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# AN-6754

## Design Guideline to Replace SG6742 with FAN6754

### 1. Introduction

FAN6754 is a highly integrated PWM controller featuring green mode, frequency hopping, constant power limit, and a number of protection functions. The green-mode and burst-mode functions, with a low operating current, maximize the light-load efficiency so that the power supply can meet stringent standby power regulations. The frequency hopping reduces the Electro-Magnetic Emission (EMI) by spreading the frequency spectrum. The constant power limit function minimizes the component stress in abnormal condition and helps to optimize the power stage. Protection functions; such as brownout protection, overload / open-loop protection (OLP), over-voltage protection (OVP), and over-temperature protection (OTP); are fully integrated into FAN6754, which improves the reliability of a switched mode power supply without increasing system cost. This

application note explains how to replace old-generation PWM controller SG6742 with the newer FAN6754. These two devices have the same pin configuration and replacement can be achieved without PCB layout changes. However, because functional improvements have been made to FAN6754 for higher efficiency and better performance, several external components should be changed accordingly. Table 1 summarizes the difference between these two devices. The pulse-by-pulse current limit threshold voltage is reduced almost by half to reduce the current sensing loss, which results in 0.4~0.5% efficiency improvement. The operating current is also reduced to achieve lower standby power consumption, which allows less than 100mW standby power consumption for most of the design. The typical application circuit and internal block diagram are shown in Figure 1 and Figure 2, respectively.

**Table 1. Comparison table for SG6742 and FAN6754**

	<b>SG6742</b>	<b>FAN6754</b>
<b>Brownout Protection</b>	No	Line Sensing Using HV Pin
<b>Line Voltage compensation for Pulse-by-Pulse Current Limit (<math>V_{\text{limit-L}} / V_{\text{limit-H}}</math>)</b>	Saw-Limit (0.9V/0.56V)	Adjusted by HV Pin (0.46V/0.39V)
<b>Sense Pin Short-Circuit Protection</b>	$V_{\text{SENSE}} < 0.15\text{V}$ Longer than 150 $\mu\text{s}$	No
<b>Gate Drive Clamping Voltage</b>	18V	13V
<b>FB Impedance (<math>Z_{\text{FB}}</math>)</b>	5K $\Omega$	15.5K $\Omega$
<b>Operating Current (<math>I_{\text{DD-OP}}</math>)</b>	2.7mA	1.7mA
<b>Leading Edge Blanking Time (<math>t_{\text{LEB}}</math>)</b>	150ns	280ns
<b>Soft Start</b>	5ms	8ms
<b>Maximum Duty Cycle</b>	65%	90%
<b><math>V_{\text{FB-G}} / V_{\text{FB-N}}</math> for Green Mode</b>	2.4V / 3.0V	2.3V / 2.8V
<b><math>V_{\text{ZDC}} / V_{\text{ZDCR}}</math> for Burst Mode</b>	1.6V / 1.7V	2.0V / 2.1V

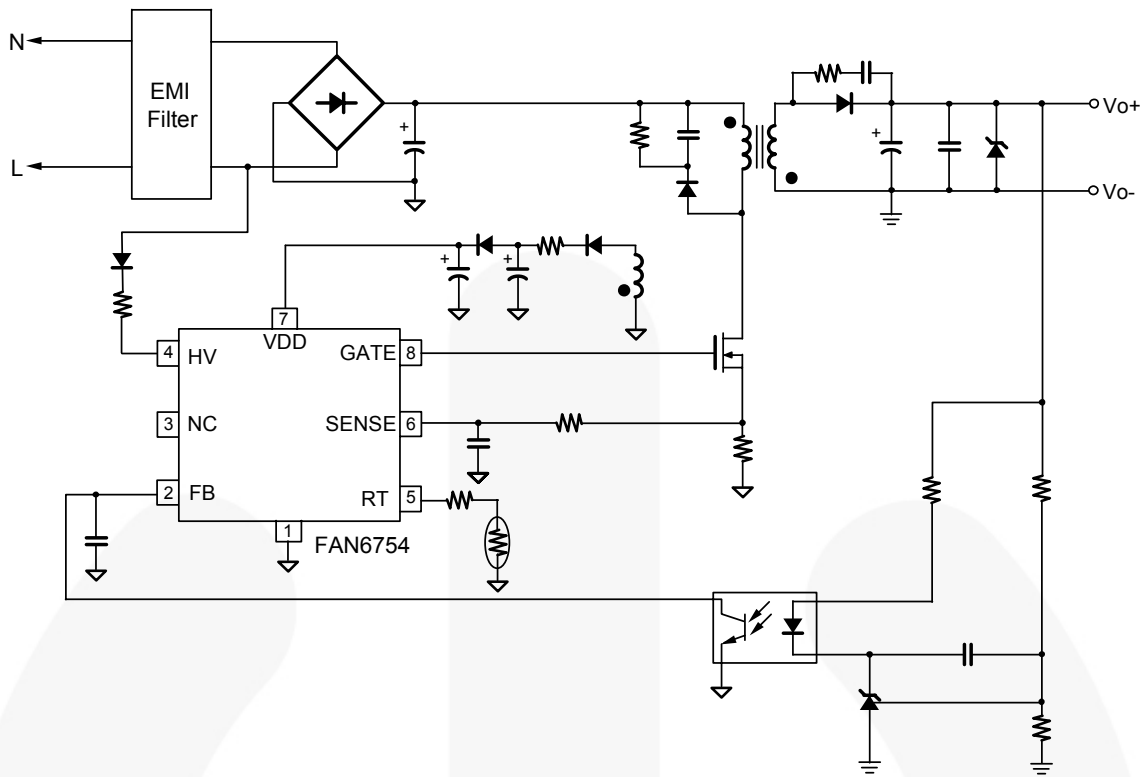


Figure 1. Typical Application

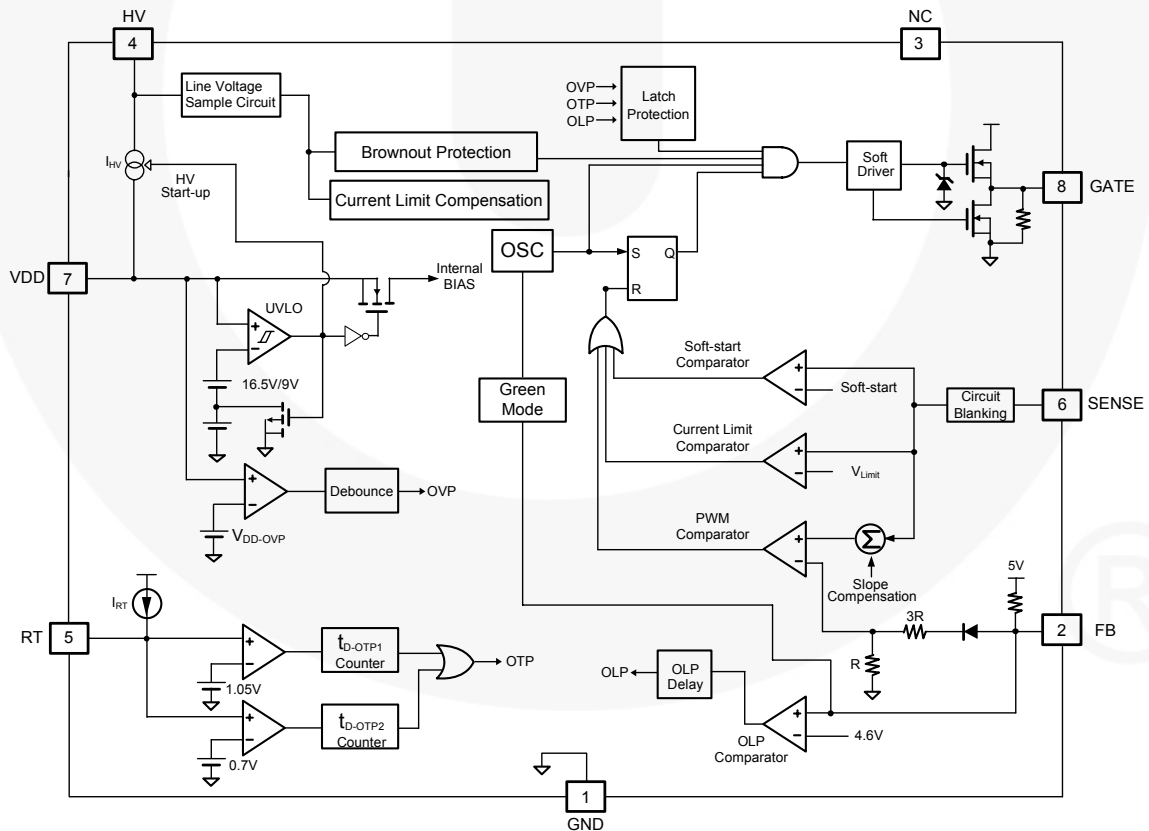


Figure 2. Internal Block Diagram

### HV Startup Circuit

Figure 3 shows the simplified schematic for the HV startup circuit. When the AC line is applied to the power supply, the internal high-voltage current source charges the hold-up capacitor,  $C_1$ , through a startup resistor,  $R_{HV}$ . As the  $V_{DD}$  pin voltage reaches the turn-on threshold,  $V_{DD-ON}$ , the PWM controller is enabled and starts normal operation. Then the high-voltage current source is switched off and the supply current is drawn from the auxiliary winding of the main transformer, as shown in Figure 3. For better line surge immunity of HV pin, it is typical to use a HV resistor larger than 150k $\Omega$ . When large capacitor is required for  $V_{DD}$ , the HV resistor limits the charging current for  $V_{DD}$  capacitor increasing the startup time. In that case, a two-stage  $V_{DD}$  capacitor circuit, as shown in Figure 3, is typically used.

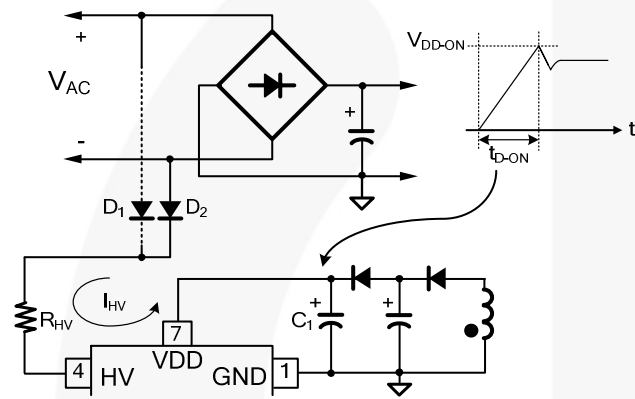


Figure 3. Startup Circuit

### Soft-Start

FAN6754 has an internal soft-start circuit that progressively increases the pulse-by-pulse current limit level as shown in Figure 4. The built-in soft-start circuit significantly reduces the input current overshoot during startup, which also minimizes output voltage overshoot.

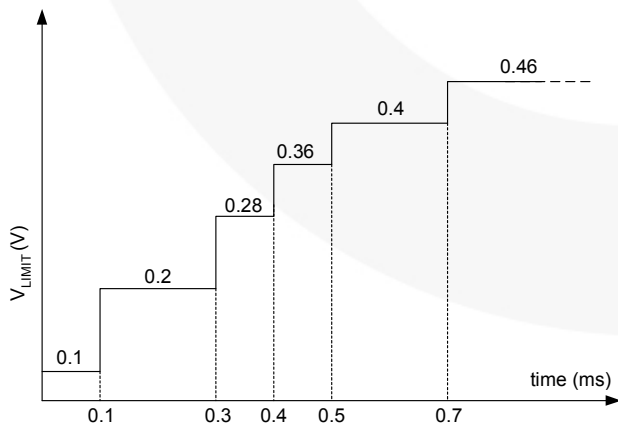


Figure 4. Pulse-by-Pulse Current Limit for Soft-Start

### Under-Voltage Lockout (UVLO)

The FAN6754 has an under-voltage lockout for  $V_{DD}$ . Figure 5 shows the turn-on ( $V_{DD-ON}$ ) and turn-off ( $V_{DD-OFF}$ ) threshold levels. It is worthwhile to notice that there is another  $V_{DD}$  turn-off level ( $V_{DD-OLP}$ ) to minimize the power dissipation of the power stage during the overload protection / open-loop protection condition by extending the  $V_{DD}$  discharge time.

If output short is overloaded or the feedback loop is opened, the FB voltage remains above  $V_{FB-OLP}$  for OLP delay time ( $t_{D-OLP}$ ) until the protection is triggered. During that time, the MOSFET drain-to-source current reaches its pulse-by-pulse current limit level for every switching cycle, causing a large amount of power dissipation to the switching devices and transformer. With the two-step UVLO mechanism, the average input power during overload or open-loop condition is greatly reduced.

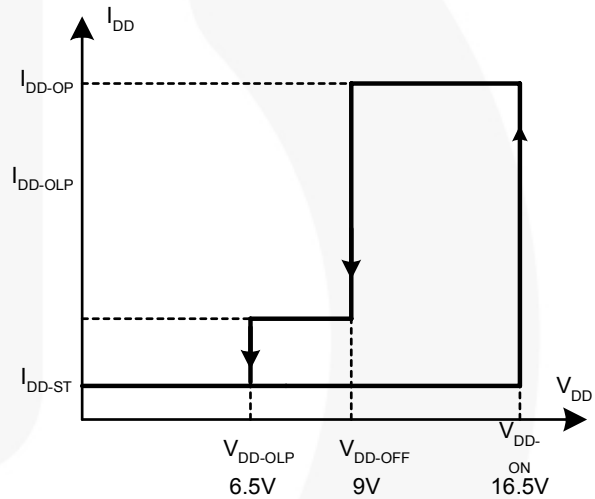


Figure 5. UVLO Specification

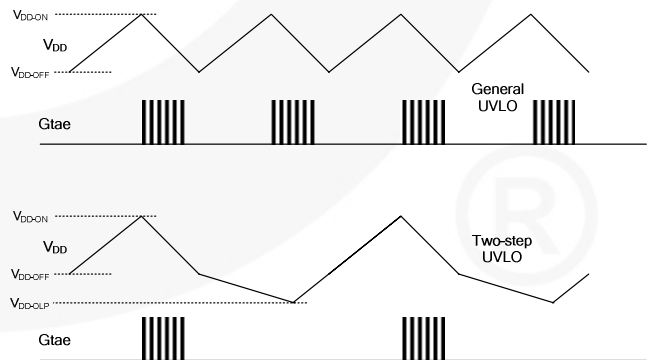


Figure 6. Two-Level UVLO

### Green-Mode Operation

The FAN6754 uses feedback voltage ( $V_{FB}$ ) as an indicator of the output load and modulates the PWM frequency, as shown in Figure 7, such that the switching frequency decreases as load decreases. In heavy load conditions, the switching frequency is 65KHz. Once  $V_{FB}$  decreases below  $V_{FB-N}$  (2.8V), the PWM frequency starts to linearly decrease from 65KHz to 22kHz to reduce the switching losses. As  $V_{FB}$  decreases below  $V_{FB-G}$  (2.3V), the switching frequency is fixed at 22kHz. As  $V_{FB}$  decreases below  $V_{FB-ZDC}$  (2.0V), FAN6754 enters burst-mode operation. When  $V_{FB}$  drops below  $V_{FB-ZDC}$ , FAN6754 stops switching and the output voltage starts to drop, which causes the feedback voltage to rise. Once  $V_{FB}$  rises above  $V_{FB-ZDCR}$ , switching resumes. Burst mode alternately enables and disables switching, thereby reducing switching loss in standby mode, as shown in Figure 8.

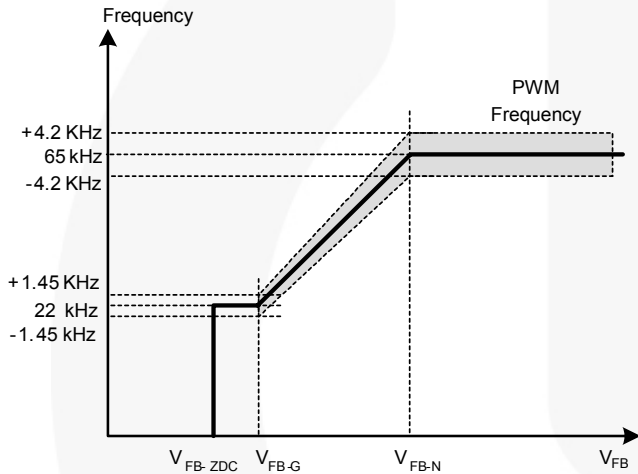


Figure 7. Frequency Modulation

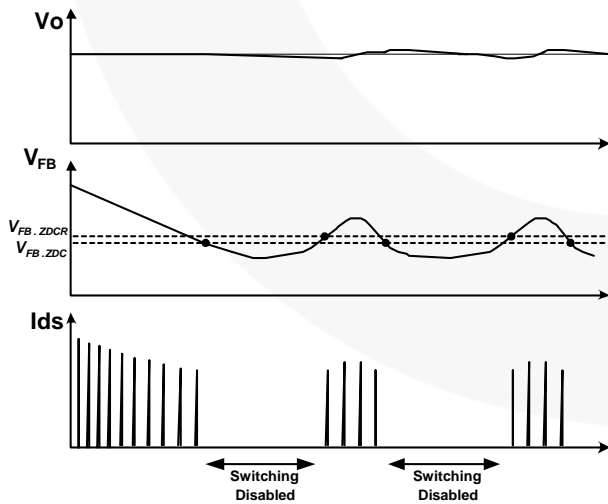


Figure 8. Burst-Mode Operation

### FB Input

The FAN6754 employs peak-current-mode control as shown in Figure 9. A current-to-voltage conversion is accomplished externally with current-sense resistor  $R_{CS}$ .

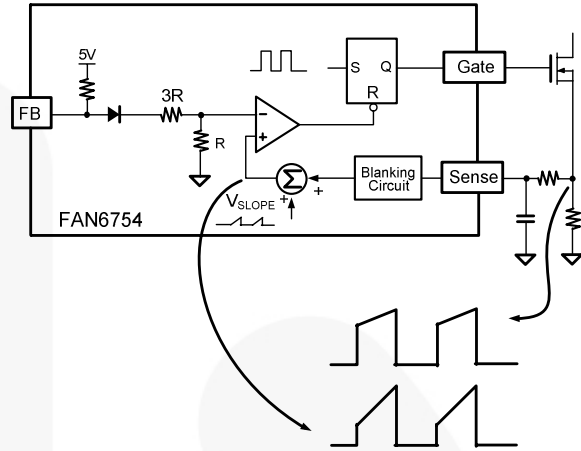


Figure 9. Synchronized Slope Compensation

Figure 10 is a typical feedback circuit, mainly consisting of a shunt regulator and an opto-coupler.  $R_1$  and  $R_2$  form a voltage divider for output voltage regulation.  $R_3$  and  $C_1$  are adjusted for control-loop compensation. A small-value RC filter (e.g.  $R_{FB}=10\Omega$ ,  $C_{FB}=1nF$ ) placed between the FB pin and GND can increase loop stability substantially.

The maximum source current of the FB pin is about  $330\mu A$  (FB through  $15.5k\Omega$  pulled to 5V reference internally). The phototransistor must be capable of sinking this current to pull the FB level down at no-load condition.  $R_b$  and internal FB pull-up resistor determine the gain feedback loop. The internal pull-up resistor in SG6742 is  $5k\Omega$ , but FAN6754 has a larger pull-up resistor ( $15k\Omega$ ) to reduce power consumption. Therefore,  $R_b$  should be three times the original value when SG6742 is replaced with FAN6754 to have to same loop gain.

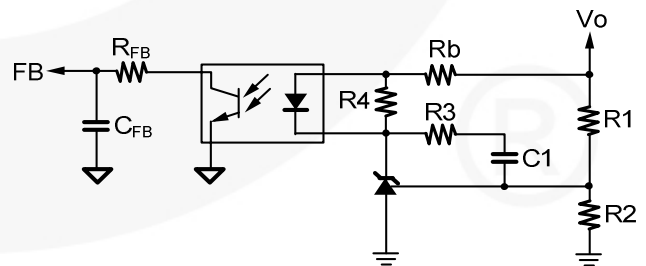


Figure 10. Feedback Circuit

### Leading-Edge Blanking (LEB)

Each time the power MOSFET is switched on, a turn-on spike occurs across the sense-resistor, caused by primary-side capacitance and secondary-side rectifier reverse recovery. To avoid premature termination of the switching pulse, a leading-edge blanking time is built in. During this blanking period (280ns), the PWM comparator is disabled and cannot switch off the gate driver. Thus, RC filter with a small RC time constant (e.g. 100Ω + 470pF) is enough for current sensing. A non-inductive resistor for  $R_S$  is recommended.

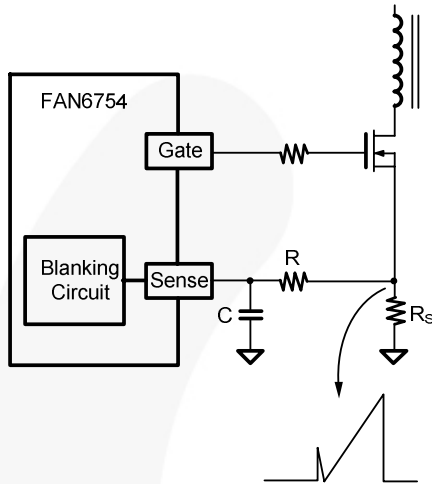


Figure 11. Turn-on Spike

### Output Driver / Soft Driving

The output stage is a fast totem-pole gate driver capable of directly driving external MOSFETs. An internal Zener diode clamps the driver voltage under 13V to protect the MOSFET gate from over voltage. By integrating circuits to control the slew rate of switch-on rising time, the external resistor  $R_G$  may not be necessary to reduce switching noise.

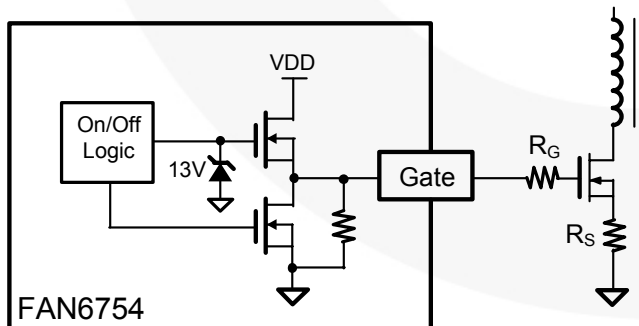


Figure 12. Gate Driver

### High/Low Line Compensation in HV Pin

The conventional pulse-by-pulse current limiting scheme has a constant threshold for current limit comparator, which results in higher power limit for high line voltage. FAN6754

has a current limit threshold that decreases as line voltage increases to makes the actual power limit level almost constant over different line voltages of universal input range, as shown in Figure 14. In the FAN6754, the peak-current limiting threshold is adjusted by the peak voltage of the HV pin. When the internal circuit samples the line voltage information, internal 1.62kΩ is connected to HV pin to scale down the line voltage by forming a voltage divider with  $R_{HV}$  and an internal resistor.

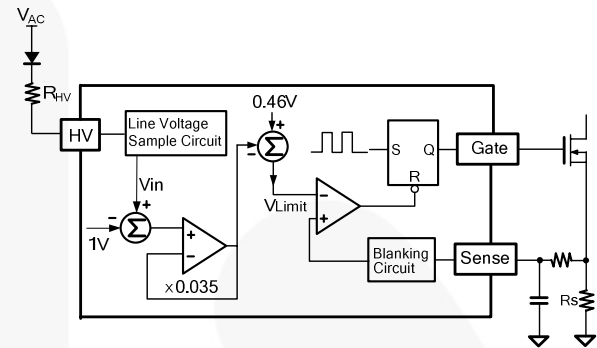


Figure 13. Universal Line Voltage Compensation for Constant Output Power Limit

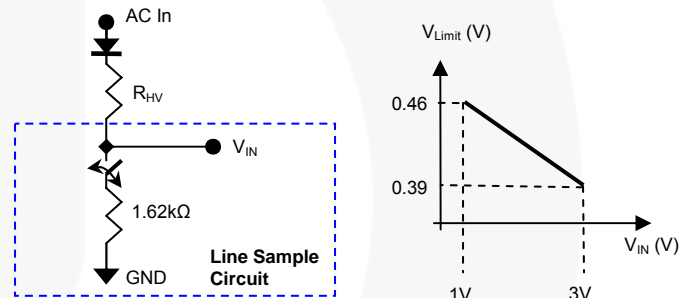


Figure 14. HV Sampling Circuit and  $V_{Limit}$  Level vs.  $V_{IN}$

### Brownout Protection in HV Pin

As shown in Figure 15, the AC line voltage is monitored by the HV pin using a resistor ( $R_{HV}$ ), a diode ( $D_1$ ), and an internal line voltage sample circuit. Figure 16 shows brownout protection behavior when the circuit uses a half-wave of AC line input ( $V_{HV}$ ) at the HV pin. When the  $V_{HV}$  is larger than the brown-in detection voltage threshold ( $V_{AC-ON}$ ) and  $V_{DD}$  is higher than  $V_{DD-AC}$ , the PWM begins to operate without any debounce time. Meanwhile, the PWM stops operating when  $V_{HV}$  is less than the detection voltage threshold ( $V_{AC-OFF}$ ) for more than debounce time.

The  $V_{AC-ON}$  and  $V_{AC-OFF}$  are calculated using below equations:

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

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

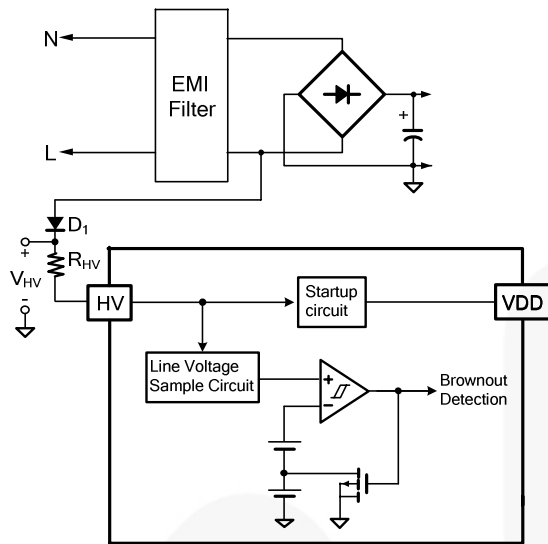


Figure 15. Brownout Circuit

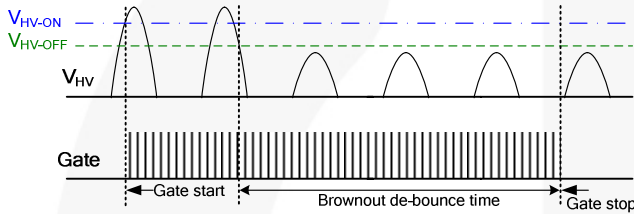


Figure 16. Brownout Protection Behavior

### Overload / Open-Loop Protection (OLP)

When output is overloaded, the drain current reaches its pulse-by-pulse current-limit level, limiting the input power. Then, the output voltage drops and no current flows through the opto-diode, which causes the feedback voltage to increase above the OLP protection threshold (4.6V). The same thing takes place when the feedback loop is open and no current flows through the opto-diode.

When the feedback voltage is higher than 4.6V for longer than the OLP delay time, the OLP protection is triggered as shown in Figure 17.

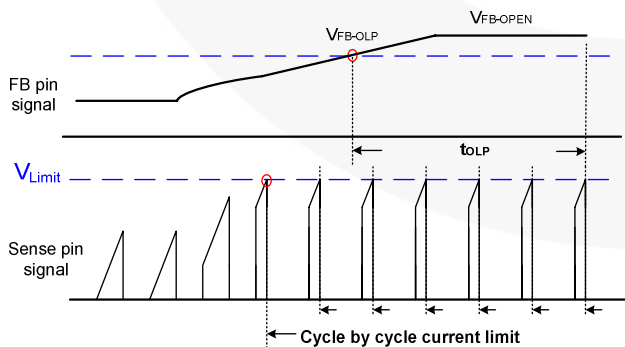


Figure 17. OLP Behavior

### V<sub>DD</sub> Over-Voltage Protection (VDD\_OVP)

V<sub>DD</sub> over-voltage protection protects the V<sub>DD</sub> pin from damage by over-voltage. The V<sub>DD</sub> voltage rises when an open-feedback loop failure occurs. Once the V<sub>DD</sub> voltage exceeds 25V (V<sub>DD-OVP</sub>) for longer than 165μs, the power supply is latched off until V<sub>DD</sub> is discharged below V<sub>DD-LH</sub>.

### Thermal Protection

A constant current source I<sub>RT</sub> (100μA) is connected to RT pin for over-temperature protection. A NTC thermistor (R<sub>NTC</sub>) in series with resistor R<sub>A</sub> is typically connected between the RT and GND pins. When V<sub>RT</sub> is less than 1.035V (V<sub>RTTH1</sub>) and larger than 0.7V, the PWM is disabled after debounce time t<sub>D-OTP-1</sub>. If V<sub>RT</sub> is less than 0.7V (V<sub>RTTH2</sub>), PWM output is latched off after a very short debounce time of t<sub>D-OTP-2</sub>. This function is used for external protection.

If the thermal protection is not used, connect a small capacitor (around 0.47nF is recommended) between the RT pin and the GND pin to prevent noise interference. The RT capacitor cannot be larger than 1nF; otherwise, the thermal protection is triggered during startup.

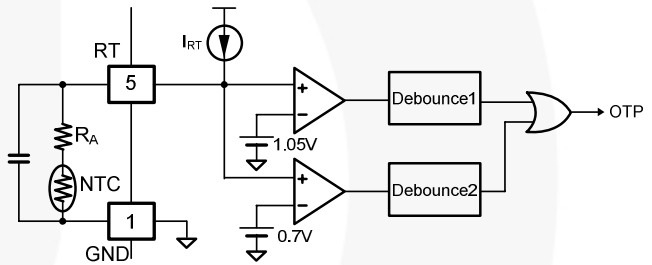


Figure 18. Thermal Protection Circuit

### Lab Note

Before rework or solder / de-solder on the power supply, discharge the bulk capacitors in the primary-side by an external bleeding resistor. Otherwise, the PWM IC may be damaged by external high voltage during solder / de-solder.

This device is sensitive to ESD discharge. To improve production yield, the production line should be ESD protected according to ANSI ESD S1.1, ESD S1.4, ESD S7.1, ESD STM 12.1, and EOS/ESD S6.1.

## Printed Circuit Board (PCB) Layout

High-frequency switching current/voltage makes PCB layout a very important design issue. Good PCB layout minimizes excessive EMI and helps the power supply survive during surge/ESD tests.

### Guidelines:

- To get better EMI performance and reduce line frequency ripples, the output of the bridge rectifier should be connected to capacitor C1 first, then to the switching circuits.
- The high-frequency current loop is in **C1 – Transformer – MOSFET –  $R_s$  – C1**. The area enclosed by this current loop should be as small as possible. Keep the traces (especially 4→1) short, direct, and wide. High-voltage traces related to the drain of MOSFET and RCD snubber should be kept far away from control circuits to prevent unnecessary interference. If a heatsink is used for the MOSFET, connect this heatsink to ground.
- As indicated by 3, the ground of control circuits should be connected first, then to other circuitry.
- As indicated by 2, the area enclosed by **transformer auxiliary winding, D1, C2, D2, and C3** should also be kept small. Place C3 close to the FAN6754 for good decoupling.

Two suggestions with different pro and cons for ground connections are offered:

- GND3 → 2 → 4 → 1**: This could avoid common impedance interference for sense signal.
- GND3 → 2 → 1 → 4**: This could be better for ESD testing where the earth ground is not available on the power supply. Regarding the ESD discharge path, the charges go from the secondary through the transformer stray capacitance to GND2 first. The charges then go from GND2 to GND1 and back to the mains. Note that control circuits should not be placed on the discharge path. Point discharge for common choke can decrease high-frequency impedance and increase ESD immunity.
- Should a Y-cap between primary and secondary be required, connect this Y-cap to the **positive terminal of C1**. If this Y-cap is connected to the primary GND, it should be connected to the **negative terminal of C1 (GND1)** directly. Point discharge of this Y-cap also helps for ESD. However, the creepage between these two pointed ends should be large enough to satisfy the requirements of applicable standards.

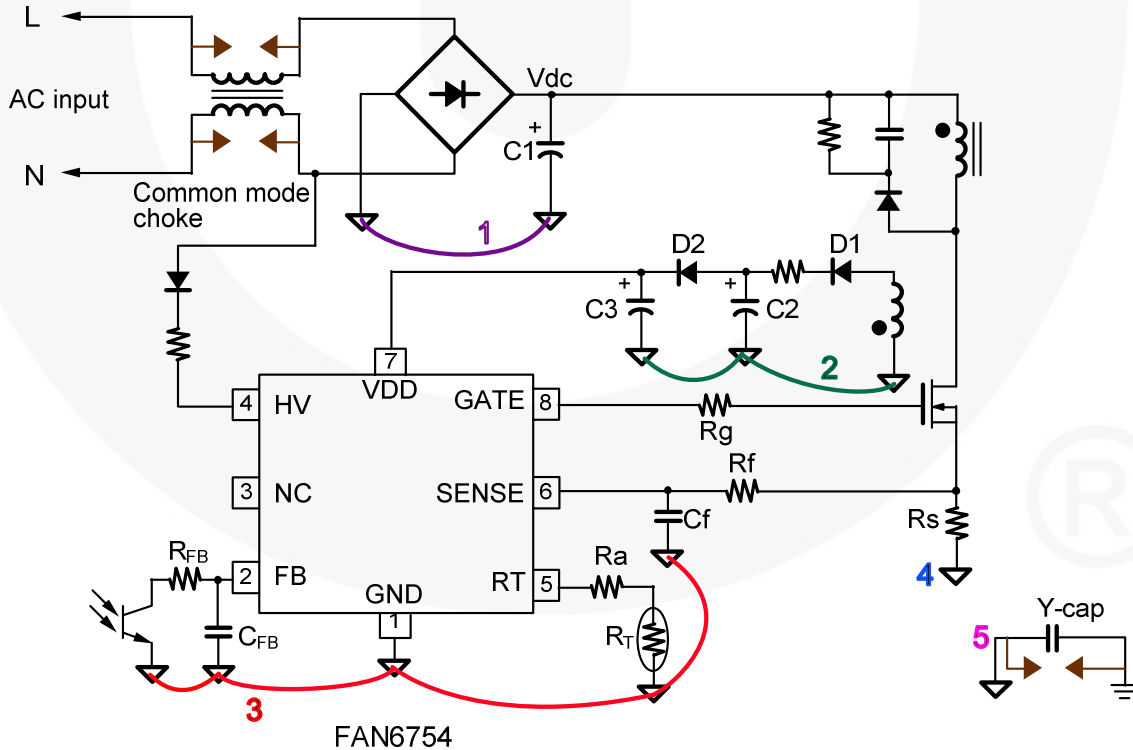


Figure 19. Layout Considerations



## Related Datasheets

[FAN6754 — Highly Integrated Green-Mode PWM Controller \(Brownout and Constant Power Limited by HV Pin\)](#)

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