# FAN7554
## Versatile PWM Controller

## Features

- Current Mode Control
- Pulse by Pulse Current Limiting
- Low External Components
- Under Voltage Lockout(UVLO): 9V/15V
- Stand-by Current: Typ. 100uA
- Power Saving Mode Current: Typ. 200uA
- Operating Current: Typ. 7mA
- Soft Start
- On/Off Control
- Over Load Protection(OLP)
- Over Voltage Protection(OVP)
- Over Current Protection(OCP)
- Over Current Limit(OCL)
- Operating Frequency up to 500kHz
- 1A Totem-Pole Output Current

## Applications

- Off-Line & DC-DC Converter

## Description

The FAN7554 is a fixed frequency current mode PWM controller. It is specially designed for off-line and DC to DC converter applications with minimal external components. These integrated circuits feature a trimmed oscillator for precise duty cycle control, a temperature compensated reference, an ON/OFF control, a high gain error amplifier, a current sensing comparator, and a high current totem-pole output. The FAN7554 has various protection functions such as an over load protection, an over current protection, and the over voltage protection, which include built-in auto restart circuit. The FAN7554 is available in the 8-DIP package as well as the 8-SOP package.



**8-DIP**

**8-SOP**

Rev. 1.0.2
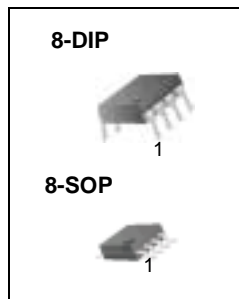
## Internal Block Diagram
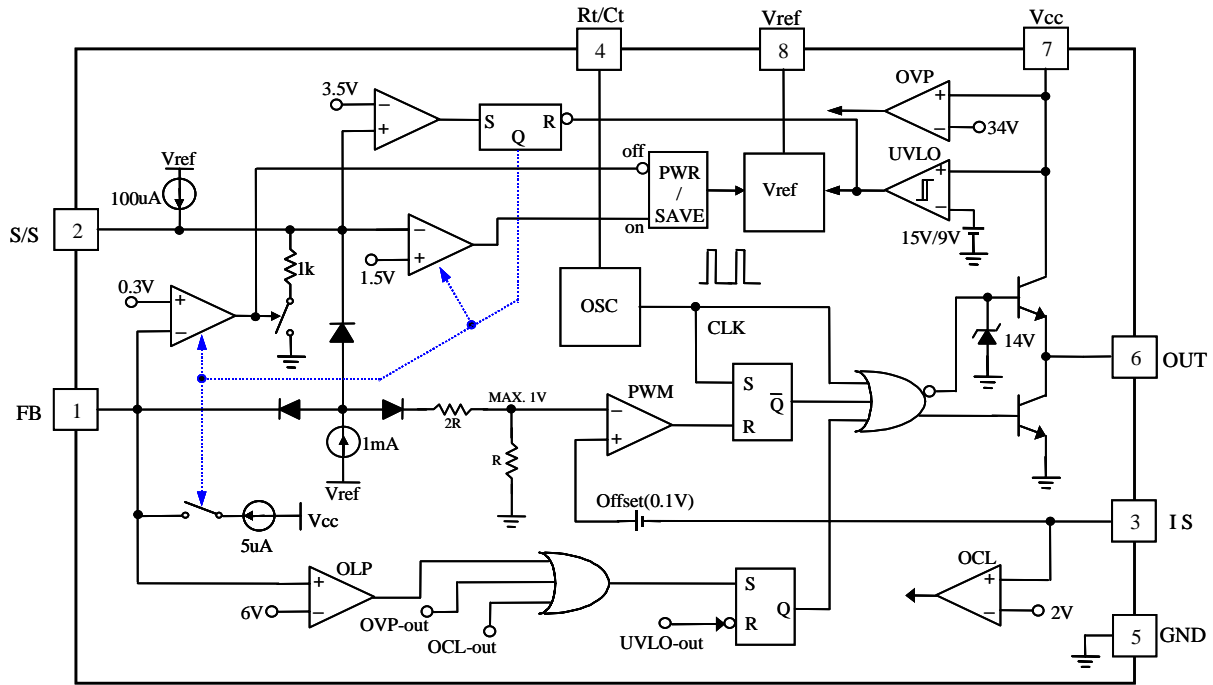


## Absolute Maximum Ratings

( Ta = 25°C, unless otherwise specified )

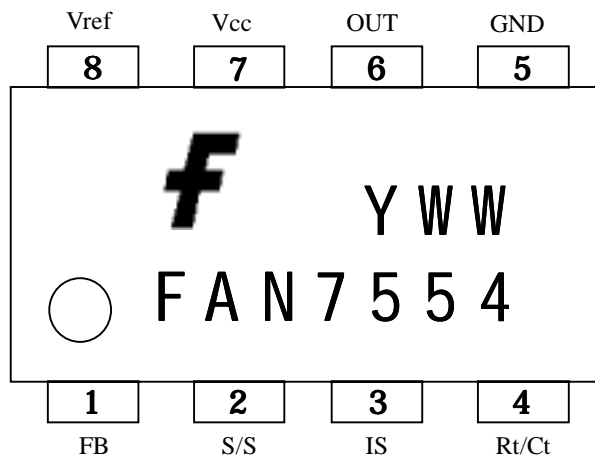| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| Supply Voltage | Vcc | 30 | V |
| Output Current | $I_O$ | ±1 | A |
| Input Voltage to FB Pin | $V_{FB}$ | -0.3 to $V_{SD}$ | V |
| Input Voltage to IS Pin | $V_{IS}$ | -0.3 to $V_{OC}$ | V |
| Power Dissipation at $T_A \leq 25°C$ <br> 8-DIP <br> 8-SOP | $P_D$ | 0.85 <br> 0.42 | W |
| Operating Temperature | $T_{OPR}$ | -25 to +85 | °C |
| Storage Temperature | $T_{STG}$ | -55 to +150 | °C |
| Thermal Resistance, Junction-to-Air (Note1) <br> 8-DIP <br> 8-SOP | $R\theta_{ja}$ | 147.8 <br> 291.4 | °C/W |

**Note:**

**1.** Junction -to -air thermal resistance test environments.

-. Pneumatic heat sink fixture.

-. Clamping pressure 60psi through 12mm diameter cylinder.

-. Thermal grease applied between PKG and heat sink fixture

## Temperature Characteristics

( -25°C ≤ Ta ≤ 85°C )

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| Vref Temperature Stability | $\Delta V_{REF}3$ | ±0.5 | % |
| Fosc Temperature Stability | $\Delta F_{OSC}2$ | ±5 | % |

## PIN Array

| | | | |
|---|---|---|---|
| Vref | Vcc | OUT | GND |
| **8** | **7** | **6** | **5** |

YWW

FAN7554

| | | | |
|---|---|---|---|
| **1** | **2** | **3** | **4** |
| FB | S/S | IS | Rt/Ct |

## PIN Definitions

| Pin Number | Pin Name | Pin Function Description |
|---|---|---|
| 1 | FB | Inverting(-) Input of PWM Comparator, ON/OFF Control & OLP Sensing Terminal. |
| 2 | S/S | Soft Start |
| 3 | IS | Non-Inverting(+) Input of PWM Comparator, OCL Sensing Terminal |
| 4 | Rt/Ct | Oscillator Time Constant(Rt/Ct) |
| 5 | GND | Ground |
| 6 | OUT | Output of Gate Driver |
| 7 | Vcc | Power Supply |
| 8 | Vref | Output of 5V Reference |

## Electrical Characteristics

(Ta = 25°C, Vcc=16V, Rt=10kΩ, Ct=3.3nF unless otherwise specified)

| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| **< REFERENCE SECTION >** | | | | | | |
| Reference Output Voltage | $V_{REF}$ | $T_j$ =25°C , Iref =1mA | 4.90 | 5.00 | 5.10 | V |
| Line Regulation | $\Delta V_{REF1}$ | Vcc =12V ~ 25V | - | 6 | 20 | mV |
| Load Regulation | $\Delta V_{REF2}$ | Iref =1mA ~ 20mA | - | 6 | 25 | mV |
| Short Circuit Output Current | $I_{SC}$ | $T_j$ = 25°C | - | 0.1 | 0.18 | A |
| **< OSCILLATOR SECTION >** | | | | | | |
| Oscillation Frequency | $F_{OSC}$ | $T_j$ = 25°C | 45 | 50 | 55 | kHz |
| Frequency Change with Vcc | $\Delta F_{OSC1}$ | Vcc = 12V ~ 25V | - | 0.05 | 1.0 | % |
| Ramp High Voltage | $V_{RH}$ | - | - | 2.8 | - | V |
| Ramp Low Voltage | $V_{RL}$ | - | - | 1.2 | - | V |
| Discharge Current | Idisch | $V_{RT/CT}$ = 3.3V | 6.1 | - | 9.4 | mA |
| **< PWM SECTION >** | | | | | | |
| Sense Threshold Voltage | $V_{TH(IS)}$ | $V_{FB}$ = 5V | 0.8 | 1.0 | 1.2 | V |
| Feedback Threshold Voltage | $V_{TH(FB)}$ | $V_{IS}$ = 0V | 0.2 | 0.3 | 0.4 | V |
| Feedback Source Current | $I_{FB}$ | $V_{FB}$ = 0V, $V_{S/S}$ = 5V | - | 1.0 | - | mA |
| Max. Duty Cycle | $D_{(MAX)}$ | - | 92 | 95 | 98 | % |
| Min. Duty Cycle | $D_{(MIN)}$ | - | - | - | 0 | % |
| **< PROTECTION SECTION >** | | | | | | |
| Shutdown Delay Current | $I_{SD}$ | $4V \leq V_{FB} \leq V_{SD}$ | 3.5 | 5 | 6.5 | uA |
| Shutdown Feedback Voltage | $V_{SD}$ | $V_{FB}$ > 5V | 5.4 | 6 | 6.6 | V |
| Over Current Protection | $V_{OC}$ | $V_{IS}$ > 1.5V, ton > 500nS | 1.6 | 2 | 2.4 | V |
| Over Voltage Protection | $V_{OVP}$ | - | 30 | 34 | 38 | V |
| **< ON/OFF CONTROL SECTION >** | | | | | | |
| Off Mode Sink Current | $I_{SINK}$ | $V_{FB}$ < $V_{TH(FB)}$, $V_{S/S}$ = 5V | - | 4 | - | mA |
| Off Threshold Voltage | $V_{OFF}$ | $V_{FB}$ < $V_{TH(FB)}$ | 1.2 | 1.5 | 1.8 | V |
| **< SOFT-START SECTION >** | | | | | | |
| Soft Start Current | $I_{S/S}$ | $V_{FB}$ = 5V, $V_{S/S}$ = 0V | - | 1.1 | - | mA |
| Soft Start Limit Voltage | $V_{LIM(S/S)}$ | Vcc = 16V | - | 5.2 | - | V |
| **<OUTPUT SECTION>** | | | | | | |
| Low Output Voltage1 | $V_{OL1}$ | $V_{CC}$ = 18V, $I_O$ = 50mA | - | 0.15 | 0.4 | V |
| High Output Voltage1 | $V_{OH1}$ | $V_{CC}$ = 18V, $I_O$ = -50mA | 13 | 15 | 17 | V |
| Low Output Voltage2 | $V_{OL2}$ | $V_{CC}$ = 18V, $I_O$ = 200mA | - | 1.5 | 2.5 | V |
| High Output Voltage2 | $V_{OH2}$ | Vcc = 18V, Io = -200mA | 12 | 14 | 16 | V |
| Rising Time (Note1) | $t_R$ | $T_j$ = 25°C, $C_L$ = 1nF | - | 80 | - | ns |
| Falling Time (Note1) | $t_F$ | $T_j$ = 25°C, $C_L$ = 1nF | - | 40 | - | ns |
| **<UVLO SECTION>** | | | | | | |
| Start Threshold Voltage | $V_{TH(ST)}$ | - | 13.2 | 15 | 16.2 | V |
| Min. Operating Voltage | $V_{OPR(M)}$ | - | 8.2 | 9 | 10.2 | V |

## Electrical Characteristics (Continued)

(Ta = 25°C, Vcc=16V, Rt =10kΩ, Ct = 3.3nF unless otherwise specified)

| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| **<TOTAL STAND-BY CURRENT SECTION>** | | | | | | |
| Start-up Current | $I_{ST}$ | - | - | 0.1 | 0.2 | mA |
| Operating Supply Current | $I_{OP}$ | - | - | 7 | 10 | mA |
| Off State Current | $I_{OFF}$ | $V_{FB}<V_{TH(FB)}, V_{S/S}<V_{OFF}$ | - | 0.2 | 0.4 | mA |

**Note:**

1. These parameters, although guaranteed, are not 100% tested in production.

## Typical Perfomance Characteristics



**Figure 1. Rt vs. Frequency**
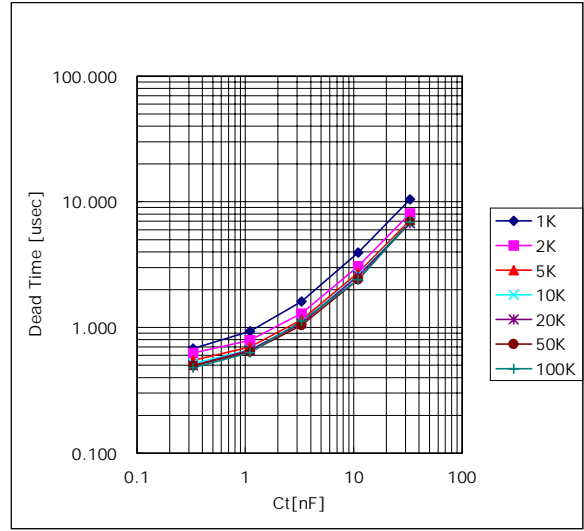


**Figure 2. Ct vs. Dead Time**
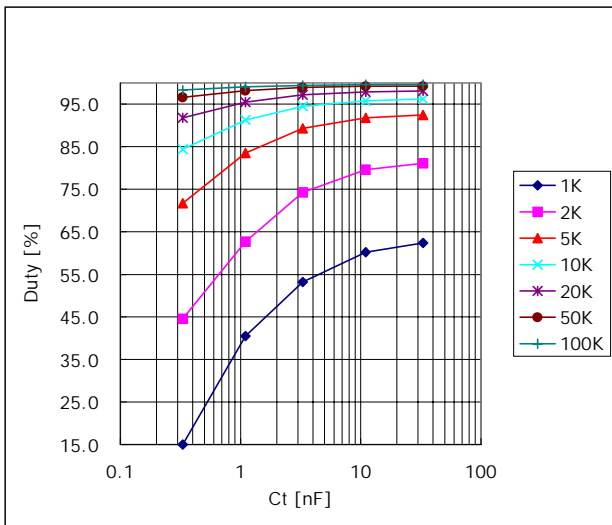


**Figure 3. Ct vs. Duty**
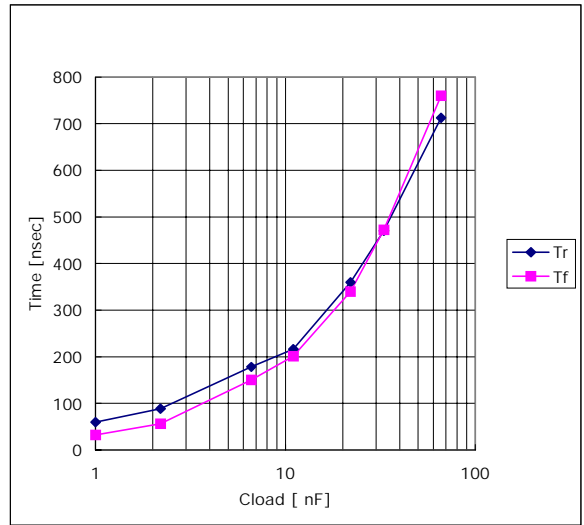


**Figure 4. Cload vs. Tr & Tf**

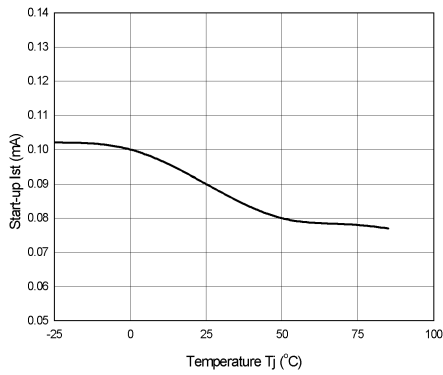# Typical Performance Characteristics(Continued)

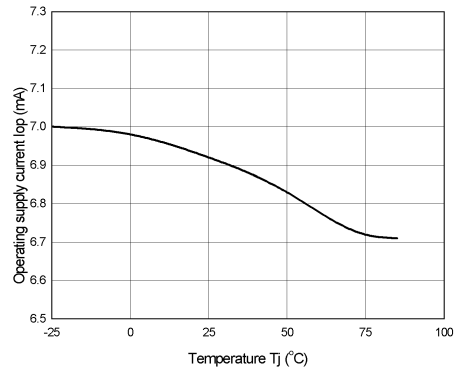**Figure 5. Temperature vs. Start-up Current**
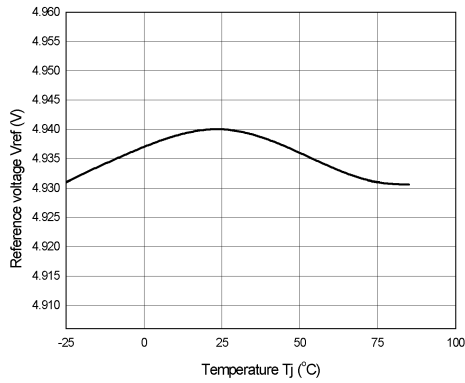
**Figure 6. Temperature vs. Operating Supply Current**
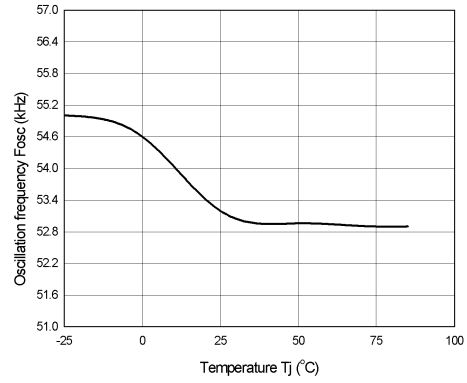
**Figure 7. Temperature vs. Reference Voltage**

**Figure 8. Temperature vs. Oscillation frequency**
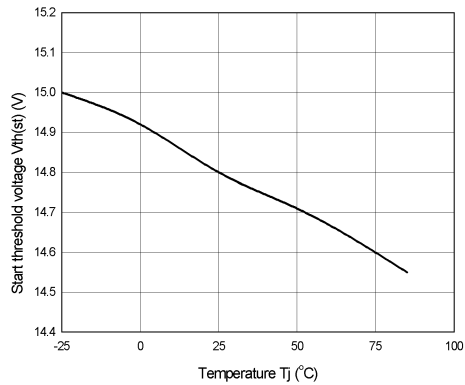
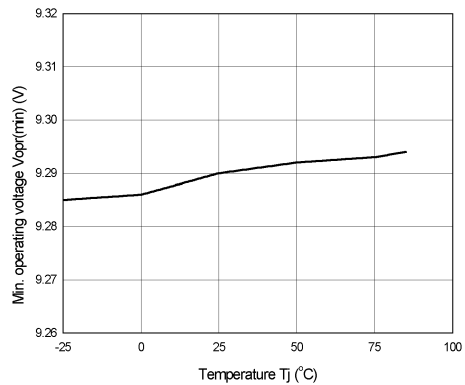**Figure 9. Temperature vs. Start Threshold Voltage**

**Figure 10. Temperature vs. Min. Operating Voltage**

# Operation Description

The FAN7554 has all the basic features of the current mode SMPS control IC. Its basic configuration includes the UVLO with 6V hysteresis, a band gap reference, the oscillator that can oscillate up to 500kHz according to $R_t/C_t$ (connected externally), a PWM logic circuit , a gate driver, and the feedback circuit that has the current source and soft start function. The FAN7554 has various functions such as an over load protection, an over current protection, and an over voltage protection. The over load protection forces the FAN7554 to stop its operation if the load current is higher than the preset value. The protection circuit can also be prevented from operating during transient states by ensuring that a certain amount of the time passes before the protection circuit operates. The shutdown circuit is configured for an auto-restart, so the FAN7554 automatically restarts when Vcc drops to 9V (stop voltage).

## Start-Up

The start-up circuit is made up of an under voltage lock out (UVLO), the protection for low voltage conditions, and the 5V reference ($V_{ref}$), which supplies  bias voltage to the control circuit after start-up. The start voltage of the UVLO is 15V , and the stop voltage after turn on is 9V. It has a 6V hysteresis. The minimum operating current for start-up threshold is typically 100uA, and this can reduce the power dissipation on the start-up resistor. The Vref is composed of the band gap reference circuit with its superior temperature characteristics and supplies power to all the FAN7554 circuits and $R_t/C_t$, with the exceptions of the ULVO circuit and ON/OFF control circuit.
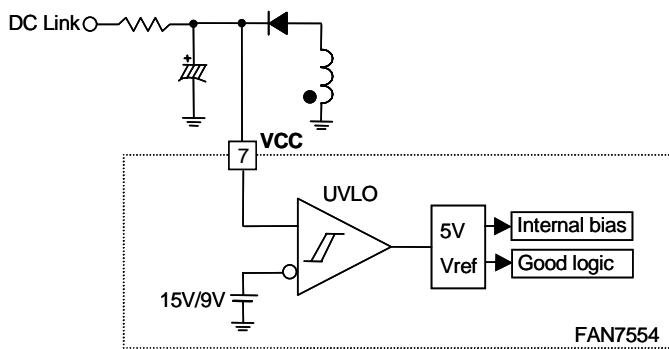


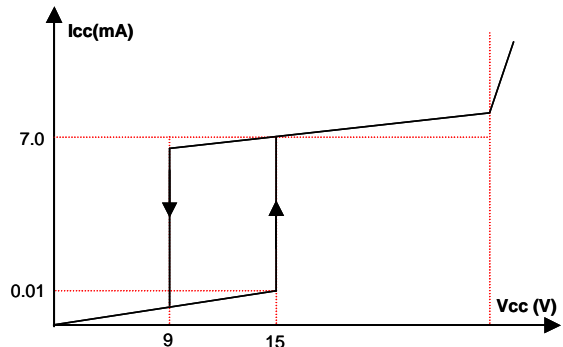Figure 11. Low Current Start-Up & Bandgap Reference Circuit



Figure 12. Start-Up & Circuit Characteristics

## Soft Start

The SMPS output load usually contains a capacitive load component. During initial start-up, the output voltage increases at a fixed time constant because of this component.  If the feedback loop, which controls the output voltage, was to start without the soft start circuit, the feedback loop would appear to be open during initial start-up , so, at start-up, the feedback voltage applied to the PWM comparator's inverting input (-) reaches its maximum value(1V).

During this time, the peak value of the drain current would stay at the maximum value, and the maximum power would be delivered to the secondary load side from the start. When the maximum power is delivered to the secondary side for this initial fixed time, the entire circuit is seriously stressed. The use of a soft start can avoid such stresses. At start-up, the soft start capacitor Cs is charged by 1mA and 100uA current sources.

The voltage of the inverting terminal of the PWM comparator increases to 1/3 of the Cs voltage at a fixed time constant. Subsequently, the drain peak current is limited by the gradual increase in the Cs voltage and this causes the output voltage to increase smoothly. When the Cs voltage becomes greater than 3V, the diode Ds turns off consequently, the feedback capacitor Cfb is charged by 1mA and 5uA current sources. This charge voltage determines the comparator's inverting voltage. Then, Cs voltage charges to 5V by 100uA current source. The soft start capacitor Cs is discharged when the UVLO good logic starts, so the soft start is repeated at re-start.
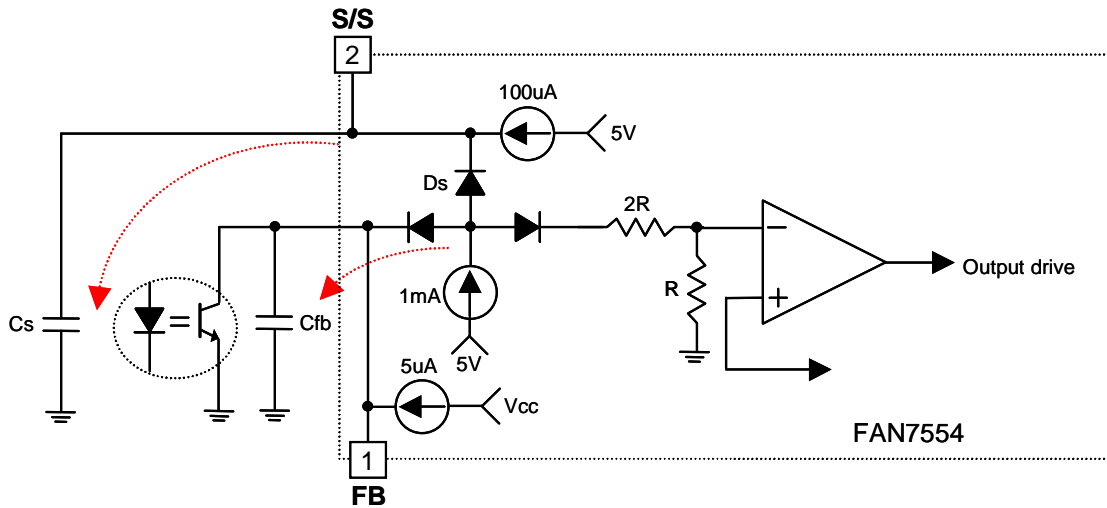
**Figure 13. Soft Start Circuit & Circuit Flow**

## Oscillator

As shown in figure14, the oscillator frequency is programmed by values selected for timing components Rt and $C_t$. Capacitor $C_t$ is charged to almost 2.8V through resistor Rt from the 5V reference and discharged to 1.2V by an internal current source. The oscillator generates the clock signal while the timing capacitor $C_t$ is discharged. The gate drive output becomes low during the clock time. Rt and $C_t$ selection determine the oscillator frequency and maximum duty cycle. Charge and discharge times can be calculated through the equations below.

$$\text{Charging time : tc} = 0.55 \times R_t \times C_t$$

$$\text{Discharging time : td} = R_t \times C_t \times \ln[(0.0063 \times R_t - 2.8) / (0.0063 \times R_t - 3.8)]$$

$$\text{where the oscillator frequency : fosc} = (tc + td)^{-1} (\pm 10\%)$$

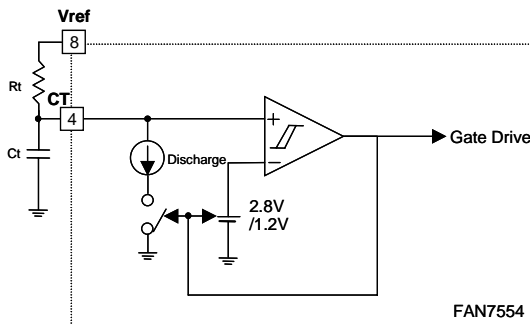$$\text{When } R_t > 5k\Omega, \text{ fosc} = 1 / (0.55 \times R_t \times C_t) = 1.8 / (R_t \times C_t)$$



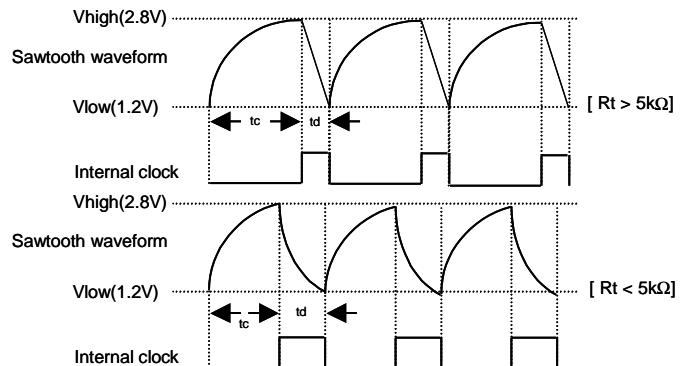**Figure 14. Oscillator Circuit**



**Figure 15. Sawtooth & Clock Waveform**

## Feedback

As shown in figure16, the internal oscillator clock turns on the MOSFET. The feedback comparator operates to turn it off again, when the MOSFET current reaches a set value proportional to Vfb. The feedback capacitor Cfb is charged by the internal current sources , 1mA and 5uA, and is discharged by the secondary side photo-coupler to control the output voltage.
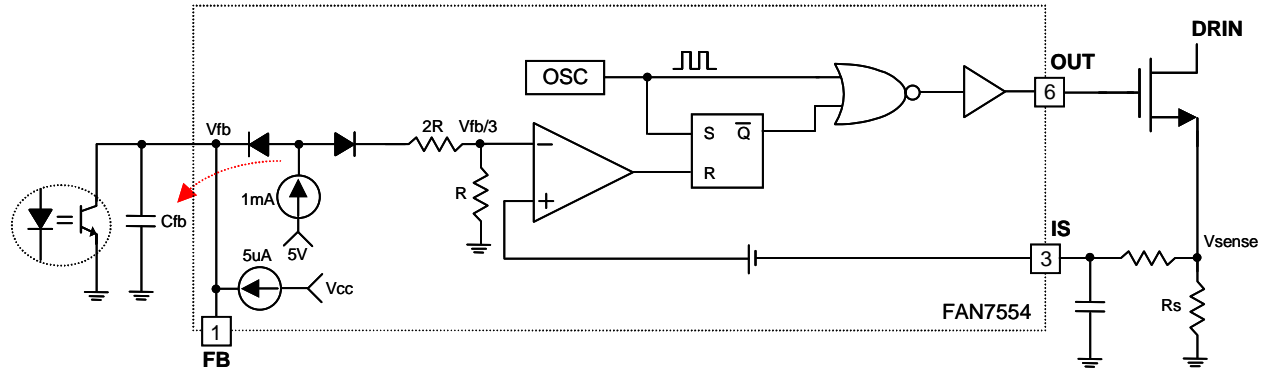


**Figure 16. Feedback & PWM Circuit**

## Delayed Shutdown

During the normal operation, the feedback voltage is between 0~3V.  If the output terminal overloads or an error happens to the feedback loop, the delayed shutdown circuit operates. When the feedback voltage is less than 3V, the feedback capacitor is charged by current sources, 1mA and 5uA; when the feedback voltage becomes greater than 3V, the capacitor is charged by the 5uA current source because diode D1 turns off. When the feedback voltage is less than 3V, the charge slope becomes an exponential function and, when it is greater than 3V, the charge slope becomes linear. When the feedback voltage reaches almost 6V, the FAN7554 shuts down. The shut down circuit is configured for
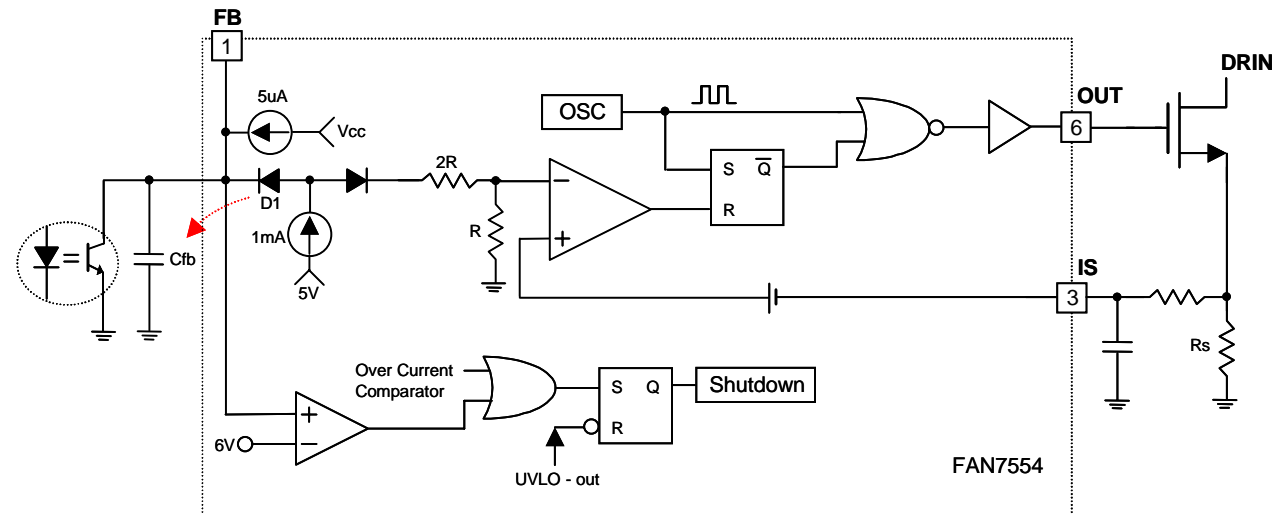auto-restart, so it automatically restarts when Vcc reaches the under voltage 9V.
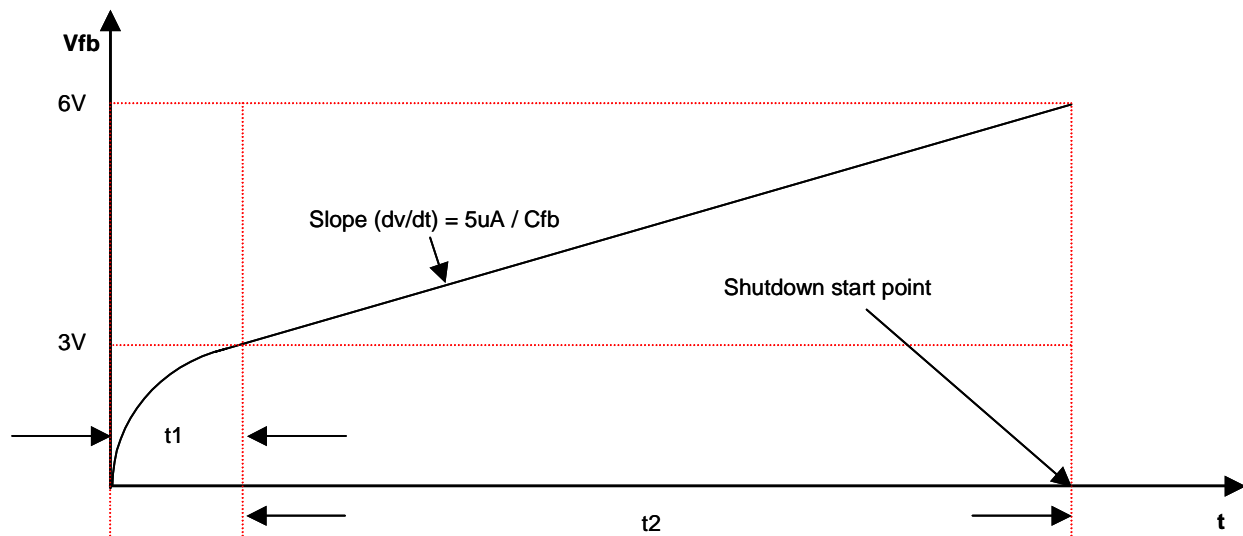


**Figure 17-A . Delayed Shutdown & Feedback Circuit**

**Figure 17-B . Delayed Shutdown & Feedback Waveform**

## Gate Driver

The gate drive circuit has the totem-pole output configuration. The output has 1A peak current and 200mA  average current drive ability.
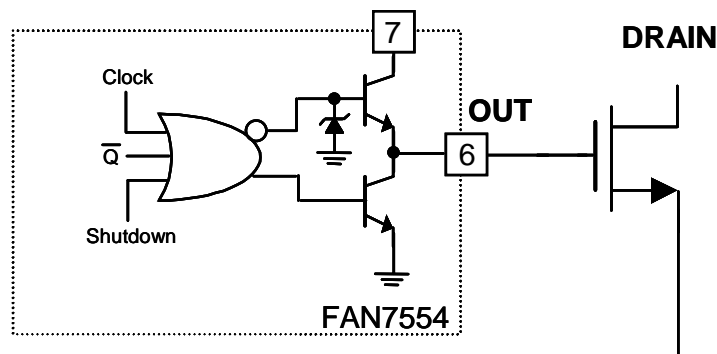


**Figure 18. Gate Drive Circuit**

## ON/OFF Control

The FAN7554 is able to use the feedback pin for ON/OFF control  by placing NPN transistor between the cathode of the KA431 and ground as shown in figure 19. When the transistor turns on, the current flows through the photo diode and saturates the photo transistor. As a result, the feedback voltage is dropped to zero. When the feedback voltage is below 0.3V, the soft start voltage starts to discharge by connecting the internal resistor 1kΩ in parallel with the external capacitor Cs. When the soft start voltage becomes less than 1.5V, all the blocks in the FAN7554 are turned off , with the exceptions of the UVLO block and ON/OFF control block. The operation current is about 200uA. So the stand-by power is reduced and SMPS efficiency is improved. When the feedback voltage exceeds 0.3V, the FAN7554 normally operates by turning on Vref block.
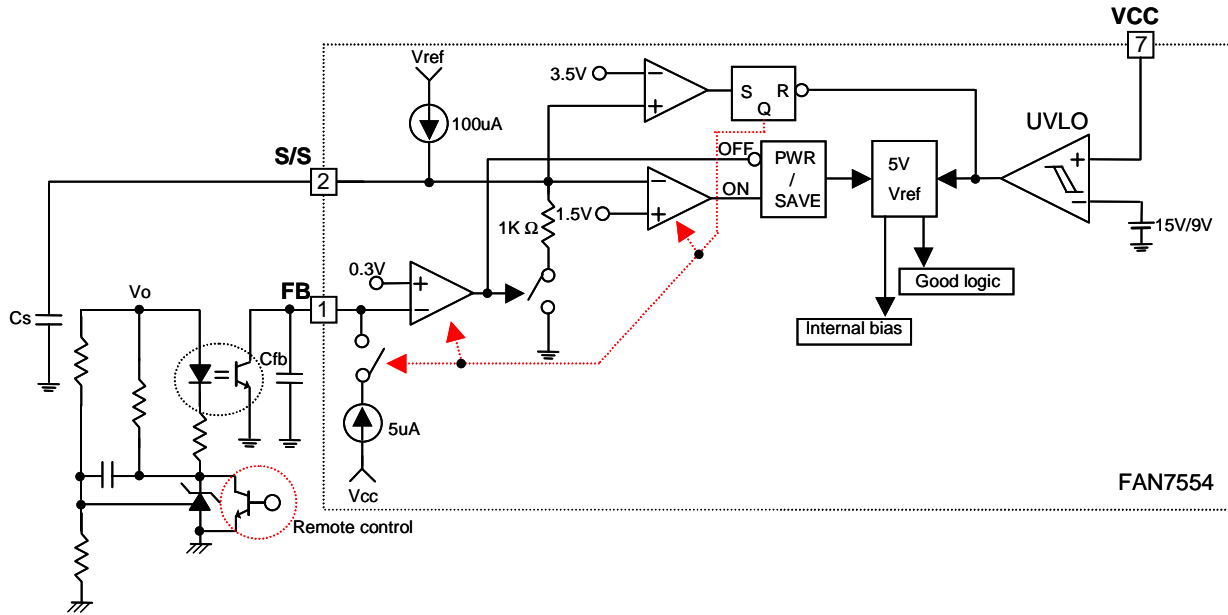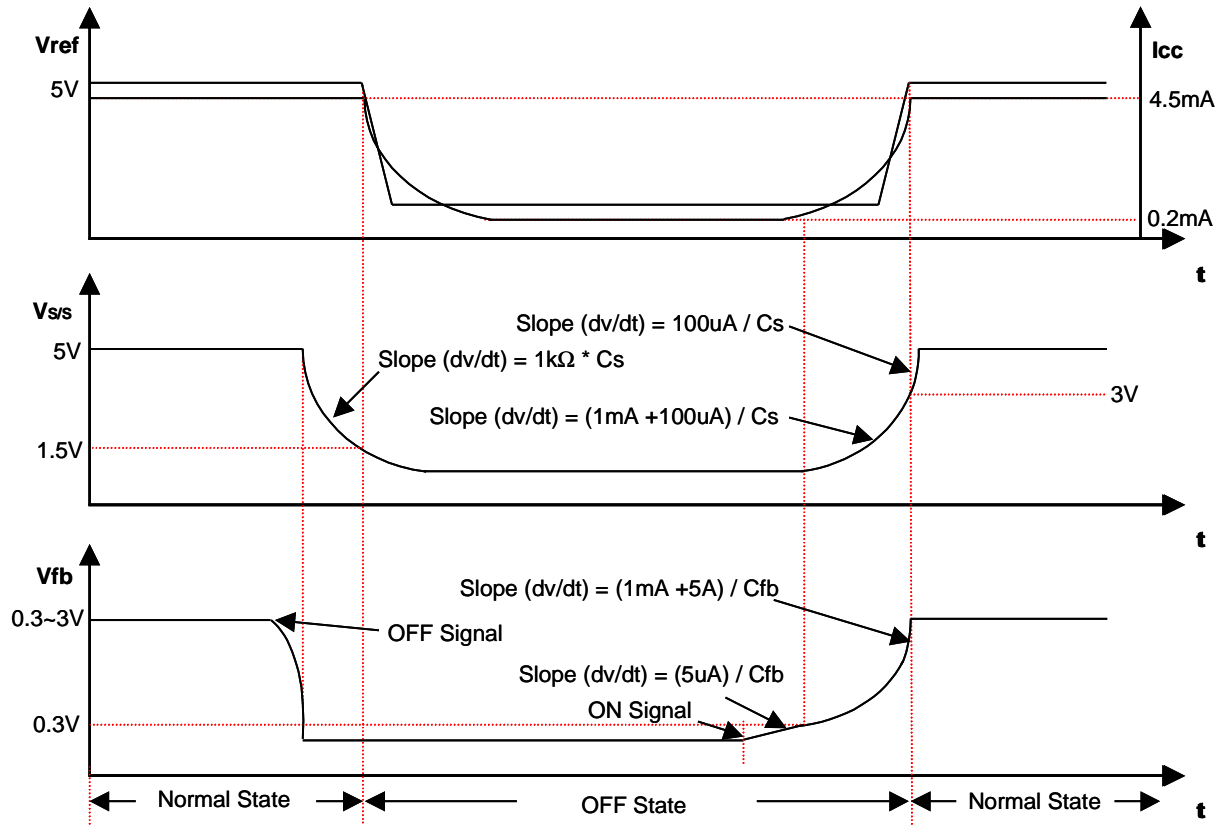
**Figure 19. ON/OFF Control Circuit**



**Figure 20. ON-OFF Control Circuit Waveforms**

## Protection Circuits

The FAN7554 has many built-in protection circuits that do not need additional components, providing reliability without cost increase. These protection circuits have the auto-restart configuration. In this configuration, the protection circuits reset when Vcc is below UVLO stop threshold (9V) and restarts when Vcc is above UVLO start threshold voltage (15V)

## Over Voltage Protection

Abnormalities may occur in the SMPS secondary side feedback circuit. First, when the feedback pin is short to the ground, the feedback voltage is zero and the FAN7554 is unable to start switching. Second, when the feedback circuit is open, the secondary voltage generally becomes much greater than the rated voltage as the primary side continues to switch at the maximum current level. This may cause the blowing off the fuse or, in serious cases, fires. It is possible that the devices directly connected to the secondary output without a regulator could be destroyed. Even in these cases, the over voltage protection circuit operates. Since Vcc is proportional to the output , in an over voltage situation, it also will increase. In the FAN7554, the protection circuit operates when Vcc exceeds 34V. Therefore ,in normal operation, Vcc must be set below 34V.

## Over Load Protection

An overload is the state in which the load is operating normally but in excess of the preset load. The overload protection circuit can force the FAN7554 to stop its operation . The protection can also operate in transient states such as initial SMPS operation. Because the transient state returns to the normal state after a fixed time, the protection circuit need not to operate during this time. That is, the FAN7554 needs the time to detect and decide whether it is an overload condition or not. The protection circuit can be prevented from operating during transient states by ensuring that a certain amount of time passes before the protection circuit operates. The above operations are executed as follows:  Since the FAN7554 adopts a current mode, it is impossible for current to flow above a maximum level. For a fixed input voltage, this limits power. Therefore, if the power at the output exceeds this maximum, Vo, shown in figure21, becomes less than the set voltage, and the KA431pulls in only the given minimum current. As a result, the photo-coupler's secondary side current becomes zero. The same goes for the photo-coupler's primary side current. Consequently, when the full current 1mA flows through the internal resistor (2R + R = 3R), Vfb becomes approximately 3V  and from that time, the 5uA current source begins to charge Cfb, the photo-coupler's secondary current is almost zero. The FAN7554 shuts down when Vfb reaches 6V.
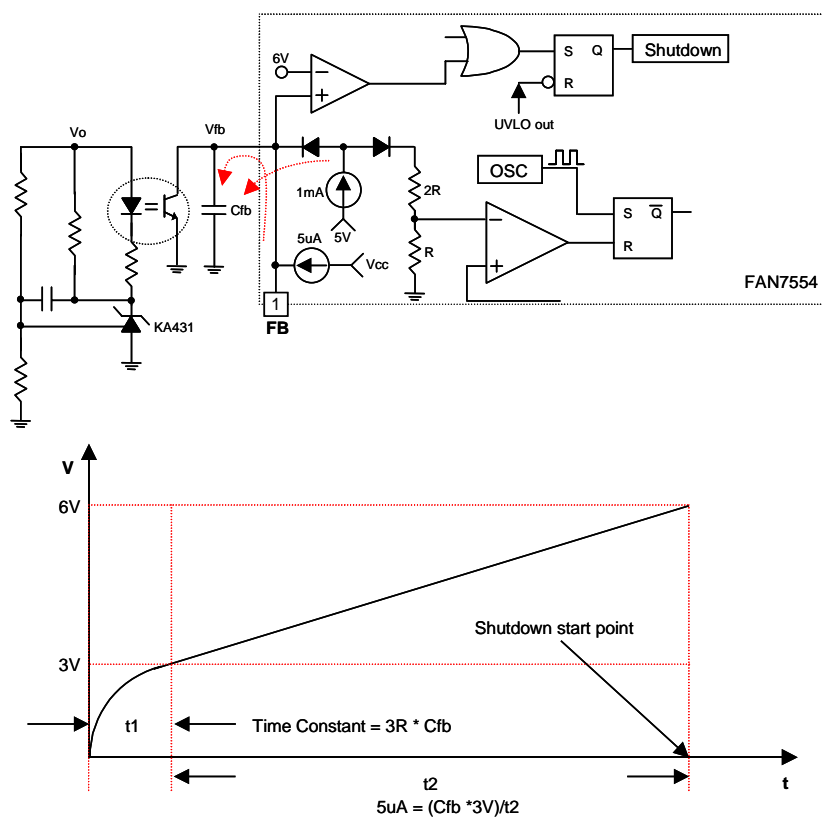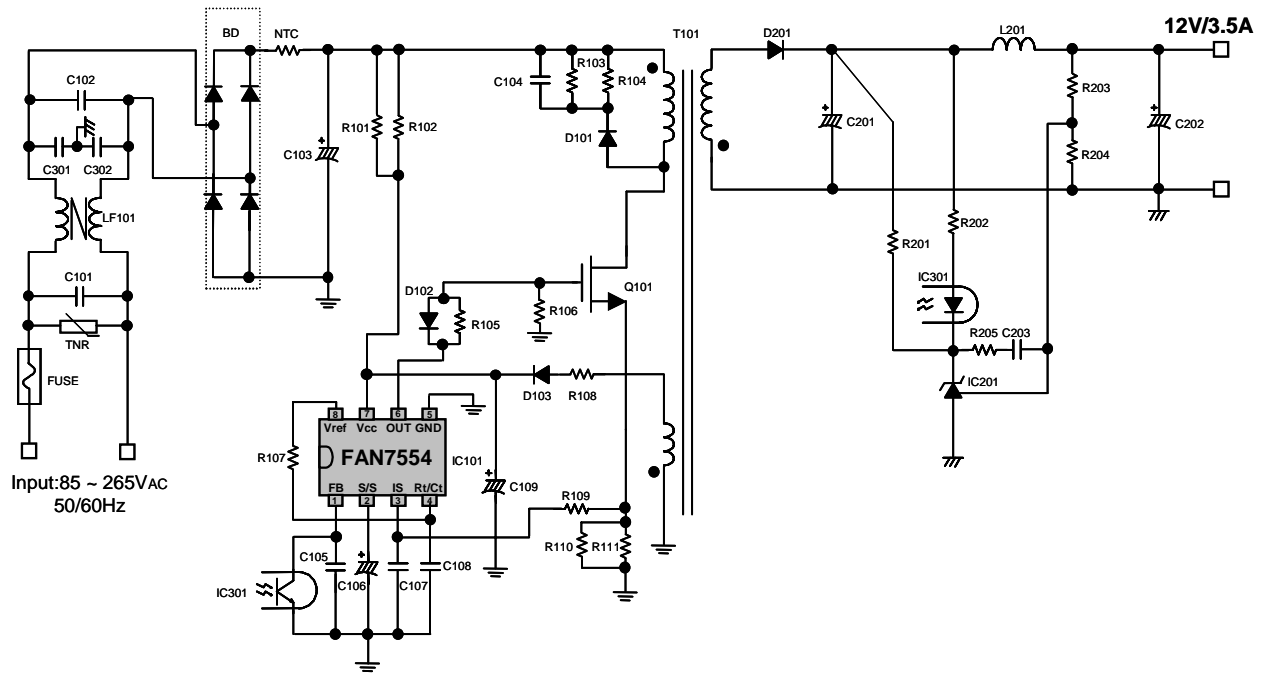
Figure 21. Delayed Shutdown

## FAN7554 Flyback Converter Demo Circuit (Fsw:100kHz)



Input:85 ~ 265VAC
50/60Hz

## Part List For FAN7554 Flyback Converter Demo Board

| Part | Value | Note | Part | Value | Note |
|---|---|---|---|---|---|
| **FUSE** | | | **CAPACITOR** | | |
| FUSE | 250 2A | - | C101 | 100nF/ 275V | Box Capacitor |
| **NTC** | | | C102 | 100nF/ 275V | Box Capacitor |
| NTC | 5D-11 | - | C103 | 470nF/ 400WV | Electrolytic |
| **RESISTOR** | | | C104 | 103/ 1kV | Film Capacitor |
| R101 | 330kΩ | 1W | C105 | 104 | Ceramic |
| R102 | - | - | C106 | 1uF/ 10V | Electrolytic |
| R103, R104 | 100kΩ | 1W | C107 | 101 | Ceramic |
| R105 | 22Ω | - | C108 | 122 | Ceramic |
| R106 | 4.7kΩ | - | C109 | 22uF/ 50V | Electrolytic |
| R107 | 12kΩ | - | C201 | 330uF | Electrolytic |
| R108 | 10Ω | - | C202 | 330uF | Electrolytic |
| R109 | 1kΩ | - | C203 | 104 | Ceramic |
| R110 | 0.5Ω | 2W | C301 | - | - |
| R201 | 1kΩ | - | C302 | - | - |
| R202 | 1kΩ | - | | | |
| R203 | 4.7kΩ | - | **INDUCTOR** | | |
| R204 | 1.2kΩ | - | LF101 | 30mH | - |
| R205 | - | - | L201 | 6.4uH | - |
| **MOSFET** | | | **DIODE** | | |
| Q101 | FQP6N70 | Fairchild | D201 | MBRF10100CT | - |
| **IC** | | | D101 | UF4007 | Fairchild |
| IC101 | FAN7554 | Fairchild | D102 | 1N4148 | - |
| IC201 | KA431 | Fairchild | D103 | UF4004 | Fairchild |
| IC301 | Opto-coupler | Fairchild | BD | G3SBA60 | - |

# Transformer Specification

**Schematic Diagram (Top view)**
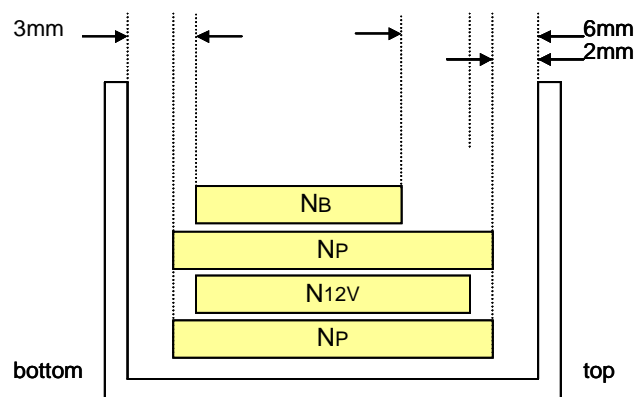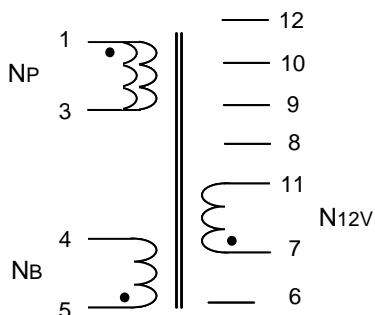


## Winding Specification

| No. | Pin(S → F) | Wire | Turns | Winding Method |
|---|---|---|---|---|
| $N_P$ | 1 → 3 | $0.35\phi \times 1$ | 44 | - |
| $N_{12V}$ | 7 → 11 | $0.35\phi \times 4$ | 12 | - |
| $N_P$ | 1 → 3 | $0.35\phi \times 1$ | 44 | - |
| $N_B$ | 5 → 4 | $0.35\phi \times 1$ | 13 | - |

## Electrical Characteristic

| Closure | Pin | Spec. | Remarks |
|---|---|---|---|
| Inductance | 1 - 3 | 400uH ±10% | 100kHz, 1V |
| Leakagel | 1 - 3 | 10uH MAX . | 2nd All short |

## FAN7554  forward converter demo circuit ( fsw:100kHz)
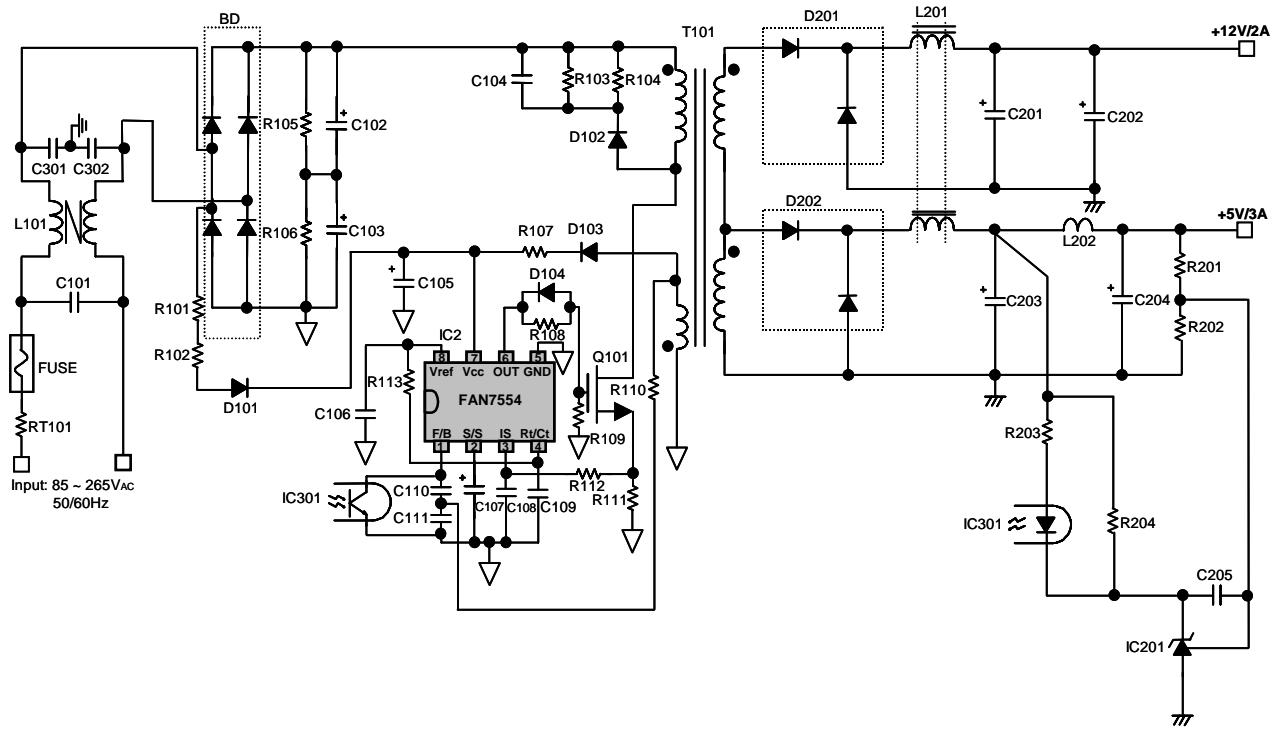
## Part List For FAN7554 Forward Converter Demo Board

| Part | Value | Note | Part | Value | Note |
|---|---|---|---|---|---|
| **FUSE** | | | **CAPACITOR** | | |
| FUSE | 250 2A | - | C101 | 470nF/ 275V | Box Capacitor |
| **NTC** | | | C102, C103 | 470nF/ 400WV | Electrolytic |
| RT101 | DSC 10D-11 | - | C104 | 223/ 630V | Film |
| **RESISTOR** | | | C105 | 33uF/ 35V | Film Capacitor |
| R101 | 330kΩ | 1W | C106 | 104 | Ceramic |
| R102 | - | - | C107 | 1uF/ 35V | Electrolytic |
| R103, R104 | 56kΩ | 1W | C108 | 101 | Ceramic |
| R105, R106 | 220kΩ | 1W | C109 | 122 | Ceramic |
| R107 | 10Ω | - | C110 | 272 | Film |
| R108 | 20Ω | - | C111 | 333 | Film |
| R109 | 4.7kΩ | - | C201, C202 | 1000uF/ 35V | Electrolytic |
| R110 | 1.2kΩ | - | C203 | 330uF/ 16V | Electrolytic |
| R111 | 0.5Ω//0.5Ω//0.5Ω | 2W | C204 | 2200uF/ 16V | Electrolytic |
| R112 | 1kΩ | - | C205 | 104 | Ceramic |
| R113 | 12kΩ | - | C301, C302 | 332/ 1kV | Ceramic |
| R201, R202 | 10kΩ | - | **INDUCTOR** | | |
| R203 | 1kΩ | - | LF101 | 30mH | - |
| R204 | 330Ω | - | L201 | - | - |
| **MOSFET** | | | **DIODE** | | |
| Q101 | SSH8N80 | Fairchild | D101 | 1N4004 | - |
| **IC** | | | D102 | FR157 | - |
| IC101 | FAN7554 | Fairchild | D103 | UF4007 | - |
| IC201 | KA431 | Fairchild | D201 | MBRF10100CT | - |
| IC301 | Opto-Coupler | Fairchild | D202 | MBR3045PT | - |
| - | - | - | BD | PBS406GU | |

# Transformer specification

**Schematic Diagram (Top view)**
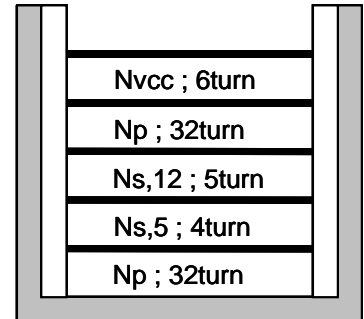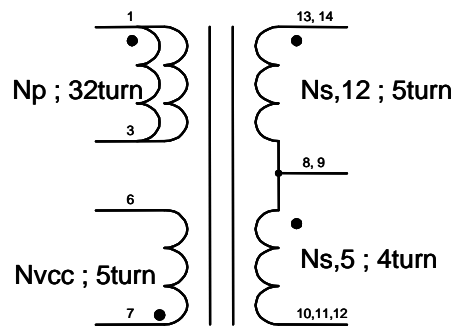


## Winding Specification

| No. | Pin(S → F) | Wire | Turns |
|---|---|---|---|
| N$_P$ | 1 → 3 | 0.65 $\phi \times 1$ | 32 |
| N$_S$, 5 | 8 → 11 | 0.65 $\phi \times 4$ | 4 |
| N$_S$, 12 | 4 → 9 | 0.65 $\phi \times 4$ | 5 |
| N$_P$ | 1 → 3 | 0.65 $\phi \times 1$ | 32 |
| N$_{VCC}$ | 7 → 6 | 0.65 $\phi \times 1$ | 5 |

Core : Powder 27 pi 16grade
5V : 12T ( 1 $\phi \times 2$ )
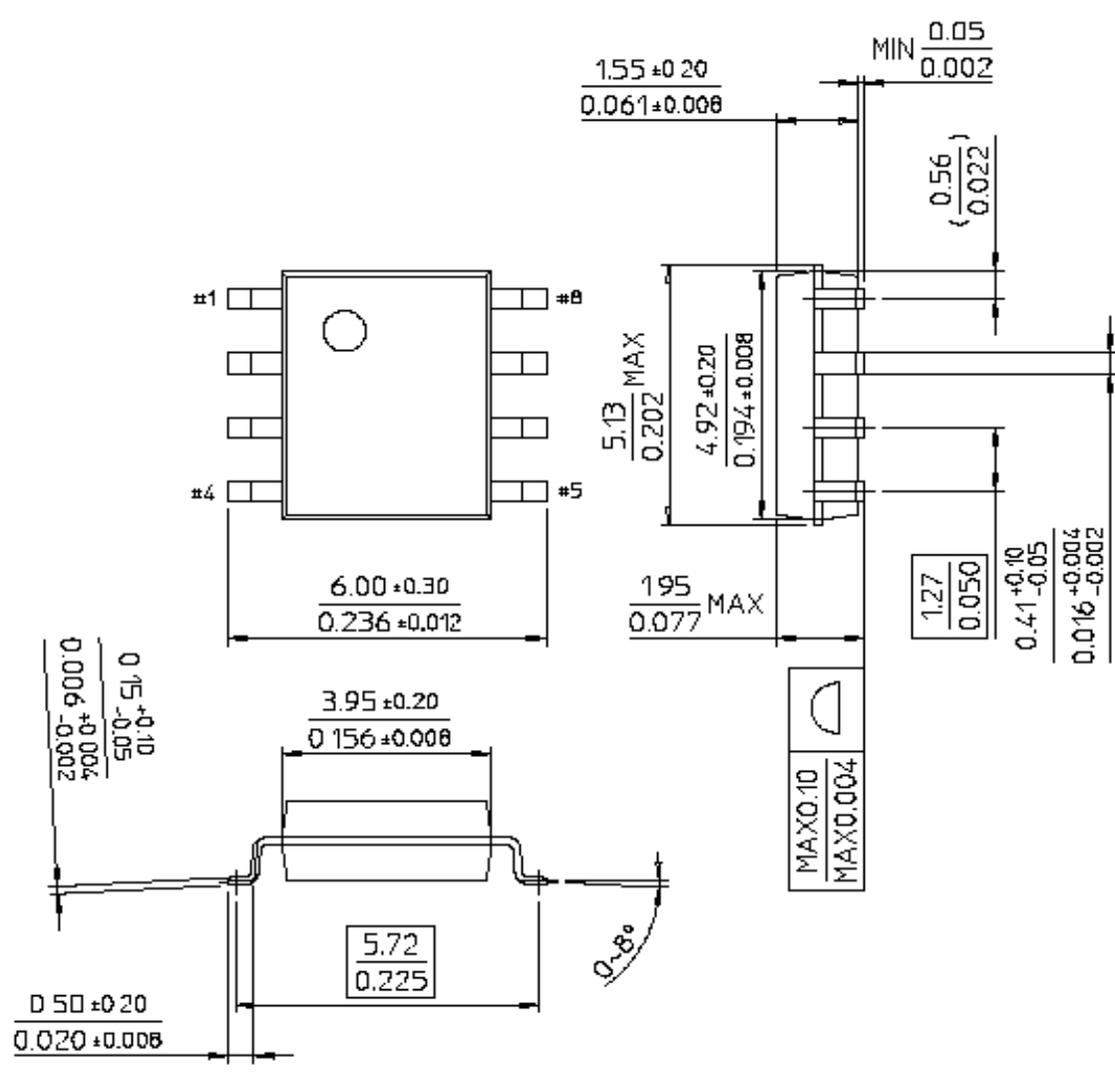12V : 27T ( 1.2 $\phi \times 1$ )

# Mechanical Dimensions

## Package

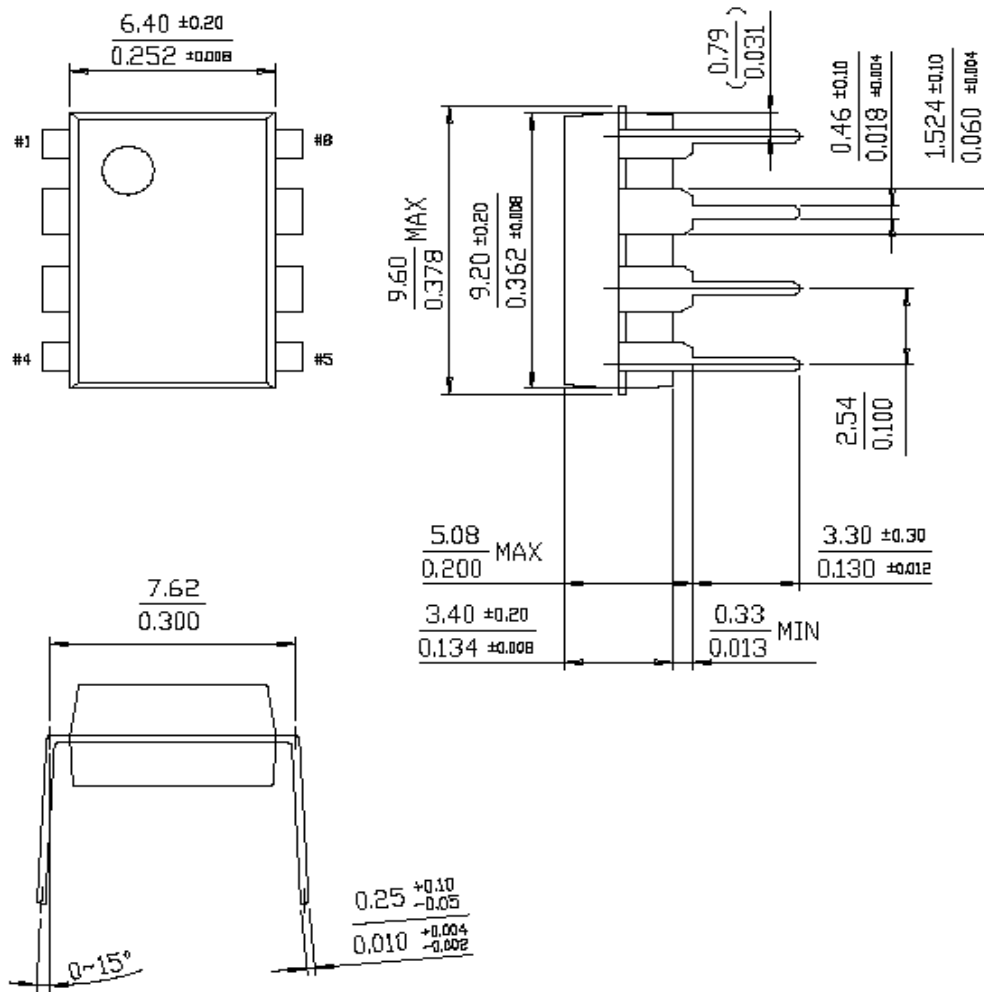**Dimensions in millimeters**

# 8-SOP

# Mechanical Dimensions (Continued)

**Package**

**Dimensions in millimeters**

# 8-DIP

## Ordering Information

| Product Number | Package | Operating Temperature |
|---|---|---|
| FAN7554 | 8-DIP | -25°C ~ 85°C |
| FAN7554D | 8-SOP | |

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