Inverting Charge Pump Voltage Doublers with Active Low 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 TC3682**
  - **.....225μA (typ.) for TC3683**
  - **.....700μA (typ.) for TC3684**
- **Fully Compatible with 1.8V Logic Systems**

TYPICAL APPLICATIONS

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

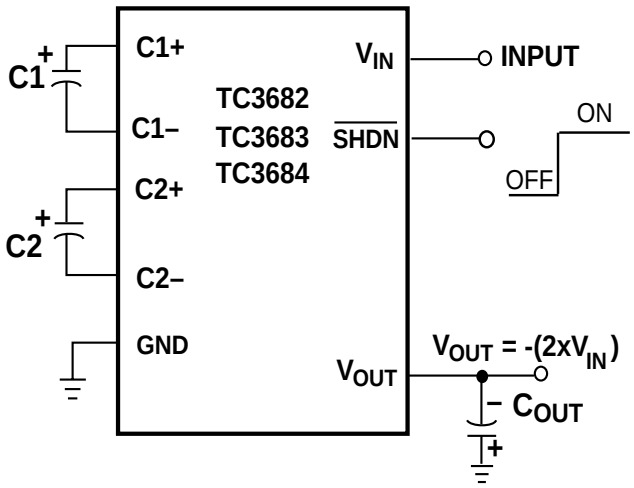
GENERAL DESCRIPTION

The TC3682, TC3683 and TC3684 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 TC3682, 35kHz for the TC3683, and 125kHz for the TC3684. When the $\overline{SHDN}$ pin is held at a logic low, 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 TC3682, TC3683 and TC3684 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 parts count, small physical size, and shutdown mode make this family of products useful for a wide variety of negative bias power supply applications.

TYPICAL OPERATING CIRCUIT

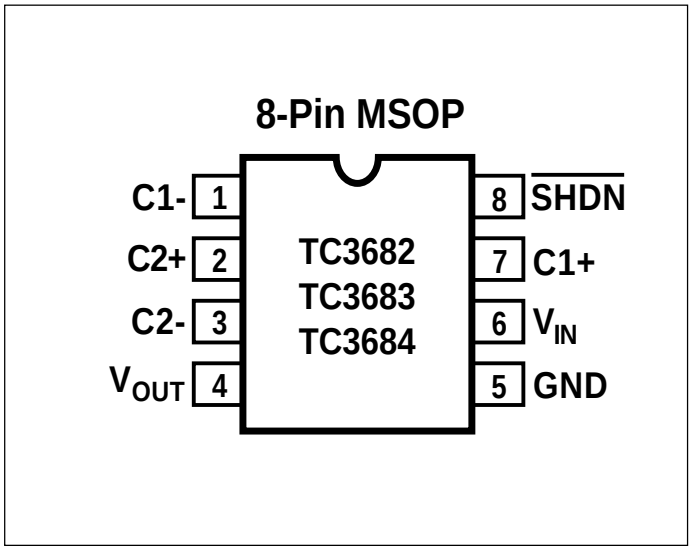


Notes: 1) C1 must have a voltage rating greater than or equal to V_{IN}
2) C2 and C_{OUT} must have a voltage rating greater than or equal to $2V_{IN}$

ORDERING INFORMATION

Part No.	Package	Osc Freq (kHz)	Temp. Range
TC3682EUA	8-Pin MSOP	12	– 40°C to +85°C
TC3683EUA	8-Pin MSOP	35	– 40°C to +85°C
TC3684EUA	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 (TC3682); C1 = C2 = 1µF (TC3683); C1 = C2 = 0.33µF (TC3684); $\overline{SHDN}$ = 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	TC3682	$\overline{SHDN} = V_{IN}$	—	95	160	µA
		TC3683	$\overline{SHDN} = V_{IN}$	—	225	480	
		TC3684	$\overline{SHDN} = V_{IN}$	—	700	1500	
I_{SHDN}	Shutdown Supply Current	All	$\overline{SHDN}$ = GND, 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	TC3682		8.4	12	15.6	kHz
		TC3683		24.5	35	45.5	
		TC3684		65	125	170	
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	TC3682	R_{LOAD} = 2kΩ	—	1800	—	µsec
		TC3683		—	600	—	
		TC3684		—	200	—	

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	$\overline{SHDN}$	Shutdown Input (Active Low)

DETAILED DESCRIPTION

The TC3682, TC3683 and TC3684 charge pumps perform –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 low, both stages go into a very low power mode of operation consuming less than 1µA of supply current.

Figure 1 (below) is a block diagram representation of the TC3682, TC3683 and TC3684 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 TC3682 synchronously switches at 12kHz, the TC3683 synchronously switches at 35kHz, and the TC3684 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 low state, the oscillator and both switch matrices are powered off placing the TC3682, TC3683 and TC3684 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.

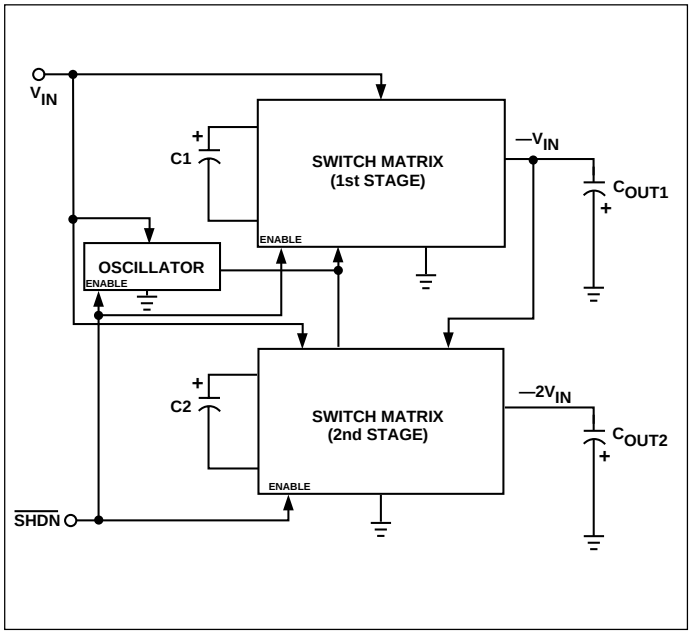


Figure 1. Functional Block Diagram

APPLICATIONS INFORMATION

Output Voltage Considerations

The TC3682, TC3683 and TC3684 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 respective load currents. The value of the equivalent output resistance of the '$-V_{IN}$' output is approximately 50Ω nominal at +25°C and V_{IN} = +5V. The value of the '$-2V_{IN}$' output and is approximately 140Ω nominal at +25°C and V_{IN} = +5V. In this particular case, '$-V_{IN}$' is approximately – 5V and '$–2V_{IN}$' is approximately –10V at very light loads, and each stage 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)	TC3682 R_{OUT} (Ω)	TC3683 R_{OUT} (Ω)	TC3684 R_{OUT} (Ω)
0.33	633	184	120
1	262	120	102
3.3	120	95	84

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

C_{OUT} (µF)	TC3682 V_{RIPPLE} (mV)	TC3683 V_{RIPPLE} (mV)	TC3684 V_{RIPPLE} (mV)
0.33	192	60	27
1	63	21	16
3.3	17	8	7

Input Supply Bypassing

TheV_{IN} input should be capacitively bypassed to reduce AC impedance and minimize noise effects due to the internal switching in the device. 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 TC3682, TC3683 and TC3684 are enabled when $\overline{SHDN}$ is high, and disabled when $\overline{SHDN}$ is low. This input cannot be allowed to float. (If $\overline{SHDN}$ is not required, see the TC2682/2683/2684 data sheet.) The $\overline{SHDN}$ input should be limited to 0.3V above V_{IN}.

Inverting Voltage Doubler

The most common application for the TC3682/3683/3684 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.

Device	C_{IN}	C1	C2	C_{OUT}
TC3682	3.3µF	3.3µF	3.3µF	3.3µF
TC3683	1µF	1µF	1µF	1µF
TC3684	0.33µF	0.33µF	0.33µF	0.33µF

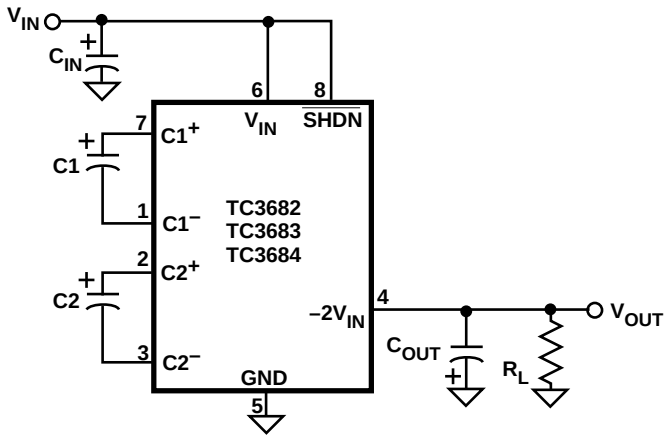


Figure 2. Dual Voltage Inverter Test Circuit

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.

TC3682 Demo Card

The TC3682 DEMO Card is a 2.0" x 2.0" card containing both a TC3682 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.

Figure 3 is a schematic of the TC3682 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. TC3682 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	TC3682 (U2) SUPPLY VOLTAGE
TP7	TC3682 (U2) OUTPUT VOLTAGE [V_{OUT2}]
TP8	TC3682 (U2) $\overline{SHDN}$ INPUT VOLTAGE
TP9	DEMO CARD /SHUTDOWN INPUT

Table 4. TC3682 DEMO Card Jumpers

JUMPER	CURRENT MEASUREMNT
J1	TC682 (U1) QUIESCENT CURRENT
J2	TC3682 (U2) QUIESCENT CURRENT
J3	TC682 (U1) V_{OUT1} LOAD CURRENT
J4	TC3682 (U2) V_{OUT2} LOAD CURRENT
J5	TC3682 (U2) $\overline{SHDN}$ INPUT CURRENT
J6	CONNECT DEMO CARD /SHUTDOWN INPUT TO GND

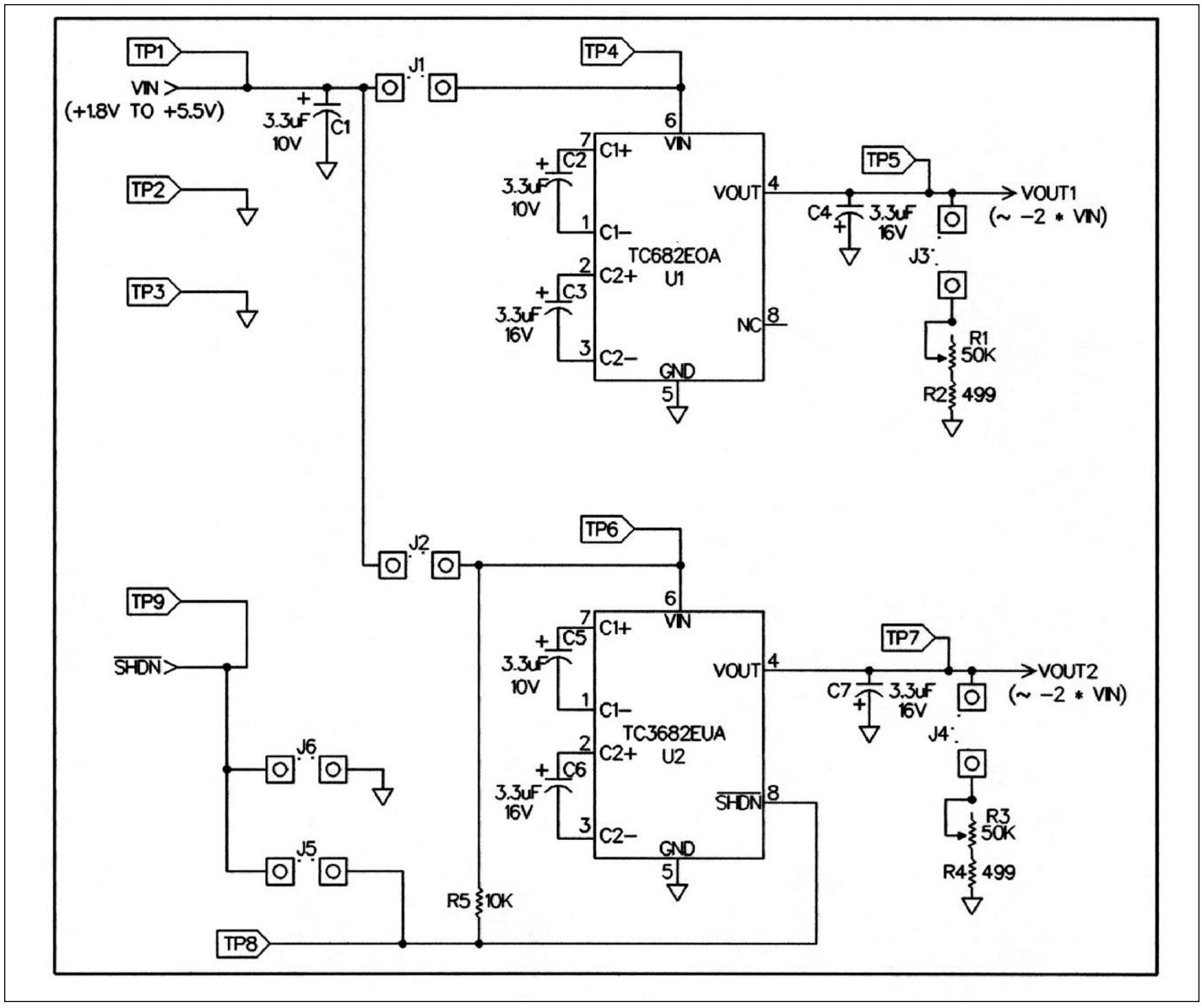


Figure 3. TC3682 DEMO Card Schematic

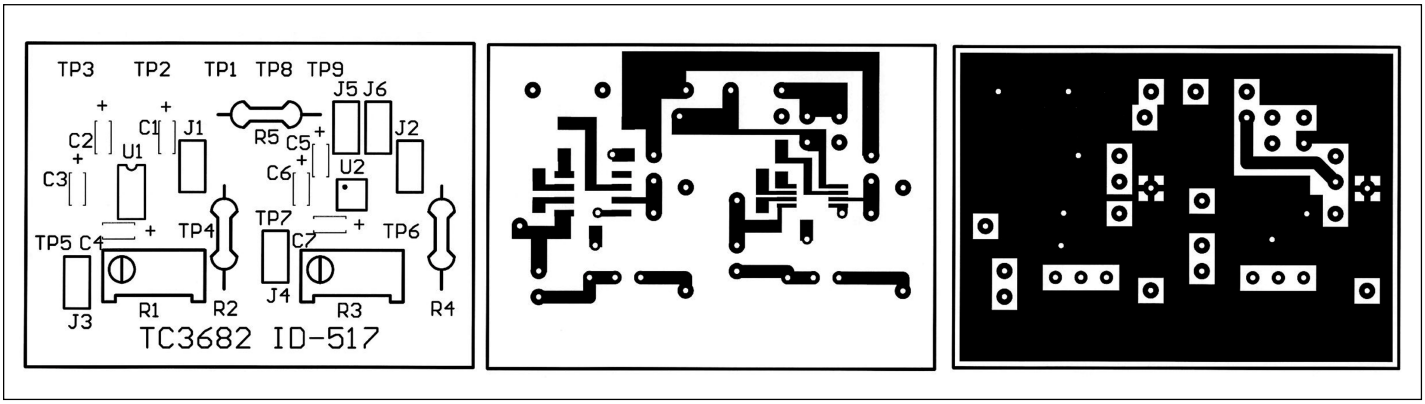
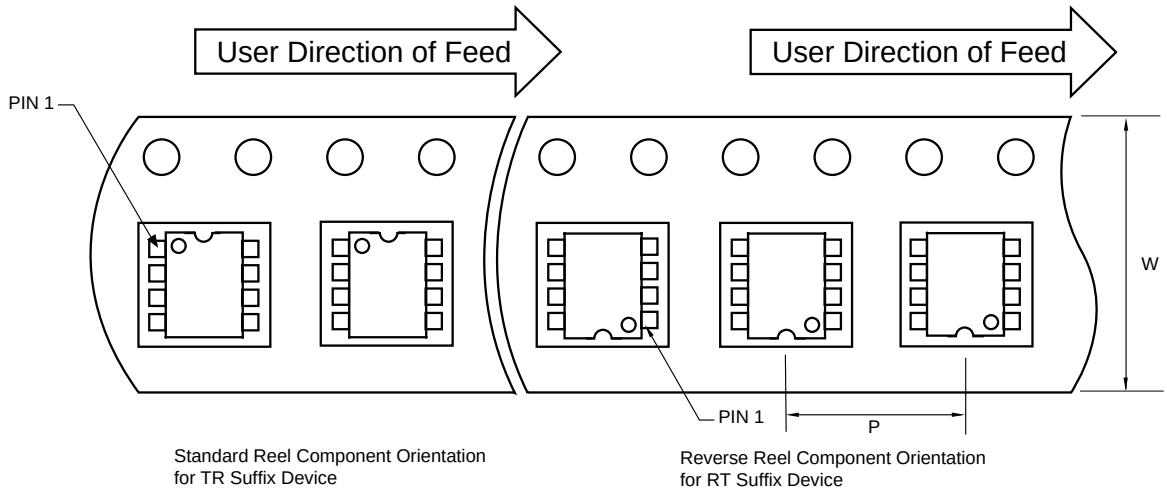


Figure 4. TC3682 DEMO Card Assembly Drawing and Artwork

TAPING FORM

Component Taping Orientation for 8-Pin MSOP Devices



Standard Reel Component Orientation
for TR Suffix Device

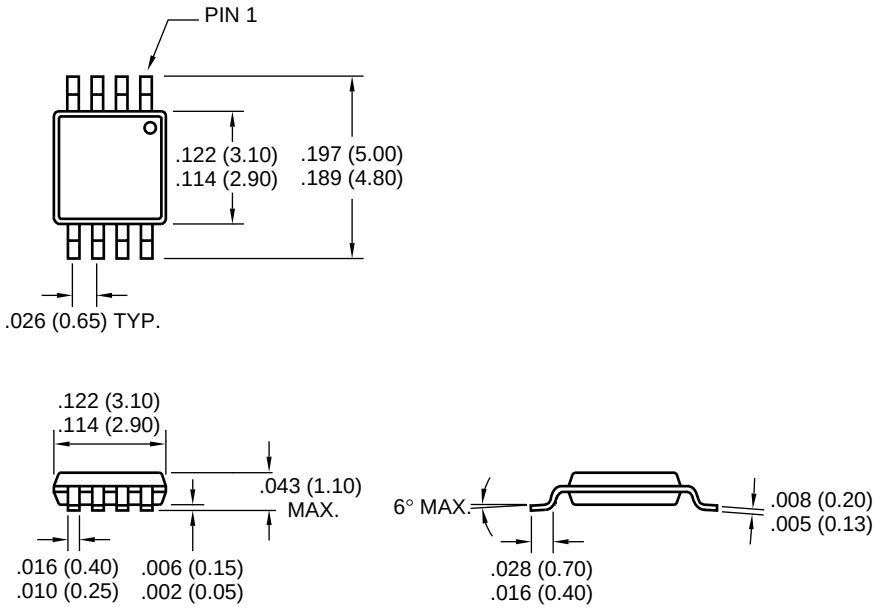
Reverse Reel Component Orientation
for RT Suffix Device

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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