

# MC642

## PWM Fan Speed Controller with Fault Detection

The MC642 is a pulse width modulation (PWM) fan speed controller for use with DC motors. It provides temperature proportional speed control. A thermistor connected to the  $V_{IN}$  input furnishes the required control voltage of 1.25 V to 2.65 V 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 stalled, open, or unconnected fan causes the MC642 to trigger its start-up timer *once*. If the fault persists, the **FAULT** output goes low, and the device is latched in Shutdown Mode.

### Features

- Shutdown Mode for Power Saving
- Supports Low Cost NTC/PTC Thermistors
- Temperature Proportional Speed for Acoustic Control/ Longer Fan Life
- Fan Voltage Independent of MC642 Supply Voltage
- Fault Detection Circuits Protect Against Fan Failure and Aid System Testing
- Operating Temperature Range: 0°C to +85°C

### Typical Applications

- Power Supplies
- Personal Computers
- UPS's, Power Amplifiers, etc.

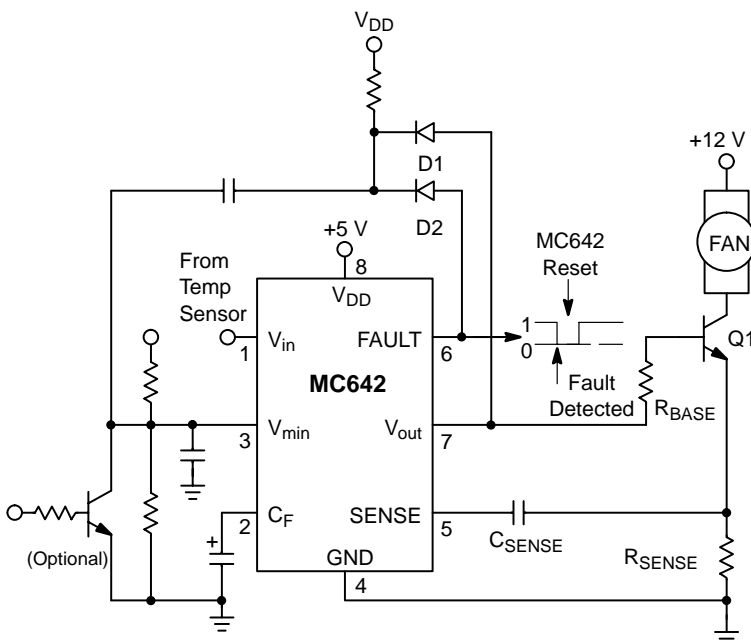


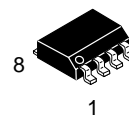
Figure 1. Typical Application Diagram



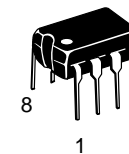
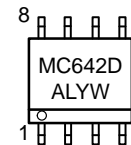
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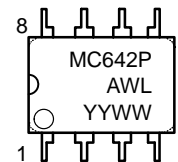
### MARKING DIAGRAMS



SO-8  
D SUFFIX  
CASE 751

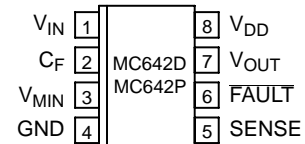


PDIP-8  
P SUFFIX  
CASE 626



A = Assembly Location  
WL, L = Wafer Lot  
YY, Y = Year  
WW, W = Work Week

### PIN CONFIGURATION



### ORDERING INFORMATION

Device	Package	Shipping
MC642DR2	SO-8	2500 Tape/Reel
MC642P	PDIP-8	50 Units/Rail

## MC642

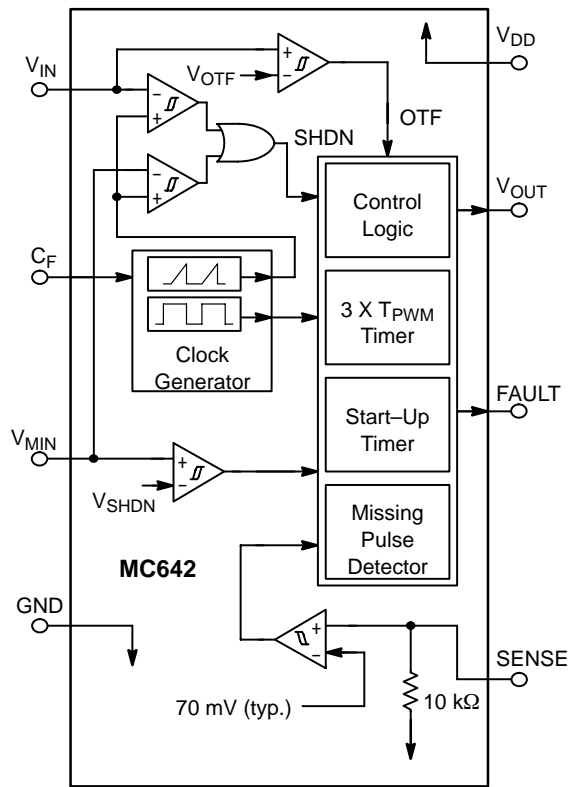


Figure 2. Functional Block Diagram

### PIN DESCRIPTION

Pin No.	Symbol	Description
1	$V_{IN}$	The thermistor network (or other temperature sensor) connects to this input. A voltage range of 1.25 V to 2.65 V (typical) on this pin drives an active duty cycle of 0% to 100% on the $V_{OUT}$ pin.
2	$C_F$	Positive terminal for the PWM ramp generator timing capacitor. The recommended $C_F$ is 1 $\mu$ F for 30 Hz PWM operation.
3	$V_{MIN}$	An external resistor divider connected to this input sets the minimum fan speed by fixing the minimum PWM duty cycle (1.25 V to 2.65 V = 0% to 100%, typical). The MC642 enters Shutdown mode when $0 \leq V_{MIN} \leq V_{SHDN}$ . During Shutdown, the FAULT output is inactive, and supply current falls to 25 $\mu$ A (typical). The MC642 exits Shutdown mode when $V_{MIN} \geq V_{REL}$ . See <i>Applications</i> section for more details.
4	GND	Ground Terminal
5	SENSE	Pulses are detected at this pin as fan rotation chops the current through a sense resistor. The absence of pulses indicates a fault.
6	FAULT	Fault (open collector) output. This line goes low to indicate a fault condition. When FAULT goes low due to a fan fault, the device is latched in Shutdown Mode until deliberately cleared or until power is cycled. $\overline{FAULT}$ may be connected to $V_{MIN}$ if a hard shutdown is desired. $\overline{FAULT}$ will also be asserted when the PWM reaches 100% duty cycle, however the device will not latch itself off unless $\overline{FAULT}$ is tied to $V_{MIN}$ externally.
7	$V_{OUT}$	PWM signal output. This active high complimentary output connects to the base of an external NPN motor drive transistor. This output has asymmetrical drive. – See <i>Electrical Characteristics</i> section.
8	$V_{DD}$	Power Supply Input. May be independent of fan power supply. See <i>Electrical Characteristics</i> section.

# MC642

## ABSOLUTE MAXIMUM RATINGS\*

Parameter	Value	Unit
Package Power Dissipation ( $T_A \leq 70^\circ\text{C}$ ) Plastic DIP Small Outline (SOIC)	730 470	mW
Derating Factors	8.0	mW/ $^\circ\text{C}$
Supply Voltage	6.0	V
Input Voltage, Any Pin	(GND – 0.3) to ( $V_{CC} + 0.3$ )	V
Operating Temperature Range	0 to +85	$^\circ\text{C}$
Maximum Chip Temperature	150	$^\circ\text{C}$
Storage Temperature Range	–65 to +150	$^\circ\text{C}$
Lead Temperature (Soldering, 10 Seconds)	+300	$^\circ\text{C}$

\* Maximum Ratings are those values beyond which damage to the device may occur.

## ELECTRICAL CHARACTERISTICS ( $T_{MIN} < T_A < T_{MAX}$ , $V_{DD} = 3.0\text{ V to } 5.5\text{ V}$ , unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
Supply Voltage	$V_{DD}$	3.0	–	5.5	V
Supply Current, Operating Pins 3, 5, 7 Open, $C_F = 1\ \mu\text{F}$ , $V_{IN} = V_{C(MAX)}$	$I_{DD}$	–	0.5	1.0	mA
Supply Current, Shutdown Mode Pins 1, 5, 6, 7 Open, $C_F = 1\ \mu\text{F}$ , $V_{IN} = 0.35\text{ V}$ (Note 1.)	$I_{DD(SHDN)}$	–	25	–	$\mu\text{A}$
$V_{IN}$ , $V_{MIN}$ Input Leakage (Note 1.)	$I_{IN}$	–1.0	–	1.0	$\mu\text{A}$

### $V_{OUT}$ Output

$V_{OUT}$ Rise Time ( $I_{OH} = 5.0\text{ mA}$ ) (Note 1.)	$t_R$	–	–	50	$\mu\text{sec}$
$V_{OUT}$ Fall Time ( $I_{OH} = 1.0\text{ mA}$ ) (Note 1.)	$t_F$	–	–	50	$\mu\text{sec}$
Pulse Width (On $V_{MIN}$ ) to Clear Fault Mode $V_{SHDN}$ , $V_{HYST}$ Specifications	$t_{(SHDN)}$	30	–	–	$\mu\text{sec}$
Sink Current at $V_{OUT}$ Output $V_{OL} = 10\%$ of $V_{DD}$	$I_{OL}$	1.0	–	–	mA
Source Current at $V_{OUT}$ Output $V_{OH} = 80\%$ of $V_{DD}$	$I_{OH}$	5.0	–	–	mA

### $V_{IN}$ , $V_{MIN}$ , Inputs

Input Voltage at $V_{IN}$ or $V_{MIN}$ for 100% PWM Duty Cycle	$V_{C(MAX)}$ , $V_{OTF}$	2.5	2.65	2.8	V
$V_{C(MAX)} - V_{C(MIN)}$	$V_{C(SPAN)}$	1.3	1.4	1.5	V
Voltage Applied to $V_{MIN}$ to Guarantee Shutdown Mode	$V_{SHDN}$	–	–	$V_{DD} \times 0.13$	V
Voltage Applied to $V_{MIN}$ to Release Shutdown Mode $V_{DD} = 5\text{ V}$	$V_{REL}$	$V_{DD} \times 0.19$	–	–	V

### Pulse-Width Modulator

PWM Frequency ( $C_F = 1.0\ \mu\text{F}$ )	F	26	30	34	Hz
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### Sense Input

SENSE Input Threshold Voltage with Respect to GND	$V_{TH(SENSE)}$	50	70	90	mV
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### Fault Output

Output Low Voltage ( $I_{OH} = 2.5\text{ mA}$ )	VOL	–	–	0.3	V
Missing Pulse Detector Timeout	$t_{MP}$	–	32/F	–	Sec
Startup Time	$t_{STARTUP}$	–	32/F	–	Sec
Diagnostic Timer Period	$t_{DIAG}$	–	3/F	–	Sec

1. Guaranteed by design, not tested.

## DETAILED OPERATING DESCRIPTION

**PWM**

The PWM (Pulse Width Modulation) 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  $C_F$  input. A frequency of 30 Hz is recommended ( $C_F = 1 \mu\text{F}$ ). The PWM is also the timebase for the startup and fault timer (see below). The PWM voltage control range is 1.25 V to 2.65 V (typical) for 0% to 100% output duty cycle.

**V<sub>OUT</sub> 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 are shown in the following pages. This output has asymmetric complementary drive and is optimized for driving NPN transistors or N-channel MOSFET's. Since the system relies on PWM rather than linear power control, the dissipation in the power switch is kept to a minimum. Generally, very small devices (TO-92 or SOT package) will suffice. (See Output Drive Transistor Selection paragraph in Applications Information section.)

**Start-Up Timer**

To ensure reliable fan startup, the StartUp 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 mode. If the PWM frequency is 30Hz ( $C_F = 1 \mu\text{F}$ ), the resulting start-up time will be about one second. If a Fault is detected (see below), the Diagnostic Timer is triggered once, followed by the Startup-Up Timer. If the fault persists, the device is shut down. See *FAULT Output* below.

**Shutdown Control (Optional)**

When  $V_{MIN}$  (pin 3) is pulled below  $V_{SHDN}$ , the MC642 will go into Shutdown mode. This can be accomplished by driving  $V_{MIN}$  with an open drain logic signal or using an external transistor as shown in Figure 3. All functions are suspended until the voltage on  $V_{MIN}$  becomes higher than  $V_{REL}$  (0.85 V @  $V_{DD} = 5.0$  V). Pulling  $V_{MIN}$  below  $V_{SHDN}$  will always result in complete device shutdown and reset. The  $\overline{FAULT}$  output is unconditionally inactive in Shutdown mode.

A small amount of hysteresis, typically one percent of  $V_{DD}$  (50 mV at  $V_{DD} = 5.0$  V), is designed into the  $V_{SHDN}/V_{REL}$  threshold. The levels specified for  $V_{SHDN}$  and  $V_{REL}$  in the *Electrical Characteristics* section 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. i.e., the fan will not activate regardless of the voltage on  $V_{IN}$ . (Note: The fan should not be shut down until all heat-producing activity in the system is at a negligible level.)

**SENSE Input**

The SENSE input, pin 5, is connected to a low-value current sensing resistor in the ground return leg of the fan circuit. During normal fan operation commutation occurs as each pole of the fan is energized. This commutation causes brief interruptions in the fan current, which is seen as pulses across the sense resistor. When the device is not in Shutdown Mode and pulses are not appearing at the SENSE input, a fault condition exists.

The short, rapid changes in fan current (high  $dI/dt$ ) cause corresponding  $dV/dt$  pulses across the sense resistor,  $R_{SENSE}$ . The waveform on  $R_{SENSE}$  is differentiated and converted to a logic-level pulse-train by  $C_{SENSE}$  and the internal signal processing circuitry (See Figure 3). The presence and frequency of this pulse-train is a direct indication of fan operation. See the *Applications Information* section for more details.

 **$\overline{FAULT}$  Output**

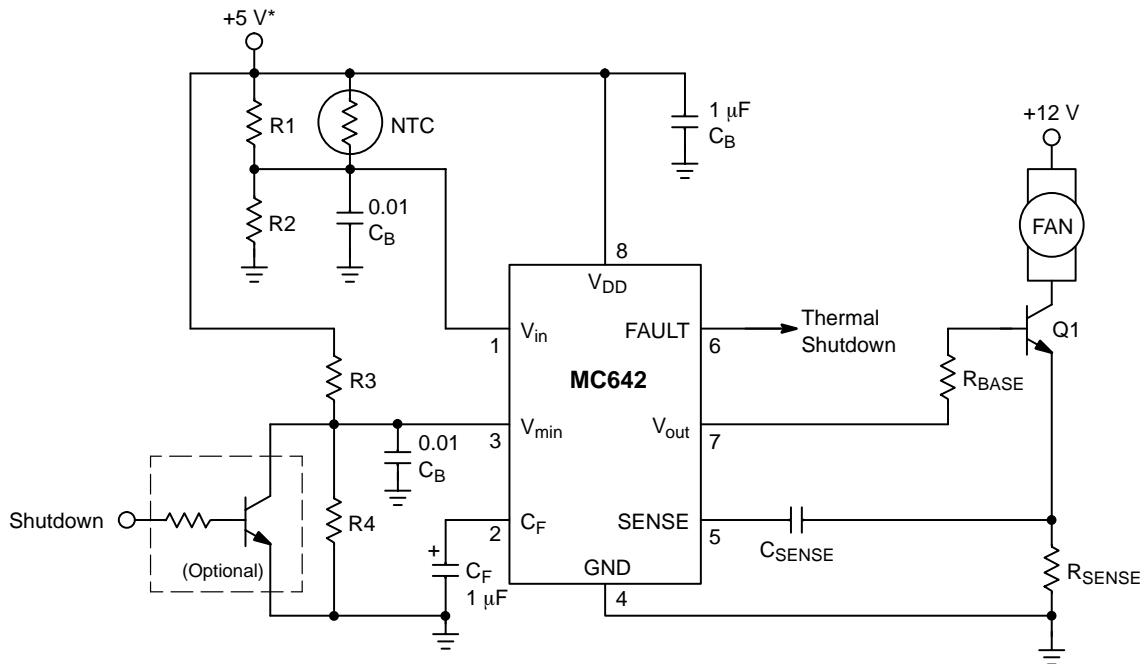
The MC642 detects faults in two ways:

(1) Pulses appearing at SENSE due to the PWM turning on are blanked and the remaining pulses are filtered by a missing pulse detector. If consecutive pulses are not detected for 32 PWM cycles (1 Sec if  $C_F = 1 \mu\text{F}$ ), the Diagnostic Timer is activated and  $V_{OUT}$  is driven continuously for three PWM cycles (100 msec if  $C_F = 1 \mu\text{F}$ ). If a pulse is not detected within this window, the Startup-Timer is triggered. This should clear a transient fault condition. If the Missing Pulse Detector times out again, the PWM is stopped and  $\overline{FAULT}$  goes low. When  $\overline{FAULT}$  is activated due to this condition, the device is latched in Shutdown mode and will remain off indefinitely. (Diodes  $D_1$ ,  $D_2$  and resistor  $R_5$  (See Figure 3) are provided to ensure that fan restarting is the result of a fan fault, and not an over-temperature fault. A CMOS logic OR gate may be substituted for these components if available).

When  $\overline{FAULT}$  is activated due to this condition, the device is latched in Shutdown mode and will remain off indefinitely. **Important: At this point, action *must* be taken to restart the fan by momentarily pulling  $V_{MIN}$  below  $V_{SHDN}$ , or by cycling system power. In either case the fan *cannot* be permitted to remain disabled due to a fault condition, as severe system damage could result. If the fan cannot be restarted, the system should be shut down.** The MC642 may be configured to continuously attempt fan restarts if so desired.



## MC642



NOTE: \*See Cautions Regarding Latch-Up Considerations in the Applications Section.

**Figure 4. Typical Fan Control Application Using NTC Thermistor**

### Normal Operation

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

1. Reset the Missing Pulse Detector
2. Is MC642 in Shutdown? If so...
  - a.  $V_{OUT}$  duty-cycle goes to zero.
  - b.  $FAULT$  is disabled.
  - c. Exit the loop and wait for  $V_{MIN} > V_{REL}$  to resume operation (indistinguishable from Power-Up).
3. If an over-temperature fault occurs ( $V_{IN} > V_{OTF}$ ) then activate  $\overline{FAULT}$ ; release  $\overline{FAULT}$  when  $V_{IN} < V_{OTF}$ .
4. Drive  $V_{OUT}$  to a duty-cycle proportional to greater of  $V_{IN}$  and  $V_{MIN}$  on a cycle by cycle basis.
5. If a fan pulse is detected, branch back to the start of the loop.
6. If the missing pulse detector times out ...

7. Activate the 3-cycle Diagnostic Timer and look for pulses; if a fan pulse is detected, branch back to the start of the loop; if none are received...
8. Activate the 32-cycle Startup Timer and look for pulses; if a fan pulse is detected, branch back to the start of the loop; if none are received...
9. Quit Normal Operation and go to Fan Fault.
10. End

### Fan Fault

Fan Fault is essentially an infinite loop wherein the MC642 is latched in Shutdown Mode. This mode can only be released by a Reset, i.e.,  $V_{MIN}$  being brought below  $V_{SDHN}$ , then above  $V_{REL}$ , or by power-cycling.

1. While in this state,  $\overline{FAULT}$  is latched on (low), and the  $V_{OUT}$  output is disabled.
2. A Reset sequence applied to the  $V_{MIN}$  pin will exit the loop to Power Up.
3. End

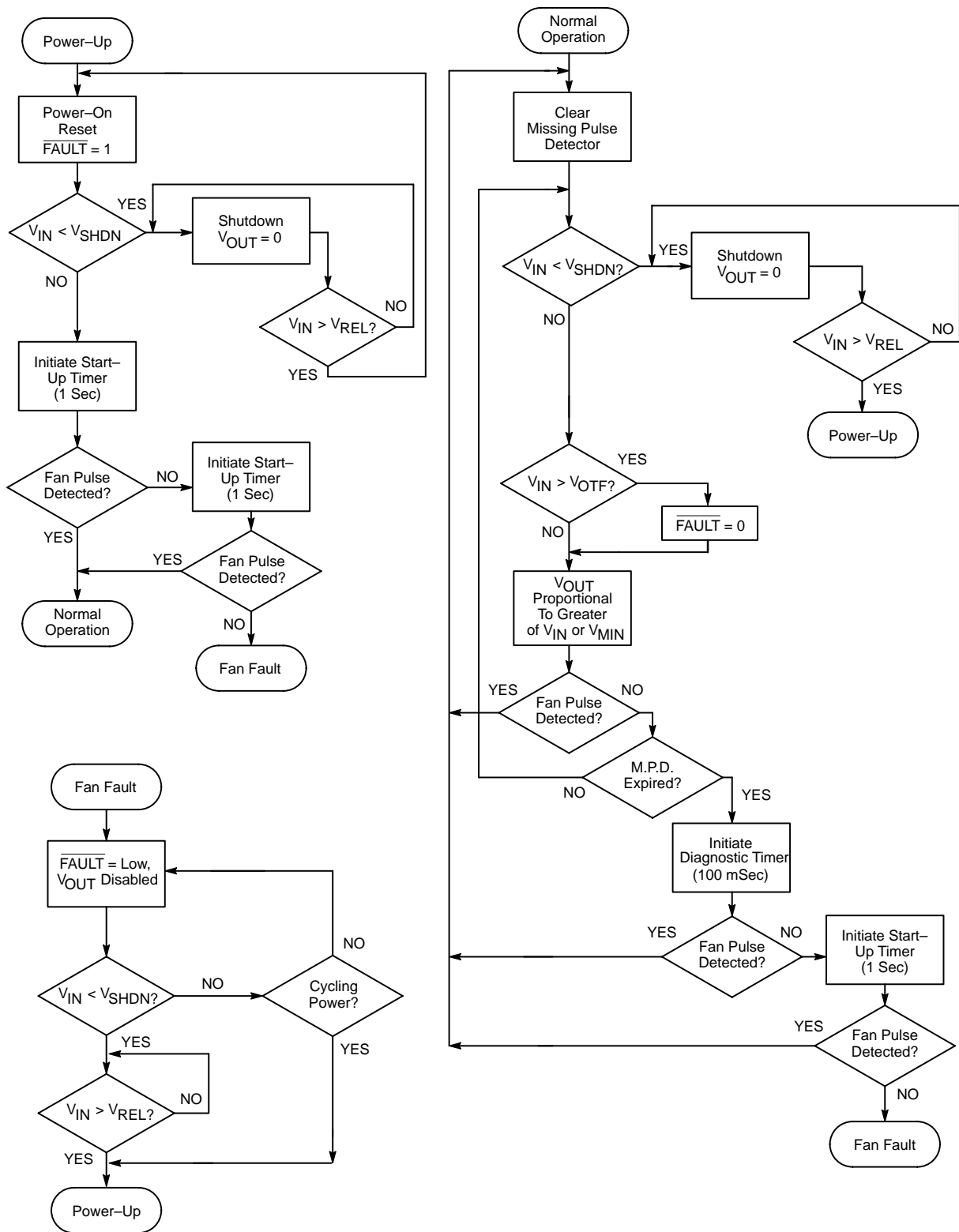


Figure 5. MC642 Behavioral Algorithm Flowchart

APPLICATIONS INFORMATION

Designing with the MC642 involves the following:

1. The temp sensor network must be configured to deliver 1.25 V to 2.65 V on  $V_{IN}$  for 0% to 100% of the temperature range to be regulated.
2. The minimum fan speed ( $V_{MIN}$ ) must be set.
3. The output drive transistor and associated circuitry must be selected.
4. The Sense Network,  $R_{SENSE}$  and  $C_{SENSE}$ , must be designed for maximum efficiency while delivering adequate signal amplitude.

5. If Shutdown capability is desired, the drive requirements of the external signal or circuit must be considered.

Temperature Sensor Design

The temperature signal connected to  $V_{IN}$  must output a voltage in the range of 1.25 V to 2.65 V (typical) for 0% to 100% of the temperature range of interest. The circuit of Figure 6 is a convenient way to provide this signal.

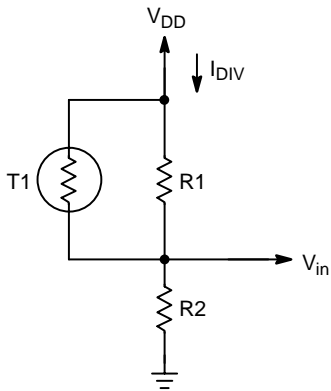


Figure 6. Temperature Sensing Circuit

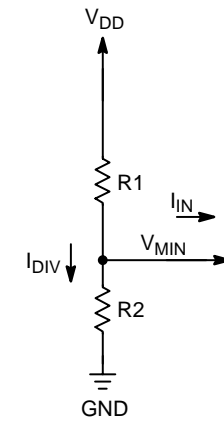


Figure 7.  $V_{MIN}$  Circuit

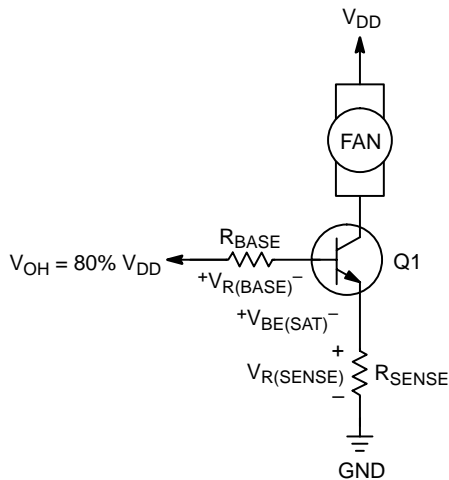


Figure 8. Circuit for Determining  $R_{BASE}$

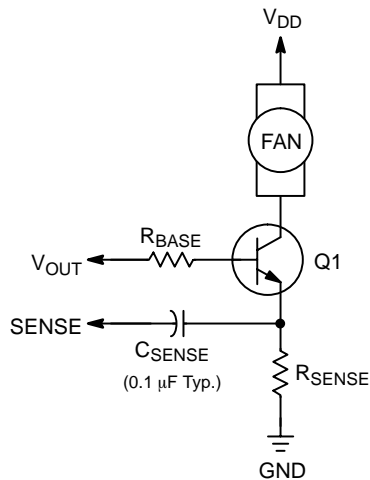


Figure 9. SENSE Network



Figure 6 illustrates a simple temperature dependent voltage divider circuit. T1 is a conventional NTC thermistor, and R1 and R2 are standard resistors. The supply voltage,  $V_{DD}$ , is divided between R2 and the parallel combination of T1 and R1. (For convenience, the parallel combination of T1 and R1 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. A thermistor with a 25°C resistance on the order of 100 kΩ will result in reasonable values for R1, R2, and  $I_{DIV}$ . In order to determine R1 and R2, we must specify the fan duty-cycle, i.e.  $V_{IN}$ , at any two temperatures. Equipped with these two points on the system's operating curve and the thermistor data, we can write the defining equations:

$$\frac{V_{DD} \times R2}{R_{TEMP}(t1) + R2} = V(t1) \quad (\text{eq. 1})$$

$$\frac{V_{DD} \times R2}{R_{TEMP}(t2) + R2} = V(t2)$$

Where  $t1$  and  $t2$  are the chosen temperatures and  $R_{TEMP}$  is the parallel combination of the thermistor and R1. These two equations permit solving for the two unknown variables, R1 and R2. Note that resistor R1 is not absolutely necessary, but it helps to linearize the response of the network.

#### Minimum Fan Speed

A voltage divider on  $V_{MIN}$  sets the minimum PWM duty cycle and, thus, the minimum fan speed. As with the  $V_{IN}$  input, 1.25 V to 2.65 V corresponds to 0% to 100% duty cycle. Assuming that fan speed is linearly related to duty-cycle, the minimum speed voltage is given by the equation:

$$V_{MIN} = \frac{\text{Minimum Speed}}{\text{Full Speed}} \times (1.4V) + 1.25 V = 1.81 V \quad (\text{eq. 2})$$

For example, if 2500 RPM equates to 100% fan speed, and a minimum speed of 1000 RPM is desired, then the  $V_{MIN}$  voltage is:

$$V_{MIN} = \frac{1000}{2500} \times (1.4V) + 1.25 V = 1.81 V \quad (\text{eq. 3})$$

The  $V_{MIN}$  voltage may be set using a simple resistor divider as shown in Figure 7. Per the *Electrical Characteristics*, the leakage current at the  $V_{MIN}$  pin is no more than 1 μA. It would be very conservative to design for a divider current,  $I_{DIV}$ , of 100 μA. If  $V_{DD} = 5.0 V$  then...

$$I_{DIV} = 1e^{-4}A = \frac{5.0V}{R1 + R2}, \text{ therefore} \quad (\text{eq. 4})$$

$$R1 + R2 = \frac{5.0V}{1e^{-4}A} = 50,000\Omega = 50k\Omega$$

We can further specify R1 and R2 by the condition that the divider voltage is equal to our desired  $V_{MIN}$ . This yields the following equation:

$$V_{MIN} = V_{DD} \times \frac{R2}{R1 + R2} \quad (\text{eq. 5})$$

Solving for the relationship between R1 and R2 results in the following equation:

$$R1 = R2 \times \frac{V_{DD} - V_{MIN}}{V_{MIN}} \quad (\text{eq. 6})$$

In the case of this example,  $R1 = (1.762) R2$ . Substituting this relationship back into Equation 4 yields the resistor values:

$$R2 = 18.1 k\Omega, \text{ and} \\ R1 = 31.9 k\Omega$$

In this case, the standard values of 32 kΩ and 18 kΩ are very close to the calculated values and would be more than adequate.

One boundary condition which may impact the selection of the minimum fan speed is the irregular activation of the Diagnostic Timer due to the MC642 "missing" fan commutation pulses at low speeds. Typically, this only occurs at very low duty-cycles (25% or less). It is a natural consequence of low PWM duty-cycles. Recall that the SENSE function detects commutation of the fan as disturbances in the current through  $R_{SENSE}$ . These can only occur when the fan is energized, i.e.,  $V_{OUT}$  is "on". At very low duty-cycles, the  $V_{OUT}$  output is "off" most of the time. The fan may be rotating normally, but the commutation events are occurring during the PWM's off-time.

The phase relationship between the fan's commutation and the PWM edges tends to "walk around" as the system operates. At certain points, the MC642 may fail to capture a pulse within the 32-cycle Missing Pulse Detector window. When this happens, the 3-cycle Diagnostic Timer will be activated, the  $V_{OUT}$  output will be active continuously for three cycles and, if the fan is operating normally, a pulse will be detected. If all is well, the system will return to normal operation. There is no harm in this behavior, but it may be audible to the user as the fan will accelerate briefly when the Diagnostic Timer fires. For this reason, it is recommended that  $V_{MIN}$  be set no lower than 1.8 V.

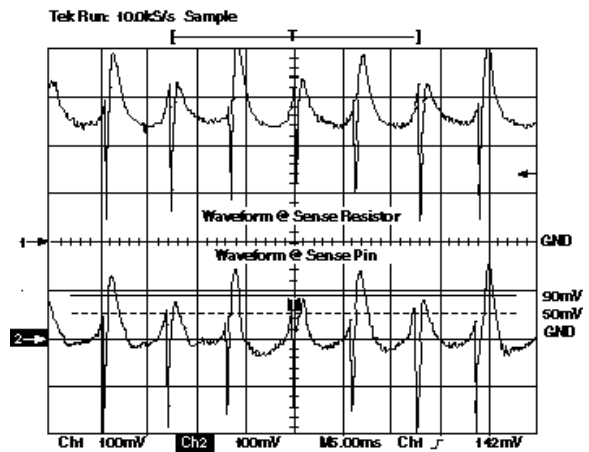
**SENSE Network ( $R_{SENSE}$  and  $C_{SENSE}$ )**

The network comprised of  $R_{SENSE}$  and  $C_{SENSE}$  allow the MC642 to detect commutation of the fan motor. This network can be thought of as a differentiator and threshold detector. The function of  $R_{SENSE}$  is to convert the fan current into a voltage.  $C_{SENSE}$  serves to AC-couple this voltage signal and provide a ground-referenced input to the SENSE pin. Designing a proper SENSE Network is simply a matter of scaling  $R_{SENSE}$  to provide the necessary amount of gain, i.e., the current-to-voltage conversion ratio. A 0.1  $\mu\text{F}$  ceramic capacitor is recommended for  $C_{SENSE}$ . Smaller values require larger sense resistors, and higher value capacitors are bulkier and more expensive. Using a 0.1  $\mu\text{F}$  results in reasonable values for  $R_{SENSE}$ . Figure 9 illustrates a typical SENSE Network. Figure 10 shows the waveforms observed using a typical SENSE Network.

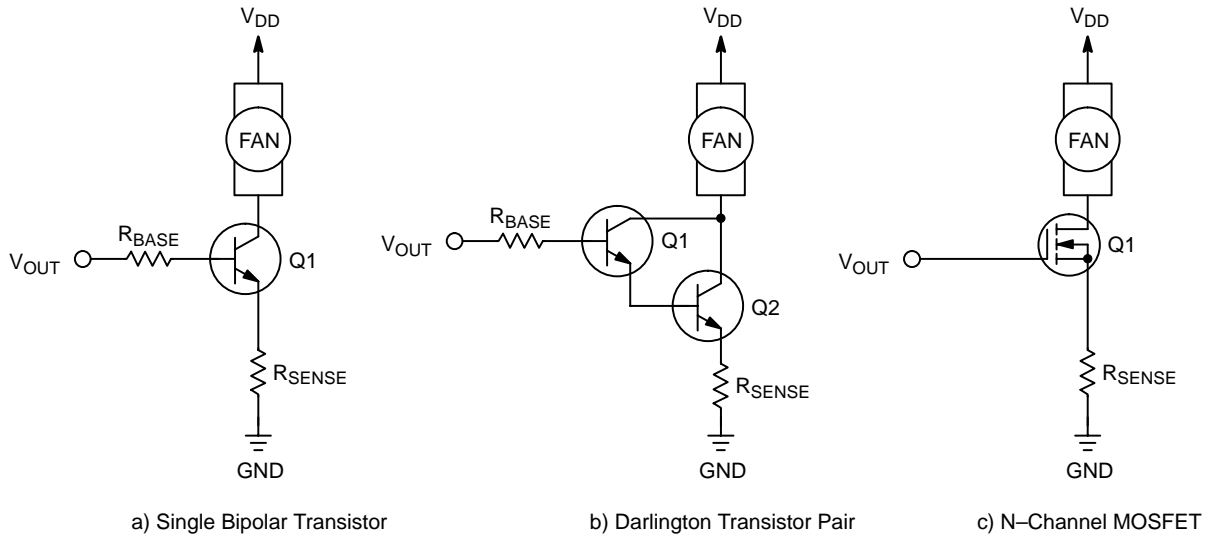
Table 1 lists the recommended values of  $R_{SENSE}$  according to the nominal operating current of the fan. Note that the current draw specified by the fan manufacturer may not be the fan's nominal operating current, but may be a worst-case rating for near-stall conditions. The values in the table refer to actual average operating current. If the fan current falls between two of the values listed, use the higher resistor value. The end result of employing Table 1 is that the signal developed across the sense resistor is approximately 450 mV in amplitude.

**Table 1.  $R_{SENSE}$  vs. Fan Current**

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



**Figure 10. SENSE Waveforms**



**Figure 11. Output Drive Transistor Circuit Topologies**

**Output Drive Transistor Selection**

The MC642 is designed to drive an external transistor for modulating power to the fan. This is shown as “Q1” in Figures 4, 8, 9, 11, 12, and 13. The V<sub>OUT</sub> pin has a minimum source current of 5 mA and a minimum sink current of 1mA at V<sub>DD</sub> = 5.0 V. Bipolar transistors or MOSFET’s may be used as the power switching element as shown below. 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 11: (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 MC642’s PWM control scheme versus linear speed control is that the 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 fan sensing function to work correctly it is imperative that the pass transistor be fully saturated when “on”. The minimum gain (h<sub>FE</sub>) of the transistor in question must be adequate to fully saturate the transistor when passing the full fan current while being driven within the 5 mA I<sub>OH</sub> of the V<sub>OUT</sub> output.

Table 2 gives examples of some commonly available transistors. This table is a guide only. There are many transistor types which might work as well as those listed. The only critical issues when choosing a device to use as Q1 are: (1) the breakdown voltage, V<sub>CE(BR)</sub>, must be large enough to stand off the highest voltage applied to the fan (NOTE: this may be when the fan is off!); (2) the gain (h<sub>FE</sub>) must be high enough for the device to remain fully saturated while conducting the maximum expected fan current and being driven with no more than 5 mA of base/gate drive at maximum temperature; (3) rated fan current draw must be within the transistor’s current handling capability; and (4) power dissipation must be kept within the limits of the chosen device.

**Table 2. Transistors for Q1**

Device	V <sub>BE(SAT)</sub>	MIN h <sub>FE</sub>	V <sub>BR(CEO)</sub>	I <sub>C</sub>	R <sub>BASE</sub> (Ω)
MPS2222	1.3	100	30	150	800
MPS2222A	1.2	100	40	150	800
2N4400	0.95	50	40	150	820
2N4401	0.95	100	40	150	820
MPS6601	1.2	50	25	500	780
MPS6602	1.2	50	40	500	780

A base–current limiting resistor is required with bipolar transistors. This is shown in Figure 8. The correct value for this resistor can be determined as follows: (see Figure 8).

$$\begin{aligned}
 V_{OH} &= V_{SENSE} + V_{BE(SAT)} + V_{RBASE} \\
 V_{RSENSE} &= I_{FAN} \times R_{SENSE} \\
 V_{RBASE} &= V_{BASE} \times I_{BASE} \\
 I_{BASE} &= I_{FAN}/h_{FE}
 \end{aligned}
 \tag{eq. 7}$$

V<sub>OH</sub> is specified as 80% of V<sub>DD</sub> in the *Electrical Characteristics* table; V<sub>BE(SAT)</sub> is given in the transistor datasheet. It is now possible to solve for R<sub>BASE</sub>.

$$R_{BASE} = \frac{V_{OH} - V_{BE(SAT)} - V_{RSENSE}}{I_{BASE}} \tag{eq. 8}$$

Some applications require the fan to be powered from the negative 12 V supply to keep motor noise out of the positive voltage power supplies. As shown in Figure 12, Zener diode D2 offsets the –12 V power supply voltage holding transistor Q1 OFF when V<sub>OUT</sub> is LOW. When V<sub>OUT</sub> is HIGH, the voltage at the anode of D2 increases by V<sub>OH</sub>, causing Q1 to turn ON. Operation is otherwise the same as the case of fan operation +12 V.

**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<sub>MIN</sub> divider, shutdown circuit, or fan, are powered by a supply different from that of the MC642. Care should be taken to ensure that the MC642’s V<sub>DD</sub> supply powers–up *first*. If possible, the networks attached to V<sub>IN</sub> and V<sub>MIN</sub> should connect to the V<sub>DD</sub> 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.

**Power Supply Routing and Bypassing**

Noise present on the V<sub>IN</sub> and V<sub>MIN</sub> inputs may cause erroneous operation of the FAULT 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 particularly true of V<sub>IN</sub>, which usually is driven from a high impedance source (such as a thermistor). In addition, the V<sub>DD</sub> input should be bypassed with a 1 μF capacitor. Grounds should be kept as short as possible. To keep fan noise off the MC642 ground pin, individual ground returns for the MC642 and the low side of the fan current sense resistor should be used.

## MC642

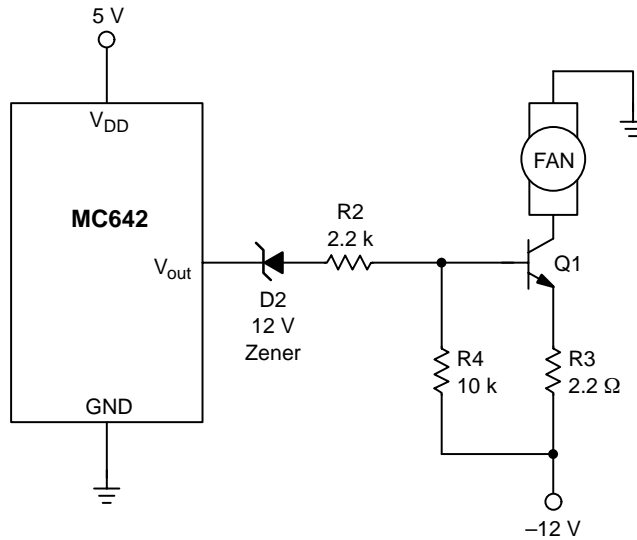


Figure 12. Powering Fan From -12V Supply

### Design Example (Figure 13)

**Step 1.** Circulate R1 and R2 based on using an NTC having a resistance of 4.6 kΩ at  $T_{MIN}$  and 1.1 kΩ at  $T_{MAX}$ .

$$R1 = 75 \text{ k}\Omega$$

$$R2 = 1 \text{ k}\Omega$$

**Step 2.** Set minimum fan speed

$$V_{MIN} = 1.8 \text{ V}$$

Limit the divider current to 100  $\mu\text{A}$  from which  $R5 = 33 \text{ k}\Omega$  and  $R6 = 18 \text{ k}\Omega$

**Step 3.** Design the output circuit

Maximum fan motor current = 250 mA. Q1 beta is chosen at 100 from which  $R7 = 1.5 \text{ k}\Omega$

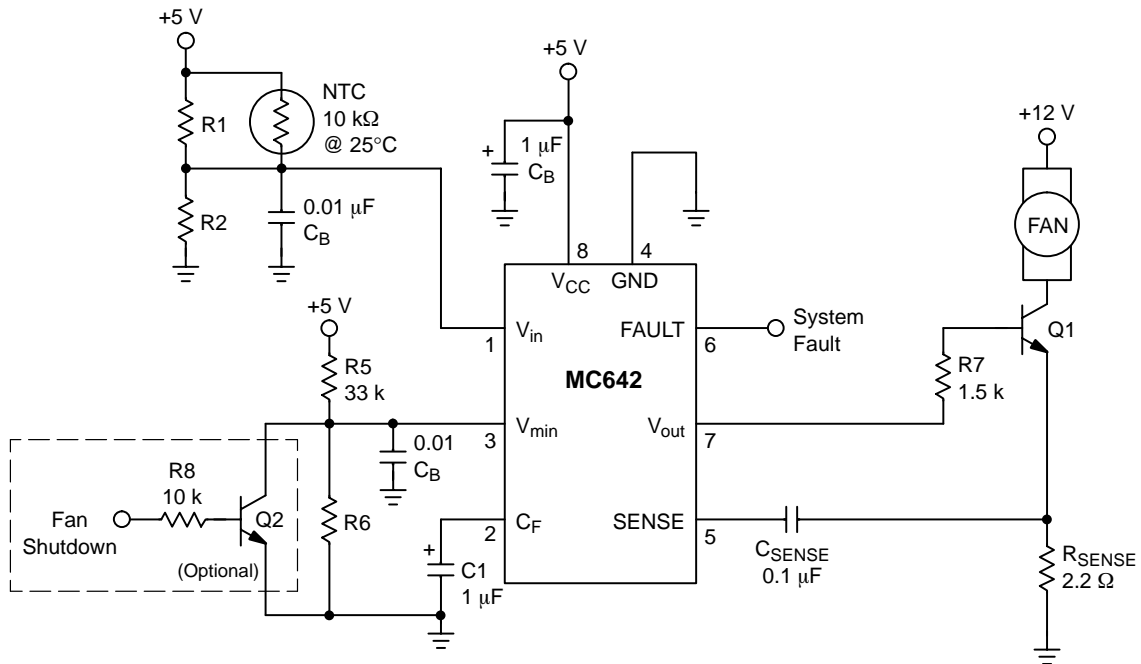


Figure 13. Design Example

**MC642 as a Microcontroller Peripheral (Figure 14)**

In a system containing a microcontroller or other host intelligence, the MC642 can be effectively managed as a CPU peripheral. Routine fan control functions can be performed by the MC642 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 R1 through R6 (5% tolerance) form a crude 3-bit DAC that

translates the 3-bit code from the processor's outputs into a 1.6 V DC control signal. (A monolithic DAC or digital pot may be used instead of the circuit shown.)

With  $V_{MIN}$  set to 1.8 V, the MC642 has a minimum operating speed of approximately 40% of full rated speed when the processor's output code is 000. Output codes 001 to 111 operate the fan from roughly 40% to 100% of full speed. An open drain output from the processor can be used to reset the MC642 following detection of a fault condition. The FAULT output can be connected to the processor's interrupt input, or to an I/O pin for polled operation.

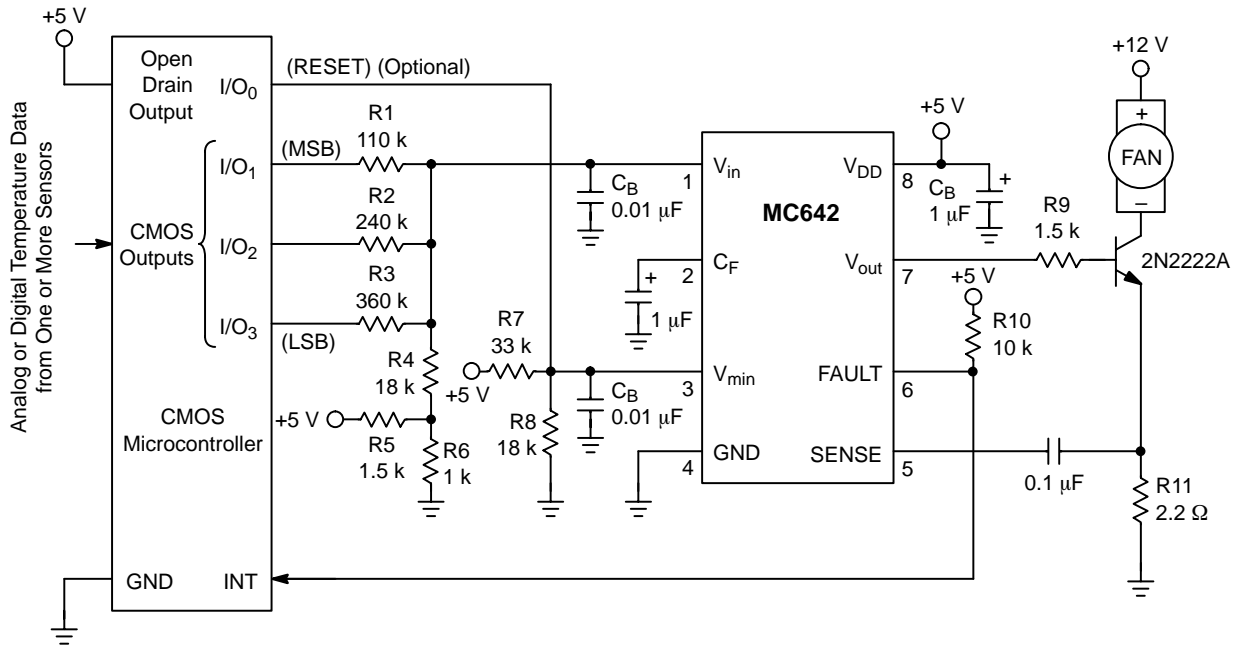
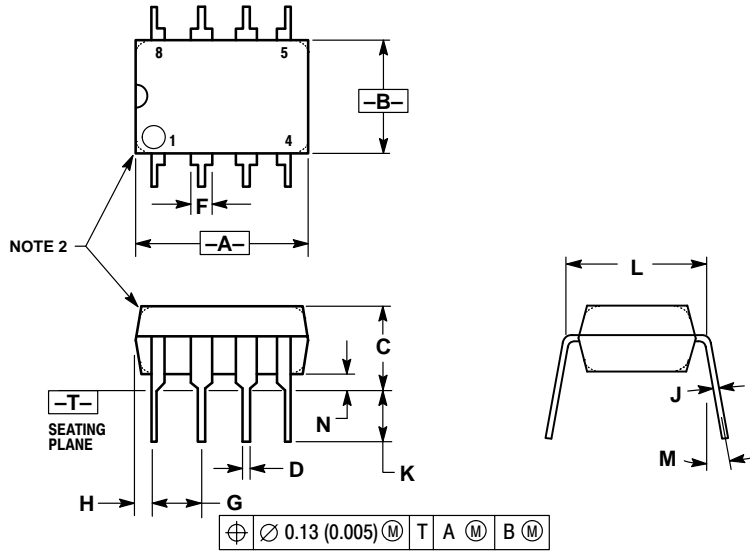


Figure 14. Design Example

# MC642

## PACKAGE DIMENSIONS

PDIP-8  
P SUFFIX  
CASE 626-05  
ISSUE L



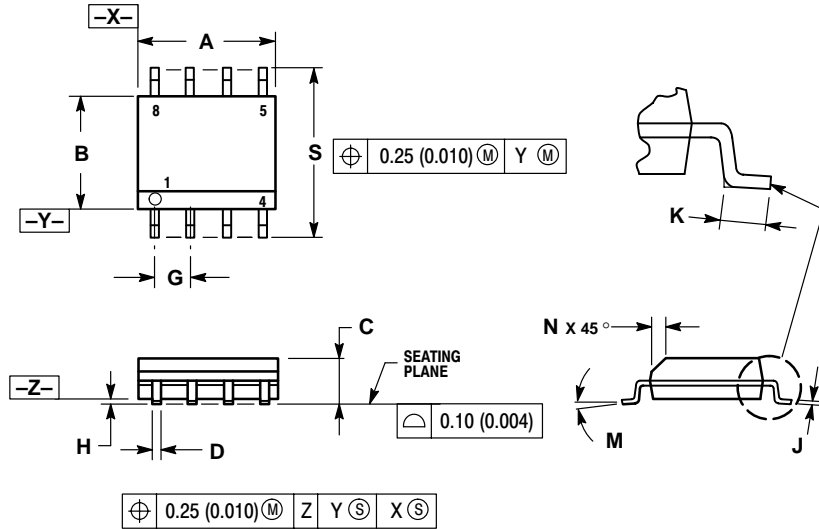
- NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
  2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
  3. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	9.40	10.16	0.370	0.400
B	6.10	6.60	0.240	0.260
C	3.94	4.45	0.155	0.175
D	0.38	0.51	0.015	0.020
F	1.02	1.78	0.040	0.070
G	2.54 BSC		0.100 BSC	
H	0.76	1.27	0.030	0.050
J	0.20	0.30	0.008	0.012
K	2.92	3.43	0.115	0.135
L	7.62 BSC		0.300 BSC	
M	---	10°	---	10°
N	0.76	1.01	0.030	0.040

# MC642

## PACKAGE DIMENSIONS

SO-8  
D SUFFIX  
CASE 751-07  
ISSUE W



**NOTES:**

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.197
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.053	0.069
D	0.33	0.51	0.013	0.020
G	1.27 BSC		0.050 BSC	
H	0.10	0.25	0.004	0.010
J	0.19	0.25	0.007	0.010
K	0.40	1.27	0.016	0.050
M	0 °	8 °	0 °	8 °
N	0.25	0.50	0.010	0.020
S	5.80	6.20	0.228	0.244

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