TC648

Fan Speed Controller with Auto-Shutdown and Over-Temperature Alert

Features

- Temperature Proportional Fan Speed for Acoustic Control and Longer Fan Life
- Efficient PWM Fan Drive
- 3.0V to 5.5V Supply Range:
  - Fan Voltage Independent of TC648 Supply Voltage
  - Supports any Fan Voltage
- Over-temperature Fault Detection
- Automatic Shutdown Mode for “Green” Systems
- Supports Low Cost NTC/PTC Thermistors
- Space Saving 8-Pin MSOP Package

Applications

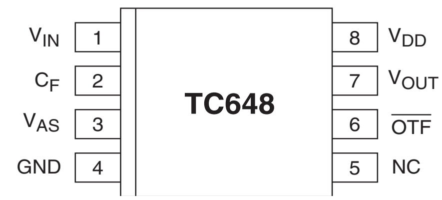
- Power Supplies
- Computers
- Portable Computers
- Telecom Equipment
- UPSs, Power Amps
- General Purpose Fan Speed Control

Available Tools

- Fan Controller Demonstration Board (TC642DEMO)
- Fan Controller Evaluation Kit (TC642EV)

Package Types

SOIC/PDIP/MSOP



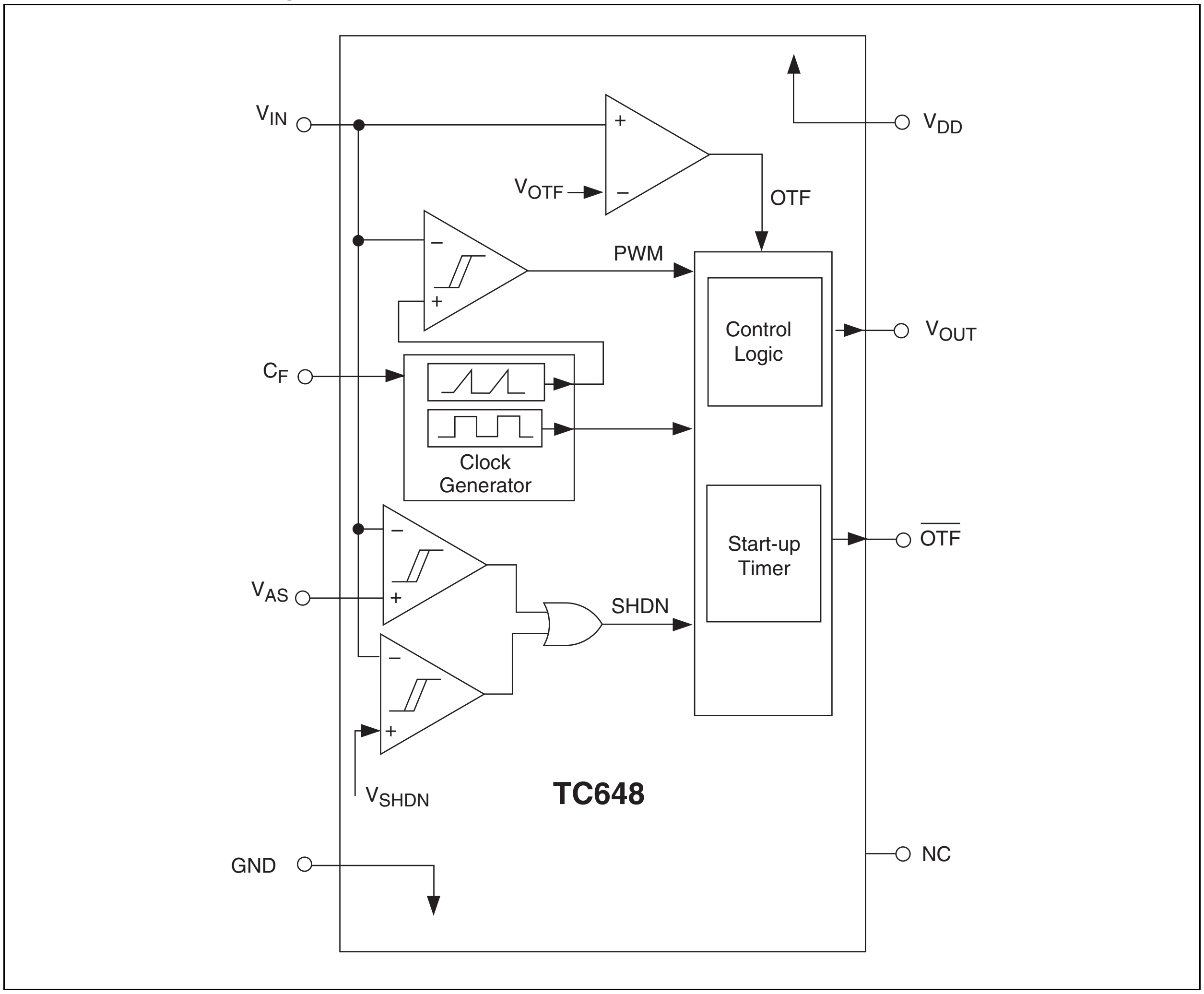
General Description

The TC648 is a switch mode, fan speed controller for use with brushless DC fans. Temperature proportional speed control is accomplished using pulse width modulation (PWM). A thermistor (or other voltage output temperature sensor) connected to the V_{IN} input furnishes the required control voltage of 1.25V to 2.65V (typical) for 0% to 100% PWM duty cycle. The TC648 can be configured to operate in either auto-shutdown or minimum speed mode. In auto-shutdown mode, fan operation is automatically suspended when measured temperature (V_{IN}) is lower than a user programmed minimum setting (V_{AS}). The fan is automatically restarted, and proportional speed control restored, when V_{IN} exceeds V_{AS} (plus hysteresis). Operation in minimum speed mode is similar to auto-shutdown mode, with the exception that the fan is operated at a user programmed minimum setting when the measured temperature is low. An integrated Start-up Timer ensures reliable motor start-up at turn-on, and when coming out of shutdown or auto-shutdown mode.

The over-temperature fault output ($\overline{OTF}$) is asserted when the PWM reaches 100% duty cycle, indicating a possible thermal runaway situation.

The TC648 is available in the 8-pin plastic DIP, SOIC and MSOP packages and is available in the industrial and extended commercial temperature ranges.

Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings*

Supply Voltage 6V

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

Package Thermal Resistance:

PDIP ($R_{\theta JA}$) .... 125°C/W
SOIC ($R_{\theta JA}$) .... 155°C/W
MSOP ($R_{\theta JA}$) .... 200°C/W

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

Storage Temperature Range .... -65°C to +150°C

*Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operation sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC ELECTRICAL SPECIFICATIONS

Electrical Characteristics: Unless otherwise specified, $T_{MIN} \le T_A \le T_{MAX}$, V_{DD} = 3.0V to 5.5V

Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
V_{DD}	Supply Voltage	3.0	—	5.5	V	
I_{DD}	Supply Current, Operating	—	0.5	1.0	mA	Pins 6, 7 Open, C_F = 1 µF, V_{IN} = $V_{C(MAX)}$
$I_{DD(SHDN)}$	Supply Current, Shutdown/ Auto-shutdown Mode	—	25	—	µA	Pins 6, 7 Open; **Note 1** C_F =1 µF, V_{IN} = 0.35V
I_{IN}	V_{IN}, V_{AS} Input Leakage	-1.0	—	+1.0	µA	**Note 1**
V_{OUT} Output						
t_R	V_{OUT} Rise Time	—	—	50	µsec	I_{OH} = 5 mA, **Note 1**
t_F	V_{OUT} Fall Time	—	—	50	µsec	I_{OL} = 1 mA, **Note 1**
I_{OL}	Sink Current at V_{OUT} Output	1.0	—	—	mA	V_{OL} = 10% of V_{DD}
I_{OH}	Source Current at V_{OUT} Output	5.0	—	—	mA	V_{OH} = 80% of V_{DD}
SENSE Input						
$V_{TH(SENSE)}$	SENSE Input Threshold Voltage with Respect to GND	50	70	90	mV	**Note 1**
$\overline{OTF}$ Output						
V_{OL}	Output Low Voltage	—	—	0.3	V	I_{OL} = 2.5 mA
V_{IN}, V_{AS} Inputs						
$V_{C(MAX)}$, V_{OTF}	Voltage at V_{IN} for 100% Duty Cycle and Overtemp. Fault	2.5	2.65	2.8	V	
$V_{C(SPAN)}$	$V_{C(MAX)}$ - $V_{C(MIN)}$	1.3	1.4	1.5	V	
V_{AS}	Auto-shutdown Threshold	$V_{C(MAX)}$ ~ $V_{C(SPAN)}$	—	$V_{C(MAX)}$	V	
V_{SHDN}	Voltage Applied to V_{IN} to Ensure Reset/Shutdown	—	—	V_{DD} x 0.13	V	
V_{REL}	Voltage Applied to V_{IN} to Release Reset Mode	V_{DD} x 0.19	—	—	V	V_{DD} = 5V
V_{HYST}	Hysteresis on V_{SHDN}, V_{REL}	—	0.01 x V_{DD}	—	V	
V_{HAS}	Hysteresis on Auto-shutdown Comparator	—	70	—	mV	

Note 1: Ensured by design, not tested.

DC ELECTRICAL SPECIFICATIONS (CONTINUED)

Electrical Characteristics: Unless otherwise specified, $T_{MIN} \leq T_A \leq T_{MAX}$, V_{DD} = 3.0V to 5.5V						
Symbol	**Parameter**	**Min**	**Typ**	**Max**	**Units**	**Test Conditions**
Pulse Width Modulator						
F_{OSC}	PWM Frequency	26	30	34	Hz	C_F = 1.0 µF
$t_{STARTUP}$	Start-up Timer	—	32/F	—	Sec	C_F = 1.0 µF

Note 1: Ensured by design, not tested.

2.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 2-1.

TABLE 2-1: PIN FUNCTION TABLE

Pin No.	Symbol	Description
1	V_{IN}	Analog Input
2	C_F	Analog Output
3	V_{AS}	Analog Input
4	GND	Ground Terminal
5	NC	No Internal Connection
6	$\overline{OTF}$	Digital (Open Collector) Output
7	V_{OUT}	Digital Output
8	V_{DD}	Power Supply Input

2.1 Analog Input (V_{IN})

The thermistor network (or other temperature sensor) connects to the V_{IN} input. A voltage range of 1.25V to 2.65V (typical) on this pin drives an active duty cycle of 0% to 100% on the V_{OUT} pin (see Section 5.0, “Typical Applications”, for more details).

2.2 Analog Output (C_F)

C_F is the positive terminal for the PWM ramp generator timing capacitor. The recommended C_F is 1 µF for 30 Hz PWM operation.

2.3 Analog Input (V_{AS})

An external resistor divider connected to the V_{AS} input sets the auto-shutdown threshold. Auto-shutdown occurs when $V_{IN} \leq V_{AS}$. During shutdown, supply current falls to 25 µA (typical). The fan is automatically restarted when $V_{IN} \geq (V_{AS} + V_{HAS})$ (see Section 5.0, “Typical Applications” for more details).

2.4 Ground (GND)

GND denotes the ground Terminal.

2.5 No Connect

No internal connection.

2.6 Digital Output ($\overline{OTF}$)

$\overline{OTF}$ goes low to indicate an over-temperature condition. This occurs when the voltage at $V_{IN} > V_{OTF}$ (see Section 1.0, "Electrical Characteristics"). An over-temperature indication is a non-latching condition.

2.7 Digital Output (V_{OUT})

V_{OUT} is an active high complimentary output that 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 (see Section 1.0, “Electrical Characteristics”).

2.8 Power Supply Input (V_{DD})

V_{DD} may be independent of the fan’s power supply (see Section 1.0, “Electrical Characteristics”).

3.0 DETAILED DESCRIPTION

3.1 PWM

The PWM circuit consists of a ramp generator and threshold detector. The frequency of the PWM is determined by the value of the capacitor connected to the C_F pin. A frequency of 30 Hz is recommended for most applications (C_F = 1 µF). The PWM is also the time base for the Start-up Timer (see Section 3.3, “Start-up Timer”). The PWM voltage control range is 1.25V to 2.65V (typical) for 0% to 100% output duty cycle.

3.2 V_{OUT} Output

The V_{OUT} pin is designed to drive a low cost transistor or MOSFET as the low side power switching element in the system. Various examples of driver circuits will be shown throughout this data sheet. This output has asymmetric complementary drive and is optimized for driving NPN transistors or N-channel MOSFETs. Since the system relies on PWM rather than linear control, the power dissipation in the power switch is kept to a minimum. Generally, very small devices (TO-92 or SOT packages) will suffice.

3.3 Start-Up Timer

To ensure reliable fan start-up, the Start-up Timer turns the V_{OUT} output on for 32 cycles of the PWM whenever the fan is started from the off state. This occurs at power-up and when coming out of shutdown or auto-shutdown mode. If the PWM frequency is 30 Hz (C_F = 1 µF), the resulting start-up time will be approximately one second.

3.4 Over-Temperature Fault ($\overline{OTF}$) Output

$\overline{OTF}$ is asserted when the PWM control voltage applied to V_{IN} becomes greater than that needed to drive 100% duty cycle (see Section 1.0, “Electrical Characteristics”). This indicates that the fan is at maximum drive, and the potential exists for system overheating. Either heat dissipation in the system has gone beyond the cooling system’s design limits, or some subtle fault exists (such as fan bearing failure or an airflow obstruction). This output may be treated as a “System Overheat” warning and used to trigger system shutdown or some other corrective action. $\overline{OTF}$ will become inactive when $V_{IN} < V_{OTF}$.

3.5 Auto-Shutdown Mode

If the voltage on V_{IN} becomes less than the voltage on V_{AS}, the fan is automatically shut off (auto-shutdown mode). The TC648 exits auto-shutdown mode when the voltage on V_{IN} becomes higher than the voltage on V_{AS} by V_{HAS} (the auto-shutdown hysteresis voltage (see Figure 3-1)). The Start-up Timer is triggered and normal operation is resumed upon exiting auto-shutdown mode. The V_{AS} input should be grounded if auto-shutdown mode is not used.

3.6 Shutdown Mode (Reset)

If an unconditional shutdown and/or device reset is desired, the TC648 may be placed in shutdown mode by forcing V_{IN} to a logic low (i.e., $V_{IN} < V_{SHDN}$) (see Figure 3-1). In this mode, all functions cease and the $\overline{OTF}$ output is unconditionally inactive. The TC648 should not be shut down unless all heat producing activity in the system is at a negligible level. The TC648 exits shutdown mode when V_{IN} becomes greater than V_{REL}, the release voltage.

Entering shutdown mode also performs a complete device reset. Shutdown mode resets the TC648 into its power-up state. $\overline{OTF}$ is unconditionally inactive in shutdown mode. Upon exiting shutdown mode ($V_{IN} > V_{REL}$), the Start-up Timer will be triggered and normal operation will resume, assuming $V_{IN} > V_{AS} + V_{HAS}$

> **Note:** If $V_{IN} < V_{AS}$ when the device exits shutdown mode, the fan will not restart as it will be in auto-shutdown mode.

If V_{IN} is not greater than ($V_{AS} + V_{HAS}$) upon exiting shutdown mode, the fan will not be restarted. To ensure that a complete reset takes place, the user’s circuitry must ensure that $V_{IN} > (V_{AS} + V_{HAS})$ when the device is released from shutdown mode. A recommended algorithm for management of the TC648 by a host microcontroller or other external circuitry is given in Section 5.0, “Typical Applications”. A small amount of hysteresis, typically one percent of V_{DD} (50 mV at V_{DD} = 5.0V), is designed into the V_{SHDN}/V_{REL} threshold. The levels specified for V_{SHDN} and V_{REL} in Section 1.0, “Electrical Characteristics”, include this hysteresis plus adequate margin to account for normal variations in the absolute value of the threshold and hysteresis.

> **CAUTION:** Shutdown mode is unconditional. That is, the fan will remain off as long as the V_{IN} pin is being held low or $V_{IN} < V_{AS} + V_{HAS}$.

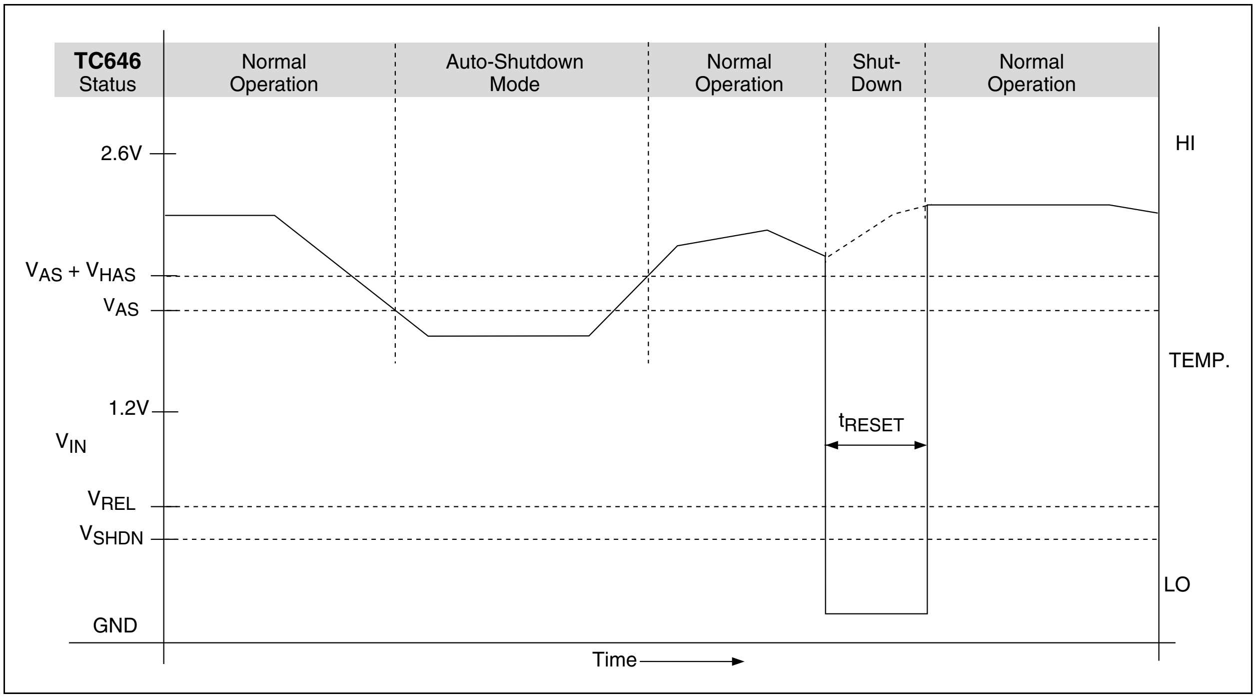


FIGURE 3-1: TC648 Nominal Operation.

4.0 SYSTEM BEHAVIOR

The flowcharts describing the TC648's behavioral algorithms are shown in Figure 4-1. They can be summarized as follows:

4.1 Power-Up

(1) Assuming the device is not being held in shutdown or auto-shutdown mode ($V_{IN} > V_{AS}$)..........

(2) Turn V_{OUT} output on for 32 cycles of the PWM clock. This ensures that the fan will start from a dead stop.

(3) Branch to Normal Operation.

(4) End.

4.2 Normal Operation

Normal Operation is an endless loop which may only be exited by entering shutdown or auto-shutdown mode. The loop can be thought of as executing at the frequency of the oscillator and PWM.

(1) Drive V_{OUT} to a duty cycle proportional to V_{IN} on a cycle by cycle basis.

(2) If an over-temperature fault occurs, ($V_{IN} > V_{OTF}$), activate $\overline{OTF}$; release $\overline{OTF}$ when $V_{IN} < V_{OTF}$.

(3) Is the TC648 in shutdown or auto-shutdown mode?

If so.....

a. V_{OUT} duty cycle goes to zero.

b. $\overline{OTF}$ is disabled.

c. Exit the loop and wait for $V_{IN} > (V_{AS} + V_{HAS})$, then execute Power-up sequence.

(4) End.

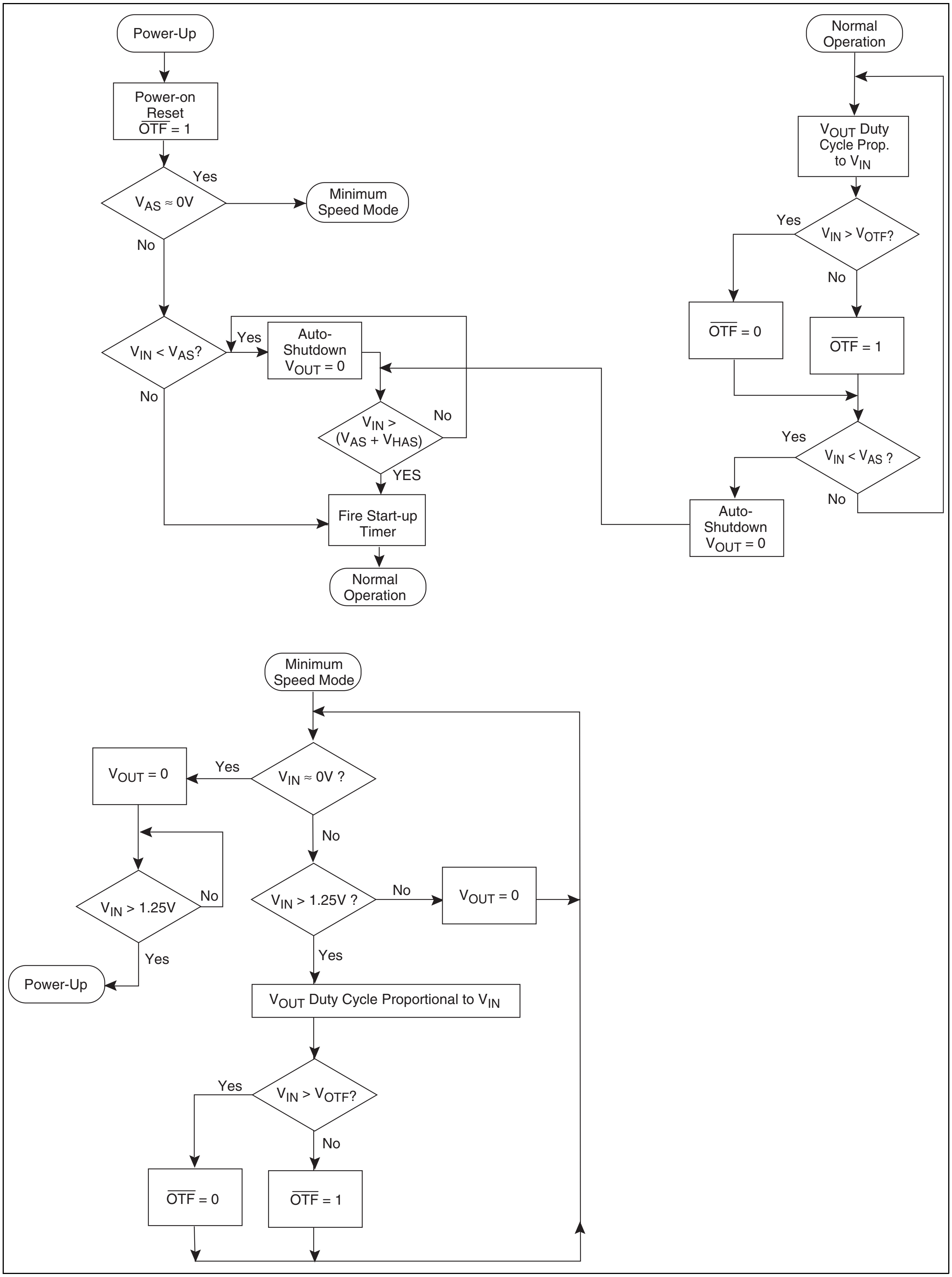


FIGURE 4-1: *TC648 Behavioral Algorithm Flowcharts.*

5.0 TYPICAL APPLICATIONS

Designing with the TC648 involves the following:

(1) The temperature sensor network must be configured to deliver 1.25V to 2.65V on V_{IN} for 0% to 100% of the temperature range to be regulated.

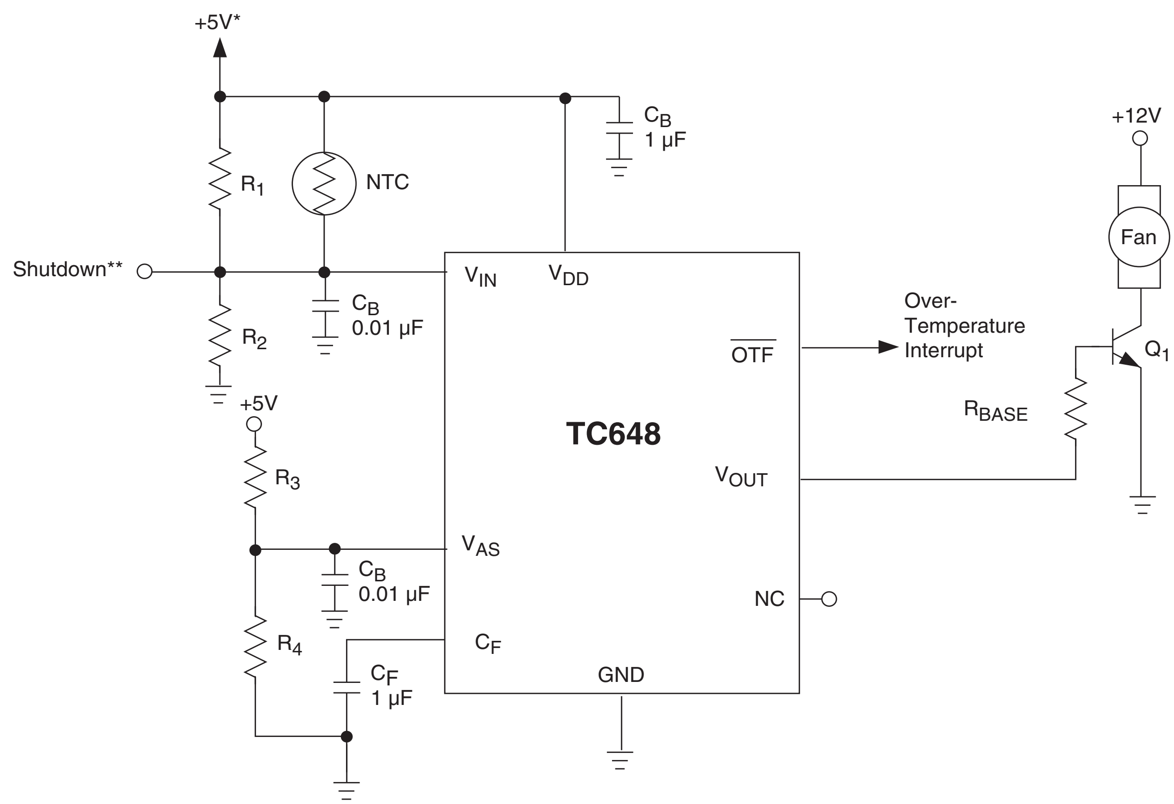
(2) The auto-shutdown temperature must be set with a voltage divider on V_{AS} (if used).

(3) The output drive transistor and base resistor must be selected.

(4) If reset/shutdown capability is desired, the drive requirements of the external signal or circuit must be considered.

The TC642 demonstration and prototyping board (TC642DEMO) and the TC642 Evaluation Kit (TC642EV) provide working examples of TC648 circuits and prototyping aids. The TC642DEMO is a printed circuit board optimized for small size and ease of inclusion into system prototypes. The TC642EV is a larger board intended for benchtop development and analysis. At the very least, anyone contemplating a design using the TC648 should consult the documentation for both the TC642EV (DS21403) and TC642DEMO (DS21401). Figure 5-1 shows the base schematic for the TC642DEMO.

An Excel-based spreadsheet is also available for designing the thermistor network for the TC64X fan controllers. This file (TC64X Therm) is available for downloading from the Microchip website at www.microchip.com.



NOTES: *See cautions regarding latch-up considerations in Section 5.0, "Typical Applications".
**Optional. See Section 5.0, "Typical Applications", for details.

FIGURE 5-1: *Typical Application Circuit.*

5.1 Temperature Sensor Design

The temperature signal connected to V_{IN} must output a voltage in the range of 1.25V to 2.65V (typical) for 0% to 100% of the temperature range of interest. The circuit in Figure 5-2 illustrates a convenient way to provide this signal using a temperature dependent voltage divider circuit.

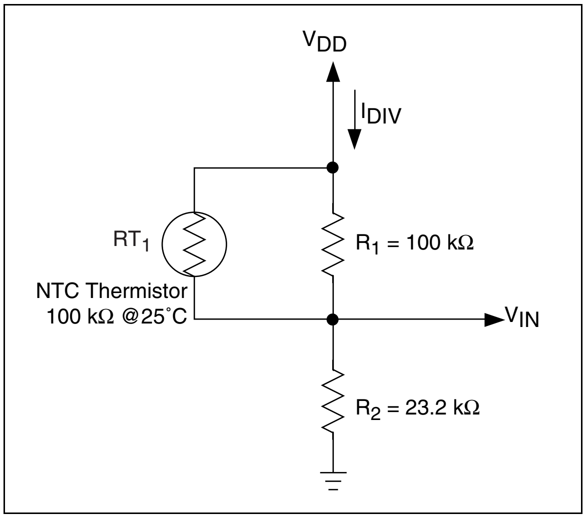


FIGURE 5-2: *Temperature Sensing Circuit.*

RT_1 is a conventional NTC thermistor and R_1 and R_2 are standard resistors. The supply voltage (V_{DD}) is divided between R_2 and the parallel combination of RT_1 and R_1. For convenience, the parallel combination of RT_1 and R_1 will be referred to as R_{TEMP}. The resistance of the thermistor at various temperatures is obtained from the manufacturer's specifications. Thermistors are often referred to in terms of their resistance at 25°C.

Generally, the thermistor shown in Figure 5-2 is a non-linear device with a negative temperature coefficient (also called an NTC thermistor). In Figure 5-2, R_1 is used to linearize the thermistor temperature response and R_2 is used to produce a positive temperature coefficient at the V_{IN} node. As an added benefit, this configuration produces an output voltage delta of 1.4V, which is well within the range of the $V_{C(SPAN)}$ specification of the TC648. A 100 kΩ NTC thermistor is selected for this application in order to keep I_{DIV} to a minimum.

For the voltage range at V_{IN} to be equal to 1.25V to 2.65V, the temperature range of this configuration is 0°C to 50°C. If a different temperature range is required from this circuit, R_1 should be chosen to equal the resistance value of the thermistor at the center of this new temperature range. It is suggested that a maximum temperature range of 50°C be used with this circuit due to thermistor linearity limitations. With this change, R_2 is adjusted according to the following equations:

EQUATION

$$\frac{V_{DD} \times R_2}{R_{TEMP}(T_1) + R_2} = V(T_1)$$

$$\frac{V_{DD} \times R_2}{R_{TEMP}(T_2) + R_2} = V(T_2)$$

Where T_1 and T_2 are the chosen temperatures and R_{TEMP} is the parallel combination of the thermistor and R_1.

These two equations facilitate solving for the two unknown variables, R_1 and R_2. More information about thermistors may be obtained from AN679, *"Temperature Sensing Technologies"*, and AN685, *"Thermistors in Single Supply Temperature Sensing Circuits"*, which can be downloaded from Microchip's web site at www.microchip.com.

5.2 Minimum Speed Mode

The TC648 is configured for minimum speed mode by grounding V_{AS} and designing the temperature sensor network such that V_{IN} operates the fan at relatively constant, minimum speed when the thermistor is at minimum temperature. Figure 5-3 shows operation in minimum speed mode. The 0% and 100% fan speeds correspond to V_{IN} values of 1.25V and 2.65V, typical. Minimum system temperature (T_{MIN}) is defined as the lowest measured temperature at which proportional fan speed control is required by the system. The fan operates at minimum speed for all temperatures below T_{MIN} and at speeds proportional to the measured temperature between T_{MIN} and T_{MAX}.

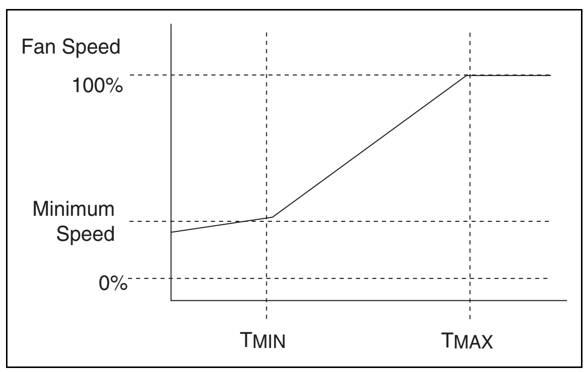


FIGURE 5-3: *Minimum Fan Speed Mode Operation.*

Temperature sensor design consists of a two-point calculation: one at T_{MIN} and one at T_{MAX}. At T_{MIN}, the ohmic value of the thermistor must be much higher than that of R_1 so that minimum speed is determined primarily by the values of R_1 and R_2. At T_{MAX}, the ohmic value of the thermistor must result in a V_{IN} of 2.65V nominal. The design procedure consists of initially choosing R_1 to be 10 times smaller than the thermistor resistance at T_{MIN}. R_2 is then calculated to deliver the desired speed at T_{MIN}. The values for R_1, R_2 and RT_1 are then checked at T_{MAX} for 2.65V nominal. It may be necessary to adjust the values of R_1 and R_2 after the initial calculation to obtain the desired results. The design equations are:

EQUATION

$$R_1 = (0.1)(RT_{1MIN})$$

Where: RT_1 *= Thermistor resistance at* T_{MIN}

EQUATION

$$R_2 = \frac{(RT_{1MIN})(R_1)(V_{MIN})}{(RT_{1MIN} + R_1)(V_{DD} - V_{MIN})}$$

Where V_{MIN} *= the value of* V_{IN} *required for minimum fan speed.* V_{DD} *= Power Supply Voltage*

EQUATION

$$V_{MAX} = \frac{(RT_{1MIN})(R_1)(V_{MIN})}{R_2\,(R_1 + RT_{1MAX})(V_{DD})}$$

Where RT_{1MAX} *= thermistor resistance at* T_{MAX}*,* V_{MAX} *= the value of* V_{IN} *required for maximum fan speed.*

Because the thermistor characteristics are fixed, it may not be possible, in certain applications, to obtain the desired values of V_{MIN} and V_{MAX} using the above equations. In this case, the circuit in Figure 5-4 can be used. Diode D_1 clamps V_{IN} to the voltage required to sustain minimum speed. The calculations of R_1 and R_2 for the temperature sensor are identical to the equation on the previous page.

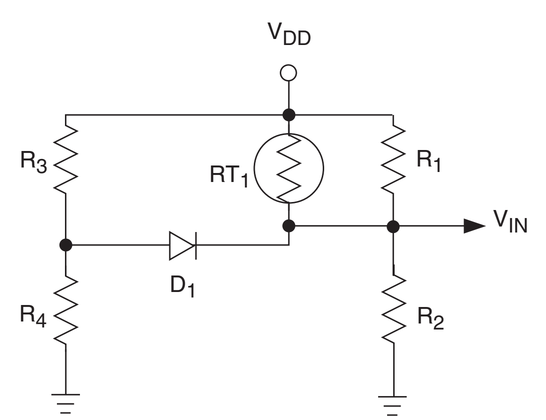


FIGURE 5-4: *Minimum Fan Speed Circuit.*

5.3 Auto-Shutdown Temperature Design

A voltage divider on V_{AS} sets the temperature at which the part is automatically shut down if the sensed temperature at V_{IN} drops below the set temperature at V_{AS} (i.e. $V_{IN} < V_{AS}$).

As with the V_{IN} input, 1.25V to 2.65V corresponds to the temperature range of interest from T_1 to T_2, respectively. Assuming that the temperature sensor network designed previously is linearly related to temperature, the shutdown temperature T_{AS} is related to T_2 and T_1 by:

EQUATION

$$\frac{2.65 - 1.25V}{T_2 - T_1} = \frac{V_{AS} - 1.25}{T_{AS} - T_1}$$

$$V_{AS} = \left(\frac{1.4V}{T_2 - T_1}\right)(T_{AS} - T_1) + 1.25$$

For example, if 1.25V and 2.65V at V_{IN} corresponds to a temperature range of $T_1 = 0°C$ to $T_2 = 125°C$, and the auto-shutdown temperature desired is 25°C, then the V_{AS} voltage is:

EQUATION

$$V_{AS} = \frac{1.4V}{(125 - 0)}\ (25 - 0) + 1.25 = 1.53V$$

The V_{AS} voltage may be set using a simple resistor divider, as shown in Figure 5-5.

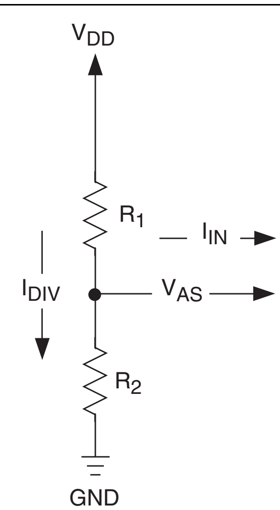


FIGURE 5-5: *V_{AS} Circuit.*

Per Section 1.0, “Electrical Characteristics”, the leakage current at the V_{AS} pin is no more than 1 µA. It is conservative to design for a divider current, I_{DIV}, of 100 µA. If V_{DD} = 5.0V then…

EQUATION

$$I_{DIV} = 1e^{-4}A = \frac{5.0V}{R_1 + R_2}, \text{ therefore}$$

$$R_1 + R_2 = \frac{5.0V}{1e^{-4}A} = 50{,}000\Omega = 50\ k\Omega$$

We can further specify R_1 and R_2 by the condition that the divider voltage is equal to our desired V_{AS}. This yields the following:

EQUATION

$$V_{AS} = \frac{V_{DD} \times R_2}{R_1 + R_2}$$

Solving for the relationship between R_1 and R_2 results in the following equation:

EQUATION

$$R_1 = R_2 \times \frac{V_{DD} - V_{AS}}{V_{AS}} = \frac{R_2 \times (5 - 1.53)}{1.53}$$

For this example, R_1 = (2.27) R_2. Substituting this relationship back into the original equation yields the resistor values:

R_2 = 15.3 kΩ, and R_1 = 34.7 kΩ

In this case, the standard values of 34.8 kΩ and 15.4 kΩ are very close to the calculated values and would be more than adequate.

5.4 Output Drive Transistor Selection

The TC648 is designed to drive an external transistor or MOSFET for modulating power to the fan. This is shown as Q_1 in Figures 5-1, 5-6, 5-7,and 5-8. The V_{OUT} pin has a minimum source current of 5 mA and a minimum sink current of 1 mA. Bipolar transistors or MOSFETs may be used as the power switching element, as is shown in Figure 5-6. When high current gain is needed to drive larger fans, two transistors may be used in a Darlington configuration. These circuit topologies are shown in Figure 5-6: (a) shows a single NPN transistor used as the switching element; (b) illustrates the Darlington pair; and (c) shows an N-channel MOSFET.

One major advantage of the TC648’s PWM control scheme versus linear speed control is that the power dissipation in the pass element is kept very low. Generally, low cost devices in very small packages, such as TO-92 or SOT, can be used effectively. For fans with nominal operating currents of no more than 200 mA, a single transistor usually suffices. Above 200 mA, the Darlington or MOSFET solution is recommended. For the power dissipation to be kept low, it is imperative that the pass transistor be fully saturated when "on".

Table 5-1 gives examples of some commonly available transistors and MOSFETs. This table should be used as a guide only since there are many transistors and MOSFETs which will work just as well as those listed. The critical issues when choosing a device to use as Q1 are: (1) the breakdown voltage ($V_{(BR)CEO}$ or V_{DS} (MOSFET)) must be large enough to withstand the highest voltage applied to the fan (**Note:** This will occur when the fan is off); (2) 5 mA of base drive current must be enough to saturate the transistor when conducting the full fan current (transistor must have sufficient gain); (3) the V_{OUT} voltage must be high enough to sufficiently drive the gate of the MOSFET to minimize the $R_{DS(on)}$ of the device; (4) rated fan current draw must be within the transistor's/MOSFET's current handling capability; and (5) power dissipation must be kept within the limits of the chosen device.

A base-current limiting resistor is required with bipolar transistors. The correct value for this resistor can be determined as follows:

$V_{OH} = V_{BE(SAT)} + V_{RBASE}$
$V_{RBASE} = R_{BASE} \times I_{BASE}$
$I_{BASE} = I_{FAN} / h_{FE}$

V_{OH} is specified as 80% of V_{DD} in Section 1.0, “Electrical Characteristics”; $V_{BE(SAT)}$ is given in the chosen transistor data sheet. It is now possible to solve for R_{BASE}.

EQUATION

$$R_{BASE} = \frac{V_{OH} - V_{BE(SAT)}}{I_{BASE}}$$

Some applications benefit from the fan being powered from a negative supply to keep motor noise out of the positive supply rails. This can be accomplished by the method shown in Figure 5-7. Zener diode D_1 offsets the -12V power supply voltage, holding transistor Q_1 off when V_{OUT} is low. When V_{OUT} is high, the voltage at the anode of D_1 increases by V_{OH}, causing Q_1 to turn on. Operation is otherwise the same as in the case of fan operation from +12V.

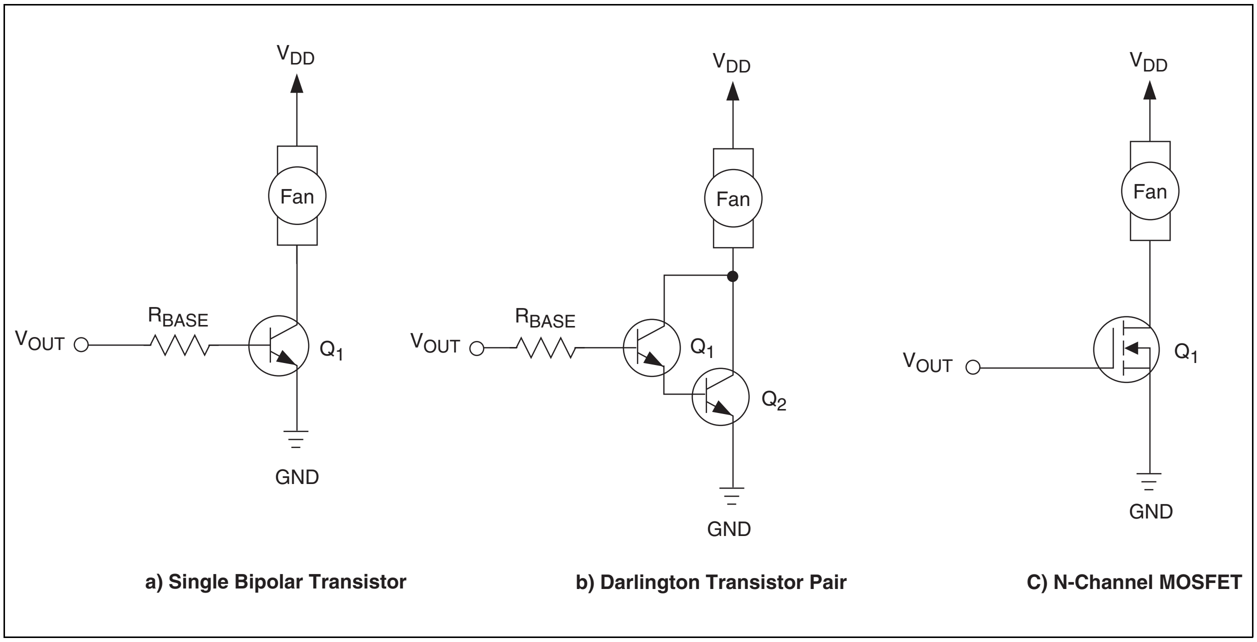
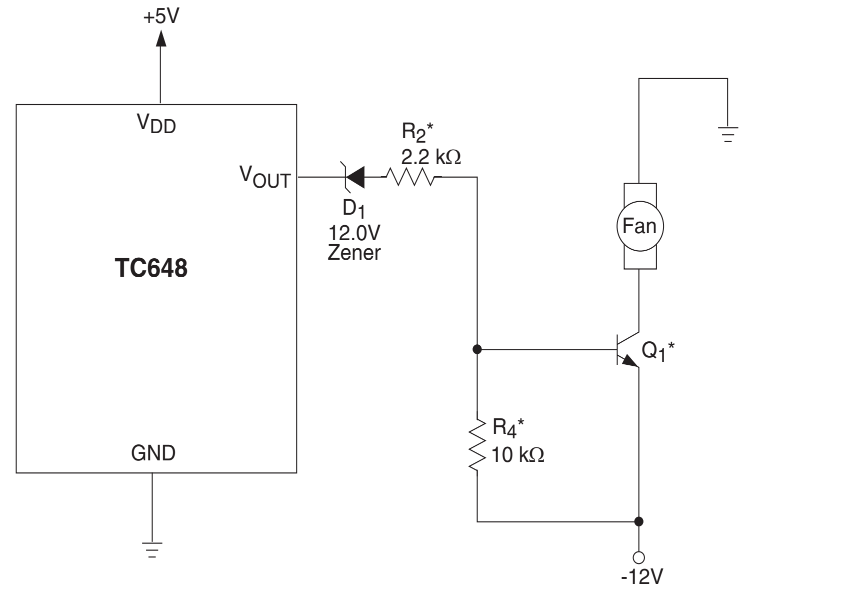


FIGURE 5-6: Output Drive Transistor Circuit Topologies.

TABLE 5-1: TRANSISTORS AND MOSFETS FOR Q_1 (V_{DD} = 5V)

Device	Package	Max. $V_{BE(sat)}/V_{GS}$ (V)	Min. H_{FE}	V_{CEO}/V_{DS} (V)	Fan Current (mA)	Suggested R_{BASE} (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.



NOTE: *Value depends on the specific application and is shown for example only.

FIGURE 5-7: *Powering the Fan from a -12V Supply.*

5.5 Latch-up Considerations

As with any CMOS IC, the potential exists for latch-up if signals are applied to the device which are outside the power supply range. This is of particular concern during power-up if the external circuitry (such as the sensor network, V_{AS} divider or shutdown circuit) are powered by a supply different from that of the TC648. Care should be taken to ensure that the TC648's V_{DD} supply powers up first. If possible, the networks attached to V_{IN} and V_{AS} should connect to the V_{DD} supply at the same physical location as the IC itself. Even if the IC and any external networks are powered by the same supply, physical separation of the connecting points can result in enough parasitic capacitance and/ or inductance in the power supply connections to delay one power supply "routing" versus another.

5.6 Power Supply Routing and Bypassing

Noise present on the V_{IN} and V_{AS} inputs may cause erroneous operation of the $\overline{OTF}$ output. As a result, these inputs should be bypassed with a 0.01 µF capacitor mounted as close to the package as possible. This is especially true of V_{IN}, which is usually driven from a high impedance source (such as a thermistor). Additionally, the V_{DD} input should be bypassed with a 1 µF capacitor and grounds should be kept as short as possible. To keep fan noise off the TC648 ground pin, individual ground returns for the TC648 and the low side of the fan drive device should be used.

Auto-Shutdown Mode Design Example

Step 1. Calculate R_1 and R_2 based on using an NTC having a resistance of 10 kΩ at T_{MIN} (25°C) and 4.65 kΩ at T_{MAX} (45°C) (see Figure 5-8).

R_1 = 20.5 kΩ
R_2 = 3.83 kΩ

Step 2. Set auto-shutdown level.

V_{AS} = 1.8V
Limit the divider current to 100 µA
R_5 = 33 kΩ
R_6 = 18 kΩ

Step 3. Design the output circuit

Maximum fan motor current = 250 mA.
Q_1 beta is chosen at 50 from which
R_7 = 800 Ω.

5.7 Minimum Speed Mode Design Example

Given:

Minimum speed = 40%(1.8V)
T_{MIN} = 30°C, T_{MAX} = 95°C
Thermistor = 100 kΩ at 25°C
RT_{MIN} = 79.4 kΩ, RT_{MAX} = 6.5 kΩ

Step 1: Calculate R_1:
R_1 = 7.9 kΩ (Use closest standard value: 7.87 kΩ)

Calculate R2:
R_2 = 4.05 kΩ (Use closest standard value: 4.02 kΩ)

Step 2: Verify V_{MAX}:
V_{MAX} = 2.64V

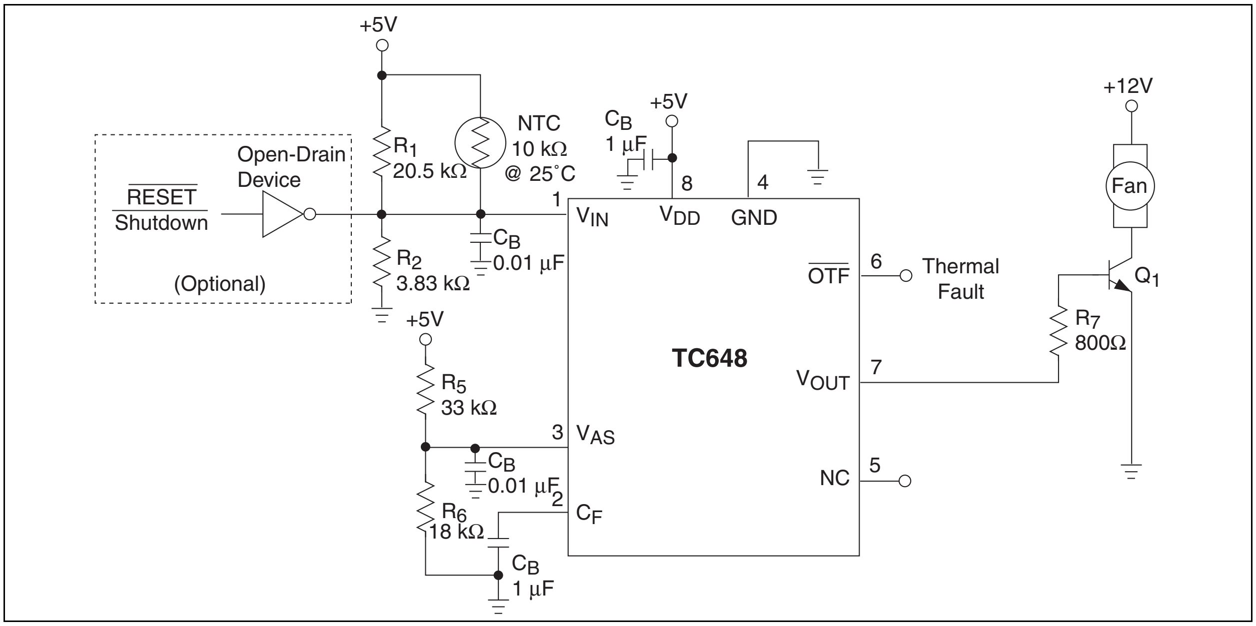


FIGURE 5-8: Design Example.

5.8 TC648 as a Microcontroller Peripheral

In a system containing a microcontroller or other host intelligence, the TC648 can be effectively managed as a CPU peripheral. Routine fan control functions can be performed by the TC648 without processor intervention. The microcontroller receives temperature data from one or more points throughout the system. It calculates a fan operating speed based on an algorithm specifically designed for the application at hand. The processor controls fan speed using complementary port bits I/O1 through I/O3.

Resistors R_1 through R_6 (5% tolerance) form a crude 3-bit DAC that translates the 3-bit code from the processor's outputs into a 1.6V DC control signal. A monolithic DAC or digital pot may be used instead of the circuit shown in Figure 5-9.

With V_{AS} set at 1.8V, the TC648 enters auto-shutdown when the processor's output code is 000[B]. Output codes 001[B] to 111[B] operate the fan from roughly 40% to 100% of full speed. An open-drain output from the processor (I/O0) can be used to reset the TC648 following detection of a fault condition. The $\overline{OTF}$ output can be connected to the processor's interrupt input, or to another I/O pin, for polled operation.

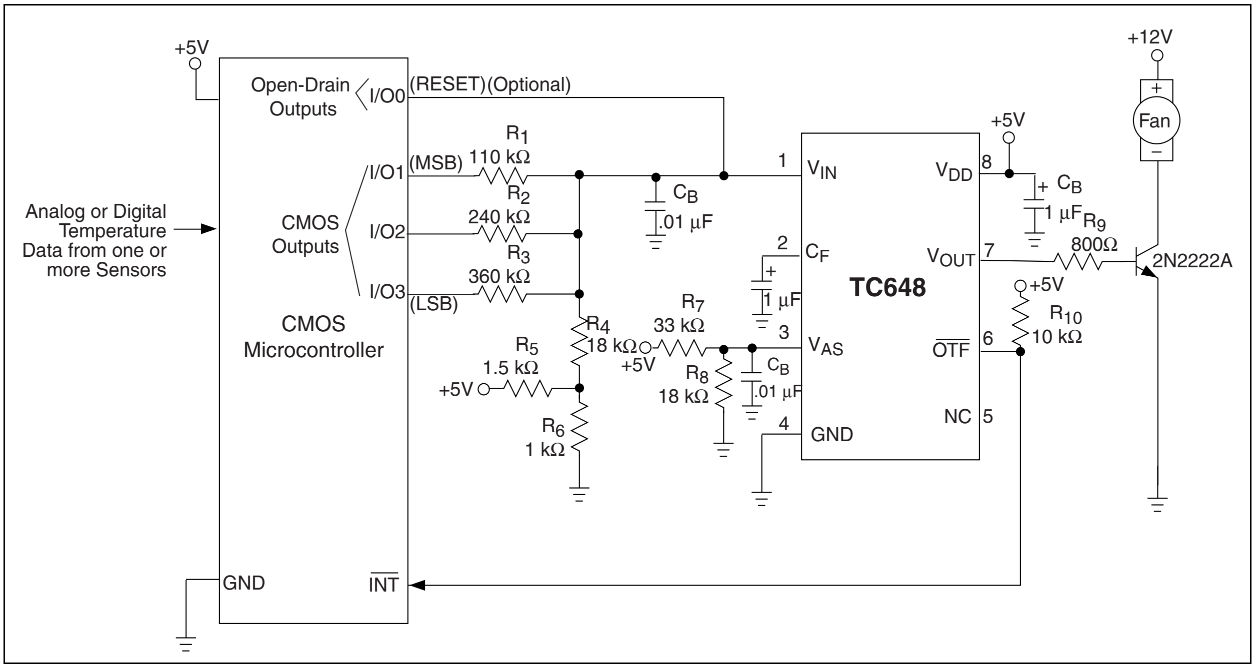
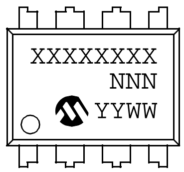


FIGURE 5-9: *TC648 as a Microcontroller Peripheral.*

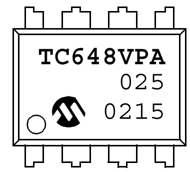
6.0 PACKAGING INFORMATION

6.1 Package Marking Information

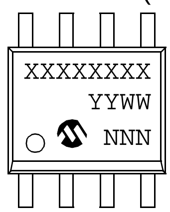
8-Lead PDIP (300 mil)



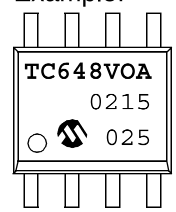
Example:



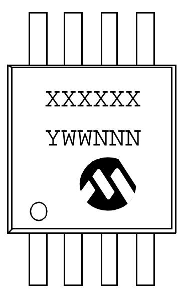
8-Lead SOIC (150 mil)



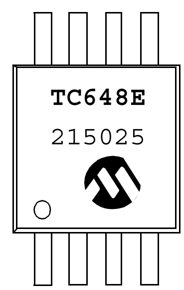
Example:



8-Lead MSOP



Example:

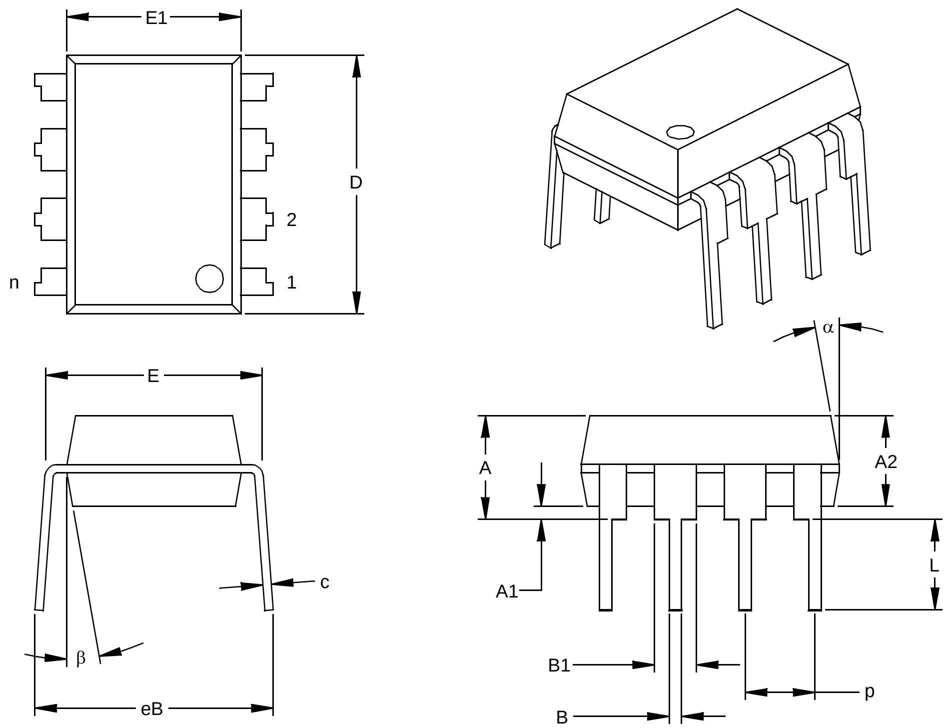


Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

8-Lead Plastic Dual In-line (P) – 300 mil (PDIP)

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



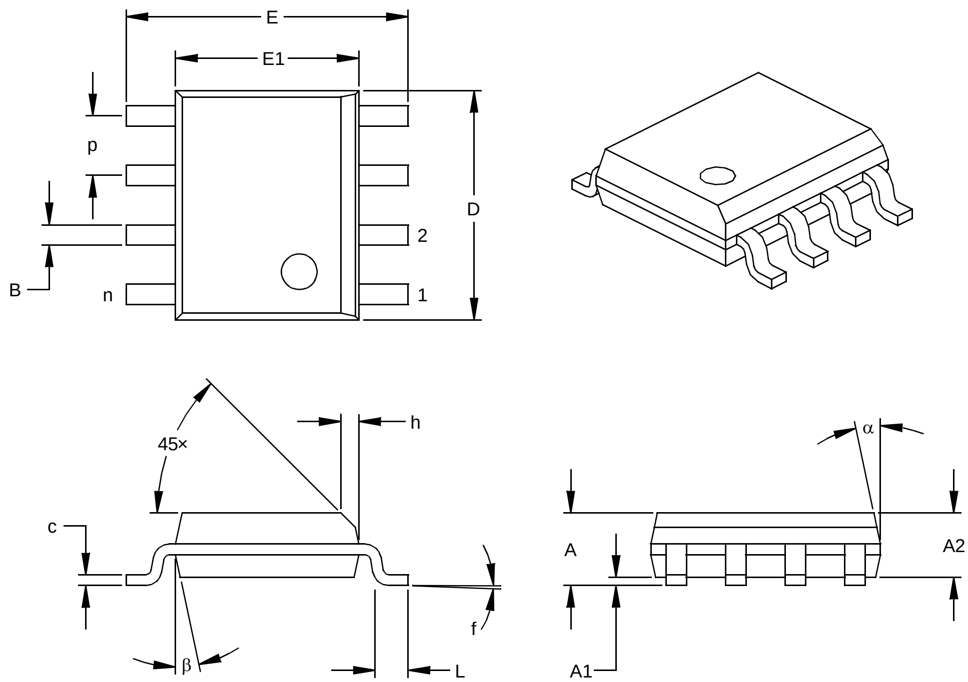
Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.155	.170	3.56	3.94	4.32
Molded Package Thickness	A2	.115	.130	.145	2.92	3.30	3.68
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.300	.313	.325	7.62	7.94	8.26
Molded Package Width	E1	.240	.250	.260	6.10	6.35	6.60
Overall Length	D	.360	.373	.385	9.14	9.46	9.78
Tip to Seating Plane	L	.125	.130	.135	3.18	3.30	3.43
Lead Thickness	c	.008	.012	.015	0.20	0.29	0.38
Upper Lead Width	B1	.045	.058	.070	1.14	1.46	1.78
Lower Lead Width	B	.014	.018	.022	0.36	0.46	0.56
Overall Row Spacing §	eB	.310	.370	.430	7.87	9.40	10.92
Mold Draft Angle Top	α	5	10	15	5	10	15
Mold Draft Angle Bottom	β	5	10	15	5	10	15

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010” (0.254mm) per side.
JEDEC Equivalent: MS-001
Drawing No. C04-018

8-Lead Plastic Small Outline (SN) – Narrow, 150 mil (SOIC)

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.050			1.27	
Overall Height	A	.053	.061	.069	1.35	1.55	1.75
Molded Package Thickness	A2	.052	.056	.061	1.32	1.42	1.55
Standoff §	A1	.004	.007	.010	0.10	0.18	0.25
Overall Width	E	.228	.237	.244	5.79	6.02	6.20
Molded Package Width	E1	.146	.154	.157	3.71	3.91	3.99
Overall Length	D	.189	.193	.197	4.80	4.90	5.00
Chamfer Distance	h	.010	.015	.020	0.25	0.38	0.51
Foot Length	L	.019	.025	.030	0.48	0.62	0.76
Foot Angle	f	0	4	8	0	4	8
Lead Thickness	c	.008	.009	.010	0.20	0.23	0.25
Lead Width	B	.013	.017	.020	0.33	0.42	0.51
Mold Draft Angle Top	α	0	12	15	0	12	15
Mold Draft Angle Bottom	β	0	12	15	0	12	15

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.
JEDEC Equivalent: MS-012
Drawing No. C04-057

8-Lead Plastic Micro Small Outline Package (MS) (MSOP)

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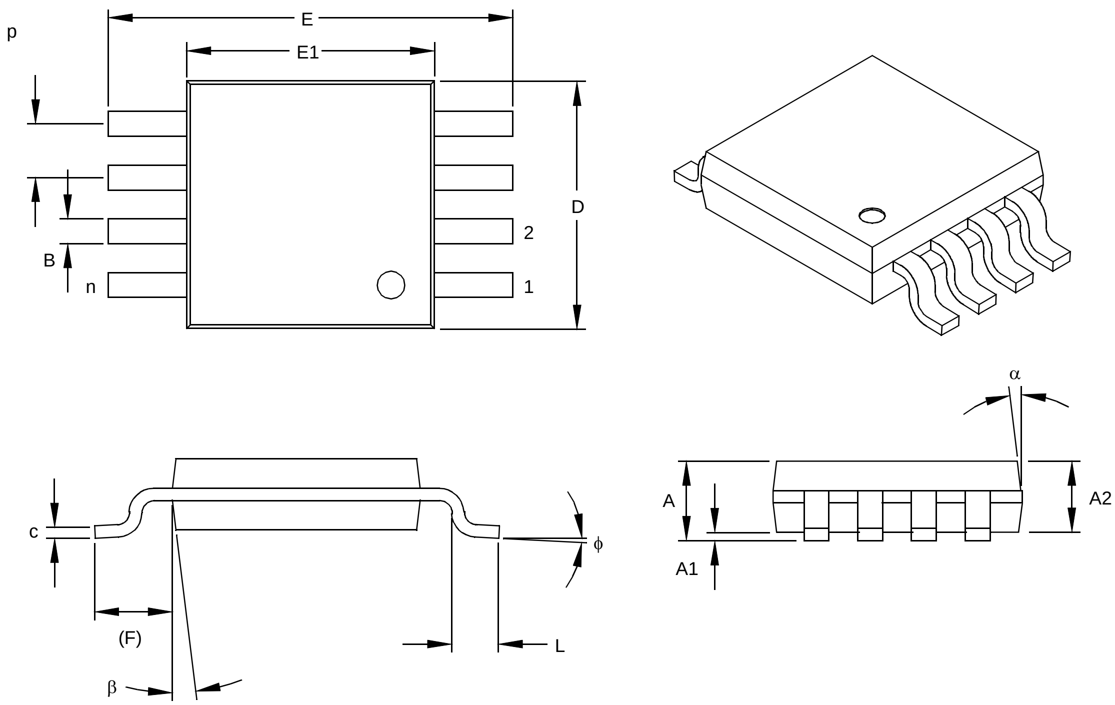


Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8				8
Pitch	p		.026			0.65	
Overall Height	A			.044			1.18
Molded Package Thickness	A2	.030	.034	.038	0.76	0.86	0.97
Standoff §	A1	.002		.006	0.05		0.15
Overall Width	E	.184	.193	.200	4.67	4.90	.5.08
Molded Package Width	E1	.114	.118	.122	2.90	3.00	3.10
Overall Length	D	.114	.118	.122	2.90	3.00	3.10
Foot Length	L	.016	.022	.028	0.40	0.55	0.70
Footprint (Reference)	F	.035	.037	.039	0.90	0.95	1.00
Foot Angle	φ	0		6	0		6
Lead Thickness	c	.004	.006	.008	0.10	0.15	0.20
Lead Width	B	.010	.012	.016	0.25	0.30	0.40
Mold Draft Angle Top	α		7			7	
Mold Draft Angle Bottom	β		7			7	

*Controlling Parameter
§ Significant Characteristic

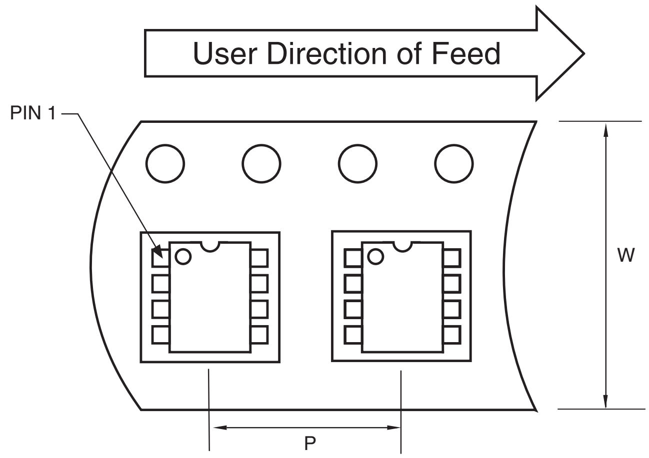
Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed. 010" (0.254mm) per side.

Drawing No. C04-111

6.2 Taping Form

Component Taping Orientation for 8-Pin SOIC (Narrow) Devices

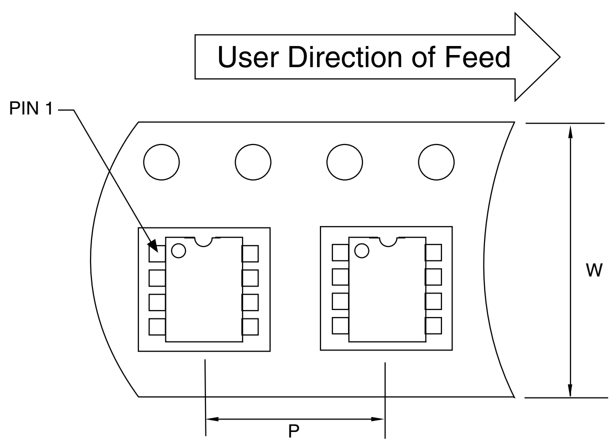


Standard Reel Component Orientation
for 713 Suffix Device

Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
8-Pin SOIC (N)	12 mm	8 mm	2500	13 in

Component Taping Orientation for 8-Pin MSOP Devices



Standard Reel Component Orientation
for 713 Suffix Device

Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
8-Pin MSOP	12 mm	8 mm	2500	13 in

7.0 REVISION HISTORY

Revision D (December 2012)

Added a note to each package outline drawing.

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PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

PART NO.	X	/XX
Device	Temperature Range	Package

Device:	TC648:	PWM Fan Speed Controller w/Auto Shutdown and Overtemperature Alert
Temperature Range:	V = 0°C to +85°C E = -40°C to +85°C	
Package:	PA = Plastic DIP (300 mil Body), 8-lead OA = Plastic SOIC, (150 mil Body), 8-lead UA = Plastic Micro Small Outline (MSOP), 8-lead	

* PDIP package is only offered in the V temp range

Examples:

a) TC648VOA: PWM Fan Speed Controller w/Auto Shutdown and Over-Temperature Alert, SOIC package.

b) TC648VUA: PWM Fan Speed Controller w/Auto Shutdown and Over-Temperature Alert, MSOP package.

c) TC648VPA: PWM Fan Speed Controller w/Auto Shutdown and Over-Temperature Alert, PDIP package.

d) TC648EOA713: PWM Fan Speed Controller w/Auto Shutdown and Over-Temperature Alert, SOIC package, Tape and Reel.

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Spain - Madrid
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UK - Wokingham
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11/29/12

ООО «ЛайфЭлектроникс» "LifeElectronics" LLC
ИНН 7805602321 КПП 780501001 Р/С 40702810122510004610 ФАКБ "АБСОЛЮТ БАНК" (ЗАО) в г.Санкт-Петербурге К/С 30101810900000000703 БИК 044030703

Компания «Life Electronics» занимается поставками электронных компонентов импортного и отечественного производства от производителей и со складов крупных дистрибьюторов Европы, Америки и Азии.

С конца 2013 года компания активно расширяет линейку поставок компонентов по направлению коаксиальный кабель, кварцевые генераторы и конденсаторы (керамические, пленочные, электролитические), за счёт заключения дистрибьюторских договоров

Мы предлагаем:

- *Конкурентоспособные цены и скидки постоянным клиентам.*
- *Специальные условия для постоянных клиентов.*
- *Подбор аналогов.*
- *Поставку компонентов в любых объемах, удовлетворяющих вашим потребностям.*

- *Приемлемые сроки поставки, возможна ускоренная поставка.*
- *Доставку товара в любую точку России и стран СНГ.*
- *Комплексную поставку.*
- *Работу по проектам и поставку образцов.*
- *Формирование склада под заказчика.*

- *Сертификаты соответствия на поставляемую продукцию (по желанию клиента).*
- *Тестирование поставляемой продукции.*
- *Поставку компонентов, требующих военную и космическую приемку.*
- *Входной контроль качества.*
- *Наличие сертификата ISO.*

В составе нашей компании организован Конструкторский отдел, призванный помогать разработчикам, и инженерам.

Конструкторский отдел помогает осуществить:

- *Регистрацию проекта у производителя компонентов.*
- *Техническую поддержку проекта.*
- *Защиту от снятия компонента с производства.*
- *Оценку стоимости проекта по компонентам.*
- *Изготовление тестовой платы монтаж и пусконаладочные работы.*

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