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TC642B/TC647B

PWM Fan Speed Controllers With Minimum Fan Speed, Fan Restart and FanSense™ Technology for Fault Detection

Features

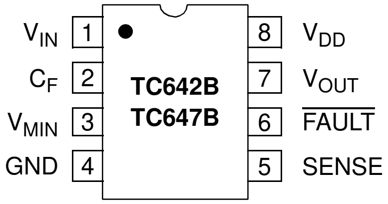
- Temperature-Proportional Fan Speed for Acoustic Noise Reduction and Longer Fan Life
- Efficient PWM Fan Drive
- 3.0V to 5.5V Supply Range:
  - Fan Voltage Independent of TC642B/TC647B Supply Voltage
  - Supports any Fan Voltage
- FanSense™ Fault Detection Circuit Protects Against Fan Failure and Aids System Testing
- Shutdown Mode for "Green" Systems
- Supports Low Cost NTC/PTC Thermistors
- Over-Temperature Indication (TC642B only)
- Fan Auto-Restart
- Space-Saving 8-Pin MSOP Package

Applications

- Personal Computers & Servers
- LCD Projectors
- Datacom & Telecom Equipment
- Fan Trays
- File Servers
- General Purpose Fan Speed Control

Package Types

MSOP, PDIP, SOIC



Description

The TC642B/TC647B devices are new versions of the existing TC642/TC647 fan speed controllers. These devices are switch mode, fan speed controllers that incorporate a new fan auto-restart function. Temperature-proportional speed control is accomplished using pulse width modulation. A thermistor (or other voltage output temperature sensor) connected to the V_{IN} input supplies the required control voltage of 1.20V to 2.60V (typical) for 0% to 100% PWM duty cycle. Minimum fan speed is set by a simple resistor divider on the V_{MIN} input. An integrated Start-Up Timer ensures reliable motor start-up at turn-on, coming out of shutdown mode or following a transient fault. A logic-low applied to V_{MIN} (pin 3) causes fan shutdown.

The TC642B and TC647B also feature Microchip Technology's proprietary FanSense™ technology for increasing system reliability. In normal fan operation, a pulse train is present at SENSE (pin 5). A missing-pulse detector monitors this pin during fan operation. A stalled, open or unconnected fan causes the TC642B/TC647B device to turn the V_{OUT} output on full (100% duty cycle). If the fault persists (a fan current pulse is not detected within a 32/f period), the $\overline{\text{FAULT}}$ output goes low. Even with the $\overline{\text{FAULT}}$ output low, the V_{OUT} output is on full during the fan fault condition in order to attempt to restart the fan. $\overline{\text{FAULT}}$ is also asserted if the PWM reaches 100% duty cycle (TC642B only), indicating that maximum cooling capability has been reached and a possible overheating condition exists.

The TC642B and TC647B devices are available in 8-pin plastic MSOP, SOIC and PDIP packages. The specified temperature range of these devices is -40 to +85ºC.

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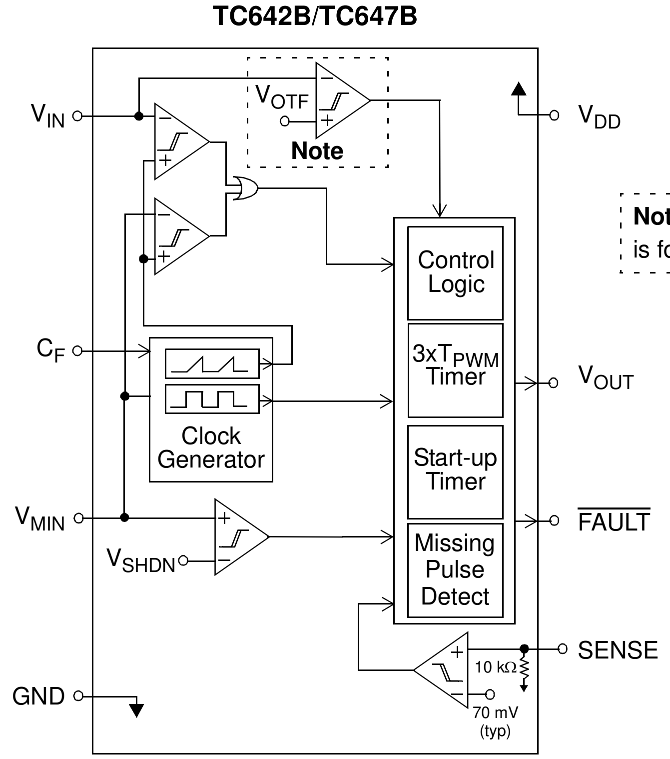
Functional Block Diagram



Note: The V_{OTF} comparator is for the TC642B device only.

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1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{DD}) 6.0V

Input Voltage, Any Pin................(GND - 0.3V) to (V_{DD} +0.3V)

Operating Temperature Range ....- 40°C to +125°C

Maximum Junction Temperature, T_J ....+150°C

ESD Protection on all pins .... > 3 kV

† **Notice:** Stresses above those listed under “Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

PIN FUNCTION TABLE

Name	Function
V_{IN}	Analog Input
C_F	Analog Output
V_{MIN}	Analog Input
GND	Ground
SENSE	Analog Input
$\overline{\text{FAULT}}$	Digital (Open-Drain) Output
V_{OUT}	Digital Output
V_{DD}	Power Supply Input

ELECTRICAL SPECIFICATIONS

Electrical Specifications: Unless otherwise specified, all limits are specified for -40°C < T_A < +85°C, V_{DD} = 3.0V to 5.5V.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Supply Voltage	V_{DD}	3.0	—	5.5	V	
Supply Current, Operating	I_{DD}	—	200	400	µA	Pins 6, 7 Open, C_F = 1 µF, $V_{IN} = V_{C(MAX)}$
Supply Current, Shutdown Mode	$I_{DD(SHDN)}$	—	30	—	µA	Pins 6, 7 Open, C_F = 1 µF, V_{MIN} = 0.35V
V_{OUT} Output						
Sink Current at V_{OUT} Output	I_{OL}	1.0	—	—	mA	V_{OL} = 10% of V_{DD}
Source Current at V_{OUT} Output	I_{OH}	5.0	—	—	mA	V_{OH} = 80% of V_{DD}
V_{IN}, V_{MIN} Inputs						
Input Voltage at V_{IN} or V_{MIN} for 100% PWM Duty Cycle	$V_{C(MAX)}$	2.45	2.60	2.75	V	
Over-Temperature Indication Threshold	V_{OTF}		$V_{C(MAX)}$ + 20 mV		V	**For TC642B Only**
Over-Temperature Indication Threshold Hysteresis	$V_{OTF-HYS}$		80		mV	**For TC642B Only**
$V_{C(MAX)} - V_{C(MIN)}$	$V_{C(SPAN)}$	1.3	1.4	1.5	V	
Minimum Speed Threshold	V_{MIN}	$V_{C(MAX)} - V_{C(SPAN)}$		$V_{C(MAX)}$	V	
Voltage Applied to V_{MIN} to Ensure Shutdown Mode	V_{SHDN}	—	—	V_{DD} x 0.13	V	
Voltage Applied to V_{MIN} to Release Shutdown Mode	V_{REL}	V_{DD} x 0.19	—	—	V	V_{DD} = 5V
Hysteresis on V_{SHDN}, V_{REL}	V_{HYST}	—	0.03 x V_{DD}	—	V	
V_{IN}, V_{MIN} Input Leakage	I_{IN}	- 1.0	—	+1.0	µA	**Note 1**
Pulse-Width Modulator						
PWM Frequency	f_{PWM}	26	30	34	Hz	C_F = 1.0 µF

Note 1: Ensured by design, tested during characterization.

2: For V_{DD} < 3.7V, $t_{STARTUP}$ and t_{MP} timers are typically 13/f.

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ELECTRICAL SPECIFICATIONS (CONTINUED)

Electrical Specifications: Unless otherwise specified, all limits are specified for -40°C < T_A < +85°C, V_{DD} = 3.0V to 5.5V.

Parameters	Sym	Min	Typ	Max	Units	Conditions
SENSE Input						
SENSE Input Threshold Voltage with Respect to GND	$V_{TH(SENSE)}$	50	70	90	mV	
Blanking time to ignore pulse due to V_{OUT} turn-on	t_{BLANK}	—	3.0	—	µsec	
$\overline{\text{FAULT}}$ Output						
Output Low Voltage	V_{OL}	—	—	0.3	V	I_{OL} = 2.5 mA
Missing Pulse Detector Timer	t_{MP}	—	32/f	—	sec	**Note 2**
Start-Up Timer	$t_{STARTUP}$	—	32/f	—	sec	**Note 2**
Diagnostic Timer	t_{DIAG}	—	3/f	—	sec	

Note 1: Ensured by design, tested during characterization.

2: For V_{DD} < 3.7V, $t_{STARTUP}$ and t_{MP} timers are typically 13/f.

TEMPERATURE SPECIFICATIONS

Electrical Characteristics: Unless otherwise noted, all parameters apply at V_{DD} = 3.0V to 5.5V

Parameters	Symbol	Min	Typ	Max	Units	Conditions
Temperature Ranges:						
Specified Temperature Range	T_A	-40	—	+85	°C	
Operating Temperature Range	T_A	-40	—	+125	°C	
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances:						
Thermal Package Resistance, 8-Pin MSOP	θ_{JA}	—	200	—	°C/W	
Thermal Package Resistance, 8-Pin SOIC	θ_{JA}	—	155	—	°C/W	
Thermal Package Resistance, 8-Pin PDIP	θ_{JA}	—	125	—	°C/W	

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TIMING SPECIFICATIONS

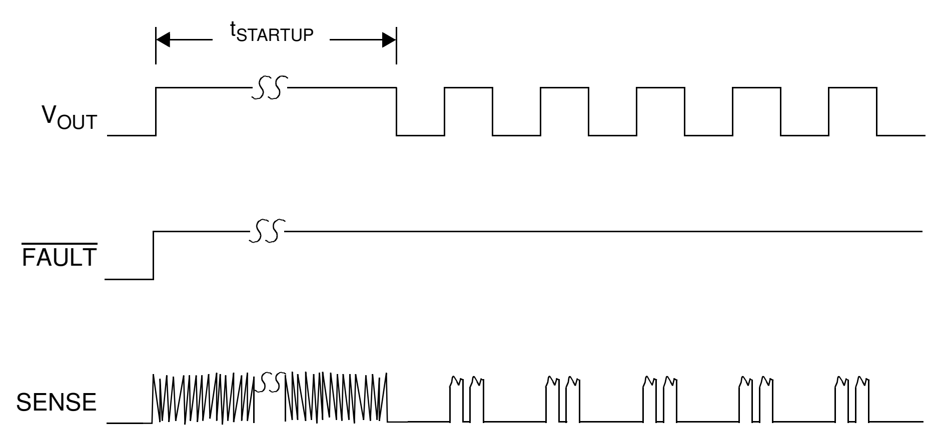


FIGURE 1-1: *TC642B/TC647B Start-Up Timing.*

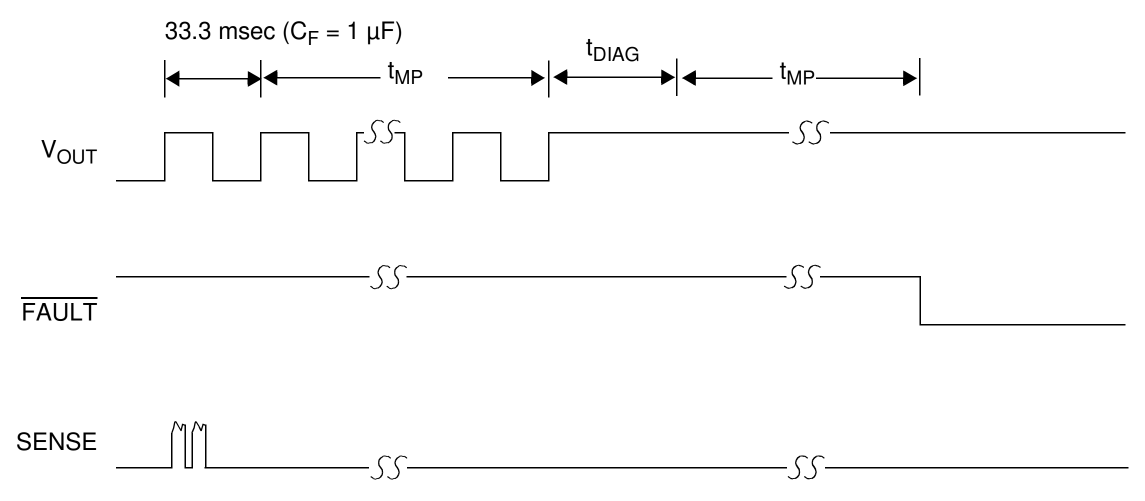


FIGURE 1-2: *Fan Fault Occurrence.*

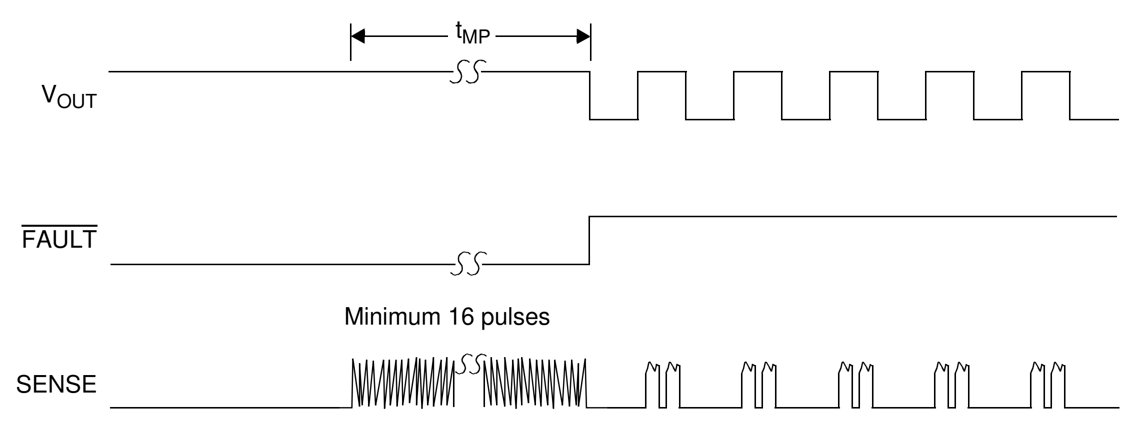
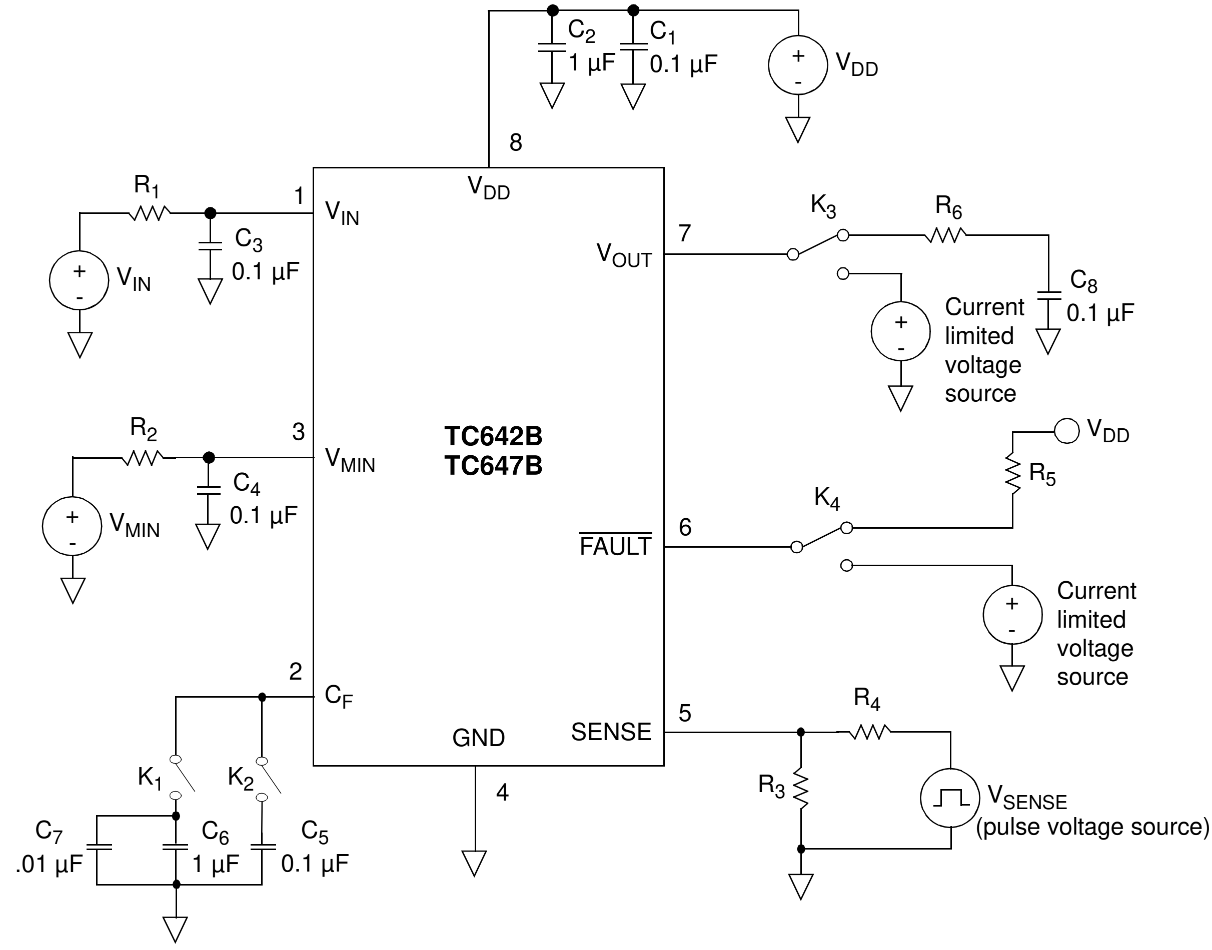


FIGURE 1-3: *Recovery From Fan Fault.*



Note: C_5 and C_7 are adjusted to get the necessary 1 µF value.

FIGURE 1-4: *TC642B/TC647B Electrical Characteristics Test Circuit.*

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2.0 TYPICAL PERFORMANCE CURVES

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

Note: Unless otherwise indicated, V_{DD} = 5V, T_A = +25°C.

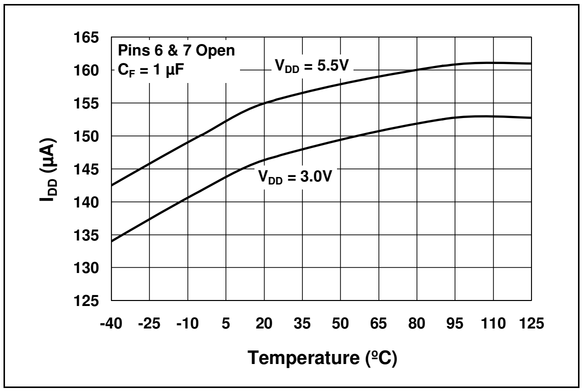

FIGURE 2-1: *I_{DD} vs. Temperature.*

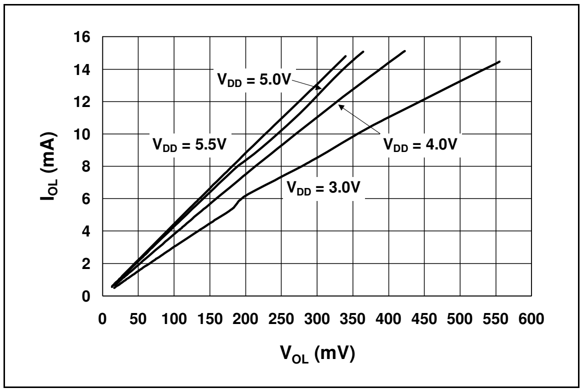

FIGURE 2-2: *PWM Sink Current (I_{OL}) vs. V_{OL}.*

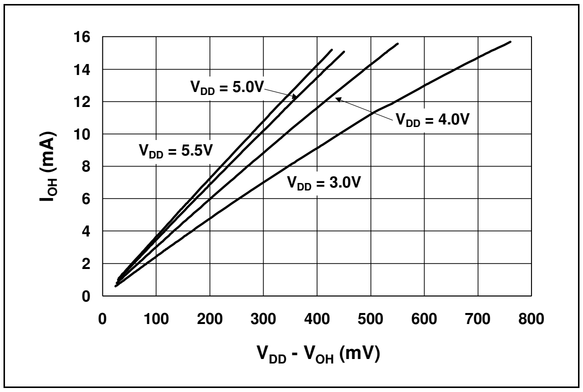

FIGURE 2-3: *PWM Source Current (I_{OH}) vs. V_{DD}-V_{OH}.*

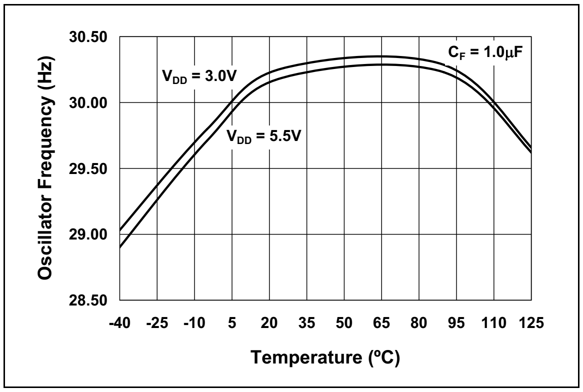

FIGURE 2-4: *PWM Frequency vs. Temperature.*

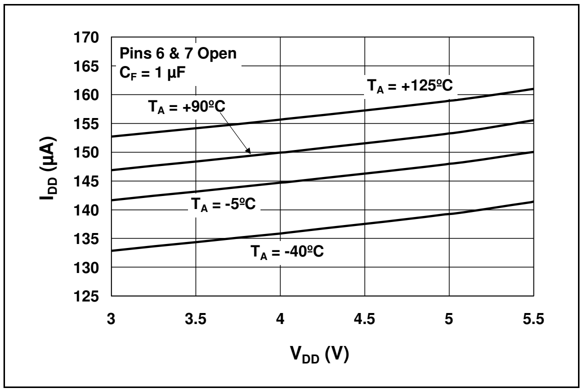

FIGURE 2-5: *I_{DD} vs. V_{DD}.*

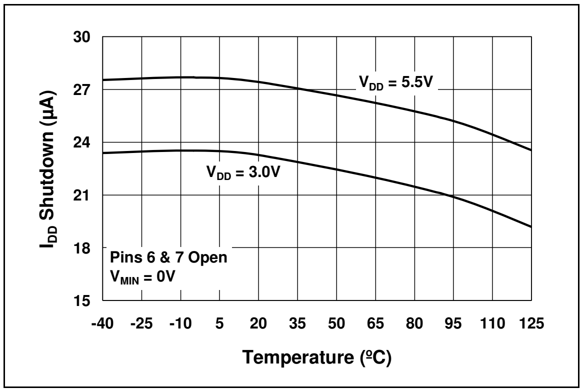

FIGURE 2-6: *I_{DD} Shutdown vs. Temperature.*

Note: Unless otherwise indicated, V_{DD} = 5V, T_A = +25°C.

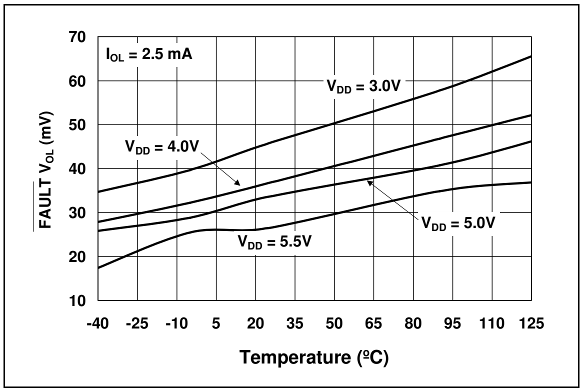

FIGURE 2-7: *$\overline{\text{FAULT}}$ V_{OL} vs. Temperature.*

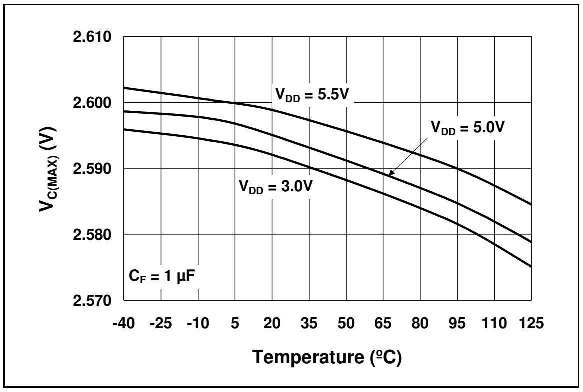

FIGURE 2-8: *$V_{C(MAX)}$ vs. Temperature.*

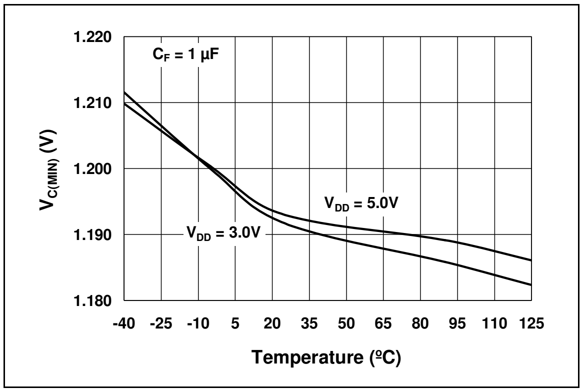

FIGURE 2-9: *$V_{C(MIN)}$ vs. Temperature.*

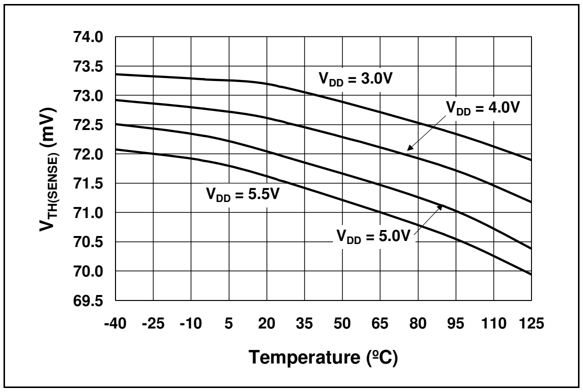

FIGURE 2-10: *Sense Threshold ($V_{TH(SENSE)}$) vs. Temperature.*

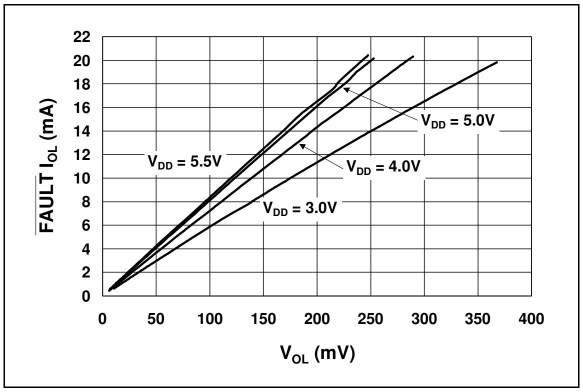

FIGURE 2-11: *$\overline{\text{FAULT}}$ I_{OL} vs. V_{OL}.*

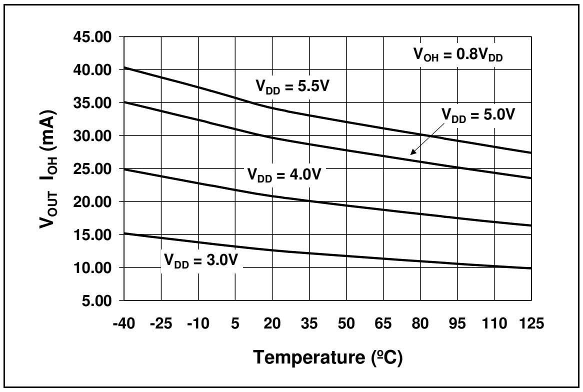

FIGURE 2-12: *PWM Source Current (I_{OH}) vs. Temperature.*

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Note: Unless otherwise indicated, V_{DD} = 5V, T_A = +25°C.

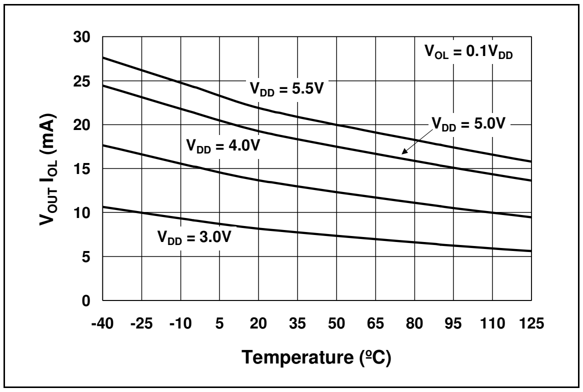

FIGURE 2-13: *PWM Sink Current (I_{OL}) vs. Temperature.*

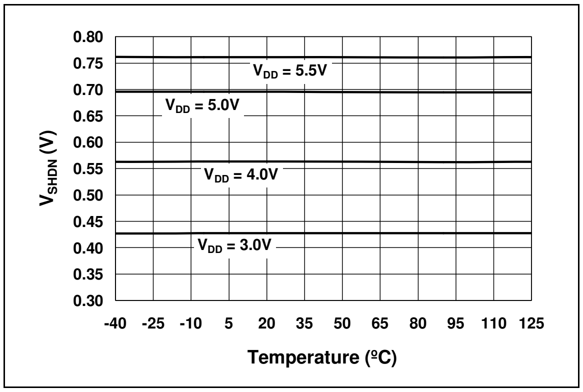

FIGURE 2-14: *V_{SHDN} Threshold vs. Temperature.*

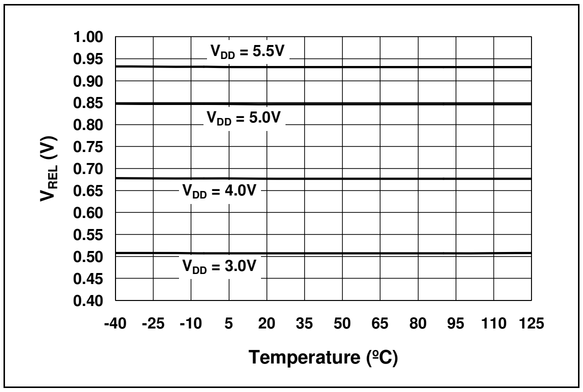

FIGURE 2-15: *V_{REL} Threshold vs. Temperature.*

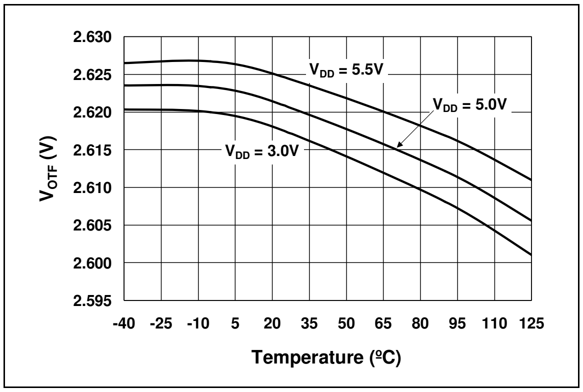

FIGURE 2-16: *V_{OTF}* Threshold *vs. Temperature.*

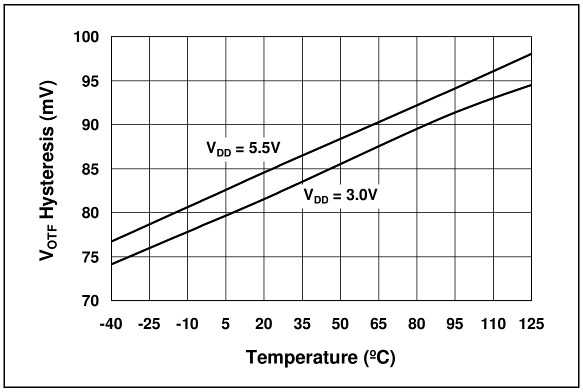

FIGURE 2-17: *Over-Temperature Hysteresis ($V_{OTF-HYS}$) vs. Temperature.*

3.0 PIN FUNCTIONS

The description of the pins are given in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin	Name	Function
1	V_{IN}	Analog Input
2	C_F	Analog Output
3	V_{MIN}	Analog Input
4	GND	Ground
5	SENSE	Analog Input
6	$\overline{\text{FAULT}}$	Digital (Open-Drain) Output
7	V_{OUT}	Digital Output
8	V_{DD}	Power Supply Input

3.1 Analog Input (V_{IN})

The thermistor network (or other temperature sensor) connects to V_{IN}. A voltage range of 1.20V to 2.60V (typical) on this pin drives an active duty cycle of 0% to 100% on the V_{OUT} pin.

3.2 Analog Output (C_F)

C_F is the positive terminal for the PWM ramp generator timing capacitor. The recommended value for the C_F capacitor is 1.0 µF for 30 Hz PWM operation.

3.3 Analog Input (V_{MIN})

An external resistor divider connected to V_{MIN} sets the minimum fan speed by fixing the minimum PWM duty cycle (1.20V to 2.60V = 0% to 100%, typical). The TC642B and TC647B devices enter shutdown mode when $0 \leq V_{MIN} \leq V_{SHDN}$. During shutdown, the $\overline{\text{FAULT}}$ output is inactive and supply current falls to 30 µA (typical).

3.4 Analog Input (SENSE)

Pulses are detected at SENSE as fan rotation chops the current through a sense resistor. The absence of pulses indicates a fan fault condition.

3.5 Digital (Open-Drain) Output ($\overline{\text{FAULT}}$)

The $\overline{\text{FAULT}}$ line goes low to indicate a fault condition. When $\overline{\text{FAULT}}$ goes low due to a fan fault, the output will remain low until the fan fault condition has been removed (16 pulses have been detected at the $\overline{\text{SENSE}}$ pin in a 32/f period). For the TC642B device, the $\overline{\text{FAULT}}$ output will also be asserted when the V_{IN} voltage reaches the V_{OTF} treshold of 2.62V (typical). This gives an over-temperature/100% fan speed indication.

3.6 Digital Output (V_{OUT})

V_{OUT} is an active-high complimentary output and drives the base of an external NPN transistor (via an appropriate base resistor) or the gate of an N-channel MOSFET. This output has asymmetrical drive. During a fan fault condition, the V_{OUT} output is continuously on.

3.7 Power Supply Input (V_{DD})

The V_{DD} pin with respect to GND provides power to the device. This bias supply voltage may be independent of the fan power supply.

4.0 DEVICE OPERATION

The TC642B/TC647B devices are a family of temperature proportional, PWM mode, fan speed controllers. Features of the family include minimum fan speed, fan auto-shutdown mode, fan auto-restart, remote shutdown, over-temperature indication and fan fault detection.

The TC642B/TC647B family is slightly different from the original TC64X family, which includes the TC642, TC646, TC647, TC648 and TC649 devices. Changes have been made to adjust the operation of the device during a fan fault condition.

The key change to the TC64XB family of devices (TC642B, TC647B, TC646B, TC648B, TC649B) is that the $\overline{\text{FAULT}}$ and V_{OUT} outputs no longer "latch" to a state during a fan fault condition. The TC64XB family will continue to monitor the operation of the fan so that when the fan returns to normal operation, the fan speed controller will also return to normal operation (PWM mode). The operation and features of these devices are discussed in the following sections.

4.1 Fan Speed Control Methods

The speed of a DC brushless fan is proportional to the voltage across it. This relationship will vary from fan to fan and should be characterized on an individual basis. The speed versus applied voltage relationship can then be used to set up the fan speed control algorithm.

There are two main methods for fan speed control. The first is pulse width modulation (PWM) and the second is linear. Using either method, the total system power requirement to run the fan is equal. The difference between the two methods is where the power is consumed.

The following example compares the two methods for a 12V, 120 mA fan running at 50% speed. With 6V applied across the fan, the fan draws an average current of 68 mA.

Using a linear control method, there is 6V across the fan and 6V across the drive element. With 6V and 68 mA, the drive element is dissipating 410 mW of power.

Using the PWM approach, the fan voltage is modulated at a 50% duty cycle with most of the 12V being dropped across the fan. With 50% duty cycle, the fan draws an RMS current of 110 mA and an average current of 72 mA. Using a MOSFET with a 1 $\Omega R_{DS(on)}$ (a fairly typical value for this low current), the power dissipation in the drive element would be: 12 mW ($Irms^2 * R_{DS(on)}$). Using a standard 2N2222A NPN transistor (assuming a Vce-sat of 0.8V), the power dissipation would be 58 mW (Iavg* Vce-sat).

The PWM approach to fan speed control results in much less power dissipation in the drive element, allowing smaller devices to be used while not requiring special heatsinking to remove the power being dissipated in the package.

The other advantage of the PWM approach is that the voltage being applied to the fan is always near 12V. This eliminates any concern about not supplying a high enough voltage to run the internal fan components, which is very relevant in linear fan speed control.

4.2 PWM Fan Speed Control

The TC642B and TC647B devices implement PWM fan speed control by varying the duty cycle of a fixed frequency pulse train. The duty cycle of a waveform is the on time divided by the total period of the pulse. For example, a 100 Hz waveform (10 ms) with an on time of 5.0 ms has a duty cycle of 50% (5.0 ms / 10.0 ms). This example is illustrated in Figure 4-1.

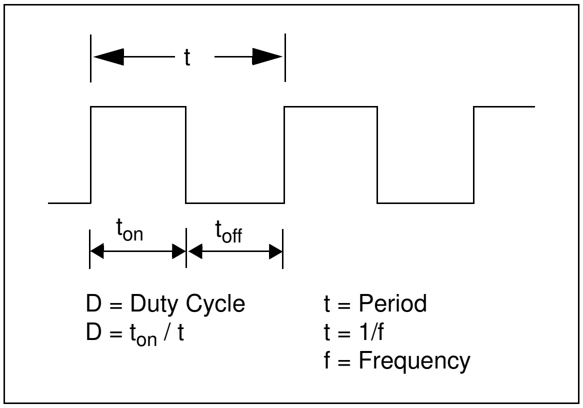

FIGURE 4-1: *Duty Cycle of a PWM Waveform.*

The TC642B and TC647B generate a pulse train with a typical frequency of 30 Hz (C_F = 1 µF). The duty cycle can be varied from 0% to 100%. The pulse train generated by the TC642B/TC647B device drives the gate of an external N-channel MOSFET or the base of an NPN transistor (shown in Figure 4-2). See Section 5.5, "Output Drive Device Selection", for more information.

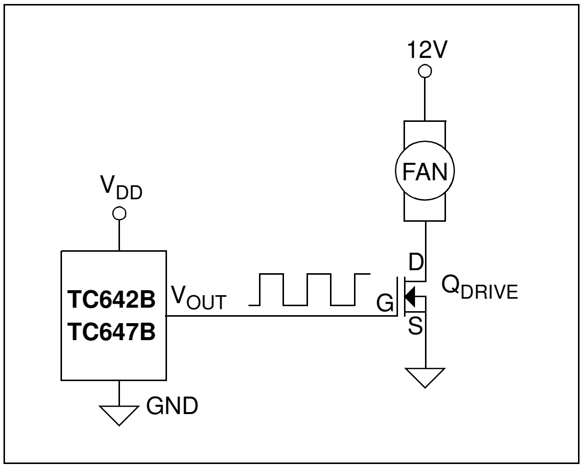

FIGURE 4-2: *PWM Fan Drive.*

By modulating the voltage applied to the gate of the MOSFET (Q_{DRIVE}), the voltage that is applied to the fan is also modulated. When the V_{OUT} pulse is high, the gate of the MOSFET is turned on, pulling the voltage at the drain of Q_{DRIVE} to zero volts. This places the full 12V across the fan for the t_{on} period of the pulse. When the duty cycle of the drive pulse is 100% (full on, $t_{on} = t$), the fan will run at full speed. As the duty cycle is decreased (pulse on time "t_{on}" is lowered), the fan will slow down proportionally. With the TC642B and TC647B devices, the duty cycle is controlled by either the V_{IN} or V_{MIN} input, with the higher voltage setting the duty cycle. This is described in more detail in Section 5.5, "Output Drive Device Selection".

4.3 Fan Start-up

Often overlooked in fan speed control is the actual start-up control period. When starting a fan from a non-operating condition (fan speed is zero revolutions per minute (RPM)), the desired PWM duty cycle or average fan voltage can not be applied immediately. Since the fan is at a rest position, the fan's inertia must be overcome to get it started. The best way to accomplish this is to apply the full rated voltage to the fan for a minimum of one second. This will ensure that in all operating environments, the fan will start and operate properly. An example of the start-up timing is shown in Figure 1-1.

A key feature of the TC642B/TC647B device is the start-up timer. When power is first applied to the device, (when the device is brought out of the shutdown mode of operation) the V_{OUT} output will go to a high state for 32 PWM cycles (one second for $C_F = 1\ \mu F$). This will drive the fan to full speed for this time-frame.

During the start-up period, the SENSE pin is being monitored for fan pulses. If pulses are detected during this period, the fan speed controller will then move to PWM operation (see Section 4.5, "Minimum Fan Speed", for more details on operation when coming out of start-up). If pulses are not detected during the start-up period, the start-up timer is activated again. If pulses are not detected at the SENSE pin during this additional start-up period, the $\overline{\text{FAULT}}$ output will go low to indicate that a fan fault condition has occurred. See Section 4.7, "$\overline{\text{FAULT}}$ Output", for more details.

4.4 PWM Frequency & Duty Cycle Control (C_F & V_{IN} Pins)

The frequency of the PWM pulse train is controlled by the C_F pin. By attaching a capacitor to the C_F pin, the frequency of the PWM pulse train can be set to the desired value. The typical PWM frequency for a 1.0 µF capacitor is 30 Hz. The frequency can be adjusted by raising or lowering the value of the capacitor. The C_F pin functions as a ramp generator. The voltage at this pin will ramp from 1.20V to 2.60V (typically) as a sawtooth waveform. An example of this is shown in Figure 4-3.

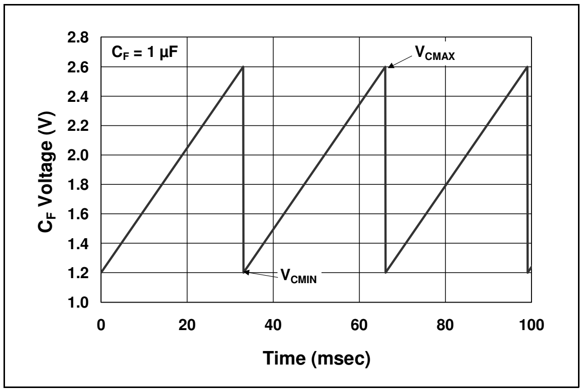

FIGURE 4-3: *C_F Pin Voltage.*

The duty cycle of the PWM output is controlled by the voltage at the V_{IN} input pin (or the V_{MIN} voltage, whichever is greater). The duty cycle of the PWM output is produced by comparing the voltage at the V_{IN} pin to the voltage ramp at the C_F pin. When the voltage at the V_{IN} pin is 1.20V, the duty cycle will be 0%. When the voltage at the V_{IN} pin is 2.60V, the PWM duty cycle will be 100% (these are both typical values). The V_{IN} to PWM duty cycle relationship is shown in Figure 4-4.

The lower value of 1.20V is referred to as V_{CMIN} and the 2.60V threshold is referred to as V_{CMAX}. A calculation for duty cycle is shown in the equation below. The voltage range between V_{CMIN} and V_{CMAX} is characterized as V_{CSPAN} and has a typical value of 1.4V with minimum and maximum values of 1.3V and 1.5V, respectively.

EQUATION PWM DUTY CYCLE

$$Duty\ Cycle\ (\%) = \frac{(V_{IN} - V_{CMIN}) * 100}{V_{CMAX} - V_{CMIN}}$$

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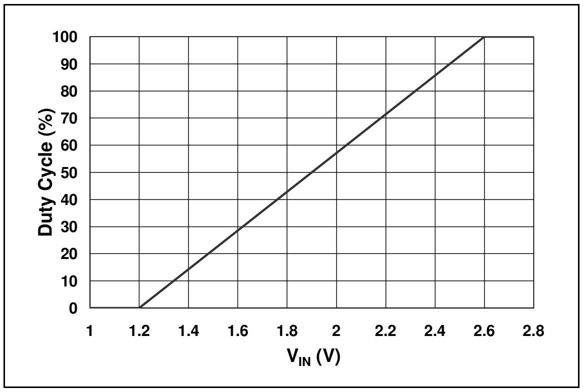

FIGURE 4-4: *V_{IN} voltage vs. PWM duty cycle(Typical).*

The PWM duty cycle is also controlled by the V_{MIN} pin See Section 4.5, "Minimum Speed (V_{MIN} Pin)", for more details on this function.

4.5 Minimum Speed (V_{MIN} Pin)

For the TC642B and TC647B devices, pin 3 is the V_{MIN} pin. This pin is used for setting the minimum fan speed threshold.

The minimum fan speed function provides a way to set a threshold for a minimum duty cycle on the V_{OUT} output. This in turn produces a minimum fan speed for the user. The voltage range for the V_{MIN} pin is the same as that for the V_{IN} pin (1.20V to 2.60V). The voltage at the V_{MIN} pin is set in this range so that as the voltage at the V_{IN} pin decreases below the V_{MIN} voltage, the output duty cycle will be controlled by the V_{MIN} voltage. The following equation can be used to determine the necessary voltage at V_{MIN} for a desired minimum duty cycle on V_{OUT}.

EQUATION V_{MIN} VOLTAGE

$$V_{MIN}(V) = \frac{(DC * 1.4)}{100} + 1.20$$

DC = Desired Duty Cycle

Example: If a minimum duty cycle of 40% is desired, the V_{MIN} voltage should be set to:

EXAMPLE 4-1:

$$V_{MIN}(V) = \frac{(40 * 1.4)}{100} + 1.20$$

$$V_{MIN} = 1.76V$$

If the voltage at the V_{IN} pin falls below 1.76V, the duty cycle of the V_{OUT} output will not decrease below the 40% value that is now set by the voltage at the V_{MIN} pin. In this manner, the fan will continue to operate at 40% speed even when the temperature (voltage at V_{IN}) continues to decrease.

For the TC642B and TC647B devices, the V_{MIN} pin is also used as the shutdown pin. The V_{SHDN} and V_{REL} threshold voltages are characterized in the "Electrical Characteristics" table of Section 1.0. If the V_{MIN} pin voltage is pulled below the V_{SHDN} threshold, the device will shut down (V_{OUT} output goes to a low state, the $\overline{\text{FAULT}}$ pin is inactive). If the voltage on the V_{MIN} pin then rises above the release threshold (V_{REL}), the device will go through a Power-Up sequence. The Power-Up sequence is shown later in Figure 4-9.

4.6 V_{OUT} Output (PWM Output)

The V_{OUT} output is a digital output designed for driving the base of a transistor or the gate of a MOSFET. The V_{OUT} output is designed to be able to quickly raise the base current or the gate voltage of the external drive device to its final value.

When the device is in shutdown mode, the V_{OUT} output is actively held low. The output can be varied from 0% duty cycle (full off) to 100% duty cycle (full on). As previously discussed, the duty cycle of the V_{OUT} output is controlled via the V_{IN} input voltage along with the V_{MIN} voltage.

A base current-limiting resistor is required when using a transistor as the external drive device in order to limit the amount of drive current that is drawn from the V_{OUT} output.

The V_{OUT} output can be directly connected to the gate of an external MOSFET. One concern when doing this, though, is that the fast turn-off time of the fan drive MOSFET can cause a problem. The fan motor looks like an inductor. When the MOSFET is turned off quickly, the current in the fan wants to continue to flow in the same direction. This causes the voltage at the drain of the MOSFET to rise. If there aren't any clamp diodes internal to the fan, this voltage can rise above the drain-to-source voltage rating of the MOSFET. For this reason, an external clamp diode is suggested. This is shown in Figure 4-5.

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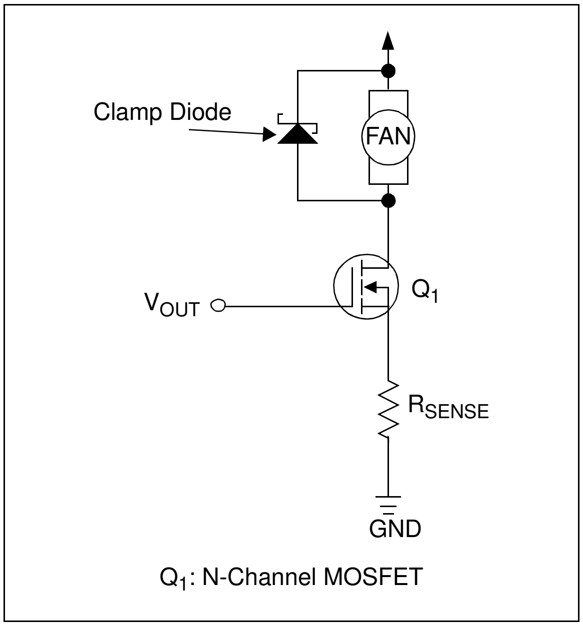

FIGURE 4-5: *Clamp Diode for Fan.*

4.7 $\overline{\text{FAULT}}$ Output

The $\overline{\text{FAULT}}$ output is an open-drain, active-low output. For the TC642B and TC647B devices, the $\overline{\text{FAULT}}$ output indicates when a fan fault condition has occurred. For the TC642B device, the $\overline{\text{FAULT}}$ output also indicates when an over-temperature (OTF) condition has occurred.

For the TC642B device, an over-temperature condition is indicated ($\overline{\text{FAULT}}$ output is pulled low) when the V_{IN} input reaches the V_{OTF} threshold voltage (the V_{OTF} threshold voltage is typically 20 mV higher than the V_{CMAX} threshold and has 80 mV of hysteresis). This indicates that maximum cooling capacity has been reached (the fan is at full speed) and that an overheating situation can occur. When the voltage at the V_{IN} input falls below the V_{OTF} threshold voltage by the hysteresis value ($V_{OTF-HYS}$), the $\overline{\text{FAULT}}$ output returns to the high-state (a pull-up resistor is needed on the $\overline{\text{FAULT}}$ output).

A fan fault condition is indicated when fan current pulses are no longer detected at the SENSE pin. Pulses at the SENSE pin indicate that the fan is spinning and conducting current.

If pulses are not detected at the SENSE pin for 32 PWM cycles, the 3-cycle diagnostic timer is fired. This means that the V_{OUT} output is high for 3 PWM cycles. If pulses are detected in this 3-cycle period, then normal PWM operation is resumed and no fan fault is indicated. If no pulses are detected in the 3-cycle period, the start-up timer is activated and the V_{OUT} output is driven high for 32 PWM cycles. If pulses are detected during this timeframe, normal PWM operation is resumed. If no pulses are detected during this time frame, a fan fault condition exists and the $\overline{\text{FAULT}}$ output is pulled low.

During a fan fault condition, the $\overline{\text{FAULT}}$ output will remain low until the fault condition has been removed. During this time, the V_{OUT} output is driven high continuously to attempt to restart the fan, and the SENSE pin is monitored for fan pulses. If a minimum of 16 pulses are detected at the SENSE input over a 32 cycle time period (one second for $C_F = 1.0\ \mu F$), the fan fault condition no longer exists. The $\overline{\text{FAULT}}$ output is then released and the V_{OUT} output returns to normal PWM operation, as dictated by the V_{IN} and V_{MIN} inputs.

If the V_{MIN} voltage is pulled below the V_{SHDN} level during a fan fault condition, the $\overline{\text{FAULT}}$ output will be released and the V_{OUT} output will be shutdown ($V_{OUT} = 0V$). If the V_{MIN} voltage then increases above the V_{REL} threshold, the device will go through the normal start-up routine.

If, during a fan fault condition, the voltage at the V_{IN} pin drops below the V_{MIN} voltage level, the TC642B/TC647B device will continue to hold the $\overline{\text{FAULT}}$ line low and drive the V_{OUT} output to 100% duty cycle. If the fan fault condition is then removed, the $\overline{\text{FAULT}}$ output will be released and the V_{OUT} output will be driven to the duty cycle that is being commanded by the V_{MIN} input.

The sink current capability of the $\overline{\text{FAULT}}$ output is listed in the “Electrical Characteristics” table of Section 1.0.

4.8 Sensing Fan Operation (SENSE)

The SENSE input is an analog input used to monitor the fan’s operation. It does this by sensing fan current pulses, which represent fan rotation. When a fan rotates, commutation of the fan current occurs as the fan poles pass the armatures of the motor. The commutation of the fan current makes the current waveshape appear as pulses. There are two typical current waveforms of brushless DC fan motors. These are shown in Figures 4-6 and 4-7.

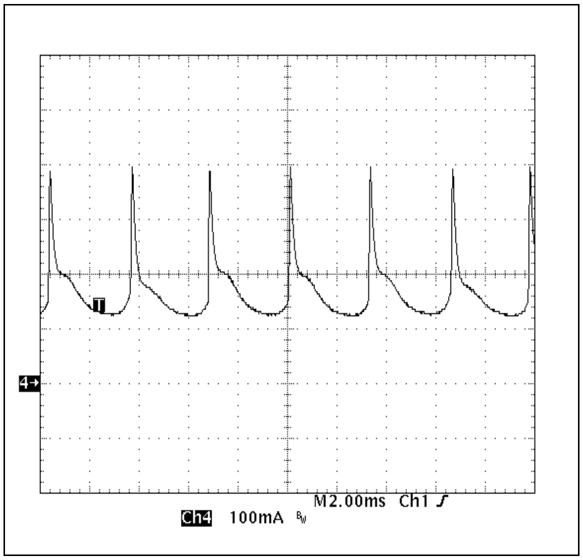

FIGURE 4-6: *Fan Current With DC Offset And Positive Commutation Current.*

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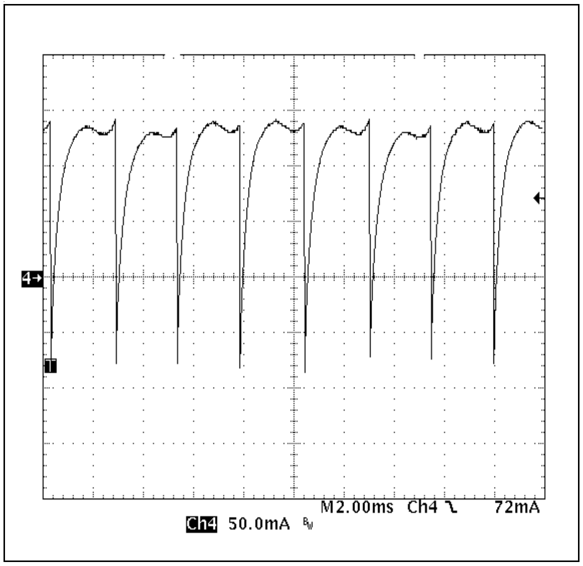

FIGURE 4-7: *Fan Current With Commutation Pulses To Zero.*

The SENSE pin senses positive voltage pulses that have an amplitude of 70 mV (typical value). When a pulse is detected, the missing pulse detector timer is reset. As previously stated, if the missing pulse detector timer reaches the time for 32 cycles, the loop for diagnosing a fan fault is engaged (diagnostic timer, then the start-up timer).

Both of the fan current waveshapes that are shown in Figures 4-6 and 4-7 can be sensed with the sensing scheme shown in Figure 4-8.

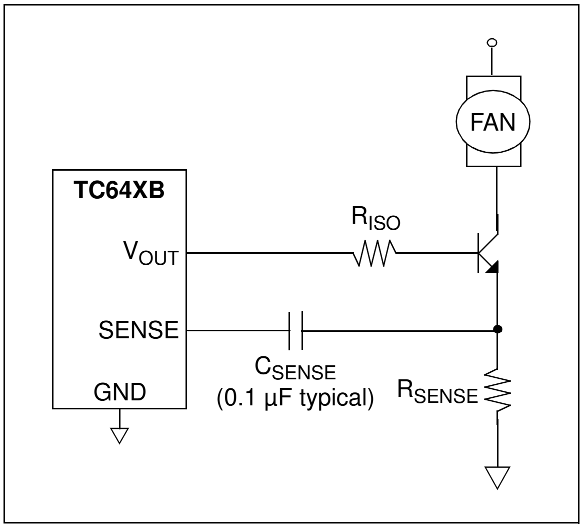

FIGURE 4-8: *Sensing Scheme For Fan Current.*

The fan current flowing through R_{SENSE} generates a voltage that is proportional to the current. The C_{SENSE} capacitor removes any DC portion of the voltage across R_{SENSE} and presents only the voltage pulse portion to the SENSE pin of the TC642B/TC647B devices.

The R_{SENSE} and C_{SENSE} values need to be selected so that the voltage pulse provided to the SENSE pin is 70 mV (typical) in amplitude. Be sure to check the sense pulse amplitude over all operating conditions (duty cycles), as the current pulse amplitude will vary with duty cycle. See Section 5.0, “Applications Information”, for more details on selecting values for R_{SENSE} and C_{SENSE}.

Key features of the SENSE pin circuitry are an initial blanking period after every V_{OUT} pulse and an initial pulse blanker.

The TC642B/TC647B sense circuitry has a blanking period that occurs at the turn-on of each V_{OUT} pulse. During this blanking period, the sense circuitry ignores any pulse information that is seen at the SENSE pin input. This stops the TC642B/TC647B device from falsely sensing a current pulse which is due to the fan drive device turn-on.

The initial pulse blanker is also implemented to stop false sensing of fan current pulses. When a fan is in a locked rotor condition, the fan current no longer commutates, it simply flows through one fan winding and is a DC current. When a fan is in a locked rotor condition and the TC642B/TC647B device is in PWM mode, it will see one current pulse each time the V_{OUT} output is turned on. The initial pulse blanker allows the TC642B/TC647B device to ignore this pulse and recognize that the fan is in a fault condition.

4.9 Behavioral Algorithms

The behavioral algorithm for the TC642B/TC647B devices is shown in Figure 4-9.

The behavioral algorithm shows the step-by-step decision-making process for the fan speed controller operation. The TC642B and TC647B devices are very similar with one exception: the TC647B device does not implement the over-temperature portion of the algorithm.

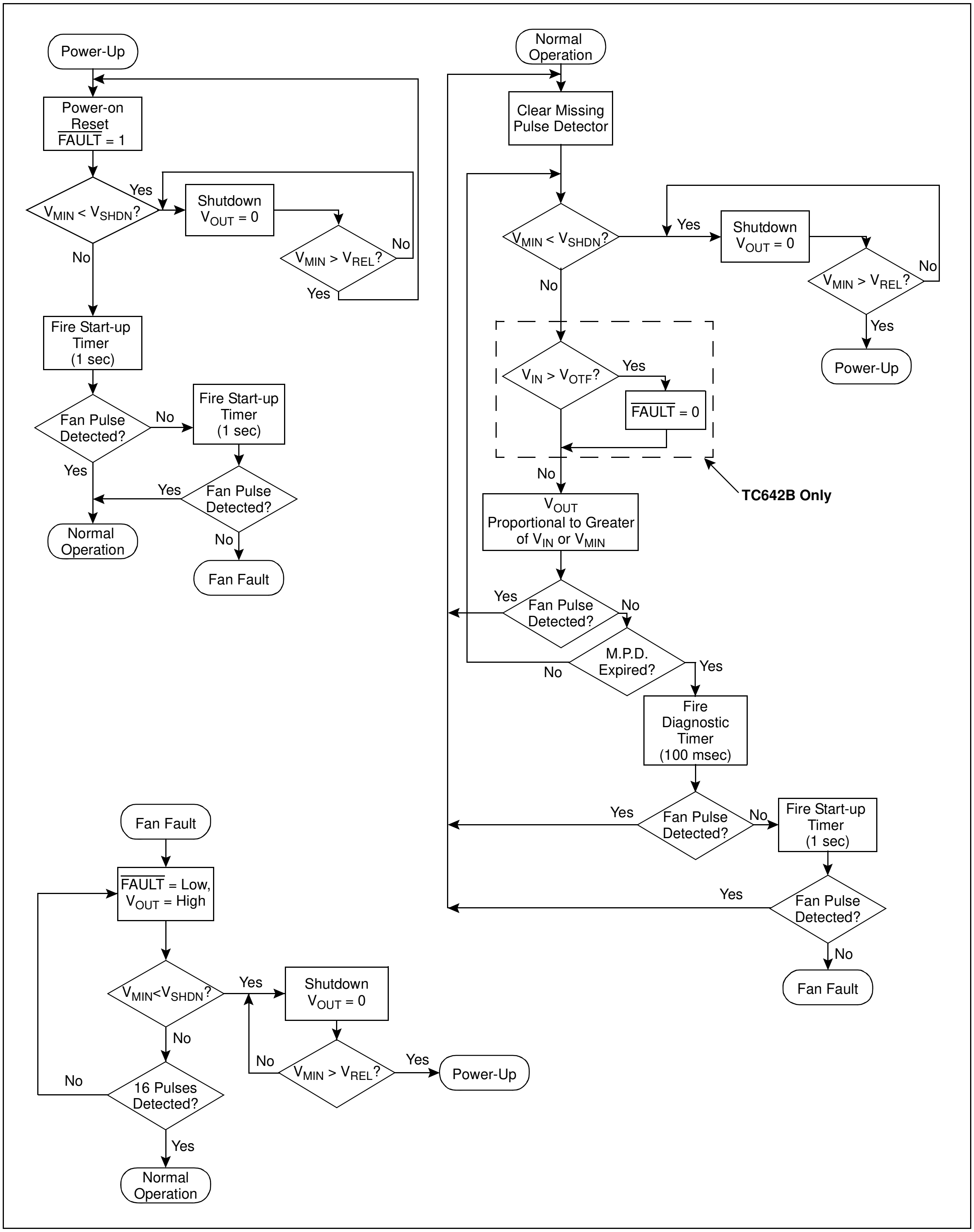

FIGURE 4-9: *TC642B/TC647B Behavioral Algorithm.*

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5.0 APPLICATIONS INFORMATION

5.1 Setting the PWM Frequency

The PWM frequency of the V_{OUT} output is set by the capacitor value attached to the C_F pin. The PWM frequency will be 30 Hz (typical) for a 1 µF capacitor. The relationship between frequency and capacitor value is linear, making alternate frequency selections easy.

As stated in previous sections, the PWM frequency should be kept in the range of 15 Hz to 35 Hz. This will eliminate the possibility of having audible frequencies when varying the duty cycle of the fan drive.

A very important factor to consider when selecting the PWM frequency for the TC642B/TC647B devices is the RPM rating of the selected fan and the minimum duty cycle that the fan will be operating at. For fans that have a full speed rating of 3000 RPM or less, it is desirable to use a lower PWM frequency. A lower PWM frequency allows for a longer time period to monitor the fan current pulses. The goal is to be able to monitor at least two fan current pulses during the on time of the V_{OUT} output.

Example: The system design requirement is to operate the fan at 50% duty cycle when ambient temperatures are below 20°C. The fan full speed RPM rating is 3000 RPM and has four current pulses per rotation. At 50% duty cycle, the fan will be operating at approximately 1500 RPM.

EQUATION

$$\text{Time for one revolution (msec.)} = \frac{60 \times 1000}{1500} = 40$$

If one fan revolution occurs in 40 msec, each fan pulse occurs 10 msec apart. In order to detect two fan current pulses, the on time of the V_{OUT} pulse must be at least 20 msec. With the duty cycle at 50%, the total period of one cycle must be at least 40 msec, which makes the PWM frequency 25 Hz. For this example, a PWM frequency of 20 Hz is recommended. This would define a C_F capacitor value of 1.5 µF.

5.2 Temperature Sensor Design

As discussed in previous sections, the V_{IN} analog input has a range of 1.20V to 2.60V (typical), which represents a duty cycle range on the V_{OUT} output of 0% to 100%, respectively. The V_{IN} voltages can be thought of as representing temperatures. The 1.20V level is the low temperature at which the system requires very little cooling. The 2.60V level is the high temperature, for which the system needs maximum cooling capability (100% fan speed).

One of the simplest ways of sensing temperature over a given range is to use a thermistor. By using an NTC thermistor, as shown in Figure 5-1, a temperature variant voltage can be created.

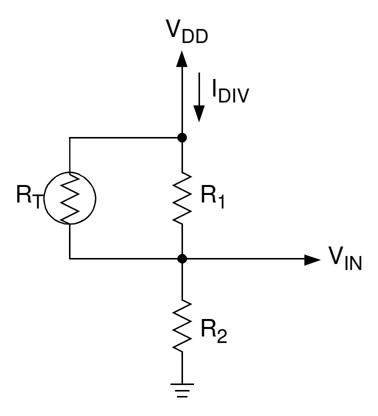

FIGURE 5-1: *Temperature Sensing Circuit.*

Figure 5-1 represents a temperature-dependent voltage divider circuit. R_T is a conventional NTC thermistor, while R_1 and R_2 are standard resistors. R_1 and R_T form a parallel resistor combination that will be referred to as R_{TEMP} ($R_{TEMP} = R_1 * R_T / R_1 + R_T$). As the temperature increases, the value of R_t decreases and the value of R_{TEMP} will decrease with it. Accordingly, the voltage at V_{IN} increases as temperature increases, giving the desired relationship for the V_{IN} input. R_1 helps to linearize the response of the sense network and aids in obtaining the proper V_{IN} voltages over the desired temperature range. An example of this is shown in Figure 5-2.

If less current draw from V_{DD} is desired, a larger value thermistor should be chosen. The voltage at the V_{IN} pin can also be generated by a voltage output temperature sensor device. The key is to get the desired V_{IN} voltage to system (or component) temperature relationship.

The following equations apply to the circuit in Figure 5-1.

EQUATION

$$V(T1) = \frac{V_{DD} \times R_2}{R_{TEMP}(T1) + R_2}$$

$$V(T2) = \frac{V_{DD} \times R_2}{R_{TEMP}(T2) + R_2}$$

In order to solve for the values of R_1 and R_2, the values for V_{IN}, and the temperatures at which they are to occur, need to be selected. The variables T1 and T2 represent the selected temperatures. The value of the thermistor at these two temperatures can be found in the thermistor data sheet. With the values for the thermistor and the values for V_{IN}, there are now two equations from which the values for R_1 and R_2 can be found.

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Example: The following design goals are desired:

- Duty Cycle = 50% (V_{IN} = 1.90 V) with Temperature (T1) = 30°C
- Duty Cycle = 100% (V_{IN} = 2.60 V) with Temperature (T2) = 60°C

Using a 100 kΩ thermistor (25°C value), look up the thermistor values at the desired temperatures:

- R_T (T1) = 79428Ω @ 30°C
- R_T (T2) = 22593Ω @ 60°C

Substituting these numbers into the given equations produces the following numbers for R_1 and R_2.

- R_1 = 34.8 kΩ
- R_2 = 14.7 kΩ

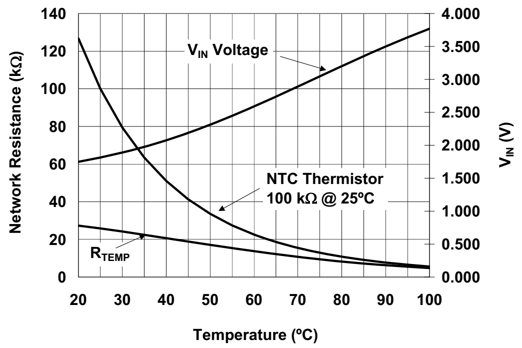


FIGURE 5-2: *How Thermistor Resistance, V_{IN}, and R_{TEMP} Vary With Temperature.*

Figure 5-2 graphs R_T, R_{TEMP} (R_1 in parallel with R_T) and V_{IN} versus temperature for the example shown above.

5.3 Thermistor Selection

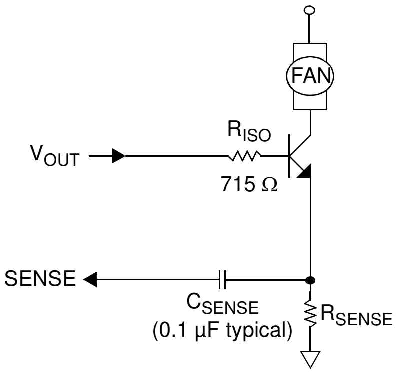
As with any component, there are a number of sources for thermistors. A listing of companies that manufacture thermistors can be found at www.temperatures.com/thermivendors.html. This website lists over forty suppliers of thermistor products. A brief list is shown here.

- Thermometrics®
- Ametherm®
- U.S. Sensors™
- Advanced Thermal Products™
- Quality Thermistor™
- Sensor Scientific™
- Vishay®
- muRata®

5.4 FanSense Network (R_{SENSE} and C_{SENSE})

The FanSense Network (comprised of R_{SENSE} and C_{SENSE}) allows the TC642B and TC647B devices to detect commutation of the fan motor. R_{SENSE} converts the fan current into a voltage. C_{SENSE} AC couples this voltage signal to the SENSE pin. The goal of the sense network is to provide a voltage pulse to the SENSE pin that has a minimum amplitude of 90 mV. This will ensure that the current pulse caused by the fan commutation is recognized by the TC642B/TC647B device.

A 0.1 µF ceramic capacitor is recommended for C_{SENSE}. Smaller values will require that larger sense resistors be used. Using a 0.1 µF capacitor results in reasonable values for R_{SENSE}. Figure 5-3 illustrates a typical SENSE network.



Note: See Table 5-1 for R_{SENSE} values.

FIGURE 5-3: *Typical Sense Network.*

The required value of R_{SENSE} will change with the current rating of the fan and the fan current waveshape. A key point is that the current rating of the fan specified by the manufacturer may be a worst-case rating, with the actual current drawn by the fan being lower. For the purposes of setting the value for R_{SENSE}, the operating fan current should be measured to get the nominal value. This can be done by using an oscilloscope current probe or by using a voltage probe with a low value resistor (0.5Ω). Another good tool for this exercise is the TC642 Evaluation Board. This board allows the R_{SENSE} and C_{SENSE} values to be easily changed while allowing the voltage waveforms to be monitored to ensure the proper levels are being reached.

Table 5-1 shows values of R_{SENSE} according to the nominal operating current of the fan. The fan currents are average values. If the fan current falls between two of the values listed, use the higher resistor value.

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TABLE 5-1: FAN CURRENT VS. R_{SENSE}

Nominal Fan Current (mA)	$R_{SENSE}(\Omega)$
50	9.1
100	4.7
150	3.0
200	2.4
250	2.0
300	1.8
350	1.5
400	1.3
450	1.2
500	1.0

The values listed in Table 5-1 are for fans that have the fan current waveshape shown in Figure 4-7. With this waveshape, the average fan current is closer to the peak value, which requires the resistor value to be higher. When using a fan that has the fan current waveshape shown in Figure 4-6, the resistor value can often be decreased since the current peaks are higher than the average and it is the AC portion of the voltage that gets coupled to the SENSE pin.

The key point when selecting an R_{SENSE} value is to try to minimize the value in order to minimize the power dissipation in the resistor. In order to do this, it is critical to know the waveshape of the fan current and not just the average value.

Figure 5-4 shows some typical waveforms for the fan current and the voltage at the SENSE pin.

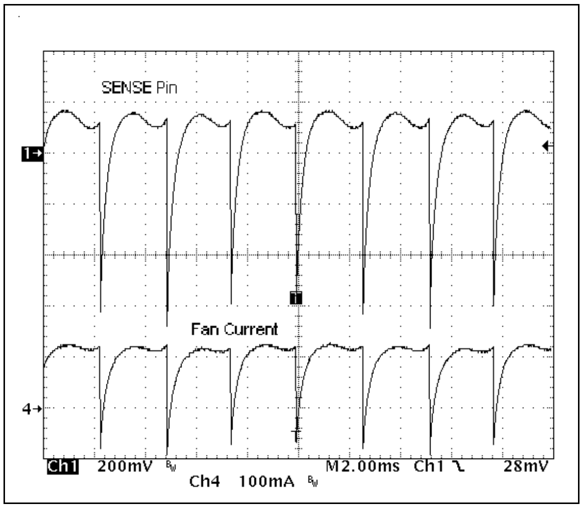


FIGURE 5-4: Typical Fan Current and SENSE Pin Waveforms.

Another important factor to consider when selecting the R_{SENSE} value is the fan current value during a locked rotor condition. When a fan is in a locked rotor condition (fan blades are stopped even though power is being applied to the fan), the fan current can increase dramatically, often 2.5 to 3.0 times the normal operating fan current. This will effect the power rating of the R_{SENSE} resistor selected.

When selecting the fan for the application, the current draw of the fan during a locked rotor condition should be considered, especially if multiple fans are being used in the application.

There are two main types of fan designs when looking at fan current draw during a locked rotor condition.

The first is a fan that will simply draw high DC currents when put into a locked rotor condition. Many older fans were designed this way. An example of this is a fan that draws an average current of 100 mA during normal operation. In a locked rotor condition, this fan will draw 250 mA of average current. For this design, the R_{SENSE} power rating must be sized to handle the 250 mA condition. The fan bias supply must also take this into account.

The second style design, which represents many of the newer fan designs today, acts to limit the current in a locked rotor condition by going into a pulse mode of operation. An example of the fan current waveshape for this style fan is shown in Figure 5-5. The fan represented in Figure 5-5 is a Panasonic®, 12V, 220 mA fan. During the on time of the waveform, the fan current is peaking up to 550 mA. Due to the pulse mode operation, however, the actual RMS current of the fan is very near the 220 mA rating. Because of this, the power rating for the R_{SENSE} resistor does not have to be oversized for this application.

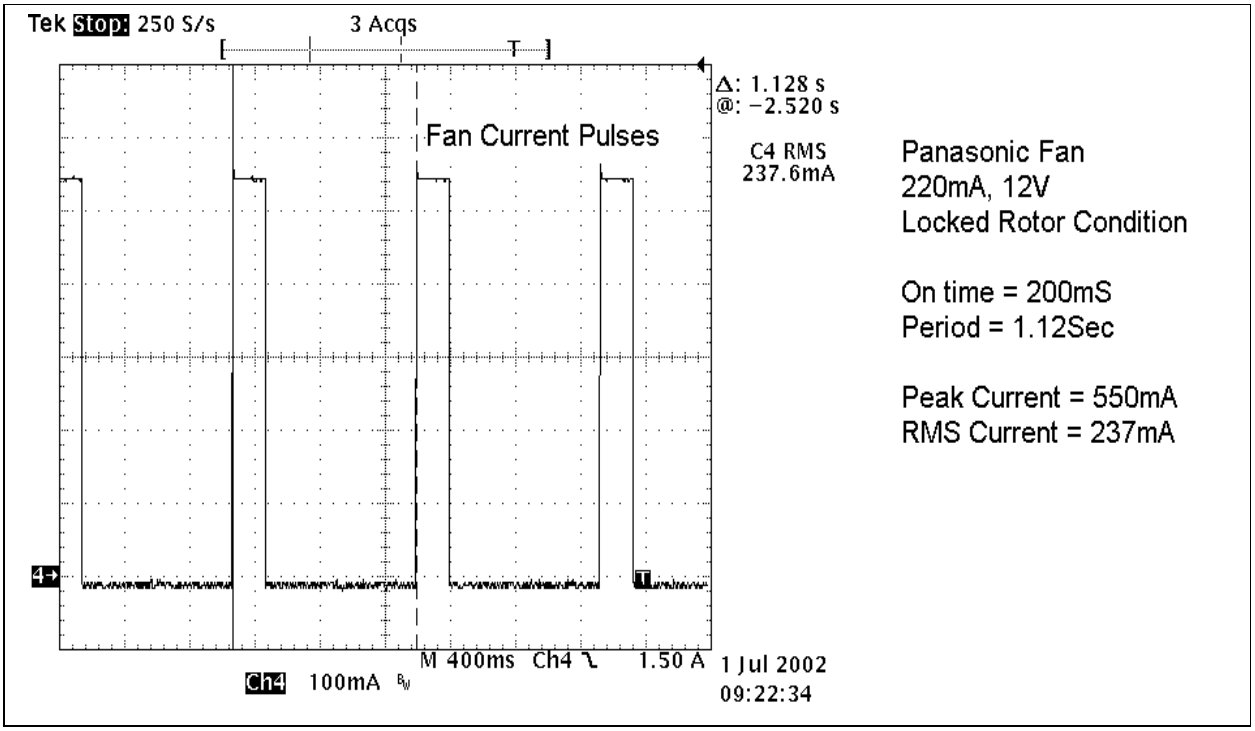


FIGURE 5-5: *Fan Current During a Locked Rotor Condition.*

5.5 Output Drive Device Selection

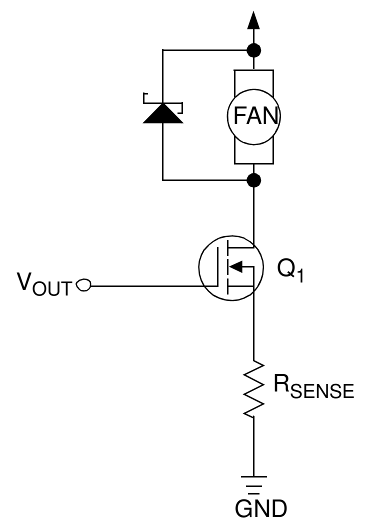
The TC642B/TC647B is designed to drive an external NPN transistor or N-channel MOSFET as the fan speed modulating element. These two arrangements are shown in Figure 5-7. For lower current fans, NPN transistors are a very economical choice for the fan drive device. It is recommended that, for higher current fans (300 mA and above), MOSFETs be used as the fan drive device. Table 5-2 provides some possible part numbers for use as the fan drive element.

When using a NPN transistor as the fan drive element, a base current-limiting resistor must be used, as is shown in Figure 5-7.

When using MOSFETs as the fan drive element, it is very easy to turn the MOSFETs on and off at very high rates. Because the gate capacitances of these small MOSFETs are very low, the TC642B/TC647B can charge and discharge them very quickly, leading to very fast edges. Of key concern is the turn-off edge of the MOSFET. Since the fan motor winding is essentially an inductor, once the MOSFET is turned off, the current that was flowing through the motor wants to continue to flow. If the fan does not have internal clamp diodes around the windings of the motor, there is no path for this current to flow through, and the voltage at the drain of the MOSFET may rise until the drain-to-source rating of the MOSFET is exceeded. This will most likely cause the MOSFET to go into avalanche mode. Since there is very little energy in this occurrence, it will probably not fail the device, but it would be a long-term reliability issue.

The following is recommended:

- Ask how the fan is designed. If the fan has clamp diodes internally, this problem will not be seen. If the fan does not have internal clamp diodes, it is a good idea to put one externally (Figure 5-6). Putting a resistor between V_{OUT} and the gate of the MOSFET will also help slow down the turn-off and limit this condition.



Q_1: N-Channel MOSFET

FIGURE 5-6: *Clamp Diode For Fan Turn-Off.*

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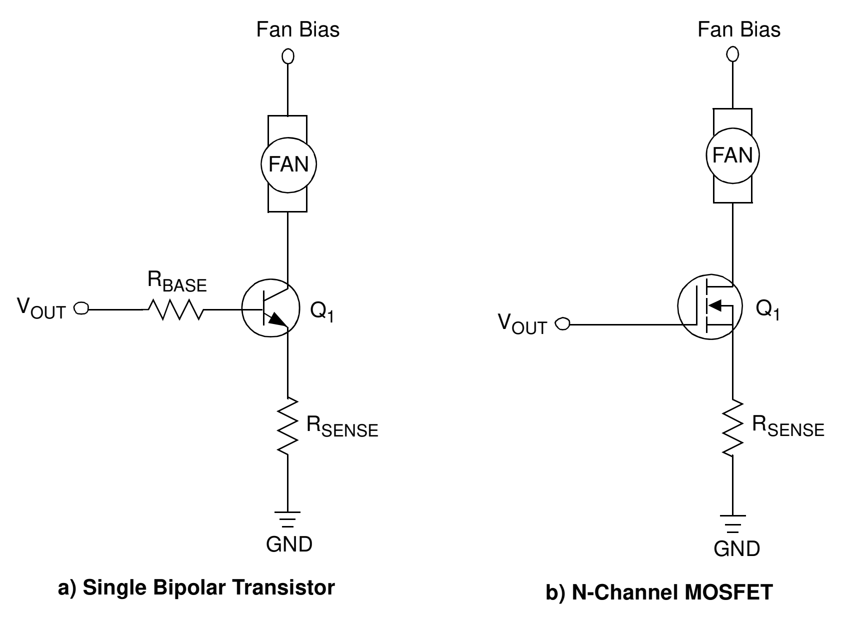

FIGURE 5-7: *Output Drive Device Configurations.*

TABLE 5-2: FAN DRIVE DEVICE SELECTION TABLE (NOTE 2)

Device	Package	Max Vbe sat / Vgs(V)	Min hfe	V_{CE}/V_{DS} (V)	Fan Current (mA)	Suggested Rbase (Ω)
MMBT2222A	SOT-23	1.2	50	40	150	800
MPS2222A	TO-92	1.2	50	40	150	800
MPS6602	TO-92	1.2	50	40	500	301
SI2302	SOT-23	2.5	NA	20	500	**Note 1**
MGSF1N02E	SOT-23	2.5	NA	20	500	**Note 1**
SI4410	SO-8	4.5	NA	30	1000	**Note 1**
SI2308	SOT-23	4.5	NA	60	500	**Note 1**

Note 1: A series gate resistor may be used in order to control the MOSFET turn-on and turn-off times.
2: These drive devices are suggestions only. Fan currents listed are for individual fans.

5.6 Bias Supply Bypassing and Noise Filtering

The bias supply (V_{DD}) for the TC642B/TC647B devices should be bypassed with a 1.0 µF ceramic capacitor. This capacitor will help supply the peak currents that are required to drive the base/gate of the external fan drive devices.

As the V_{IN} pin controls the duty cycle in a linear fashion, any noise on this pin can cause duty-cycle jittering. For this reason, the V_{IN} pin should be bypassed with a 0.01 µF capacitor.

In order to keep fan noise off of the TC642B/TC647B device ground, individual ground returns for the TC642B/TC647B and the low side of the fan current sense resistor should be used.

5.7 Design Example/Typical Application

The system has been designed with the following components and criteria.

System inlet air ambient temperature ranges from 0ºC to 50ºC. At 20ºC and below, it is desired to have the system cooling stay at a constant level. At 20ºC, the fan should be run at 40% of its full fan speed. Full fan speed should be reached when the ambient air is 40ºC.

The system has a surface mount, NTC-style thermistor in a 1206 package. The thermistor is mounted on a daughtercard, which is directly in the inlet air stream. The thermistor is a NTC, 100 kΩ @ 25ºC, Thermometrics® part number NHQ104B425R5. The given Beta for the thermistor is 4250. The system bias voltage to run the fan controller is 5V and the fan voltage is 12V.

The fan used in the system is a Panasonic®, Panaflo®-series fan, model number FBA06T12H.

A fault indication is desired when the fan is in a locked rotor condition. This signal is used to indicate to the system that cooling is not available and a warning should be issued to the user. No fault indication from the fan controller is necessary for an over-temperature condition, as this is being reported elsewhere.

Step 1: Gathering Information.

The first step in the design process is to gather the needed data on the fan and thermistor. For the fan, it is also a good idea to look at the fan current waveform, as indicated earlier in the data sheet.

Fan Information: Panasonic number: **FBA06T12H**

- Voltage = 12V
- Current = 145 mA (number from data sheet)

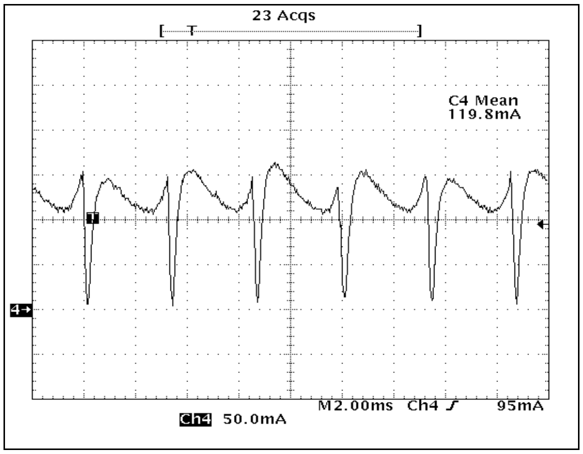

FIGURE 5-8: FBA06T12H fan current waveform.

From the waveform in Figure 5-8, the fan current has an average value of 120 mA, with peaks up to 150 mA. This information will help in the selection of the R_{SENSE} and C_{SENSE} values later on. Also of interest for the R_{SENSE} selection value is what the fan current does in a locked-rotor condition.

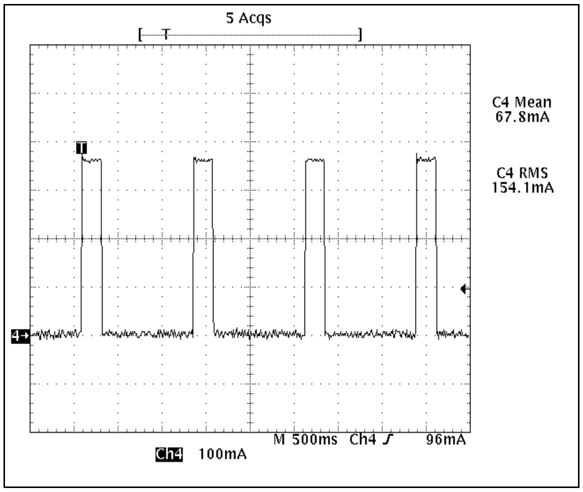

FIGURE 5-9: FBA06T12H Locked rotor fan current.

From Figure 5-9 it is seen that in a locked-rotor fault condition, the fan goes into a pulsed current mode of operation. During this mode, when the fan is conducting current, the peak current value is 360 mA for periods of 200 msec. This is significantly higher than the average full fan speed current shown in Figure 5-8. However, because of the pulse mode, the average fan current in a locked-rotor condition is lower and was measured at 68 mA. The RMS current during this mode, which is necessary for current sense resistor (R_{SENSE}) value selection, was measured at 154 mA. This is slightly higher than the RMS value during full fan speed operation.

Thermistor Information: Thermometrics part number: **NHQ104B425R5**

Resistance Value: 100 kΩ @ 25ºC

Beta Value (β): 4250

From this information, the thermistor values at 20ºC and 40ºC must be found. This information is needed in order to select the proper resistor values for R_1 and R_2 (see Figure 5-13), which sets the V_{IN} voltage.

The equation for determining the thermistor values is shown below:

EQUATION

$$R_T = R_{TO} exp\left[\frac{\beta(T_O - T)}{T^2 T_O}\right]$$

R_{T0} is the thermistor value at 25ºC. T_0 is 298.15 and T is the temperature of interest. All temperatures are given in degrees kelvin.

Using this equation, the values for the thermistor are found to be:

- R_T (20ºC) = 127,462Ω
- R_T (40ºC) = 50,520Ω

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Step 2: Selecting the Fan Controller.

The requirements for the fan controller are that it have minimum speed capability at 20ºC and also indicate a fan fault condition. No over-temperature indication is necessary. Based on these specifications, the proper selection is the TC647B device.

Step 3: Setting the PWM Frequency.

The fan is rated at 4200 RPM with a 12V input. Since the goal is to run to a 40% duty cycle (roughly 40% fan speed), which equates to approximately 1700 RPM, we can assume one full fan revolution occurs every 35 msec. The fan being used is a four-pole fan that gives four current pulses per revolution. Knowing this and viewing test results at 40% duty cycle, two fan current pulses were always seen during the PWM on time with a PWM frequency of 30 Hz. For this reason, the C_F value is selected to be 1.0 µF.

Step 4: Setting the V_{IN} Voltage.

From the design criteria, the desired duty cycle at 20ºC is 40%, while full fan speed should be reached at 40ºC. Based on a V_{IN} voltage range of 1.20V to 2.60V, which represents 0% to 100% duty cycle, the 40% duty cycle voltage can be found using the following equation:

EQUATION

$$V_{IN} = (DC * 1.4V) + 1.20V$$

$$DC = Desired\ Duty\ Cycle$$

Using the above equation, the V_{IN} values are calculated to be:

- V_{IN} (40%) = 1.76V
- V_{IN} (100%) = 2.60V

Using these values in combination with the thermistor resistance values calculated earlier, the R_1 and R_2 resistor values can now be calculated using the following equation:

EQUATION

$$V(T1) = \frac{V_{DD} \times R_2}{R_{TEMP}(T1) + R_2}$$

$$V(T2) = \frac{V_{DD} \times R_2}{R_{TEMP}(T2) + R_2}$$

R_{TEMP} is the parallel combination of R_1 and the thermistor. V(T1) represents the V_{IN} voltage at 20ºC and V(T2) represents the V_{IN} voltage at 40ºC. Solving the equations simultaneously yields the following values (V_{DD} = 5V):

- R_1 = 238,455Ω
- R_2 = 45,161Ω

Using standard 1% resistor values, the selected R_1 and R_2 values are:

- R_1 = 237 kΩ
- R_2 = 45.3 kΩ

A graph of the V_{IN} voltage, thermistor resistance and R_{TEMP} resistance versus temperature for this configuration is shown in Figure 5-10.

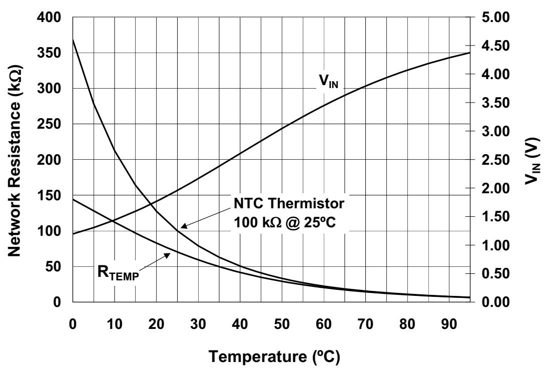

FIGURE 5-10: *Thermistor Resistance, V_{IN}, and R_{TEMP} vs. Temperature.*

Step 5: Setting the Minimum Speed Voltage (V_{MIN}).

Setting the voltage for the minimum speed is accomplished using a simple resistor voltage divider. The criteria for the voltage divider in this design is that it draw no more than 100 µA of current. The required minimum speed voltage was determined earlier in the selection of the V_{IN} voltage at 40% duty cycle, since this was also set at the temperature which minimum speed is to occur (20ºC).

- V_{MIN} = 1.76V

Given this desired setpoint, and knowing the desired divider current, the following equations can be used to solve for the resistor values for R_3 and R_4:

EQUATION

$$I_{DIV} = \frac{5V}{R_3 + R_4}$$

$$V_{MIN} = \frac{5V * R_4}{R_3 + R_4}$$

Using the equations above, the resistor values for R_3 and R_4 are found to be:

- R_3 = 32.4 kΩ
- R_4 = 17.6 kΩ

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Using standard 1% resistor values yields the following values:

- $R_3 = 32.4\ k\Omega$
- $R_4 = 17.8\ k\Omega$

Step 6: Selecting the Fan Drive Device (Q_1).

Since the fan operating current is below 200 mA, a transistor or MOSFET can be used as the fan drive device. In order to reduce component count and current draw, the drive device for this design is chosen to be a N-channel MOSFET. Selecting from Table 5-2, there are two MOSFETs that are good choices: the MGSF1N02E and the SI2302. These devices have the same pinout and are interchangeable for this design.

Step 7: Selecting the R_{SENSE} and C_{SENSE} Values.

The goal again for selecting these values is to ensure that the signal at the SENSE pin is 90 mV in amplitude under all operating conditions. This will ensure that the pulses are detected by the TC642B/TC647B device and that the fan operation is detected.

The fan current waveform is shown in Figure 5-8 and, as discussed previously, with a waveform of this shape, the current sense resistor values shown in Table 5-1 are good reference values. Given that the average fan operating current was measured to be 120 mA, this falls between two of the values listed in the table. For reference purposes, both values have been tested and these results are shown in Figures 5-11 (4.7Ω) and 5-12 (3.0Ω). The selected C_{SENSE} value is 0.1 µF as this provides the appropriate coupling of the voltage to the SENSE pin.

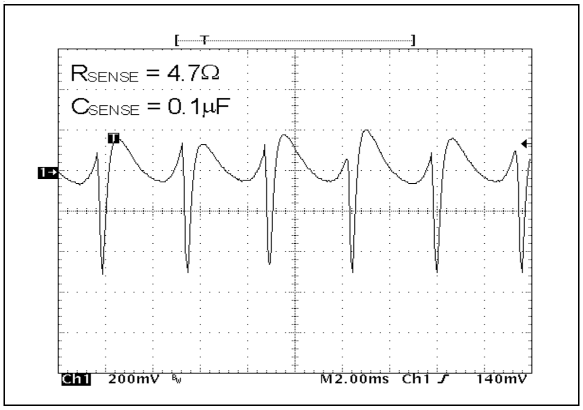

FIGURE 5-11: SENSE pin voltage with 4.7Ω sense resistor.

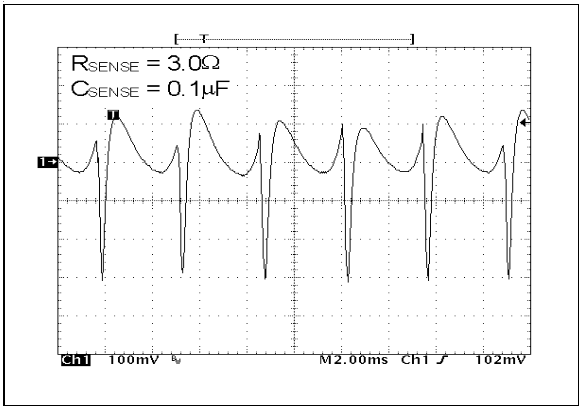

FIGURE 5-12: SENSE pin voltage with 3.0Ω sense resistor.

Since the 3.0Ω value of sense resistor provides the proper voltage to the SENSE pin, it is the correct choice for this solution as it will also provide the lowest power dissipation and the most voltage to the fan. Using the RMS fan current that was measured previously, the power dissipation in the resistor during a fan fault condition is 71 mW ($Irms^2 * R_{SENSE}$). This number will set the wattage rating of the resistor that is selected. The selected value will vary depending upon the derating guidelines that are used.

Now that all the values have been selected, the schematic representation of this design can be seen in Figure 5-13.

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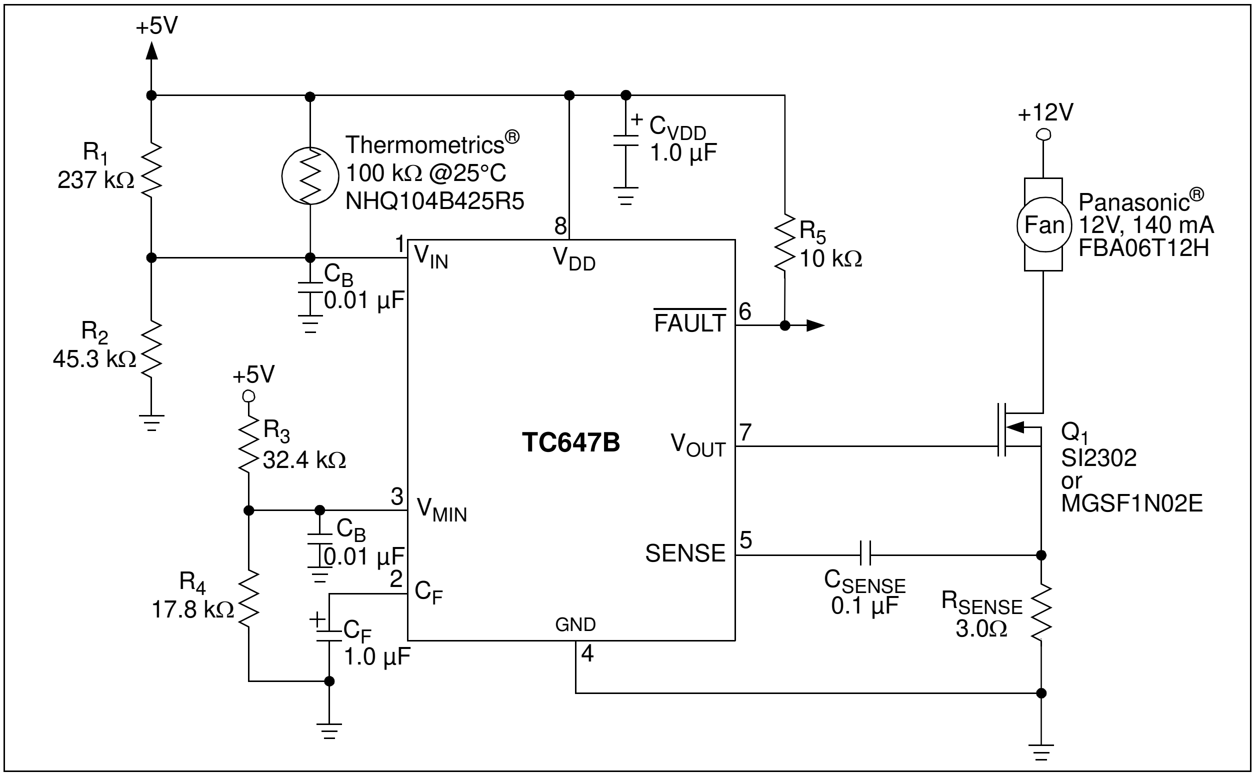

FIGURE 5-13: *Design Example Schematic.*

Bypass capacitor C_{VDD} is added to the design to decouple the bias voltage. This is good to have, especially when using a MOSFET as the drive device. This helps to give a localized low-impedance source for the current required to charge the gate capacitance of Q_1. Two other bypass capacitors, labeled as C_B, were also added to decouple the V_{IN} and V_{MIN} nodes. These were added simply to remove any noise present that might cause false triggerings or PWM jitter. R_5 is the pull-up resistor for the $\overline{\text{FAULT}}$ output. The value for this resistor is system-dependent.

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