Inverting Charge Pump Voltage Doublers with Active High Shutdown

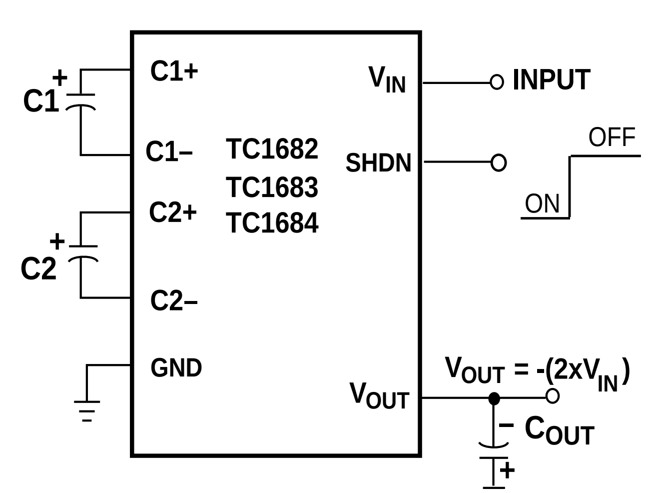
FEATURES

- **Small 8-Pin MSOP Package**
- **Operation from 1.8V to 5.5V**
- **120 Ohms (typ.) Output Resistance**
- **99% Voltage Conversion Efficiency**
- **Only 3 External Capacitors Required**
- **Power-Saving Shutdown Mode**
- **Low Active Supply Current**
  .... 95µA (typ.) for TC1682
  ....225µA (typ.) for TC1683
  .... 700µA (typ.) for TC1684
- **Fully Compatible with 1.8V Logic Systems**

TYPICAL APPLICATIONS

- **LCD Panel Bias**
- **Cellular Phones PA Bias**
- **Pagers**
- **PDAs, Portable Data Loggers**
- **Battery Powered Devices**

TYPICAL OPERATING CIRCUIT



Notes: 1) C1 must have a voltage rating greater than or equal to V_{IN}
2) C2 and C_{OUT} must have a voltage rating greater than or equal to $2V_{IN}$

GENERAL DESCRIPTION

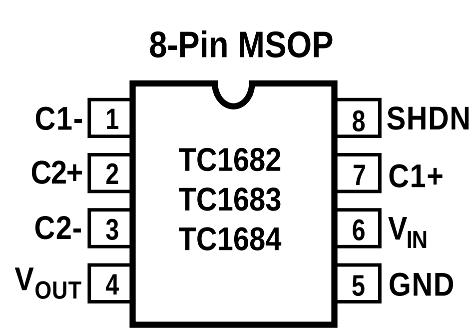
The TC1682, TC1683 and TC1684 are CMOS charge pump converters that provide an inverted doubled output from a single positive supply. An on-board oscillator provides the clock and only three external capacitors are required for full circuit implementation. Switching frequencies are 12kHz for the TC1682, 35kHz for the TC1683, and 125kHz for the TC1684. When the SHDN pin is held at a logic high, the device goes into a very low power mode of operation consuming less than 1µA (typ.) of supply current.

Low output source impedance (typically 120Ω), provides output current up to 10mA. The TC1682, TC1683 and TC1684 feature a 1.8V to 5.5V operating voltage range and high efficiency, which make them an ideal choice for a wide variety of applications requiring a negative doubled voltage derived from a single positive supply (for example: generation of -7.2V from a +3.6V lithium cell or -10V generated from a +5V logic supply).The minimum external part count, small physical size, and shutdown mode feature make this family of products useful for a wide variety of negative bias power supply applications.

ORDERING INFORMATION

Part No.	Package	Osc Freq (kHz)	Temp. Range
TC1682EUA	8-Pin MSOP	12	– 40°C to +85°C
TC1683EUA	8-Pin MSOP	35	– 40°C to +85°C
TC1684EUA	8-Pin MSOP	125	– 40°C to +85°C

PIN CONFIGURATION



ABSOLUTE MAXIMUM RATINGS*

Input Voltage (V_{IN} to GND) .... +6.0V, - 0.3V
Output Voltage (V_{OUT} to GND)................. -12.0V, + 0.3V
Current at V_{OUT} Pin 20mA
Short-Circuit Duration V_{OUT} to GND ....Indefinite
Operating Temperature Range .... 40°C to +85°C
Power Dissipation ($T_A \leq$ 70°C) 8-Pin MSOP 320mW
Storage Temperature (Unbiased) .... - 65 °C to +150°C
Lead Temperature (Soldering, 10sec) .... +260°C

*This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS: T_A = -40°C to +85°C, V_{IN} = + 5V, C1 = C2 = 3.3µF (TC1682); C1 = C2 = 1µF (TC1683); C1 = C2 = 0.33µF (TC1684); SHDN = GND, unless otherwise noted. Typical values are at T_A = +25°C

Symbol	Parameter	Device	Test Conditions	Min	Typ	Max	Unit
I_{DD}	Supply Current	TC1682 TC1683 TC1684		— — —	95 225 700	160 480 1500	µA
I_{SHDN}	Shutdown Supply Current	All	SHDN = V_{IN} = +5V	—	0.5	2	µA
V_{MIN}	Minimum Supply Voltage	All	R_{LOAD} = 1kΩ	1.8	—	—	V
V_{MAX}	Maximum Supply Voltage	All	R_{LOAD} = 1kΩ	—	—	5.5	V
F_{OSC}	Oscillator Frequency	TC1682 TC1683 TC1684		8.4 24.5 65	12 35 125	15.6 45.5 170	kHz
V_{IH}	Shutdown Input Logic High	All	$V_{IN} = V_{MIN}$ to V_{MAX}	1.4	—	—	V
V_{IL}	Shutdown Input Logic Low	All	$V_{IN} = V_{MIN}$ to V_{MAX}	—	—	0.4	V
V_{EFF}	Voltage Conversion Efficiency	All	$R_{LOAD} = \infty$	95	99	—	V
R_{OUT}	Output Resistance	All	I_{LOAD} = 0.5mA to10mA	—	120	170	Ω
T_{WK}	Wake-Up Time From Shutdown Mode	TC1682 TC1683 TC1684	R_{LOAD} = 2kΩ	— — —	1800 600 200	— — —	µsec

NOTES: 1. Capacitor contribution is approximately 20% of the output impedance (ESR = 1/pump frequency x capacitance)

PIN DESCRIPTION

Pin No.	Symbol	Description
1	$C1^-$	C1 Commutation Capacitor Negative Terminal
2	$C2^+$	C2 Commutation Capacitor Positive Terminal
3	$C2^-$	C2 Commutation Capacitor Negative Terminal
4	V_{OUT}	Doubling Inverting Charge Pump Output (– 2 x V_{IN})
5	GND	Ground
6	V_{IN}	Positive Power Supply Input
7	$C1^+$	C1 Commutation Capacitor Positive Terminal
8	SHDN	Shutdown Input (Active High)

DETAILED DESCRIPTION

The TC1682, TC1683 and TC1684 inverting charge pump converters perform a –2x multiplication of the voltage applied to the V_{IN} pin. Conversion is performed using two **synchronous** switching matrices and three external capacitors. When the shutdown input is held at a logic high, the device goes into a very low power mode of operation consuming less than 1uA of supply current.

Figure 1 (below) is a block diagram representation of the TC1682, TC1683 and TC1684 architecture. The first switching stage inverts the voltage present at V_{IN} and the second stage uses '$-V_{IN}$' generated from the first stage to produce the '–2X' output function from the second stage switching matrix.

Each device contains an on-board oscillator that synchronously controls the operation of the charge pump switching matrices. The TC1682 synchronously switches at 12kHz, the TC1683 synchronously switches at 35kHz, and the TC1684 synchronously switches at 125kHz. The different oscillator frequencies for this device family allow the user to trade-off capacitor size versus supply current. Faster oscillators can use smaller external capacitors, but will consume more supply current (see Electrical Characteristics Table).

When the shutdown input is in a high state, the oscillator and both switch matrices are powered off placing the TC1682, TC1683 and TC1684 in the shutdown mode. When the V_{IN} supply input is powered from an external battery, the shutdown mode minimizes power consumption, which in turn will extend the life of the battery.

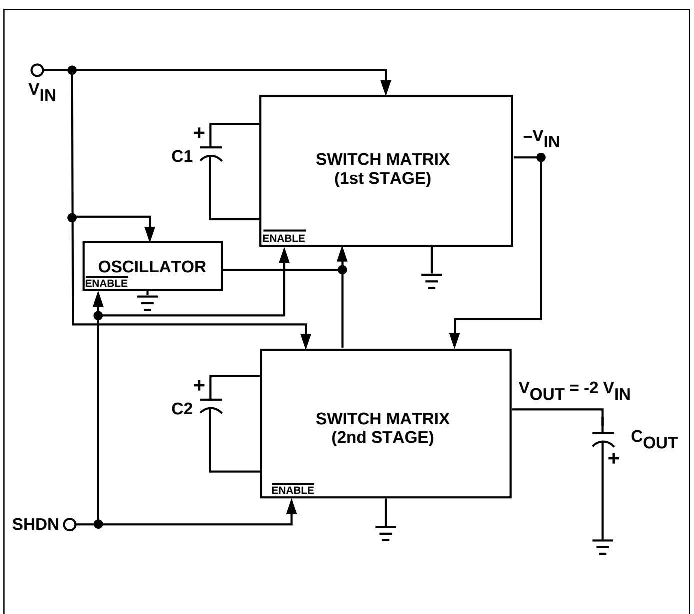


Figure 1. Block Diagram

APPLICATIONS INFORMATION

Output Voltage Considerations

The TC1682, TC1683 and TC1684 perform inverting voltage conversions but do not provide any type of regulation. The output voltage will droop in a linear manner with respect to the output load current. The value of the equivalent output resistance is approximately 120Ω nominal at +25°C and V_{IN} = +5V. In this particular case, the output is approximately –10V at very light loads, and will droop according to the equation below:

$$V_{DROOP} = I_{OUT} \times R_{OUT}$$

Capacitor Selection

In order to maintain the lowest output resistance and output ripple voltage, it is recommended that low ESR capacitors be used. Additionally, larger values of C1 and C2 will lower the output resistance and larger values of C_{OUT} will reduce output ripple. **NOTE: For proper charge pump operation, C1 must have a voltage rating greater than or equal to V_{IN}, while C2 and C_{OUT} must have a voltage rating greater than or equal to $2V_{IN}$.**

Table 1 shows various values of C1/C2 and the corresponding output resistance values for V_{IN}=5V @ +25°C

Table 2 shows the output voltage ripple for various values of C_{OUT} (again assuming V_{IN} = 5V @ +25°C). The V_{RIPPLE} values assume a 1mA output load current and a 0.1Ω ESR_{COUT}.

Table 1. Output Resistance vs. C1/C2 (ESR = 0.1Ω).

C1,C2(µF)	TC1682 R_{OUT} (Ω)	TC1683 R_{OUT} (Ω)	TC1684 R_{OUT} (Ω)
0.33	633	184	120
1	262	120	102
3.3	120	95	84

Table 2. Output Voltage Ripple vs. C_{OUT2} (ESR = 0.1Ω), I_{OUT} = 1mA (1mA)

C_{OUT} (µF)	TC1682 V_{RIPPLE} (mV)	TC1683 V_{RIPPLE} (mV)	TC1684 V_{RIPPLE} (mV)
0.33	192	60	27
1	63	21	16
3.3	17	8	7

Input Supply Bypassing

The V_{IN} input should be capacitively bypassed to reduce AC impedance and minimize noise effects due to the devices internal switching. It is recommended that a large value capacitor (at least equal to C1) be connected from V_{IN} to GND for optimal circuit performance.

Shutdown Input

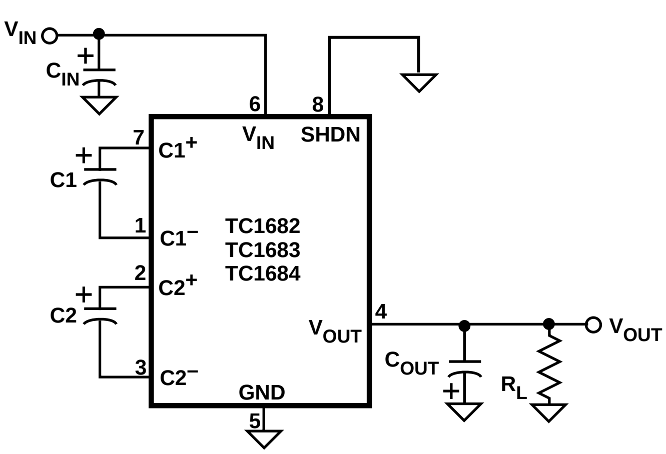
The TC1682, TC1683 and TC1684 are enabled when SHDN is low, and disabled when SHDN is high. This input cannot be allowed to float. (If SHDN is not required, see the TC2682/2683/2684 data sheet.) The SHDN input should be limited to 0.3V above V_{IN}.

Inverting Voltage Doubler

The most common application for the TC1682/1683/1684 devices is the inverting voltage doubler (Figure 2). This application uses three external capacitors: C1, C2, and C_{OUT} (NOTE: a power supply bypass capacitor is recommended). The output is equal to $-2V_{IN}$ plus any voltage drop due to loading. Refer to Tables 1 and 2 for capacitor selection guidelines.

Layout Considerations

As with any switching power supply circuit, good layout practice is recommended. Mount components as close together as possible to minimize stray inductance and capacitance. Also use a large ground plane to minimize noise leakage into other circuitry.



Device	C_{IN}	C1	C2	C_{OUT}
TC1682	3.3µF	3.3µF	3.3µF	3.3µF
TC1683	1µF	1µF	1µF	1µF
TC1684	0.33µF	0.33µF	0.33µF	0.33µF

Figure 2. Inverting Voltage Doubler Test Circuit

TC1682 DEMO CARD

The TC1682 DEMO Card is a 2.0" x 2.0" card containing both a TC1682 and a TC682 that allow the user to compare the operation of each approach for generating a –2X function. Each circuit is fully assembled with the required external capacitors along with variable load resistors that allow the user to vary the output load current of each stage. For convenience, several test points and jumpers are available for measuring various voltages and currents on the demo board.

TC1682 DEMO CARD ASSEMBLY

Figure 3 is a schematic of the TC1682 DEMO Card, and Figure 4 shows the assembly drawing and artwork for the board. Table 3 lists the voltages that are monitored by the test points and Table 4 lists the currents that can be measured using the jumpers.

Table 3. TC1682 DEMO Card Test Points

Test Point	Voltage Measurement
TP1	V_{IN} [+1.8V to +5V]
TP2	Ground
TP3	Ground
TP4	TC682 (U1) Supply Voltage
TP5	TC682 (U1) Output Voltage [V_{OUT1}]
TP6	TC1682 (U2) Supply Voltage
TP7	TC1682 (U2) Output Voltage [V_{OUT2}]
TP8	TC1682 (U2) SHDN Input Voltage
TP9	DEMO Card Shutdown Input

Table 4. TC1682 DEMO Card Jumpers

Jumper	Current Measurement
J1	TC682 (U1) Quiescent Current
J2	TC1682 (U2) Quiescent Current
J3	TC682 (U1) V_{OUT1} Load Current
J4	TC1682 (U2) V_{OUT2} Load Current
J5	TC1682 (U2) SHDN Input Current
J6	Connect DEMO Card Shutdown Input to V_{IN}

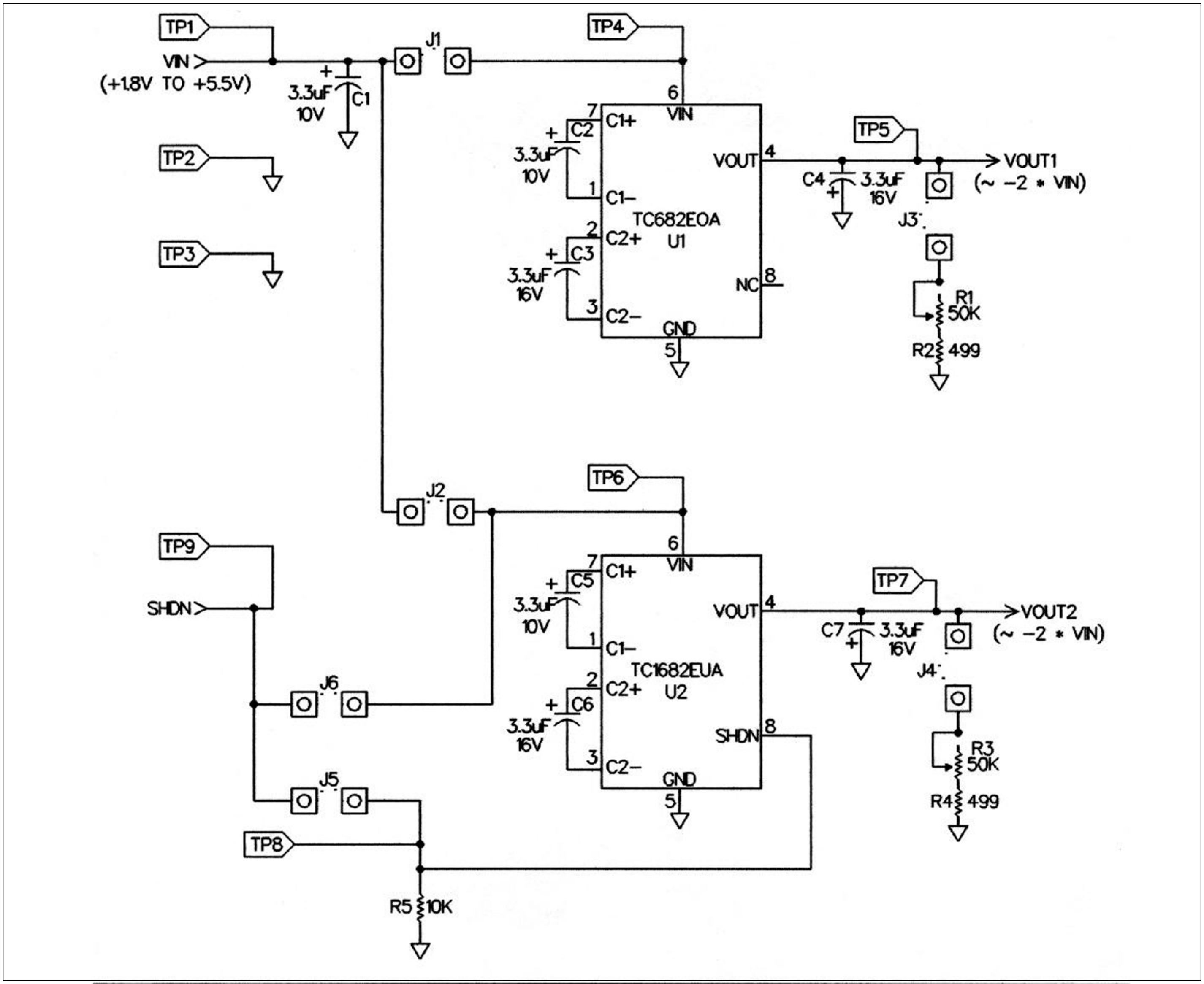


Figure 3. TC1682 DEMO Card Schematic

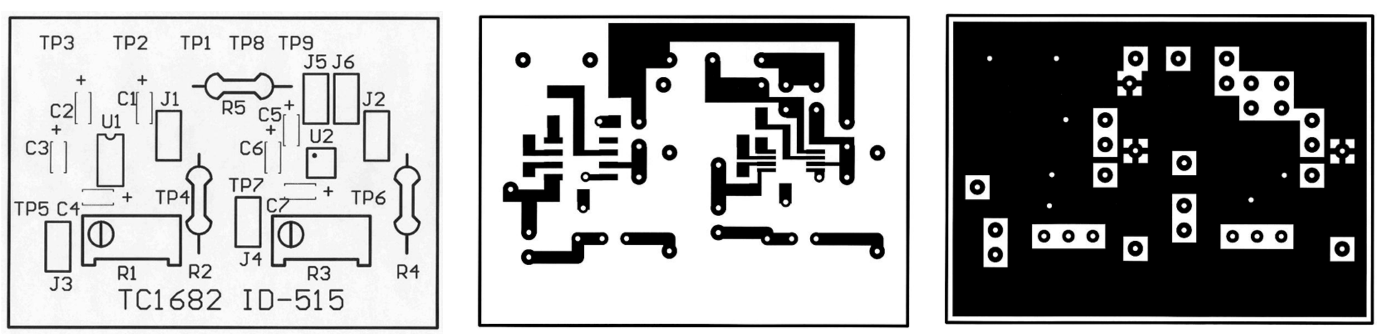
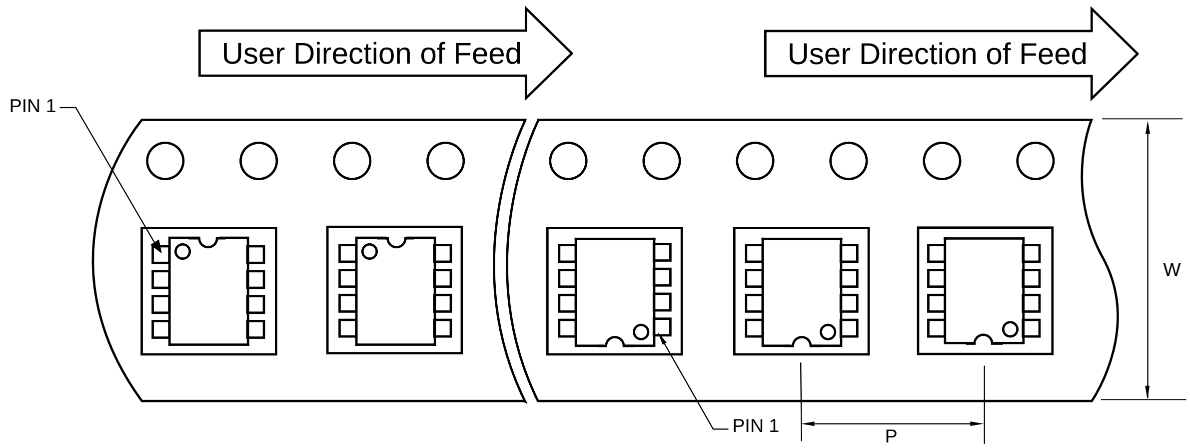


Figure 4. TC1682 DEMO Card Assembly Drawing and Artwork

TAPING FORM

Component Taping Orientation for 8-Pin MSOP Devices



Standard Reel Component Orientation
for TR Suffix Device

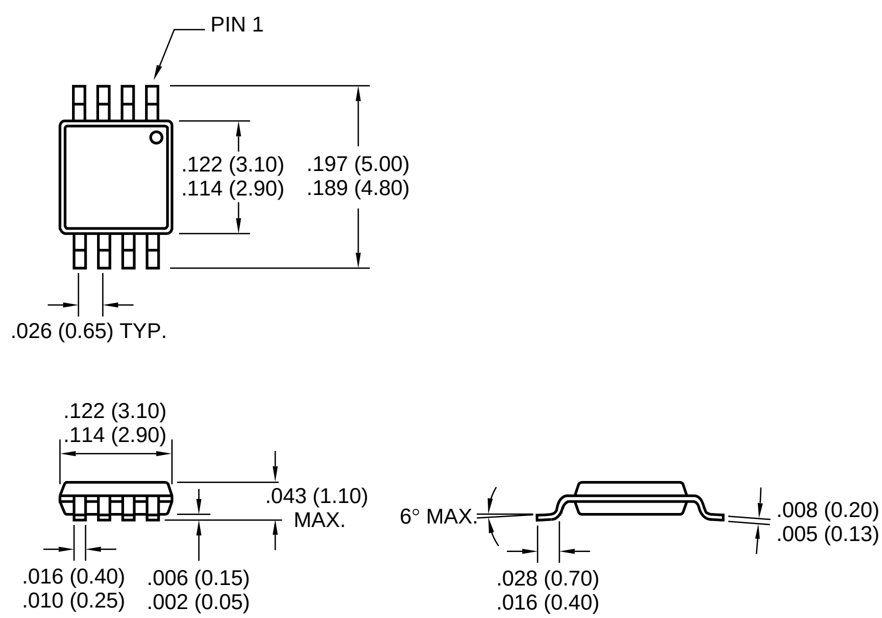
Reverse Reel Component Orientation
for RT Suffix Device

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

PACKAGE DIMENSIONS

8-Pin MSOP



Dimensions: inches (mm)

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