# TC105

## PFM/PWM Step-Down DC/DC Controller

### Features

- 57µA (Typ) Supply Current
- 1A Output Current
- 0.5µA Shutdown Mode
- 300kHz Switching Frequency for Small Inductor Size
- Programmable Soft-Start
- 92% Typical Efficiency
- Small Package: 5-Pin SOT-23A

### Applications

- Palmtops
- Battery-Operated Systems
- Portable Instruments
- Positive LCD Bias Generators
- Portable Communicators
- Hand-Held Scanners
- 5V to 3V Down Converters

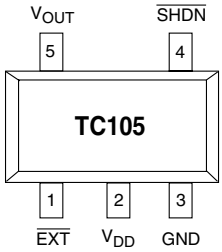
### Device Selection Table

| Part Number | Output Voltage (V)* | Package | Osc. Freq. (kHz) | Operating Temp. Range |
|---|---|---|---|---|
| TC105503ECT | 5.0 | 5-Pin SOT-23A | 300 | -40°C to +85°C |
| TC105333ECT | 3.3 | 5-Pin SOT-23A | 300 | -40°C to +85°C |
| TC105303ECT | 3.0 | 5-Pin SOT-23A | 300 | -40°C to +85°C |

*Other output voltages are available. Please contact Microchip Technology Inc. for details.

### Package Type

**5-Pin SOT-23A**



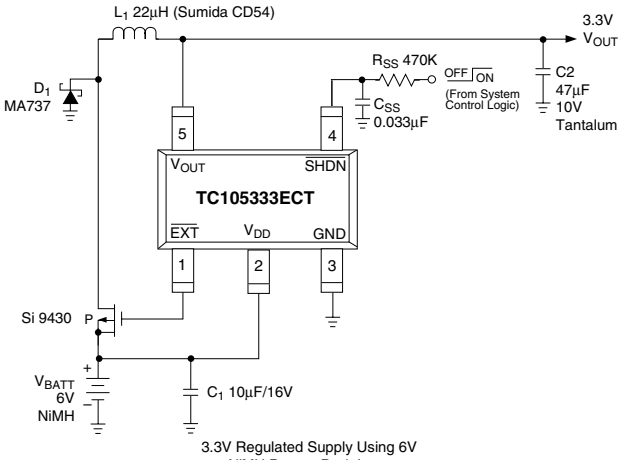

**NOTE:** 5-Pin SOT-23A is equivalent to the EIAJ SC-74A

### General Description

The TC105 is a step-down (Buck) switching controller that furnishes output currents of up to 1A (max) while delivering a typical efficiency of 92%. The TC105 normally operates in pulse width modulation mode (PWM), but automatically switches to pulse frequency modulation (PFM) at low output loads for greater efficiency. Oscillator frequency is 300kHz, allowing use of small (22µH) inductors. Supply current draw is only 102µA (max), and is reduced to less than 0.5µA when the SHDN input is brought low. Regulator operation is suspended during shutdown. The TC105 accepts a maximum input voltage of 10V.

The TC105 is available in a small 5-Pin SOT-23A package, occupies minimum board space and is ideal for a wide range of applications.

### Functional Block Diagram




3.3V Regulated Supply Using 6V NiMH Battery Pack Input

## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings*

Voltage on $V_{DD}$ ..... -0.3V to +12V
$\overline{EXT}$ Output Current ..... ±100mA
Voltage on $V_{OUT}$, $\overline{EXT}$, $\overline{SHDN}$ Pins ..... -0.3V to $V_{DD}$ +0.3V
Power Dissipation ..... 150mW
Operating Temperature Range ..... -40°C to +85°C
Storage Temperature Range ..... -40°C to +125°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.

### TC105 ELECTRICAL SPECIFICATIONS

| **Electrical Characteristics:** Note 1, $f_{OSC}$ = 300 kHz; $T_A$ = 25°C, unless otherwise noted. | | | | | | |
|---|---|---|---|---|---|---|
| **Symbol** | **Parameter** | **Min** | **Typ** | **Max** | **Units** | **Test Conditions** |
| $V_{DD}$ | Operating Supply Voltage | 2.2 | — | 10.0 | V | |
| $V_{DDMIN}$ | Minimum Input Voltage | 0.9 | — | 2.2 | V | $\overline{EXT}$ = High; No external components; $V_{OUT}$ = 0V, $\overline{SHDN}$ = $V_{IN}$ |
| $I_{DD}$ | Operating Supply Current | —<br>— | 57<br>67 | 102<br>122 | µA | No external components; $V_R$ = 3.0V, 3.3V<br>$V_{OUT}$ = 0V, $\overline{SHDN}$ = $V_{IN}$ $V_R$ = 5.0V |
| $I_{STBY}$ | Standby Supply Current | —<br>— | 15<br>16 | 27<br>29 | µA | No external components; $V_R$ = 3.0V, 3.3V<br>$V_{OUT}$ = SHDN = $V_{IN}$ $V_R$ = 5.0V |
| $I_{SHDN}$ | Shutdown Supply Current | — | — | 0.5 | µA | $\overline{SHDN}$ = GND |
| $f_{OSC}$ | Oscillator Frequency | 255 | 300 | 345 | kHz | $V_{IN}$ = $V_{OUT}$ + 0.3V |
| $V_{OUT}$ | Output Voltage | $V_R$ x 0.975 | $V_R$ | $V_R$ x 1.025 | | Note 2 |
| DTYMAX | Maximum Duty Cycle (PWM Mode) | 100 | — | — | % | |
| DTYPFM | Duty Cycle (PFM Mode) | 15 | 25 | 35 | % | $I_{OUT}$ = 0mA |
| $V_{IH}$ | $\overline{SHDN}$ Input Logic High | 0.65 | — | — | V | $V_{OUT}$ = 0V, No external components |
| $V_{IL}$ | $\overline{SHDN}$ Input Logic Low | — | — | 0.20 | V | $V_{OUT}$ = 0V, No external components |
| REXTH | $\overline{EXT}$ ON Resistance to $V_{DD}$ | —<br>—<br>— | 17<br>16<br>12 | 24<br>22<br>17 | Ω | No external components; $V_R$ = 3.0V<br>$V_R$ = 3.3V<br>$V_R$ = 5.0V<br>$V_{OUT}$ = $\overline{SHDN}$ = $V_{IN}$, $V_{EXT}$ = ($V_{IN}$ – 0.4V) |
| REXTL | $\overline{EXT}$ ON Resistance to GND | —<br>—<br>— | 15<br>14<br>10 | 20<br>19<br>14 | Ω | No external components; $V_R$ = 3.0V<br>$V_R$ = 3.3V<br>$V_R$ = 5.0V<br>$V_{OUT}$ = 0V, $\overline{SHDN}$ = $V_{IN}$, $V_{EXT}$ = 0.4V |
| η | Efficiency | — | 92 | — | % | |

**Note 1:** $V_R$ = 3.0V, $V_{IN}$ = 4.5V, $I_{OUT}$ = 200mA
$V_R$ = 3.3V, $V_{IN}$ = 5.0V, $I_{OUT}$ = 220mA
$V_R$ = 5.0V, $V_{IN}$ = 7.5V, $I_{OUT}$ = 320mA
**2:** $V_R$ is the factory output voltage setting.

## 2.0 PIN DESCRIPTIONS

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

**TABLE 2-1: PIN FUNCTION TABLE**

| Pin No. (5-Pin SOT-23A) | Symbol | Description |
|---|---|---|
| 1 | $\overline{EXT}$ | Switch transistor control output. This terminal connects to the gate of an external P-channel MOSFET (or to the base of an external PNP transistor through a current limiting resistor). |
| 2 | $V_{DD}$ | Power supply voltage input. |
| 3 | GND | Ground terminal. |
| 4 | $\overline{SHDN}$ | Shutdown input (active low). The device enters a low power shutdown state when this input is brought low. During shutdown, regulator action is suspended, and supply current is reduced to less than 0.5µA. The device resumes normal operation when $\overline{SHDN}$ is again brought high. |
| 5 | $V_{OUT}$ | Voltage sense input. This input senses output voltage for regulation and must be connected to the output voltage node as shown in the application schematic in this data sheet. |

## 3.0 DETAILED DESCRIPTION

The TC105 is a PFM/PWM step-down DC/DC controller for use in systems operating from two or more cells, or in line-powered applications. It uses PWM as the primary modulation scheme, but automatically converts to PFM at output duty cycles less than approximately 10%. The conversion to PFM provides reduced supply current, and therefore higher operating efficiency at low loads. The TC105 uses an external switching transistor, allowing construction of switching regulators with output currents of up to 1A.

The TC105 consumes only 102µA, max, of supply current when $V_{IN}$ = 5V and $V_{OUT}$ = 3.3V, and can be placed in a 0.5µA shutdown mode by bringing the shutdown input ($\overline{SHDN}$) low. The regulator remains disabled while in shutdown mode, and output voltage discharges to zero through the load. Normal operation resumes when $\overline{SHDN}$ is brought high. Other features include a built-in undervoltage lockout (UVLO) and externally programmable soft start time.

### 3.1 Low Power Shutdown Mode

The TC105 enters a low power shutdown mode when $\overline{SHDN}$ is brought low. While in shutdown, the oscillator is disabled and the output switch is shut off. Normal regulator operation resumes when $\overline{SHDN}$ is again brought high. $\overline{SHDN}$ may be tied to the input supply if not used.

### 3.2 Soft Start

Soft start allows the output voltage to gradually ramp from 0 to rated output value during start-up. This action minimizes (or eliminates) overshoot, and in general, reduces stress on circuit components. Figure 4-1 shows the circuit required to implement soft start (values of 470K and 0.033µF for $R_{SS}$ and $C_{SS}$ respectively, are adequate for most applications).

### 3.3 Undervoltage Lockout (UVLO)

The TC105 is disabled when $V_{IN}$ is below the undervoltage lockout threshold. This threshold is equal to the guaranteed minimum operating voltage for the TC105 (i.e., 2.2V). When UVLO is active, the TC105 is completely disabled.

### 3.4 Input Bypass Capacitors

Using an input bypass capacitor reduces peak current transients drawn from the input supply and reduces the switching noise generated by the regulator. The source impedance of the input supply determines the size of the capacitor that should be used.

### 3.5 Output Capacitor

The effective series resistance of the output capacitor directly affects the amplitude of the output voltage ripple. (The product of the peak inductor current and the ESR determines output ripple amplitude.) Therefore, a capacitor with the lowest possible ESR should be selected. Smaller capacitors are acceptable for light loads or in applications where ripple is not a concern. The Sprague 595D series of tantalum capacitors are among the smallest of all low ESR surface mount capacitors available. Table 4-1 lists suggested components and suppliers.

### 3.6 Inductor Selection

Selecting the proper inductor value is a trade-off between physical size and power conversion requirements. Lower value inductors cost less, but result in higher ripple current and core losses. They are also more prone to saturate since the coil current ramps faster and could overshoot the desired peak value. This not only reduces efficiency, but could also cause the current rating of the external components to be exceeded. Larger inductor values reduce both ripple current and core losses, but are larger in physical size and tend to increase the start-up time slightly.

A 22µH inductor is recommended as the best overall compromise. For highest efficiency, use inductors with a low DC resistance (less than 20 mΩ). To minimize radiated noise, consider using a toroid, pot core or shielded-bobbin inductor.

### 3.7 Output Diode

The high operating frequency of the TC105 requires a high-speed diode. Schottky diodes such as the MA737 or 1N5817 through 1N5823 (and the equivalent surface mount versions) are recommended. Select a diode whose average current rating is greater than the peak inductor current and whose voltage rating is higher than $V_{DDMAX}$.

## 3.8 External Switching Transistor Selection

$\overline{EXT}$ is a complementary output with a maximum ON resistance of 22Ω to $V_{DD}$ when high and 19Ω to ground when low. It is designed to directly drive a P-channel MOSFET or a PNP bipolar transistor through a base current limiting resistor (Figure 4-2). A PNP transistor is recommended in applications where $V_{IN}$ is less than 2.5V. Otherwise, a P-channel MOSFET is preferred as it affords the highest efficiency because it does not draw any gate drive current. However, P-channel MOSFETs are typically more expensive than bipolar transistors.

P-channel MOSFET selection is determined mainly by the on-resistance, gate-source threshold, and gate charge requirements. Also, the drain-to-source and gate-to-source breakdown voltage ratings must be greater than $V_{DDMAX}$. The total gate charge specification should be less than 100nC for best efficiency. The MOSFET must be capable of handling the required peak inductor current, and should have a very low on-resistance at that current. For example, an Si9430 MOSFET has a drain-to-source rating of -20V, and a typical on-resistance $r_{DSON}$ of 0.07Ω at 2A, with $V_{GS}$ = -4.5V. Table 4-1 lists suppliers of external components recommended for use with the TC105.

### 3.8.1 BOARD LAYOUT GUIDELINES

As with all inductive switching regulators, the TC105 generates fast switching waveforms, which radiate noise. Interconnecting lead lengths should be minimized to keep stray capacitance, trace resistance and radiated noise as low as possible. In addition, the GND pin, input bypass capacitor and output filter capacitor ground leads should be connected to a single point. The input capacitor should be placed as close to power and ground pins of the TC105 as possible. The length of the $\overline{EXT}$ trace must also be kept as short as possible.

## 4.0 APPLICATIONS

### 4.1 Circuit Examples

Figure 4-3 shows a TC105 using a PNP switching transistor (Zetex FZT749) that has an $h_{FE}$ of 180 and $V_{CESAT}$ of 100 mV at $I_C$ = 1A. Other high beta transistors can be used, but the values of $R_B$ and $C_B$ may need adjustment if $h_{FE}$ is significantly different from that of the FZT749.

The circuit of Figure 4-4 utilizes a P-channel MOSFET switching transistor (Silconix Si9430). This transistor is a member of the Littlefoot™ family of small outline MOSFETs.

**FIGURE 4-1: SOFT START CIRCUIT**

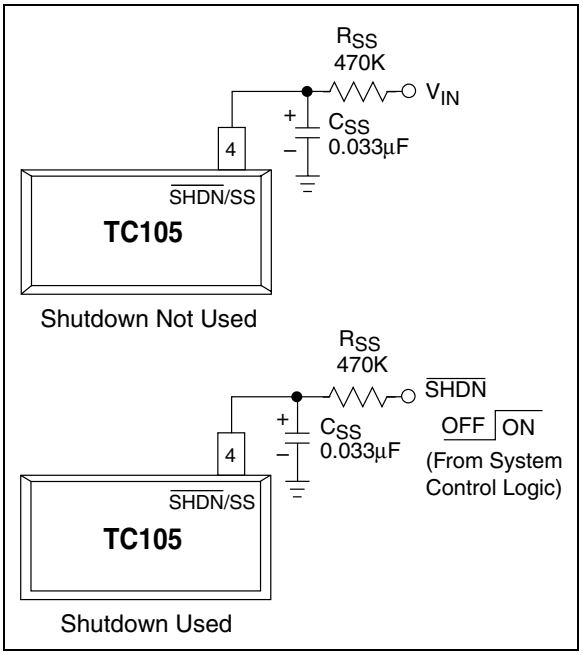



**FIGURE 4-2: EXTERNAL TRANSISTOR CONNECTION**

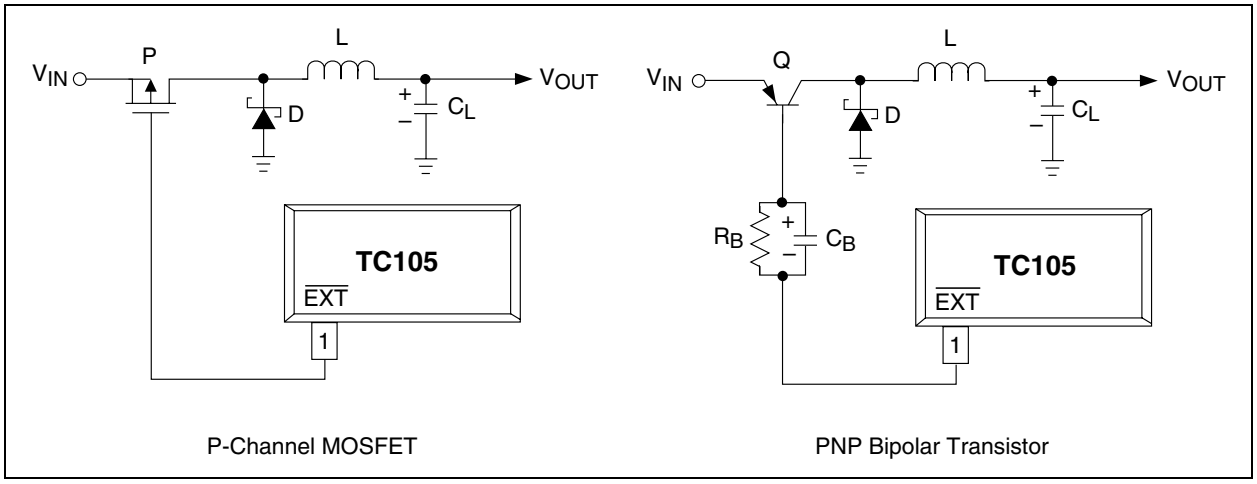


**FIGURE 4-3: REGULATOR USING PNP TRANSISTOR**

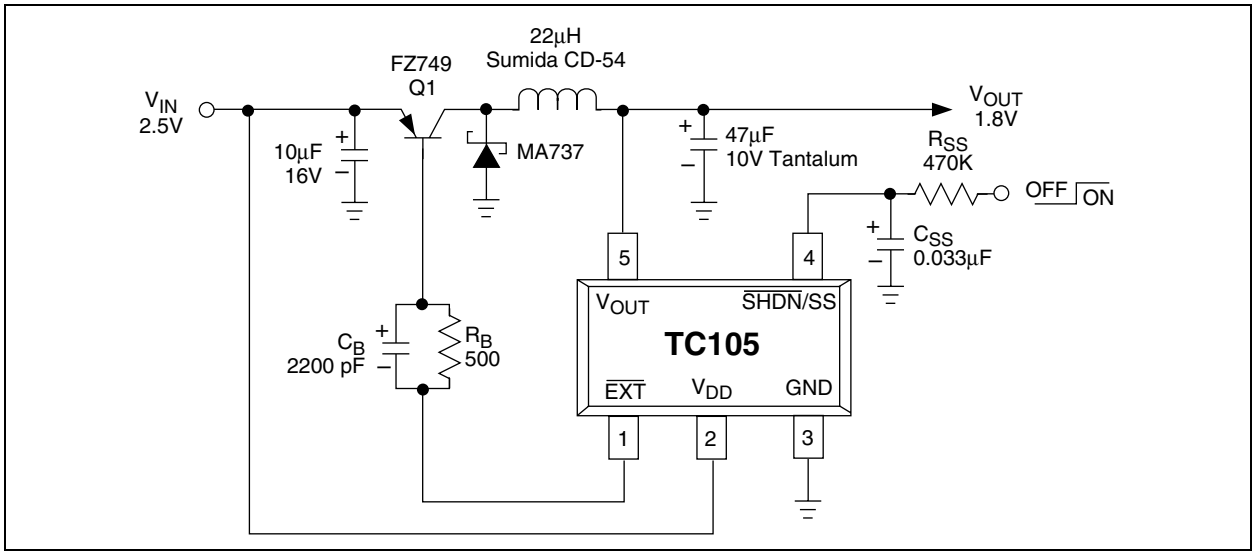



**FIGURE 4-4: REGULATOR USING P-CHANNEL MOSFET**

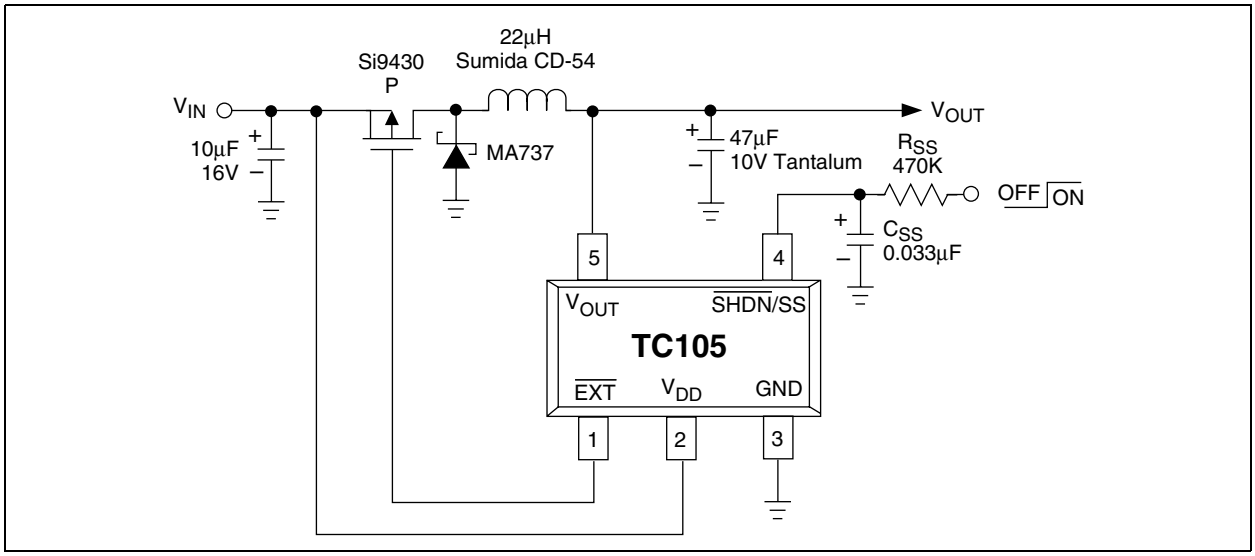
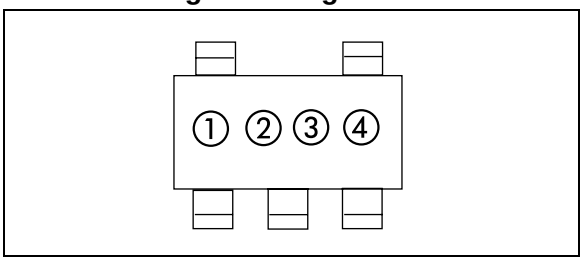



**TABLE 4-1: SUGGESTED COMPONENTS AND SUPPLIERS**

| Type | Inductors | Capacitors | Diodes | Transistors |
|---|---|---|---|---|
| **Surface Mount** | Sumida<br>CD54 Series<br>CDRH Series<br>Coilcraft<br>DO Series | AVX<br>TPS Series<br>Sprague<br>595D Series | ON Semiconductor<br>MBRS340T3<br>Nihon<br>NSQ Series<br>Matsushita<br>MA737 | Silconix<br>Little Foot MOSFET Series<br>Zetex FZT749<br>PNP Bipolar Transistor<br>Toshiba 2SA1213 PNP<br>Transistor |
| **Miniature Through-Hole** | Sumida<br>RCH Series | Sanyo<br>OS-CON Series | IRC<br>OAR Series | |
| **Standard Through-Hole** | Coilcraft<br>PCH Series<br>Coiltronics<br>CTX Series | Nichicon<br>PL Series<br>United Chemi-Con<br>LXF Series | | ON Semiconductor<br>TMOS Power MOSFETs<br>(i.e., MTP30P06V) |

## 5.0 PACKAGING INFORMATION

### 5.1 Package Marking Information




① represents product classification; TC105 = M

② represents first integer of voltage

| Symbol (300kHz) | Voltage |
|---|---|
| 1 | 1. |
| 2 | 2. |
| 3 | 3. |
| 4 | 4. |
| 5 | 5. |
| 6 | 6. |

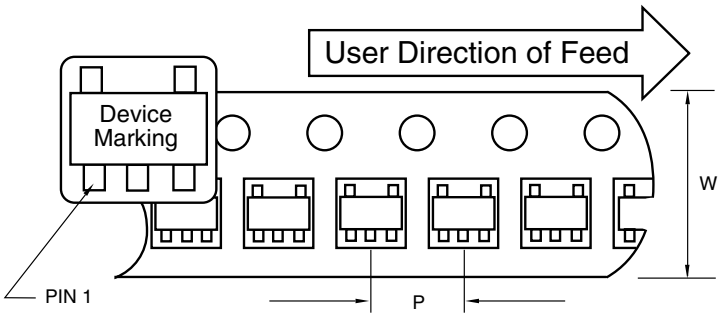
③ represents first decimal of voltage

| Symbol (300kHz) | Voltage |
|---|---|
| A | .0 |
| B | .1 |
| C | .2 |
| D | .3 |
| E | .4 |
| F | .5 |
| H | .6 |
| K | .7 |
| L | .8 |
| M | .9 |

④ represents production lot ID code

## 5.2 Taping Form

### Component Taping Orientation for 5-Pin SOT-23A (EIAJ SC-74A) Devices



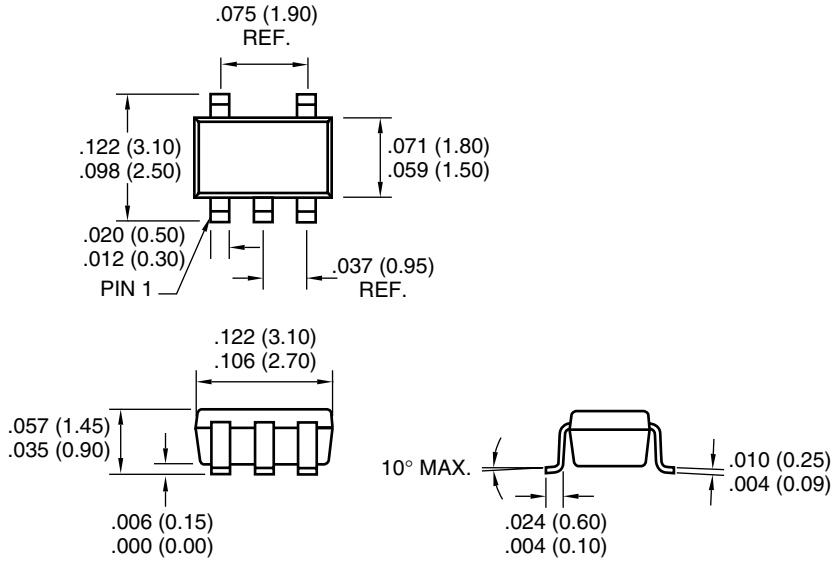

Standard Reel Component Orientation
TR Suffix Device
(Mark Right Side Up)

**Carrier Tape, Number of Components Per Reel and Reel Size**

| Package | Carrier Width (W) | Pitch (P) | Part Per Full Reel | Reel Size |
|---|---|---|---|---|
| 5-Pin SOT-23A | 8 mm | 4 mm | 3000 | 7 in |

## 5.3 Package Dimensions

### SOT-23A-5




**Dimensions: inches (mm)**

**NOTES:**

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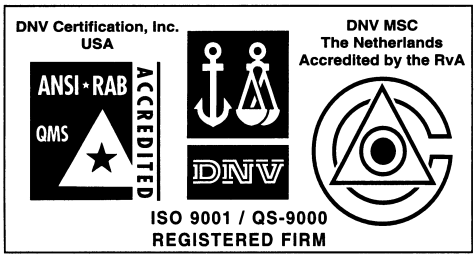


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