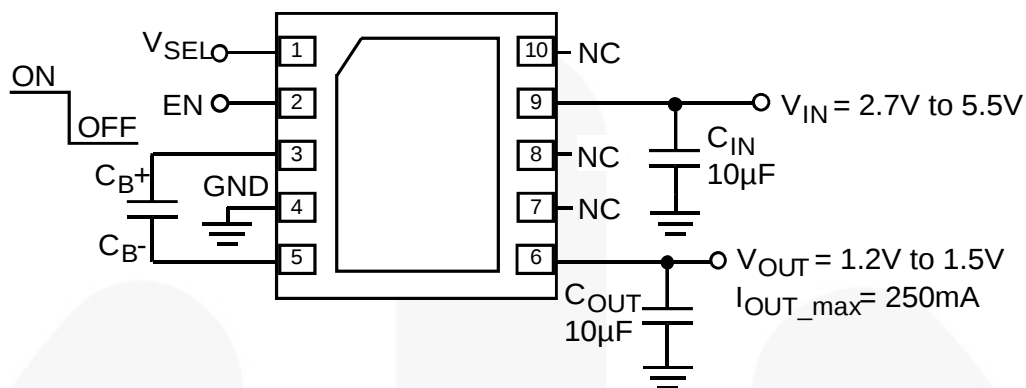
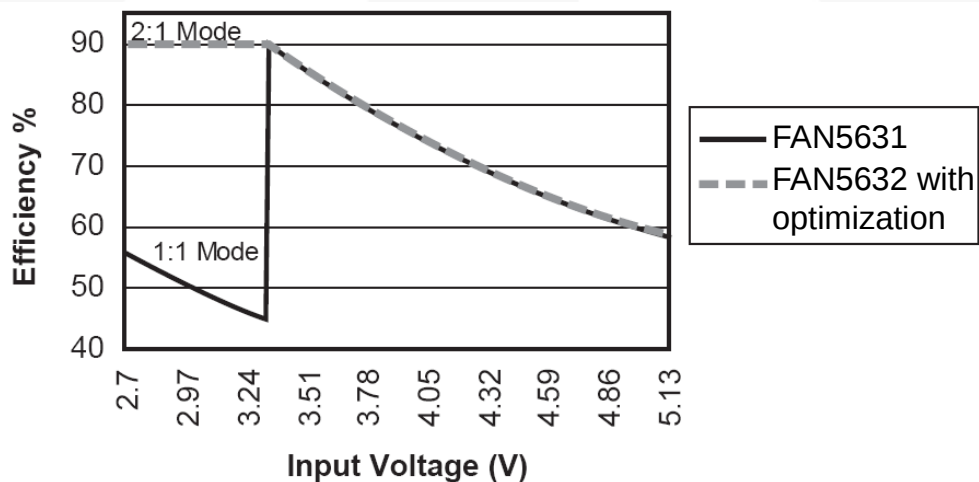


Figure 1. Typical Application



Average Efficiency (over V<sub>IN</sub>=2.7V to 5V) = 66%, with optimization = 77%  
 Average Efficiency (over V<sub>IN</sub>=2.7V to 4.2V) = 67%, with optimization = 84%

Figure 2. Typical Efficiency Graph

## Pin Configuration

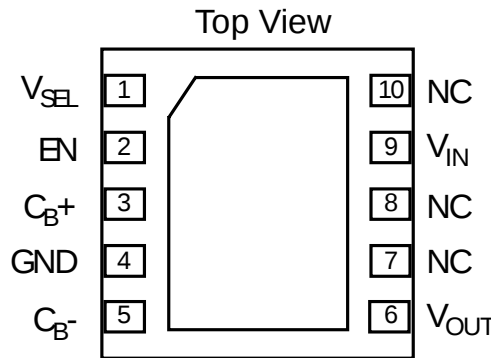


Figure 3. Pin Assignments

## Pin Definitions

| Pin # | Name      | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | $V_{SEL}$ | <p><b>Output Voltage Select Logic Input Pin.</b> The <math>V_{SEL}</math> pin cannot be left floating and must be connected to either a logic high or logic low level.</p> <p><b>FAN5631:</b> If a logic low is applied to the <math>V_{SEL}</math> pin, <math>V_{OUT}</math> is 1.2V; if a logic high is applied, <math>V_{OUT}</math> is 1.5V.</p> <p><b>FAN5632:</b> If a logic low is applied to the <math>V_{SEL}</math> pin, the efficiency optimization mode is enabled and the output voltage accuracy is relaxed to meet optimum efficiency. If a logic high is applied, the device operates like a typical charge pump converter.</p> |
| 2     | EN        | <p><b>Enable Input Pin.</b> If a logic high is applied to the EN pin, the device is enabled. If a logic low is applied, the device is disabled and the supply current is reduced to less than 1<math>\mu</math>A. The EN pin cannot be left floating and must be connected to a logic high or logic low level.</p>                                                                                                                                                                                                                                                                                                                              |
| 3     | $C_{B+}$  | <b>Bucket Capacitor Positive Pin.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 4     | GND       | <p><b>Ground Pin.</b> This pin is connected to the internal MOSFET switches. This pin must be externally connected to GND.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 5     | $C_{B-}$  | <b>Bucket Capacitor Negative Pin.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 6     | $V_{OUT}$ | <b>Output Voltage Pin.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 7     | NC        | <b>Not Connected.</b> This pin is not internally connected.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 8     | NC        | <b>Not Connected.</b> This pin is not internally connected.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 9     | $V_{IN}$  | <b>Supply Voltage Input.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 10    | NC        | <b>Not Connected.</b> This pin is not internally connected.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

## Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

| Symbol             | Parameter                                         | Min. | Max.           | Unit |
|--------------------|---------------------------------------------------|------|----------------|------|
| $V_{CC}$           | $V_{IN}$ to GND                                   | -0.3 | 6.0            | V    |
|                    | All other pins to GND                             | -0.3 | $V_{IN} + 0.3$ |      |
| $I_{LOAD}$         | Load Current                                      |      | 0.5            | A    |
| $\theta_{JC}$      | Thermal Resistance Junction-to-Tab <sup>(1)</sup> |      | 8              | °C/W |
| $T_L$              | Lead Temperature, Soldering 10 Seconds            |      | +260           | °C   |
| $T_J$              | Junction Temperature                              | -40  | +150           | °C   |
| $T_{STG}$          | Storage Temperature                               | -65  | +150           | °C   |
| ESD <sup>(2)</sup> | Human Body Model, JESD22-A114                     | 2.5  |                | kV   |
|                    | Charged Device Model, JESD22-C101                 | 0.2  |                |      |

### Notes:

1. Junction-to-ambient thermal resistance,  $\theta_{JA}$ , is a strong function of PCB material, board thickness, thickness and number of copper planes, number of via used, diameter of via used, available copper surface, and attached heat sink characteristics. The estimated value for zero air flow at 0.5W is 60°C/W.
2. Using Mil Std. 883E, method 3015.7 (Human Body Model) and EIA/JESD22C101-A (Charged Device Model).

## Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. Fairchild does not recommend exceeding them or designing to Absolute Maximum Ratings.

| Symbol    | Parameter                           | Min. | Typ. | Max. | Unit |
|-----------|-------------------------------------|------|------|------|------|
| $V_{CC}$  | Supply Voltage Range                | 2.2  |      | 5.5  | V    |
| $I_{OUT}$ | Output Current ( $V_{IN} > 2.7$ )   |      |      | 250  | mA   |
| $T_A$     | Operating Ambient Temperature Range | -40  | +25  | +85  | °C   |

## Electrical Characteristic

$V_{IN} = 2.2V$  to  $5.5V$ ,  $I_{OUT} = 1mA$ ,  $C_{IN} = 10\mu F$ ,  $C_{OUT} = 10\mu F$ ,  $C_B = 1\mu F$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise noted. Typical values are at  $T_A = 25^{\circ}C$ .

| Symbol      | Parameter                                   | Conditions                                              | Min. | Typ.                         | Max. | Units       |
|-------------|---------------------------------------------|---------------------------------------------------------|------|------------------------------|------|-------------|
| $V_{UVLO}$  | Input Under-voltage Lockout                 |                                                         |      | 2                            |      | V           |
|             | No-load Supply Current                      | No Switching                                            |      |                              | 60   | $\mu A$     |
| $V_{OUT}$   | Output Voltage                              | FAN5631, SEL to High                                    |      | 1.5                          |      | V           |
|             |                                             | FAN5631, SEL to Low                                     |      | 1.2                          |      |             |
|             |                                             | FAN5632, SEL to High                                    |      | 1.5                          |      |             |
|             |                                             | FAN5632, SEL to Low                                     |      | Variable between 1.5 and 1.2 |      |             |
|             | Output Voltage Accuracy                     | $1mA \leq I_{OUT} \leq 150mA$ , $V_{IN}=2.7V$ to $5.5V$ | -5   |                              | +5   | %           |
| $R_{LOAD}$  | Load Regulation                             | $0mA \leq I_{OUT} \leq 150mA$ , $V_{IN}=3.6V$           |      | 0.25                         |      | mV/mA       |
| $R_{LINE}$  | Line Regulation                             | $I_{OUT}=0.1mA$                                         |      | 0.2                          | 4.0  | mV/V        |
| $I_{SD}$    | Shutdown Supply Current                     | $V_{EN}=0V$                                             |      | 0.1                          | 1.0  | $\mu A$     |
| $I_{SC}$    | Output Short-circuit Current <sup>(3)</sup> | $V_{OUT} \leq 150mA$                                    |      | 25                           |      | mA          |
|             | Peak Efficiency                             |                                                         |      | 90                           |      | %           |
|             | $V_{IN}$ at Configuration Change            | $V_{IN}$ Decreasing                                     |      | $2.22 \times V_{OUT}$        |      | V           |
| $F_{OSC}$   | Oscillator Frequency                        |                                                         |      | 1.5                          |      | MHz         |
| $T_{SD}$    | Thermal Shutdown Threshold                  |                                                         |      | 150                          |      | $^{\circ}C$ |
| $T_{SDHYS}$ | Thermal Shutdown Threshold Hysteresis       |                                                         |      | 15                           |      | $^{\circ}C$ |
| $V_{IH}$    | Enable Logic Input High Voltage             |                                                         | 1.3  |                              |      | V           |
| $V_{IL}$    | Enable Logic Input Low Voltage              |                                                         |      |                              | 0.4  | V           |
| $I_{EN}$    | Enable Logic Input Current                  |                                                         | -1   |                              | 1    | $\mu A$     |
| $V_{IH}$    | $V_{SEL}$ Logic Input High Voltage          |                                                         | 1.3  |                              |      | V           |
| $V_{IL}$    | $V_{SEL}$ Logic Input Low Voltage           |                                                         |      |                              | 0.4  | V           |
| $I_{IN}$    | $V_{SEL}$ Logic Input Current               |                                                         | -1   |                              | 1    | $\mu A$     |
| $t_{ON}$    | $V_{OUT}$ Turn-On Time                      |                                                         |      | 1.6                          |      | ms          |

### Note:

- The short-circuit protection is designed to protect against pre-existing short-circuit conditions, such as assembly shorts, that exist prior to device power-up. The short-circuit current limit is  $25mA_{Average}$ . Short-circuit currents in normal operation are inherently limited by the on resistance of the internal FET. Since this resistance is in the range of  $1\Omega$ , in some cases, thermal shutdown may occur. Immediately following the first thermal shutdown event, the short-circuit condition is treated as pre-existing and the load current reduces to  $25mA_{Average}$ .

## Typical Performance Characteristics

$T_A = 25^\circ\text{C}$ ,  $V_{OUT} = 1.5\text{V}$ ,  $V_{IN} = 3.6\text{V}$ ,  $C_{IN} = 10\mu\text{F}$ ,  $C_{OUT} = 10\mu\text{F}$ ,  $C_B = 1\mu\text{F}$ , unless otherwise noted.

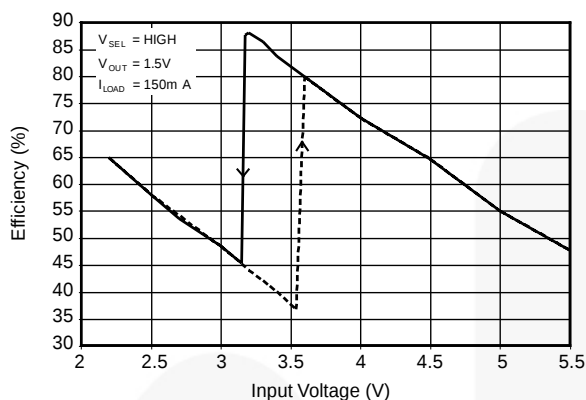


Figure 4. Efficiency vs. Input Voltage

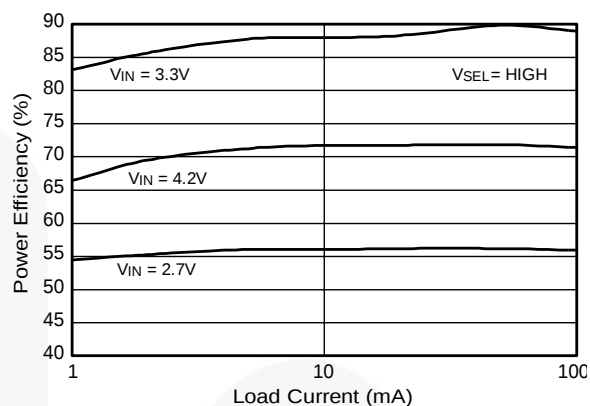


Figure 5. Efficiency vs. Load Current

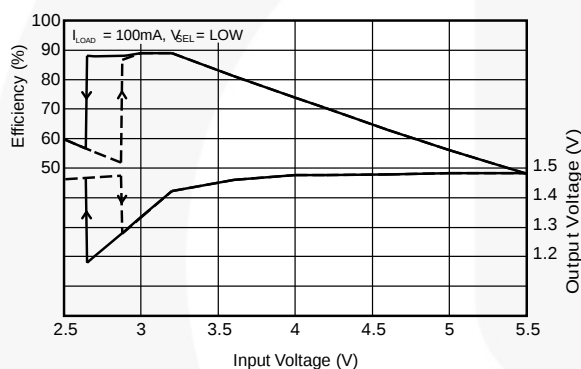


Figure 6. FAN5632 Efficiency Optimizer Efficiency and Output Voltage vs. Input Voltage

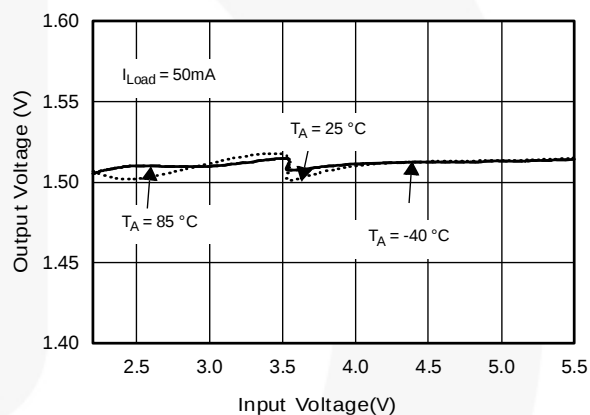


Figure 7. Line Regulation

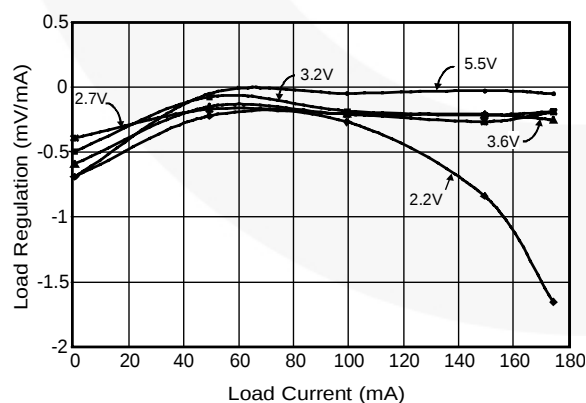


Figure 8. Load Regulation

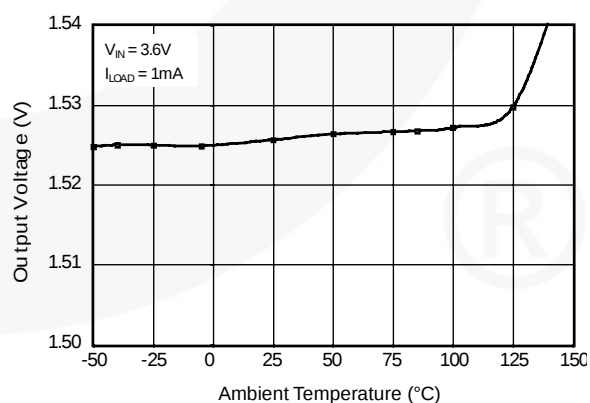


Figure 9. Thermal Regulation

## Typical Performance Characteristics (Continued)

$T_A = 25^\circ\text{C}$ ,  $V_{OUT} = 1.5\text{V}$ ,  $V_{IN} = 3.6\text{V}$ ,  $C_{IN} = 10\mu\text{F}$ ,  $C_{OUT} = 10\mu\text{F}$ ,  $C_B = 1\mu\text{F}$ , unless otherwise noted.

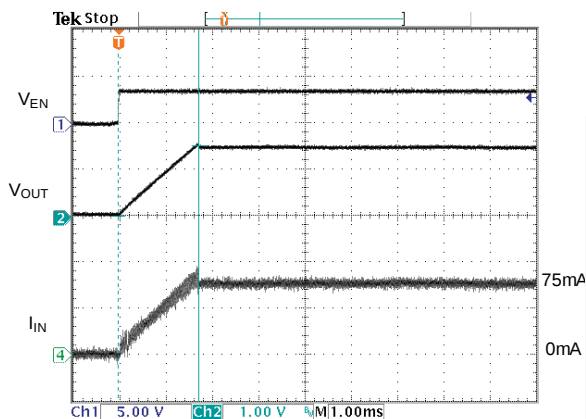


Figure 10. Start-Up

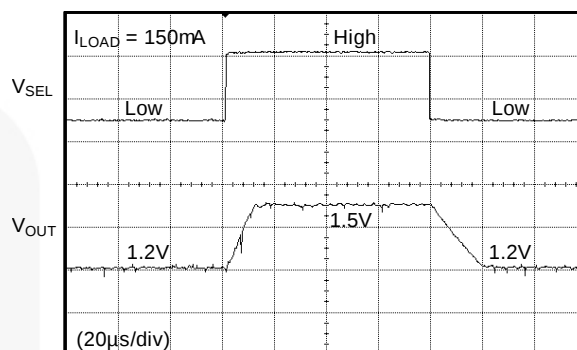


Figure 11. Dynamic  $V_{OUT}$  Change (FAN5631)

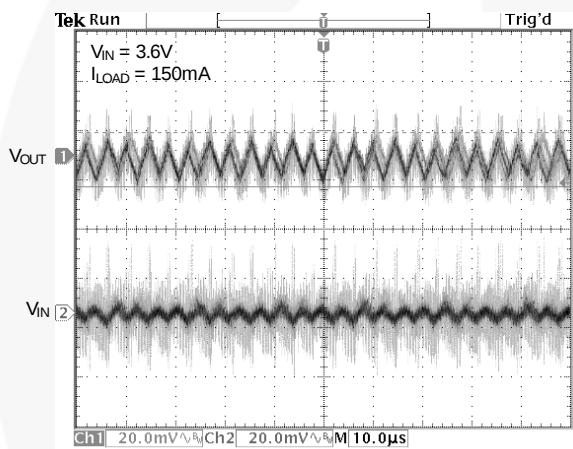


Figure 12. Voltage Ripple

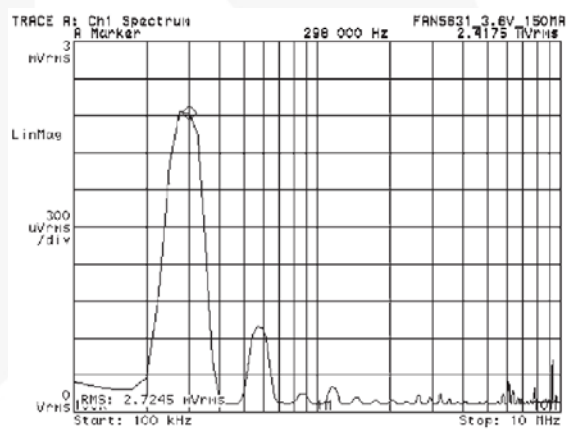


Figure 13. Output Voltage Ripple Spectrum

## Block Diagram

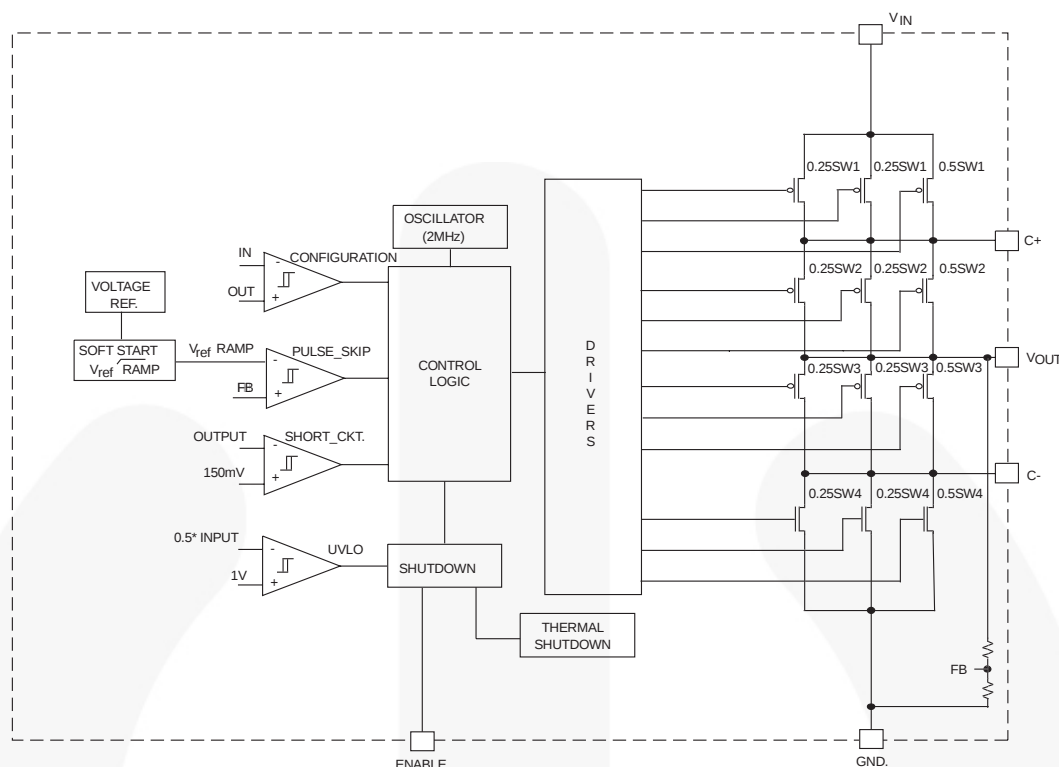


Figure 14. Block Diagram

## Detailed Description

The FAN5631 / FAN5632 switched capacitor DC/DC converter automatically configures switches to achieve high efficiency and provides a regulated output voltage by means of pulse skipping, pulse frequency modulation (PFM). An internal soft-start circuit prevents excessive inrush current from the supply. Each switch is split into three segments. Based on the values of  $V_{IN}$ ,  $V_{OUT}$ , and  $I_{OUT}$ , an internal circuit determines the number of segments used to reduce current spikes.

### Step-Down Charge Pump Operation

When  $V_{IN} \geq 2 \times V_{OUT}/9$ , the 2:1 configuration shown in Figure 15 is enabled. The factor 0.9 is used instead of 1 to account for the effect of resistive losses across the switches and to accommodate hysteresis in the voltage detector comparator. Two-phase, non-overlapping clock signals are generated to drive four switches. When switches 1 and 3 are on, switches 2 and 4 are off and  $C_B$  is charged. When switches 2 and 4 are on, 1 and 3 are off and charge is transferred from  $C_B$  to  $C_{OUT}$ .

When  $V_{IN} \geq 2 \times V_{OUT}/9$ , the 1:1 configuration shown in Figure 16 is enabled. In the 1:1 configuration, switch 3 is always off and the switch 4 is always on. At 1.6V output setting, the configuration changes from 2:1 to 1:1 at  $V_{IN}=3.56V$ . At 1.3V output setting, the change occurs at  $V_{IN}=3.06V$ .

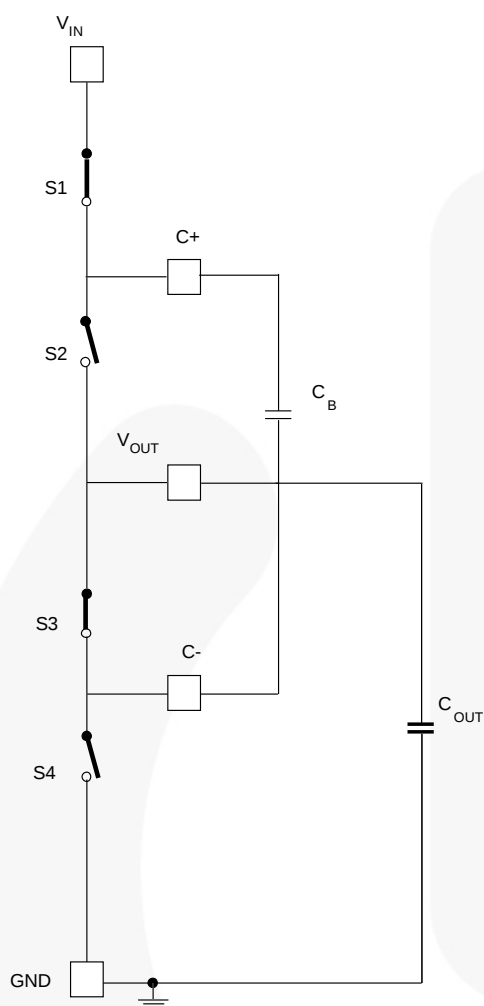
### Pulse-skipping PFM and Fractional Switch Operation

When the regulated output voltage reaches its upper limit, the switches are turned off and the output voltage reaches its lower limit. In a step-down 2:1 mode of operation, with 1.6V output as an example; when the output reaches about 1.62V (upper limit), the control logic turns off all switches: switching stops completely. This is pulse-skipping mode. Since the supply is isolated from the output, the output voltage drops. Once the output is dropped to about 1.58V (lower limit), the device returns to regular switching mode with one quarter of each switch turning on first. Another quarter of each switch is turned on if  $V_{OUT}$  cannot reach regulation by the third charge cycle. Full switch operation occurs only during start-up or under heavy-load condition, when half switch operation cannot achieve regulation within seven charge cycles.

### Soft-Start

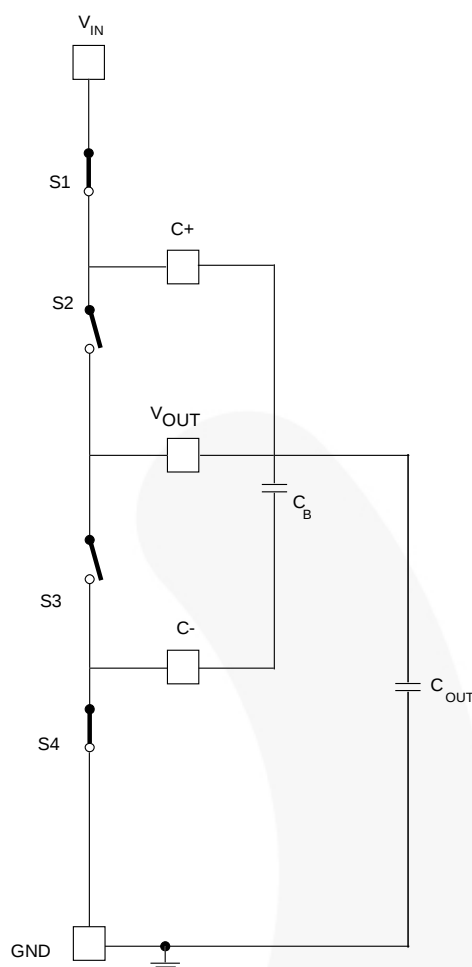
The soft-start feature limits inrush current when the device is initially powered up and enabled. The reference voltage is used to control the rate of the output voltage ramp-up to its final value. Typical start-up time is 1ms. Since the rate of the output voltage ramp-up is controlled by an internally generated slow ramp, pulse-skipping occurs and inrush current is automatically limited.

## Switch Configuration



2:1 configuration  
Switches in charging phase  
Reverse all switches for pumping phase

Figure 15. 2:1 Configuration



1:1 configuration  
Switch 3 is always off  
Switch 4 is always on  
Switches 1 and 2 are in phase 1  
Reverse position of switches 1&2 for phase 2

Figure 16. 1:1 Configuration

## Shutdown, UVLO, Short-Circuit, Current-Limit and Thermal Shutdown

The device has an active-low shutdown pin to decrease supply current to less than  $1\mu\text{A}$ . In shutdown mode, the supply is disconnected from the output. UVLO triggers when supply voltage drops below 2V. When the output voltage is lower than 150mV, a short-circuit protection is triggered. In this mode, 15 out of 16 pulses during the switching are skipped and the supply current is limited. Thermal shutdown triggers at  $150^\circ\text{C}$ .

## Efficiency Optimizer (FAN5632)

In the FAN5632,  $V_{\text{SEL}}$  can be tied to ground to enable the efficiency optimizer feature. To achieve an optimized efficiency, the switch mode configuration transition point is shifted from a 2:1 to a 1:1 mode until the output voltage falls to 20% of its nominal value. For example, when the nominal output voltage is 1.5V, the output voltage is allowed to drop to 1.2V. This maintains a peak efficiency of 85% for the input voltage range of 2.9V to 3.5V. For normal operation, tie  $V_{\text{SEL}}$  high.

## Applications Information

The FAN5631/FAN5632 requires one ceramic bucket capacitor in the 0.1 $\mu$ F to 1 $\mu$ F range, one 10 $\mu$ F output bypass capacitor, and one 10 $\mu$ F input bypass capacitor. To obtain optimum output ripple and noise performance, low-ESR ( $<0.05\Omega$ ) ceramic input and output bypass capacitors are recommended. X5R- and X7R-rated capacitors provide adequate performance over the -40°C to 85°C temperature range.

The bucket capacitor's value is dependent on load current requirements. A 1 $\mu$ F bucket capacitor works well in all applications at all load currents, while a 0.1 $\mu$ F capacitor supports most applications under 100mA of load current. The choice of bucket capacitor values should be verified in the actual application at the lowest input voltage and highest load current. A 30% margin of safety is recommended to account for the tolerance of the bucket capacitor and the variations in the on-resistance of the internal switches.

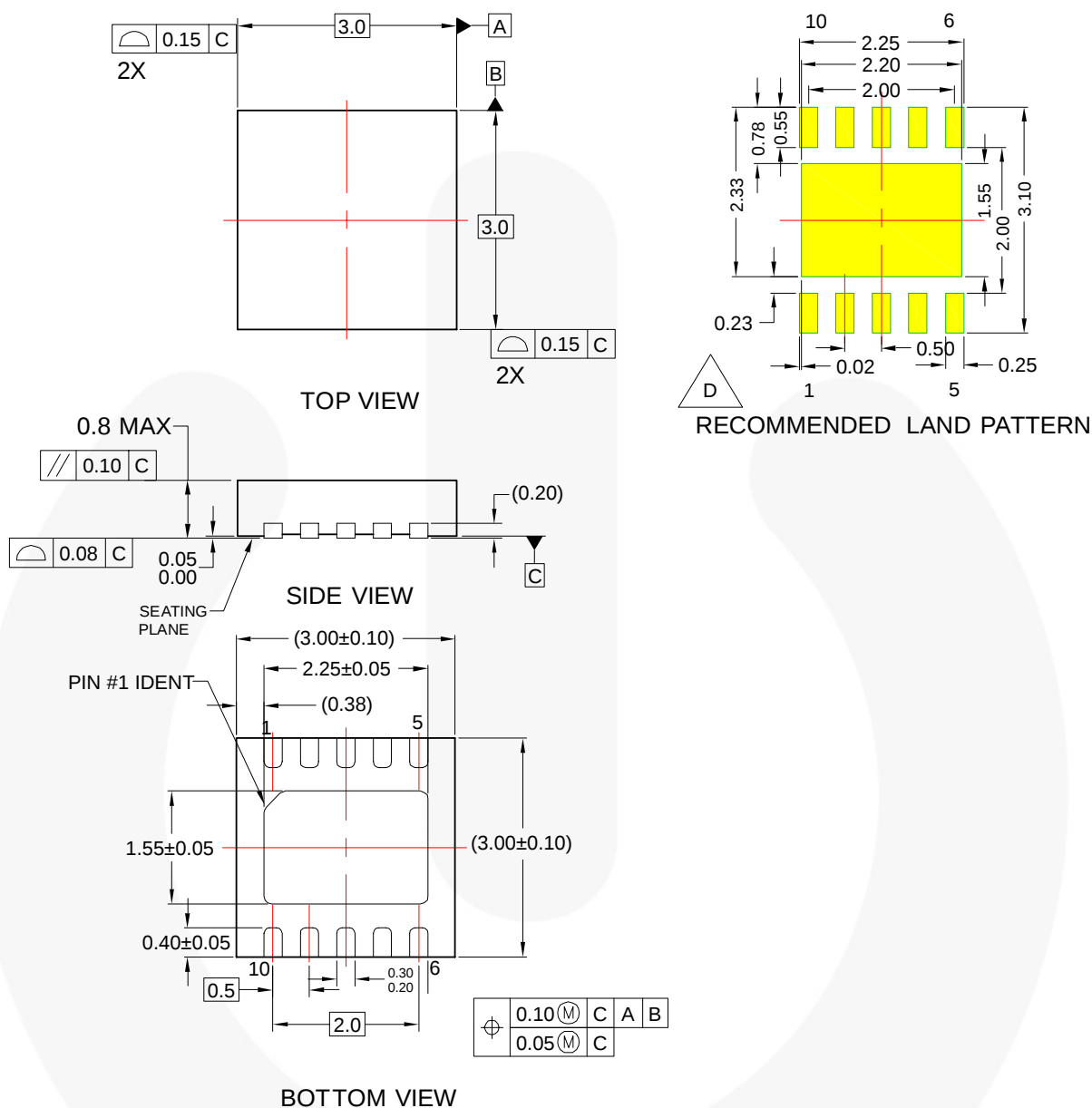
One of the key benefits of the ScalarPump architecture is that the dynamically scaled on resistance of the switches effectively reduces the peak current in the

bucket capacitor and therefore input and output ripple currents are also reduced. Nevertheless, due to the ESR of the input and output bypass capacitors, these current spikes generate voltage spikes at the input and output pins. These ESR spikes can be filtered because their frequencies lie at up to 12 times the clock frequencies. In applications where conductive and radiated EMI/RFI interference must be low as possible, consider additional input and output filtering.

## Layout Considerations

While evaluating any switched capacitor DC-DC converter, be careful to keep the power supply source impedance low; use of long wires causing high lead inductances and resistive losses should be avoided. A carefully laid-out ground plane is essential because current spikes are generated as the bucket capacitor is charged and discharged. The input and output bypass capacitors should be placed as close to the device pins as possible.

## Physical Dimensions



## NOTES:

- A. CONFORMS TO JEDEC REGISTRATION MO-229, VARIATION WEED-5
- B. DIMENSIONS ARE IN MILLIMETERS.
- C. DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994
- D. LAND PATTERN DIMENSIONS ARE NOMINAL REFERENCE VALUES ONLY

MLP10BrevA

Figure 17. 10-lead, Molded Leadless Package (MLP)



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| FPS <sup>™</sup>                     | ®                                            | SuperSOT <sup>™</sup> -3               | UniFET <sup>™</sup>              |
| FRFET <sup>®</sup>                   | PDP-SPM <sup>™</sup>                         | SuperSOT <sup>™</sup> -6               | VCX <sup>™</sup>                 |
| Global Power Resource <sup>SM</sup>  | Power220 <sup>®</sup>                        |                                        |                                  |

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As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury of the user.
2. A critical component in any component of a life support, device, or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

## PRODUCT STATUS DEFINITIONS

### Definition of Terms

| Datasheet Identification | Product Status         | Definition                                                                                                                                                                                               |
|--------------------------|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Advance Information      | Formative or In Design | This datasheet contains the design specifications for product development. Specifications may change in any manner without notice.                                                                       |
| Preliminary              | First Production       | This datasheet contains preliminary data; supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve design. |
| No Identification Needed | Full Production        | This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve design.                                                   |
| Obsolete                 | Not In Production      | This datasheet contains specifications on a product that has been discontinued by Fairchild Semiconductor. The datasheet is printed for reference information only.                                      |

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