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# FAN6604

## Highly Integrated Green-Mode PWM Controller

### Features

- High-Voltage Startup
- AC Input Brownout Protection with Hysteresis
- Line Compensation by Current Limit
- Low Operating Current: 1.5 mA
- Linearly Decreasing PWM Frequency to 22 kHz with Cycle Skipping
- Frequency Hopping to Reduce EMI Emission
- Fixed PWM Frequency: 65 kHz
- Peak-Current-Mode Control
- Cycle-by-Cycle Current Limiting
- Leading-Edge Blanking (LEB)
- Internal Open-Loop Protection
- GATE Output Maximum Voltage Clamp: 13 V
- $V_{DD}$  Under-Voltage Lockout (UVLO)
- $V_{DD}$  Over-Voltage Protection (OVP)
- Programmable Over-Temperature Protection (OTP)
- Internal Latch Circuit (OVP, OTP)
- Open-Loop Protection (OLP); Restart for FAN6604MRMX, Latch for FAN6604MLMX
- SENSE Short-Circuit Protection (SSCP)
- Built-in 8 ms Soft-Start Function

### Applications

General-purpose switch-mode power supplies (SMPS) and flyback power converters, including:

- Power Adapters

### Description

The highly integrated FAN6604 PWM controller provides several features to enhance the performance of flyback converters. To minimize standby power consumption, a proprietary Green-Mode function provides off-time modulation to continuously decrease the switching frequency under light-load conditions.

Under zero-load and very light-load conditions, FAN6604 saves PWM pulses by entering "deep" Burst Mode. Burst Mode enables the power supply to meet international power conservation requirements.

FAN6604 also integrates a frequency-hopping function that helps reduce EMI emission of a power supply with minimum line filters. The built-in synchronized slope compensation helps achieve stable peak-current control. Add in current limit to keep constant output power over universal AC input range. The gate output is clamped at 13 V to protect the external MOSFET from over-voltage damage.

Other protection functions include AC input brownout protection with hysteresis, sense pin short-circuit protection, and  $V_{DD}$  over-voltage protection. For over-temperature protection, an external NTC thermistor can be applied to sense the external switcher's temperature. When  $V_{DD}$  OVP or OTP are activated, an internal latch circuit is used to latch-off the controller. The Latch Mode is reset when the  $V_{DD}$  supply is removed.

FAN6604 is available in an 8-pin SOP package.

### Ordering Information

| Part Number | Operating Temperature Range | Package                            | Packing Method |
|-------------|-----------------------------|------------------------------------|----------------|
| FAN6604MRMX | -40 to +105°C               | 8-Pin, Small Outline Package (SOP) | Tape & Reel    |
| FAN6604MLMX |                             |                                    |                |

## Application Diagram

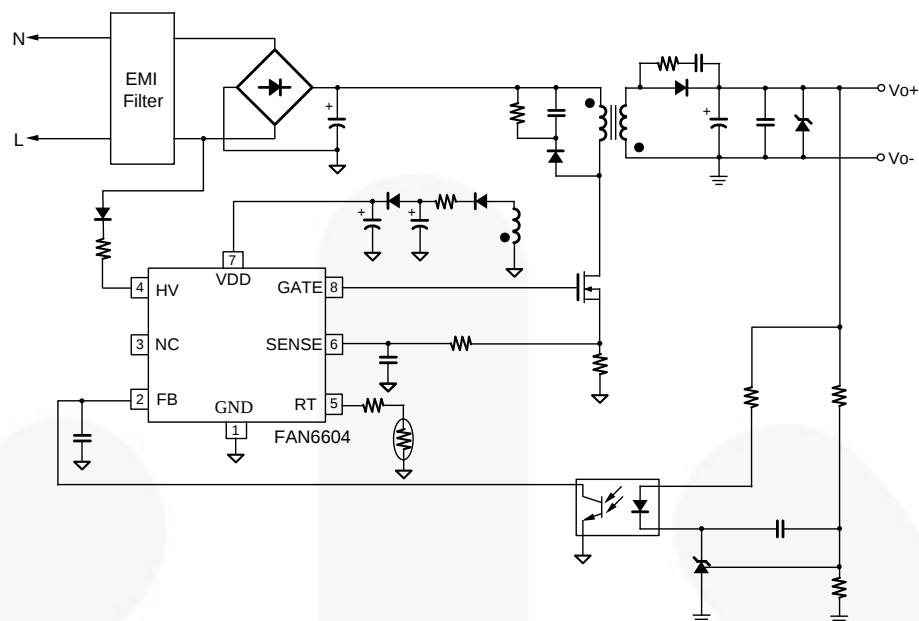


Figure 1. Typical Application

## Internal Block Diagram

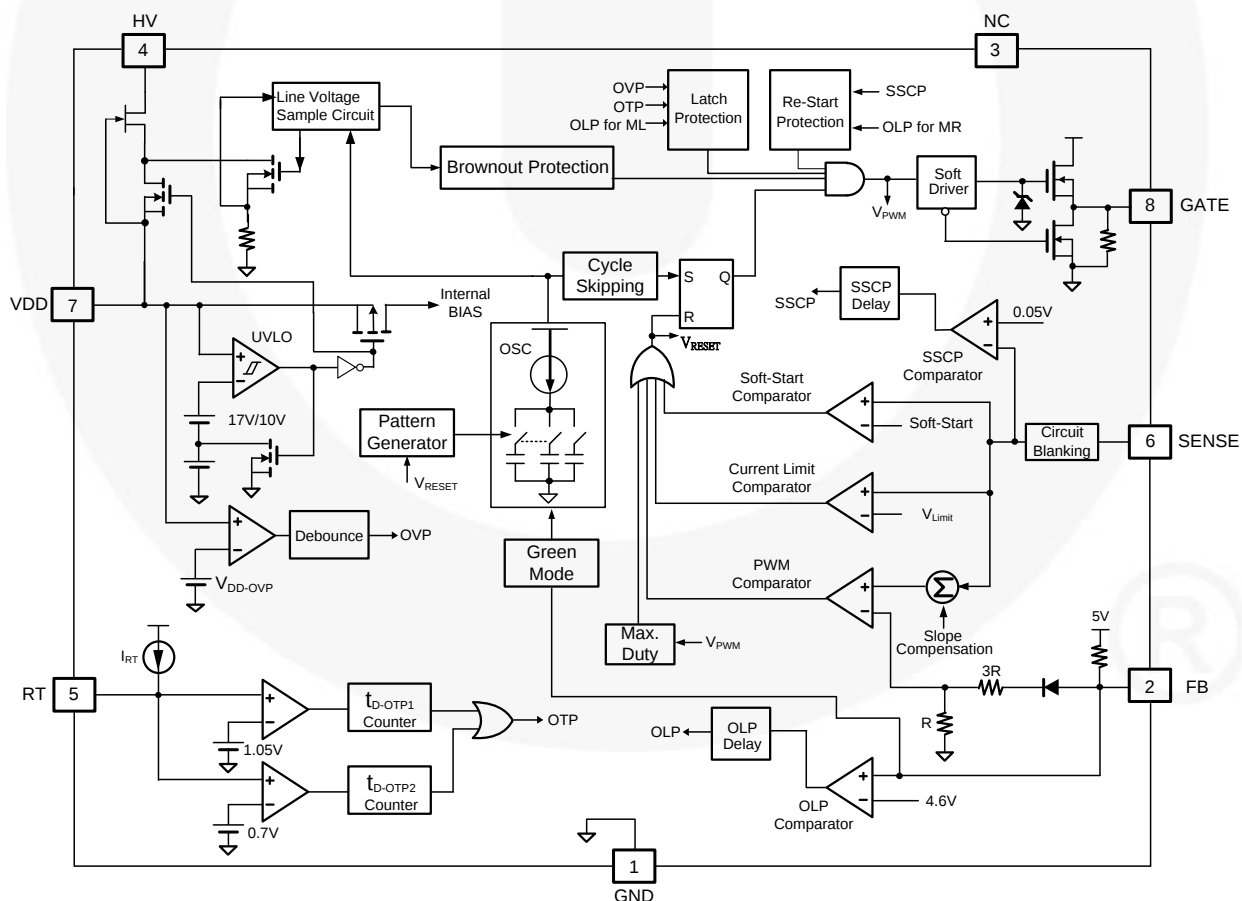


Figure 2. Functional Block Diagram

## Marking Information

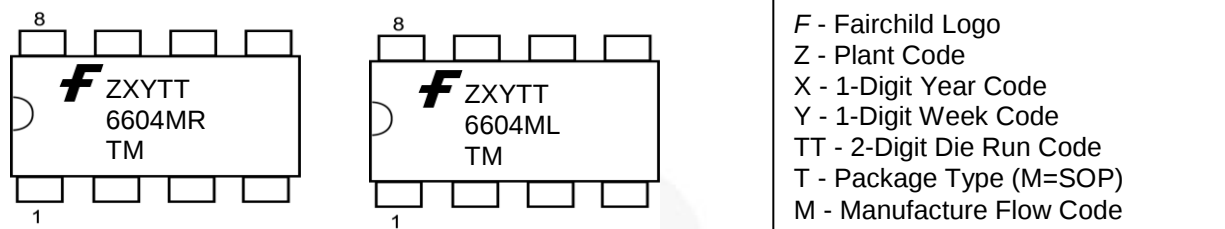


Figure 3. Top Mark

## Pin Configuration

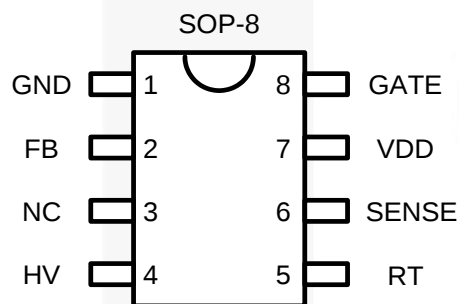


Figure 4. Pin Configuration (Top View)

## Pin Definitions

| Pin # | Name  | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | GND   | <b>Ground.</b> This pin is used for the ground potential of all the pins. A 0.1 $\mu$ F decoupling capacitor placed between VDD and GND is recommended.                                                                                                                                                                                                                                                                                                                           |
| 2     | FB    | <b>Feedback.</b> The output voltage feedback information from the external compensation circuit is fed into this pin. The PWM duty cycle is determined by this pin and the current-sense signal from Pin 6. FAN6604 performs open-loop protection (OLP); if the FB voltage is higher than a threshold voltage (around 4.6 V) for more than 56 ms, the controller latches off the PWM.                                                                                             |
| 3     | NC    | <b>No Connection</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 4     | HV    | <b>High-Voltage Startup.</b> This pin is connected to the line input via a 1N4007 and 200 k $\Omega$ resistor to achieve brownout. Once the voltage on the HV pin is lower than the brownout voltage, PWM output turns off.                                                                                                                                                                                                                                                       |
| 5     | RT    | <b>Over-Temperature Protection.</b> An external NTC thermistor is connected from this pin to GND. The impedance of the NTC decreases at high temperatures. Once the voltage on the RT pin drops below the threshold voltage, the controller latches off the PWM. If RT pin is not connected to an NTC resistor for Over-Temperature Protection, a 100 k $\Omega$ resistor is recommend to connect the RT pin to the GND pin. This pin is limited by an internal clamping circuit. |
| 6     | SENSE | <b>Current Sense.</b> This pin is used to sense the MOSFET current for the current-mode PWM and current limiting. To achieve high/low line compensation, current limit is built-in.                                                                                                                                                                                                                                                                                               |
| 7     | VDD   | <b>Supply Voltage.</b> IC operating current and MOSFET driving current are supplied using this pin. This pin is connected to an external bulk capacitor of typically 47 $\mu$ F. The threshold voltages for turn-on and turn-off are 17 V and 10 V, respectively. The operating current is lower than 2 mA.                                                                                                                                                                       |
| 8     | GATE  | <b>Gate Drive Output.</b> The totem-pole output driver for the power MOSFET. It is internally clamped below 13 V.                                                                                                                                                                                                                                                                                                                                                                 |

## 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 <sub>VDD</sub>   | DC Supply Voltage <sup>(1,2)</sup>                            |                                      |      | 30   | V    |
| V <sub>FB</sub>    | FB Pin Input Voltage                                          |                                      | -0.3 | 6.0  | V    |
| V <sub>SENSE</sub> | SENSE Pin Input Voltage                                       |                                      | -0.3 | 6.0  | V    |
| V <sub>RT</sub>    | RT Pin Input Voltage                                          |                                      | -0.3 | 6.0  | V    |
| V <sub>HV</sub>    | HV Pin Input Voltage                                          |                                      |      | 500  | V    |
| P <sub>D</sub>     | Power Dissipation (T <sub>A</sub> < 50°C)                     |                                      |      | 400  | mW   |
| Θ <sub>JA</sub>    | Thermal Resistance (Junction-to-Air)                          |                                      |      | 150  | °C/W |
| T <sub>J</sub>     | Operating Junction Temperature                                |                                      | -40  | +125 | °C   |
| T <sub>STG</sub>   | Storage Temperature Range                                     |                                      | -55  | +150 | °C   |
| T <sub>L</sub>     | Lead Temperature (Wave Soldering or IR, 10 Seconds)           |                                      |      | +260 | °C   |
| ESD                | Electrostatic Discharge Capability,<br>All Pins Except HV Pin | Human Body Model;<br>JESD22-A114     |      | 5000 | V    |
|                    |                                                               | Charged Device Model;<br>JESD22-C101 |      | 2000 |      |

### Notes:

1. All voltage values, except differential voltages, are given with respect to the network ground terminal.
2. Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device.
3. ESD with HV pin: CDM=1000 V and HBM=1000 V.

## 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 |
|-----------------|---------------------|------|------|------|------|
| R <sub>HV</sub> | HV Startup Resistor | 150  | 200  | 250  | kΩ   |

## Electrical Characteristics

$V_{DD}=11\sim 24\text{ V}$  and  $T_A=-40\sim 105^\circ\text{C}$  unless otherwise noted.

| Symbol                        | Parameter                                                                    | Condition                                                                                    | Min.               | Typ.               | Max.               | Unit          |
|-------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|--------------------|--------------------|--------------------|---------------|
| <b>V<sub>DD</sub> Section</b> |                                                                              |                                                                                              |                    |                    |                    |               |
| $V_{OP}$                      | Continuously Operating Voltage                                               |                                                                                              |                    |                    | 24                 | V             |
| $V_{DD-ON}$                   | Start Threshold Voltage                                                      |                                                                                              | 16                 | 17                 | 18                 | V             |
| $V_{DD-OFF}$                  | Minimum Operating Voltage                                                    |                                                                                              | 9                  | 10                 | 11                 | V             |
| $V_{DD-OLP}$                  | $I_{DD-OLP}$ Off Voltage                                                     |                                                                                              | 5                  | 6.5                | 8                  | V             |
| $V_{DD-LH}$                   | Threshold Voltage on VDD Pin for Latch-Off Release Voltage                   |                                                                                              | 3.5                | 4.0                | 4.5                | V             |
| $V_{DD-AC}$                   | Threshold Voltage on VDD Pin for Disable AC Recovery to Avoid Startup Failed |                                                                                              | $V_{DD-OFF} + 2.8$ | $V_{DD-OFF} + 3.3$ | $V_{DD-OFF} + 3.8$ | V             |
| $I_{DD-ST}$                   | Startup Current                                                              | $V_{DD-ON} - 0.16\text{ V}$                                                                  |                    |                    | 30                 | $\mu\text{A}$ |
| $I_{DD-OP1}$                  | Operating Supply Current, PWM Operation                                      | $V_{DD}=20\text{ V}$ , $FB=3\text{ V}$ Gate Open                                             |                    | 1.5                | 2.0                | mA            |
| $I_{DD-OP2}$                  | Operating Supply Current, Gate Stop                                          | $V_{DD}=20\text{ V}$ , $FB=3\text{ V}$                                                       |                    | 1.0                | 1.5                | mA            |
| $I_{LH}$                      | Operating Current at PWM-Off Phase Under Latch-Off Conduction                | $V_{DD}=5\text{ V}$                                                                          | 30                 | 60                 | 90                 | $\mu\text{A}$ |
| $I_{DD-OLP}$                  | Internal Sink Current Under Latch-Off Conduction                             | $V_{DD-OLP}+0.1\text{ V}$ , $T_A=25^\circ\text{C}$                                           | 150                | 180                | 210                | $\mu\text{A}$ |
| $V_{DD-OVP}$                  | $V_{DD}$ Over-Voltage Protection                                             |                                                                                              | 24                 | 25                 | 26                 | V             |
| $t_{D-VDDOVP}$                | $V_{DD}$ Over-Voltage Protection Debounce Time                               |                                                                                              | 90                 | 180                | 270                | $\mu\text{s}$ |
| <b>HV Section</b>             |                                                                              |                                                                                              |                    |                    |                    |               |
| $I_{HV}$                      | Supply Current from HV Pin                                                   | $V_{AC}=90\text{ V}$ ( $V_{DC}=120\text{ V}$ ), $V_{DD}=0\text{ V}$ , $T_A=25^\circ\text{C}$ | 2.0                | 3.5                | 5.0                | mA            |
| $I_{HV-LC}$                   | Leakage Current after Startup                                                | $HV=500\text{ V}$ , $V_{DD}=V_{DD-OFF}+1\text{ V}$                                           |                    | 1                  | 20                 | $\mu\text{A}$ |
| $V_{AC-OFF}$                  | Brownout Threshold                                                           | DC Source Series $R=200\text{ k}\Omega$ to HV Pin<br>See Equation (1)                        | 92                 | 102                | 112                | V             |
| $V_{AC-ON}$                   | Brown-In Threshold                                                           | DC Source Series $R=200\text{ k}\Omega$ to HV Pin<br>See Equation (2)                        | 104                | 114                | 124                | V             |
| $\Delta V_{AC}$               | $V_{AC-ON} - V_{AC-OFF}$                                                     | DC Source Series $R=200\text{ k}\Omega$ to HV Pin                                            | 6                  | 12                 | 18                 | V             |
| $t_{S-CYCLE}$                 | Line Voltage Sample Cycle <sup>(4)</sup>                                     | $FB > V_{FB-N}$                                                                              |                    | 220                |                    | $\mu\text{s}$ |
|                               |                                                                              | $FB < V_{FB-G}$                                                                              |                    | 650                |                    |               |
| $t_{H-TIME}$                  | Line Voltage Hold Period <sup>(4)</sup>                                      |                                                                                              |                    | 20                 |                    | $\mu\text{s}$ |
| $t_{D-AC-OFF}$                | PWM Turn-off Debounce Time                                                   | $FB > V_{FB-N}$                                                                              | 58                 | 70                 | 82                 | ms            |
|                               |                                                                              | $FB < V_{FB-G}$                                                                              | 150                | 200                | 250                | ms            |

**Note:**

4. Guaranteed by design.

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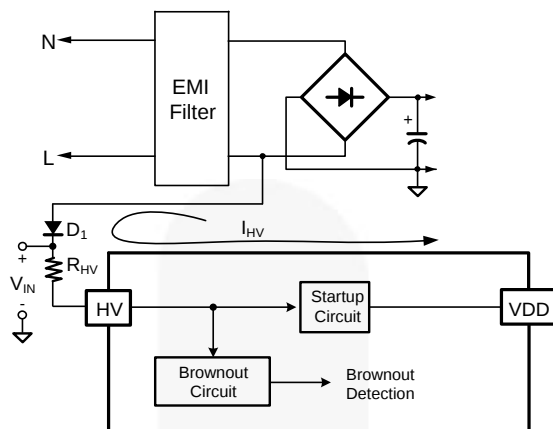


Figure 5. Brownout Circuit

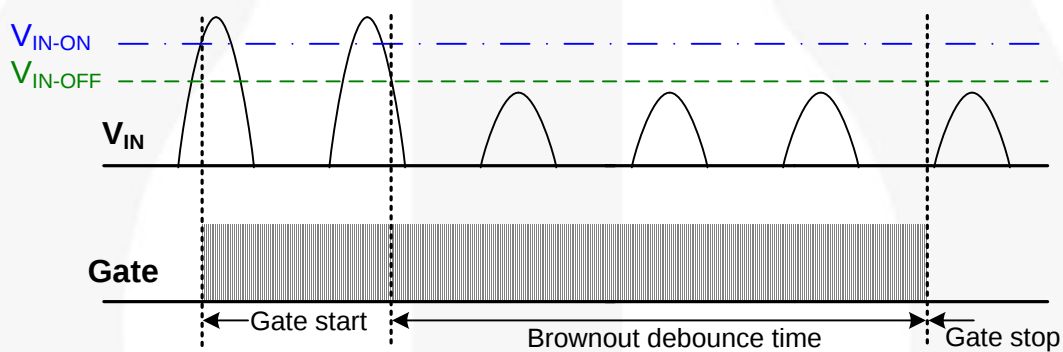


Figure 6. Brownout Behavior

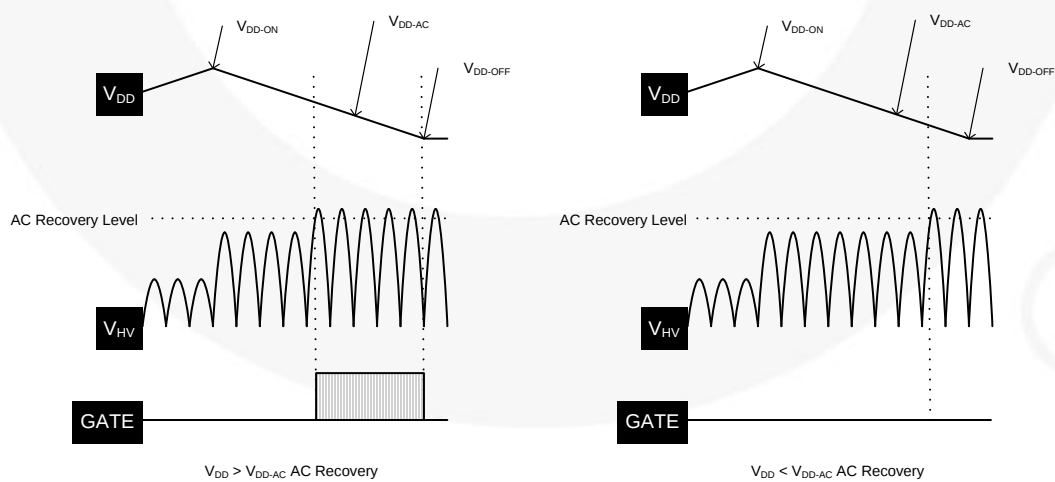


Figure 7.  $V_{DD-AC}$  and AC Recovery

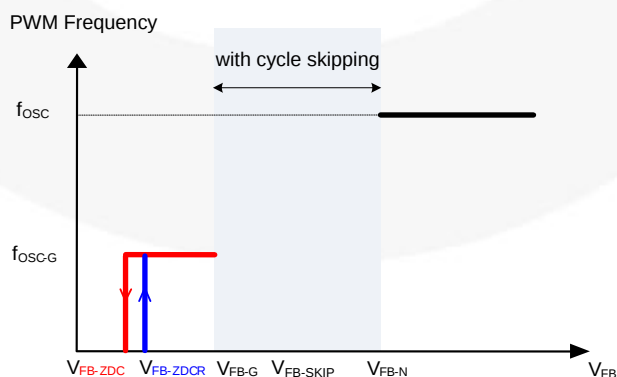
**Electrical Characteristics** (Continued)V<sub>DD</sub>=11~24 V and T<sub>A</sub>=-40~105°C unless otherwise noted.

| Symbol                        | Parameter                                                            | Conditions                                                    | Min.  | Typ.  | Max.  | Unit |
|-------------------------------|----------------------------------------------------------------------|---------------------------------------------------------------|-------|-------|-------|------|
| <b>Oscillator Section</b>     |                                                                      |                                                               |       |       |       |      |
| f <sub>OSC</sub>              | Frequency in Normal Mode                                             | Center Frequency, T <sub>A</sub> =25°C                        | 61    | 65    | 69    | kHz  |
|                               |                                                                      | Hopping Range                                                 | ±3.7  | ±4.2  | ±4.7  |      |
| t <sub>HOP</sub>              | Hopping Period                                                       |                                                               | 12.0  | 13.5  | 15.0  | ms   |
| f <sub>OSC-G</sub>            | Green-Mode Frequency                                                 |                                                               | 19    | 22    | 25    | kHz  |
| f <sub>DV</sub>               | Frequency Variation vs. V <sub>DD</sub> Deviation                    | V <sub>DD</sub> =11 V to 22 V                                 |       |       | 5     | %    |
| f <sub>DT</sub>               | Frequency Variation vs. Temperature Deviation                        | T <sub>A</sub> =-40 to +105°C                                 |       |       | 5     | %    |
| <b>Feedback Input Section</b> |                                                                      |                                                               |       |       |       |      |
| A <sub>V</sub>                | Input Voltage to Current-Sense Attenuation                           |                                                               | 1/4.5 | 1/4.0 | 1/3.5 | V/V  |
| Z <sub>FB</sub>               | Input Impedance                                                      |                                                               | 13    | 15    | 17    | kΩ   |
| V <sub>FB-OPEN</sub>          | Output High Voltage                                                  | FB Pin Open                                                   | 4.8   | 5.0   | 5.2   | V    |
| V <sub>FB-OLP</sub>           | FB Open-Loop Trigger Level                                           |                                                               | 4.3   | 4.6   | 4.9   | V    |
| t <sub>D-OLP</sub>            | Delay Time of FB Pin Open-Loop Protection                            |                                                               | 50    | 57    | 64    | ms   |
| V <sub>FB-N</sub>             | Green-Mode Entry FB Voltage                                          | Pin, FB Voltage (FB=V <sub>FB-N</sub> ), T <sub>A</sub> =25°C | 2.6   | 2.8   | 3.0   | V    |
|                               |                                                                      | Hopping Range                                                 | ±3.7  | ±4.2  | ±4.7  | kHz  |
| V <sub>FB-G</sub>             | Green-Mode Ending FB Voltage                                         | Pin, FB Voltage (FB=V <sub>FB-G</sub> )                       | 2.1   | 2.3   | 2.5   | V    |
|                               |                                                                      | Hopping Range <sup>(5)</sup>                                  | ±1.27 | ±1.45 | ±1.62 | kHz  |
| V <sub>FB-SKIP</sub>          | FB Threshold Voltage for Cycle Skipping Period Divide <sup>(5)</sup> | (V <sub>FB-N</sub> +V <sub>FB-G</sub> )/2                     | 2.35  | 2.55  | 2.75  | V    |
| t <sub>SKIP-N</sub>           | Cycle Skipping Period <sup>(5)</sup>                                 | V <sub>FB-SKIP</sub> < V <sub>FB</sub> < V <sub>FB-N</sub>    | 180   | 200   | 220   | ms   |
| t <sub>SKIP-G</sub>           | Cycle Skipping Period <sup>(5)</sup>                                 | V <sub>FB-G</sub> < V <sub>FB</sub> < V <sub>FB-SKIP</sub>    | 90    | 100   | 110   | ms   |
| V <sub>FB-ZDCR</sub>          | FB Threshold Voltage for Zero-Duty Recovery                          |                                                               | 1.9   | 2.1   | 2.3   | V    |
| V <sub>FB-ZDC</sub>           | FB Threshold Voltage for Zero-Duty                                   |                                                               | 1.8   | 2.0   | 2.2   | V    |

**Note:**

5. Guaranteed by design.

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**Figure 8. V<sub>FB</sub> vs. PWM Frequency**

**Electrical Characteristics** (Continued)V<sub>DD</sub>=11~24 V and T<sub>A</sub>=-40~105°C unless otherwise noted.

| Symbol                   | Parameter                                            | Conditions                                                                          | Min.  | Typ.  | Max.  | Unit |
|--------------------------|------------------------------------------------------|-------------------------------------------------------------------------------------|-------|-------|-------|------|
| Current-Sense Section    |                                                      |                                                                                     |       |       |       |      |
| t <sub>PD</sub>          | Delay to Output                                      |                                                                                     |       | 100   | 250   | ns   |
| t <sub>LEB</sub>         | Leading-Edge Blanking Time                           |                                                                                     | 210   | 260   | 310   | ns   |
| V <sub>STHFL</sub>       | Flat Threshold Voltage for Current Limit             | Duty>62%, FB > V <sub>FB-N</sub>                                                    | 0.46  | 0.50  | 0.54  | V    |
| V <sub>STHVA</sub>       | Valley Threshold Voltage for Current Limit           | Duty=0%                                                                             | 0.31  | 0.34  | 0.37  | V    |
| V <sub>SSCP</sub>        | Threshold Voltage for Sense Short-Circuit Protection |                                                                                     | 0.03  | 0.05  | 0.07  | V    |
| t <sub>ON-SSCP</sub>     | On Time for V <sub>SSCP</sub> Checking               |                                                                                     | 3.85  | 4.40  | 4.95  | μs   |
| t <sub>D-SSCP</sub>      | Delay for Sense Short-Circuit Protection             | V <sub>SENSE</sub> <0.05 V                                                          | 60    | 120   | 180   | μs   |
| t <sub>SS</sub>          | Soft-Start Time                                      | Startup Time                                                                        | 5.5   | 7.5   | 9.5   | ms   |
| GATE Section             |                                                      |                                                                                     |       |       |       |      |
| DCY <sub>MAX</sub>       | Maximum Duty Cycle                                   |                                                                                     | 75.0  | 82.5  | 90.0  | %    |
| V <sub>GATE-L</sub>      | Gate Low Voltage                                     | V <sub>DD</sub> =15 V, I <sub>O</sub> =50 mA                                        |       |       | 1.5   | V    |
| V <sub>GATE-H</sub>      | Gate High Voltage                                    | V <sub>DD</sub> =12 V, I <sub>O</sub> =50 mA                                        | 8     |       |       | V    |
| I <sub>GATE-SINK</sub>   | Gate Sink Current <sup>(5)</sup>                     | V <sub>DD</sub> =15 V                                                               | 300   |       |       | mA   |
| I <sub>GATE-SOURCE</sub> | Gate Source Current <sup>(5)</sup>                   | V <sub>DD</sub> =15 V, GATE=6 V                                                     | 250   |       |       | mA   |
| t <sub>r</sub>           | Gate Rising Time                                     | V <sub>DD</sub> =15 V, C <sub>L</sub> =1 nF                                         |       | 100   |       | ns   |
| t <sub>f</sub>           | Gate Falling Time                                    | V <sub>DD</sub> =15 V, C <sub>L</sub> =1 nF                                         |       | 50    |       | ns   |
| V <sub>GATE-CLAMP</sub>  | Gate Output Clamping Voltage                         | V <sub>DD</sub> =22 V                                                               | 9     | 13    | 17    | V    |
| RT Section               |                                                      |                                                                                     |       |       |       |      |
| I <sub>RT</sub>          | Output Current from RT Pin                           |                                                                                     | 92    | 100   | 108   | μA   |
| V <sub>RTTH1</sub>       | Over-Temperature Protection Threshold Voltage        | 0.7 V < V <sub>RT</sub> < 1.05 V, after 12 ms Latch Off                             | 1.000 | 1.035 | 1.070 | V    |
| V <sub>RTTH2</sub>       |                                                      | V <sub>RT</sub> < 0.7 V, After 100 μs Latch Off                                     | 0.65  | 0.70  | 0.75  |      |
| t <sub>D-OTP1</sub>      | Over-Temperature Latch-Off Debounce                  | V <sub>RTTH2</sub> < V <sub>RT</sub> < V <sub>RTTH1</sub><br>FB > V <sub>FB-N</sub> | 12    | 16    | 20    | ms   |
|                          |                                                      | V <sub>RTTH2</sub> < V <sub>RT</sub> < V <sub>RTTH1</sub><br>FB < V <sub>FB-G</sub> | 35.5  | 46.5  | 57.5  |      |
| t <sub>D-OTP2</sub>      |                                                      | V <sub>RT</sub> < V <sub>RTTH2</sub> , FB > V <sub>FB-N</sub>                       | 110   | 185   | 260   | μs   |
|                          |                                                      | V <sub>RT</sub> < V <sub>RTTH2</sub> , FB < V <sub>FB-G</sub>                       | 215   | 500   | 785   |      |

**Note:**

6. Guaranteed by design.

## Typical Performance Characteristics

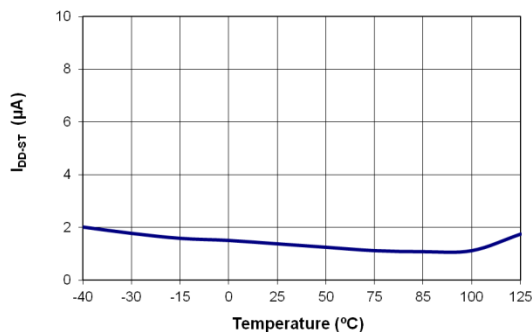


Figure 9. Startup Current ( $I_{DD-ST}$ ) vs. Temperature

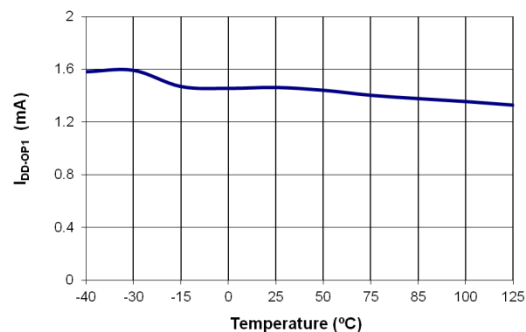


Figure 10. Operation Supply Current ( $I_{DD-OP1}$ ) vs. Temperature

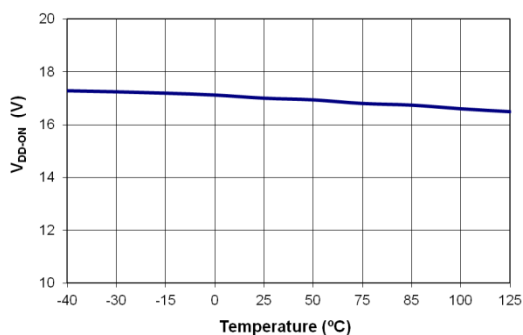


Figure 11. Start Threshold Voltage ( $V_{DD-ON}$ ) vs. Temperature

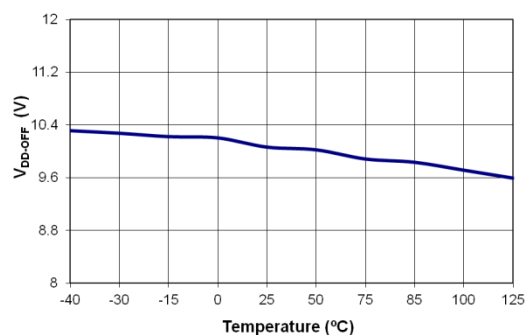


Figure 12. Minimum Operating Voltage ( $V_{DD-OFF}$ ) vs. Temperature

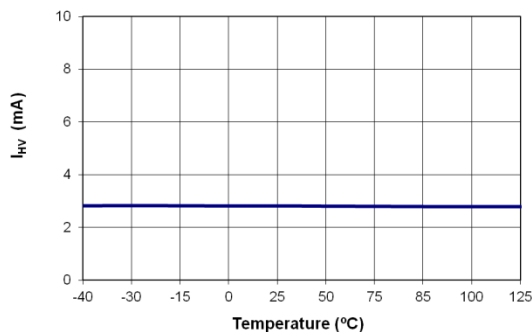


Figure 13. Supply Current Drawn from HV Pin ( $I_{HV}$ ) vs. Temperature

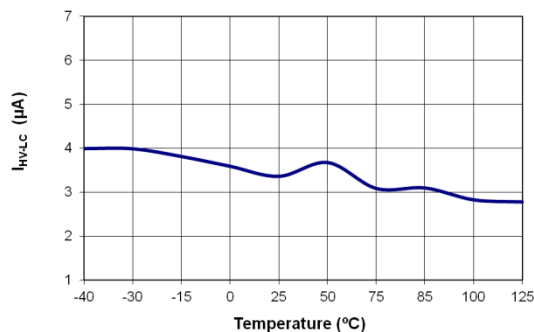


Figure 14. HV Pin Leakage Current After Startup ( $I_{HV-LC}$ ) vs. Temperature

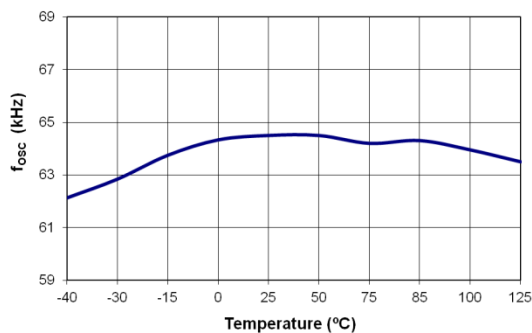


Figure 15. Frequency in Normal Mode ( $f_{osc}$ ) vs. Temperature

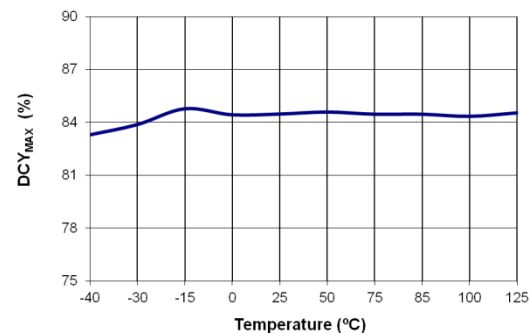
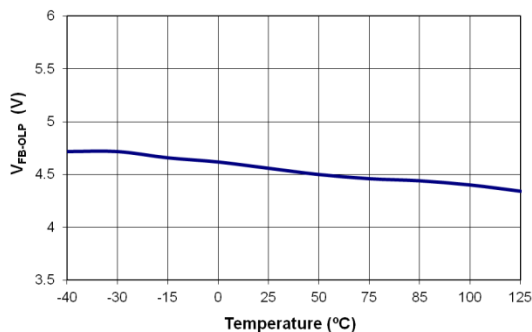
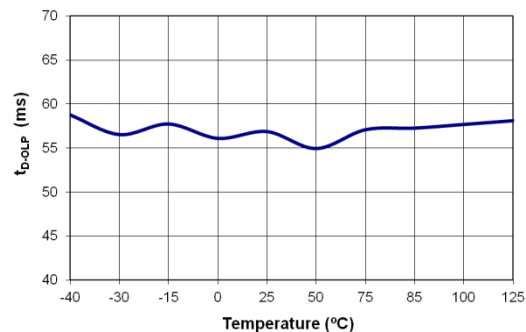
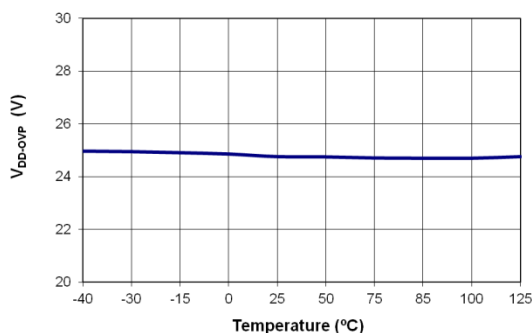
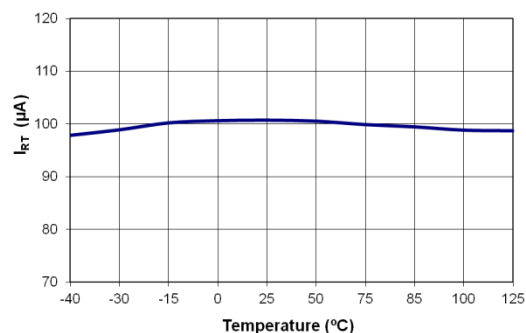
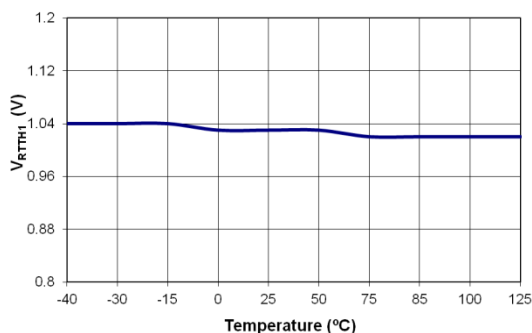
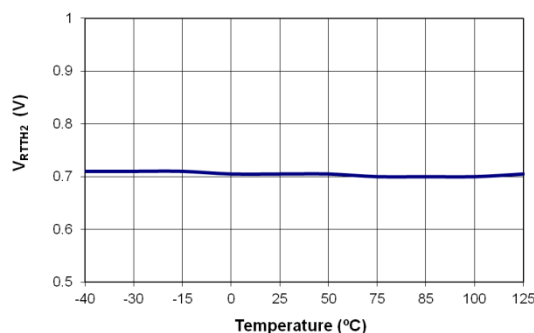
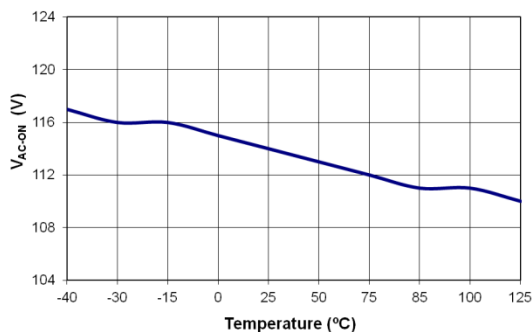
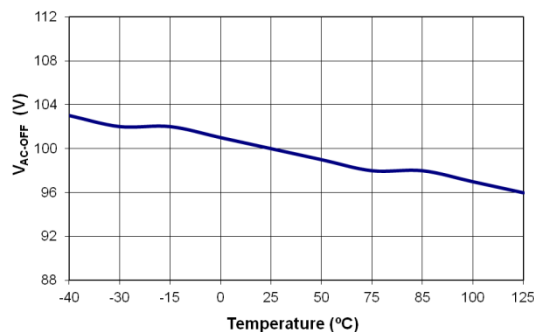


Figure 16. Maximum Duty Cycle ( $DCY_{MAX}$ ) vs. Temperature

## Typical Performance Characteristics (Continued)

Figure 17. FB Open-Loop Trigger Level ( $V_{FB-OLP}$ ) vs. TemperatureFigure 18. Delay Time of FB Pin Open-Loop Protection ( $t_{D-OLP}$ ) vs. TemperatureFigure 19.  $V_{DD}$  Over-Voltage Protection ( $V_{DD-OVP}$ ) vs. TemperatureFigure 20. Output Current from RT Pin ( $I_{RT}$ ) vs. TemperatureFigure 21. Over-Temperature Protection Threshold Voltage ( $V_{RTTH1}$ ) vs. TemperatureFigure 22. Over-Temperature Protection Threshold Voltage ( $V_{RTTH2}$ ) vs. TemperatureFigure 23. Brown-In ( $V_{AC-ON}$ ) vs. TemperatureFigure 24. Brownout ( $V_{AC-OFF}$ ) vs. Temperature

## Functional Description

### Startup Current

For startup, the HV pin is connected to the line input through an external diode and resistor;  $R_{HV}$ , (1N4007 / 200 k $\Omega$  recommended). Peak startup current drawn from the HV pin is  $(V_{AC} \times \sqrt{2}) / R_{HV}$  and charges the hold-up capacitor through the diode and resistor. When the  $V_{DD}$  capacitor level reaches  $V_{DD-ON}$ , the startup current switches off. At this moment, the  $V_{DD}$  capacitor only supplies the FAN6604 to keep the  $V_{DD}$  until the auxiliary winding of the main transformer provides the operating current.

### Operating Current

Operating current is around 1.5 mA. The low operating current enables better efficiency and reduces the requirement of  $V_{DD}$  hold-up capacitance.

### Green-Mode Operation

The proprietary Green-Mode function provides off-time modulation to reduce the switching frequency in light-load and no-load conditions.  $V_{FB}$ , which is derived from the voltage feedback loop, is taken as the reference. Once  $V_{FB}$  is lower than the threshold voltage ( $V_{FB-N}$ ), the switching frequency is continuously decreased to the minimum Green-Mode frequency of around 22 kHz with cycle skipping.

### Current Sensing / PWM Current Limiting

Peak-current-mode control is utilized to regulate output voltage and provide pulse-by-pulse current limiting. The switch current is detected by a sense resistor into the SENSE pin. The PWM duty cycle is determined by this current-sense signal and  $V_{FB}$ , the feedback voltage. When the voltage on the SENSE pin reaches around  $V_{COMP} = (V_{FB} - 0.6)/4$ , the switch cycle is terminated immediately.

### Leading-Edge Blanking (LEB)

Each time the power MOSFET is switched on, a turn-on spike occurs on the sense-resistor. To avoid premature termination of the switching pulse, a leading-edge blanking time is built in. During this blanking period, the current-limit comparator is disabled and cannot switch off the gate driver.

### Under-Voltage Lockout (UVLO)

The turn-on and turn-off thresholds are fixed internally at 17 V and 10 V, respectively. During startup, the hold-up capacitor must be charged to 17 V through the startup resistor to enable the IC. The hold-up capacitor continues to supply  $V_{DD}$  until the energy can be delivered from auxiliary winding of the main transformer.  $V_{DD}$  must not drop below 10 V during startup. This UVLO hysteresis window ensures that hold-up capacitor is adequate to supply  $V_{DD}$  during startup.

### Gate Output / Soft Driving

The BiCMOS output stage is a fast totem-pole gate driver. Cross conduction has been avoided to minimize heat dissipation, increase efficiency, and enhance reliability. The output driver is clamped by an internal 13 V Zener diode to protect power MOSFET transistors against undesirable gate over voltage. A soft driving waveform is implemented to minimize EMI.

### Soft-Start

For many applications, it is necessary to minimize the inrush current at startup. The built-in 8 ms soft-start circuit significantly reduces the startup current spike and output voltage overshoot.

### Slope Compensation

The sensed voltage across the current-sense resistor is used for peak-current-mode control and cycle-by-cycle current limiting. Built-in slope compensation improves stability and prevents sub-harmonic oscillation. FAN6604 inserts a synchronized, positive-going, ramp at every switching cycle.

### Constant Output Power Limit

When the SENSE voltage across sense resistor  $R_{SENSE}$  reaches the threshold voltage, the output GATE drive is turned off after a small delay,  $t_{PD}$ . This delay introduces an additional current proportional to  $t_{PD} \cdot V_{IN} / L_P$ . Since the delay is nearly constant, regardless of the input voltage  $V_{IN}$ , higher input voltage results in larger additional power. Therefore, the maximum output power at high line is higher than that of low line. To compensate this variation for a wide AC input range, a current limit uses to solve the unequal power-limit problem. The power limiter is fed to the inverting input of the current limiting comparator. This results in a lower current limit at high-line inputs than at low-line inputs.

### Brownout by the HV Pin

Unlike previous PWM controllers, the FAN6604 HV pin can detect the AC line voltage to perform brownout protection. Using a fast diode and startup resistor to sample the AC line voltage, the peak value refreshes and is stored in a register at each sampling cycle. When internal update time is met, this peak value is used for brownout and current-limit level judgment. Equation (1) and (2) calculate the level of brown-in or brownout converted to RMS value. For power saving, FAN6604 enlarges the sampling cycle to lower the power loss from HV sampling at light-load condition.

$$V_{AC-ON}(RMS) = (0.9V \times \frac{(R_{HV} + 1.6)}{1.6}) / \sqrt{2} \quad (1)$$

$$V_{AC-OFF}(RMS) = (0.81V \times \frac{(R_{HV} + 1.6)}{1.6}) / \sqrt{2} \quad (2)$$

where  $R_{HV}$  is in k $\Omega$ .

### V<sub>DD</sub> Over-Voltage Protection (OVP)

V<sub>DD</sub> over-voltage protection prevents damage due to abnormal conditions. If the V<sub>DD</sub> voltage exceeds the over-voltage protection level (V<sub>DD-OVP</sub>) and lasts for t<sub>D-VDDOVP</sub>, the PWM pulses are disabled and V<sub>DD</sub> begins to drop. As V<sub>DD</sub> drops to V<sub>DD-OLP</sub>, the internal HV startup circuit is activated and V<sub>DD</sub> is charged to V<sub>DD-ON</sub> to restart IC. Over-voltage conditions are usually caused by open feedback loops.

### Sense-Pin Short-Circuit Protection

The FAN6604 provides safety protection for Limited Power Source (LPS) tests. When the sense resistor is shorted by soldering during production, the pulse-by-pulse current limiting loses efficiency for the purpose of providing over-power protection for the unit. The unit may be damaged when the loading is larger than the maximum load. To protect against a short circuit across the current-sense resistor, the controller is designed to immediately shut down if a continuously low voltage (around 0.05 V/120  $\mu$ s) on the SENSE pin is detected.

### Thermal Protection

An NTC thermistor, R<sub>NTC</sub>, in series with resistor R<sub>A</sub>, can be connected from the RT pin to ground. A constant current, I<sub>RT</sub>, is output from the RT pin. The voltage on the RT pin can be expressed as  $V_{RT} = I_{RT} \cdot (R_{NTC} + R_{PTC})$ , where I<sub>RT</sub> is 100  $\mu$ A. At high ambient temperature, the R<sub>NTC</sub> is smaller and so that V<sub>RT</sub> decreased. When V<sub>RT</sub> is less than 1.035 V (V<sub>RTTH1</sub>), the PWM turns off after 16 ms (t<sub>D-OTP1</sub>). If V<sub>RT</sub> is less than 0.7 V (V<sub>RTTH2</sub>), the PWM turns off after 185  $\mu$ s (t<sub>D-OTP2</sub>). If the RT pin is not

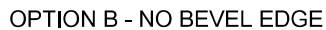
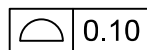
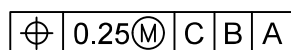
connected to NTC resistor for over-temperature protection, connecting a series one 100 k $\Omega$  resistor to ground to prevent from noise interference is recommended. This pin is limited by an internal clamping circuit.

### Limited Power Control

The FB voltage is pulled HIGH once the power supply cannot sustain the output load, such as during output-short or overload conditions. If the FB voltage remains higher than a built-in threshold for longer than t<sub>D-OLP</sub>, PWM output is turned off. As PWM output is turned off, V<sub>DD</sub> begins decreasing. When V<sub>DD</sub> goes below the turn-off threshold (10 V) the controller is totally shut down and V<sub>DD</sub> is continuously discharged to V<sub>DD-OLP</sub> (6.5 V) by I<sub>DD-OLP</sub> to lower the average input power. This is called two-level UVLO. V<sub>DD</sub> is cycled again. This protection feature continues as long as the overloading condition persists. This prevents the power supply from overheating due to overloading conditions.

### Noise Immunity

Noise on the current sense or control signal may cause significant pulse-width jitter, particularly in continuous-conduction mode. Slope compensation helps alleviate this problem. Good placement and layout practices should be followed. Avoiding long PCB traces and component leads, locating compensation and filter components near the FAN6604, and increasing the power MOS gate resistance improve performance.



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