MICROCHIP

TC1225
TC1226
TC1227

Inverting Dual (–V_{IN}, –$2V_{IN}$) Charge Pump Voltage Converters

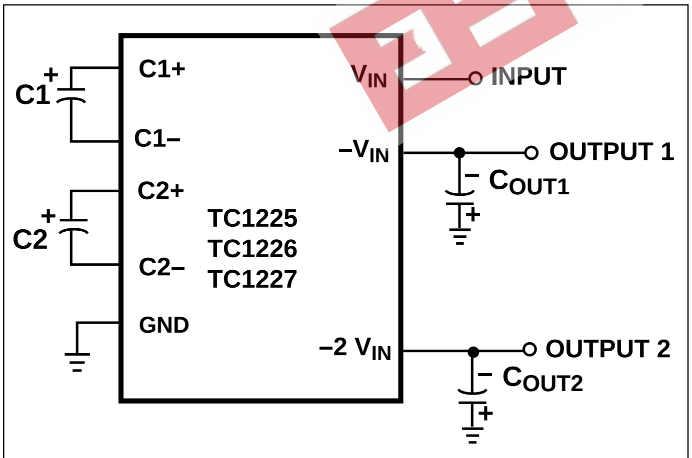
FEATURES

- Small 8-Pin MSOP Package
- Operates from 1.8V to 5.5V
- Up to 5mA Output Current at –V_{IN} Pin
- Up to 1mA Output Current at –$2V_{IN}$ Pin
- –V_{IN} and –$2V_{IN}$ Outputs Available
- Low Supply Current
  - .... 120µA (MAX) for TC1225
  - .... 360µA (MAX) for TC1226
  - .... 1.5mA (MAX) for TC1227

TYPICAL APPLICATIONS

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

TYPICAL OPERATING CIRCUIT



Notes: 1) C1 and C_{OUT1} must have a voltage rating greater than or equal to V_{IN}
2) C2 and C_{OUT2} must have a voltage rating greater than or equal to $2V_{IN}$

GENERAL DESCRIPTION

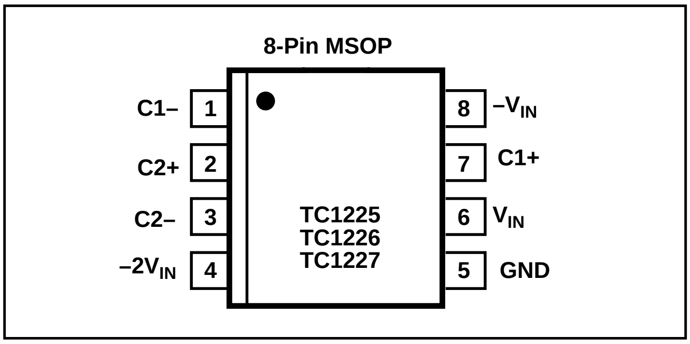
The TC1225/1226/1227 are CMOS dual inverting charge pump voltage converters in 8-Pin MSOP packages. An on-board oscillator provides the clock, and only four external capacitors are required for full circuit implementation. Switching frequencies are 12kHz for the TC1225, 35kHz for the TC1226, and 125kHz for the TC1227.

These devices provide both a negative voltage inversion (available at the –V_{IN} output) and a negative doubling voltage inversion (available at the –2 V_{IN} output), with a low output impedance capable of providing output currents up to 5mA for the –V_{IN} output and 1mA for the –$2V_{IN}$ output. The input voltage can range from +1.8V to +5.5V.

ORDERING INFORMATION

Part No.	Package	Osc Freq (kHz)	Temp Range
TC1225EUA	8-Pin MSOP	12	–40°C to +85°C
TC1226EUA	8-Pin MSOP	35	–40°C to +85°C
TC1227EUA	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_{IN}, –2V_{IN} to GND) .... –12.0V, + 0.3V
Current at –V_{IN}, –2V_{IN} Pins 10mA
Short-Circuit Duration –V_{IN}, –2V_{IN} to GND .... Indefinite
Operating Temperature Range .... – 40°C to +85°C
Power Dissipation (T_A ≤ 70°C) MSOP-8 .... 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 = 3.3µF, C2 = 1µF (TC1225); C1 = 1µF, C2 = 0.33µF (TC1226); C1 = 0.33µF, C2 = 0.1µF (TC1227) unless otherwise noted. Typical values are at T_A = +25°C.

Symbol	Parameter	Device	Test Conditions	Min	Typ	Max	Unit
I_{DD}	Supply Current	TC1225 TC1226 TC1227		— — —	75 200 625	120 360 1500	µA
V_{MIN}	Minimum Supply Voltage	All	R_{LOAD} = 1kΩ for –V_{IN} output R_{LOAD} = 10kΩ for –2V_{IN} output	1.8	—	—	V
V_{MAX}	Maximum Supply Voltage	All	R_{LOAD} = 1kΩ for –V_{IN} output R_{LOAD} = 10kΩ for –2V_{IN} output	—	—	5.5	V
F_{OSC}	Oscillator Frequency	TC1225 TC1226 TC1227		8.4 24.5 65	12 35 125	15.6 45.5 170	kHz
V_{EFF1}	Voltage Conversion Efficiency (Stage 1)	All	R_{LOAD} = ∞ for –V_{IN} output R_{LOAD} = ∞ for –2V_{IN} output	96	99.5	—	%
V_{EFF2}	Voltage Conversion Efficiency (Stage 2)	All	R_{LOAD} = ∞ for –V_{IN} output R_{LOAD} = ∞ for –2V_{IN} output	94	99	—	%
R_{OUT1}	Output Resistance for –V_{IN} output (Note 1)	All	I_{LOAD} = 0.5mA to 5mA No Load at -2V_{IN} Output	—	45	80	Ω
R_{OUT2}	Output Resistance for –2V_{IN} output (Note 1)	All	I_{LOAD} = 0.1mA to 1mA No Load at -V_{IN} Output	—	135	420	Ω

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

PIN DESCRIPTION

Pin Number	Name	Description
1	C1–	C1 Commutation Capacitor Negative Terminal.
2	C2+	C2 Commutation Capacitor Positive Terminal.
3	C2–	C2 Commutation Capacitor Negative Terminal.
4	–2V_{IN}	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	–V_{IN}	Inverting Charge Pump Output (–1 x V_{IN}).

DETAILED DESCRIPTION

The TC1225/1226/1227 dual charge pump converters perform both a –1x and –2x multiply of the voltage applied to the V_{IN} pin. Output '– V_{IN}' provides a negative voltage inversion of the V_{IN} supply, while output '-2 V_{IN}' provides a negative doubling inversion of V_{IN}. Conversion is performed using two **synchronous** switching matrices and four external capacitors.

Figure 1 (below) is a block diagram representation of the TC1225/1226/1227 architecture. The first switching stage inverts the voltage present at V_{IN} and the second stage uses the '$-V_{IN}$' output generated from the first stage to produce the '$-2V_{IN}$' 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 TC1225 synchronously switches at 12KHz, the TC1226 synchronously switches at 35KHz, and the TC1227 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**).

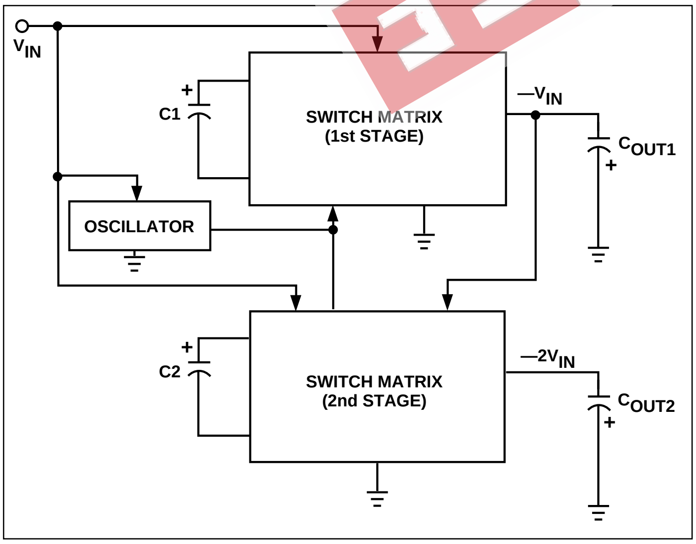


Figure 1. Functional Block Diagram

APPLICATIONS INFORMATION

Output Voltage Considerations

The TC1225/1226/1227 performs voltage conversions but does not provide any type of regulation. The two output voltage stages will droop in a linear manner with respect to their 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:

$$V_{DROOP} = I_{OUT} \times R_{OUT}$$
$$[-V_{IN}\ \text{OUTPUT}] = V_{OUT1} = -(V_{IN} - V_{DROOP1})$$
$$[-2V_{IN}\ \text{OUTPUT}] = V_{OUT2} = V_{OUT1} - (V_{IN} - V_{DROOP2})$$

where V_{DROOP1} is the output voltage droop contributed from stage 1 loading , and V_{DROOP2} is the output voltage droop from stage 2 loading.

Charge Pump Efficiency

The overall power efficiency of the two charge pump stages is affected by four factors:

(1) Losses from power consumed by the internal oscillator, switch drive, etc. (which vary with input voltage, temperature and oscillator frequency).

(2) I^2R losses due to the on-resistance of the MOSFET switches on-board each charge pump.

(3) Charge pump capacitor losses due to effective series resistance (ESR).

(4) Losses that occur during charge transfer (from the commutation capacitor to the output capacitor) when a voltage difference between the two capacitors exists.

Most of the conversion losses are due to factor (2), (3) and (4) above. The losses for the first stage are given by Equation 1a and the losses for the second stage are given by Equation 1b.

$$P1_{LOSS\,(2,\,3,\,4)} = I_{OUT1}{}^{2} \times R_{OUT1}$$
$$\text{where } R_{OUT1} = [\,1 / [\,f_{OSC}\,(C1)\,] + 8R_{SWITCH1} + 4ESR_{C1} + ESR_{COUT1}\,]$$

Equation 1a.

$$P2_{LOSS\,(2,\,3,\,4)} = I_{OUT2}{}^{2} \times R_{OUT2}$$
$$\text{where } R_{OUT2} = [\,1 / [f_{OSC}(C2)\,] + 8R_{SWITCH2} + 4ESR_{C2} + ESR_{COUT2}\,]$$

Equation 1b.

The internal switch resistance for the first stage (i.e. $R_{SWITCH1}$) is approximately 3Ω and the switch resistance for the second stage (i.e. $R_{SWITCH2}$) is approximately 7Ω.

The losses in the circuit due to factor (4) above are also shown in Equation 2a for stage 1 and Equation 2b for stage 2. The output voltage ripple for stage 1 is given by Equation 3a and the output voltage ripple for stage 2 is given by Equation 3b.

$$P_{LOSS1\,(4)} = \left[\, (0.5)(C1)(V_{IN}{}^2 - V_{OUT1}{}^2) + (0.5)(C_{OUT1})(V_{RIPPLE1}{}^2 - 2V_{OUT1}\,V_{RIPPLE1}) \,\right] \times f_{OSC}$$

Equation 2a.

$$P_{LOSS2\,(4)} = \left[\, (0.5)\,(C2)\,(V_{IN}{}^2 - V_{OUT2}{}^2) + (0.5)(C_{OUT2})(V_{RIPPLE2}{}^2 - 2V_{OUT2}\,V_{RIPPLE2}) \,\right] \times f_{OSC}$$

Equation 2b.

$$V_{RIPPLE1} = [\, I_{OUT1} / (f_{OSC})\,(C_{OUT1}) \,] + 2\,(I_{OUT1})\,(ESR_{COUT1})$$

Equation 3a.

$$V_{RIPPLE2} = [\, I_{OUT2} / (f_{OSC})\,(C_{OUT2}) \,] + 2\,(I_{OUT2})\,(ESR_{COUT2})$$

Equation 3b.

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_{OUT1} and C_{OUT2} will reduce output ripple. (See Equations 1a, 1b, 3a, and 3b). **NOTE: For proper charge pump operation, C1 and C_{OUT1} must have a voltage rating greater than or equal to V_{IN}, while C2 and C_{OUT2} must have a voltage rating greater than or equal to $2V_{IN}$.**

Table 1a shows various values of C1 and the corresponding output resistance values for V_{IN}=5V @ +25°C for stage 1 and Table 1b shows various values of C2 and the corresponding output resistance values for V_{IN}=5V @ +25°C for stage 2. It assumes a 0.1Ω ESR_{C1}, a 0.1Ω ESR_{C2}, a 3Ω $R_{SWITCH1}$, and a 7Ω $R_{SWITCH2}$.

Table 2a shows the output voltage ripple for various values of C_{OUT1} and Table 2b shows the output voltage ripple for various values of C_{OUT2} (again assuming V_{IN}=5V @ +25°C). The $V_{RIPPLE1}$ values assume a 3mA output load current for stage 1 and a 0.1Ω ESR_{COUT1}. The $V_{RIPPLE2}$ values assume a 200uA output load current for stage 2 and a 0.1Ω ESR_{COUT1}.

Table 1a. Output Resistance vs. C1 (ESR = 0.1Ω). For Stage 1

C1 (µF)	TC1225 R_{OUT} (Ω)	TC1226 R_{OUT} (Ω)	TC1227 R_{OUT} (Ω)
0.47	202	85	42
1	108	53	33
3.3	50	33	27

Table 1b. Output Resistance vs. C2 (ESR = 0.1Ω). For Stage 2

C2 (µF)	TC1225 R_{OUT} (Ω)	TC1226 R_{OUT} (Ω)	TC1227 R_{OUT} (Ω)
0.1	890	342	137
0.47	239	117	74
1	140	85	65

Table 2a. Output Voltage Ripple vs. C_{OUT1} (ESR = 0.1Ω) For Stage 1 (I_{OUT1} = 3mA)

C_{OUT1} (µF)	TC1225 $V_{RIPPLE1}$ (mV)	TC1226 $V_{RIPPLE1}$ (mV)	TC1227 $V_{RIPPLE1}$ (mV)
0.47	533	183	52
1	251	86	25
3.3	76	27	8

Table 2b. Output Voltage Ripple vs. C_{OUT2} (ESR = 0.1Ω) For Stage 2 (I_{OUT2} = 200µA)

C_{OUT2} (µF)	TC1225 $V_{RIPPLE2}$ (mV)	TC1226 $V_{RIPPLE2}$ (mV)	TC1227 $V_{RIPPLE2}$ (mV)
0.1	167	57	16
0.47	36	12	3.4
1	17	5.8	1.6

Input Supply Bypassing

The V_{IN} input should be capacitively bypassed to reduce AC impedance and minimize noise effects due to the switching internal to 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.

Dual Voltage Inverter

The most common application for the TC1225/1226/1227 devices is the dual voltage inverter (Figure 2). This application uses four external capacitors: C1, C2, C_{OUT1}, and C_{OUT2} (NOTE: a power supply bypass capacitor is recommended). The outputs are equal to – V_{IN} and –2VIN plus any voltage drops due to loading. Refer to Tables 1a, 1b, 2a, and 2b for capacitor selection guidelines.

Device	C_{IN}	C1	C2	C_{OUT1}	C_{OUT2}
TC1225	3.3μF	3.3μF	1μF	3.3μF	1μF
TC1226	1μF	1μF	0.33μF	1μF	0.33μF
TC1227	0.33μF	0.33μF	0.1μF	0.33μF	0.1μF

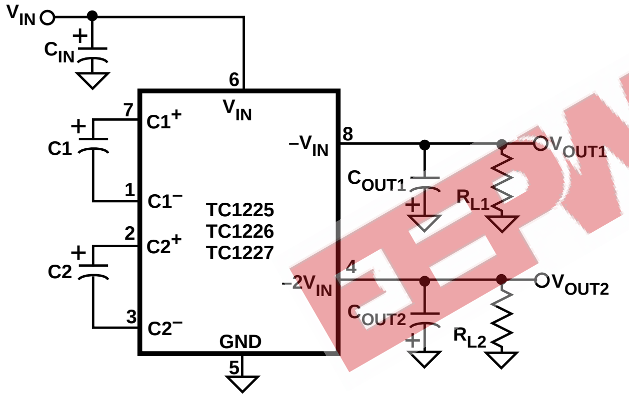


Figure 2. Dual Voltage Inverter Test Circuit

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.

TC1225 DEMO CARD

The TC1225 DEMO Card is a 2.0" x 2.0" card containing both a TC1225 and two cascaded TCM828s that allow the user to compare the operation of each approach for generating a –1X and –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 TC1225 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. TC1225 DEMO Card Test Points

TEST POINT	VOLTAGE MEASUREMENT
TP1	VIN [+5V]
TP2	GROUND
TP3	GROUND
TP4	TCM828 U1 OUTPUT [-5V(1)]
TP5	TCM828 U2 OUTPUT [-10V(1)]
TP6	TC1225 STAGE 1 OUTPUT [-5V(2)]
TP7	TC1225 STAGE 2 OUTPUT [-10V(2)]

Table 4. TC1225 DEMO Card Jumpers

JUMPER	CURRENT MEASUREMNT
J1	DUAL TCM828 QUIESCENT CURRENT
J2	TC1225 QUIESCENT CURRENT
J3	TCM828 U1 [-5V(1)] LOAD CURRENT
J4	TCM828 U2 [-10V(1)] LOAD CURRENT
J5	TC1225 STAGE 1 [-5V(2)] LOAD CURRENT
J6	TC1225 STAGE 2 [-10V(2)] LOAD CURRENT

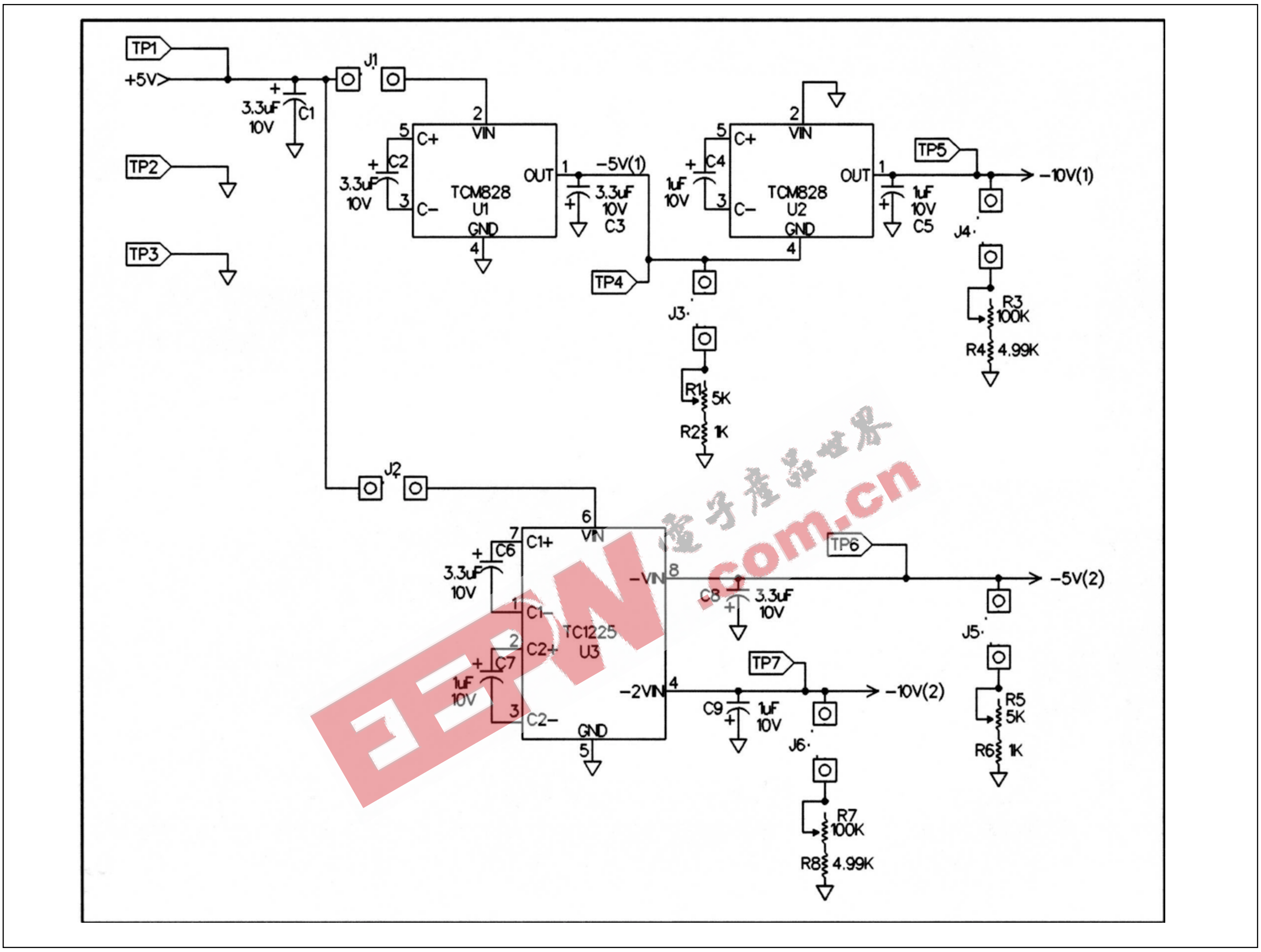


Figure 3. TC1225 DEMO Card Schematic

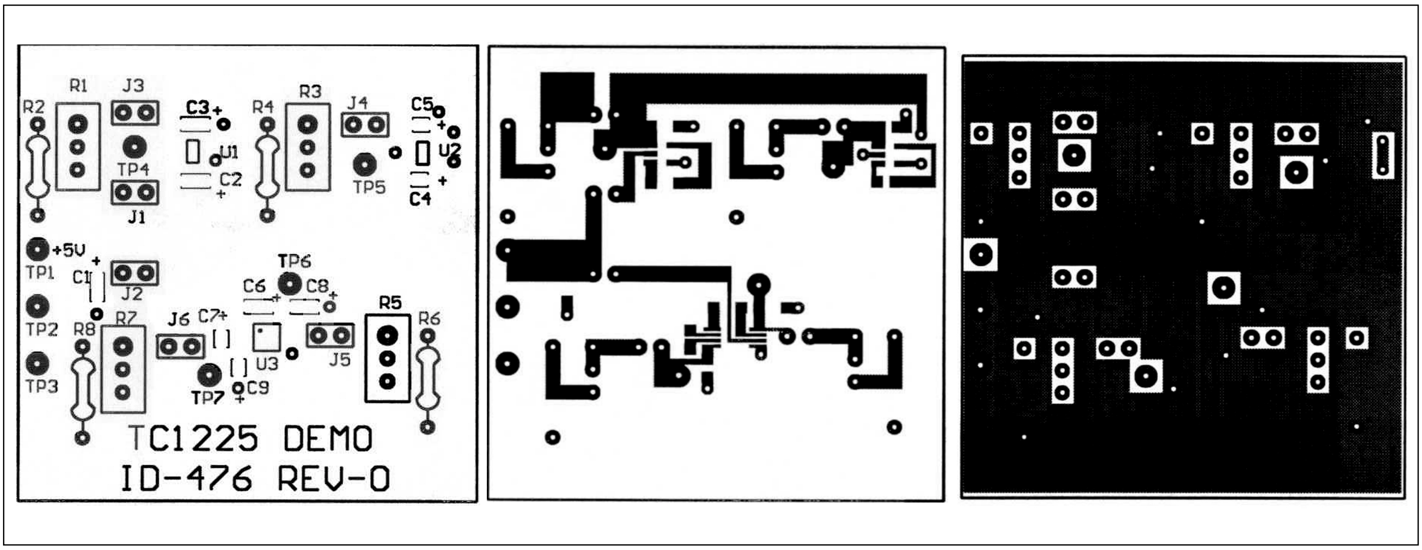
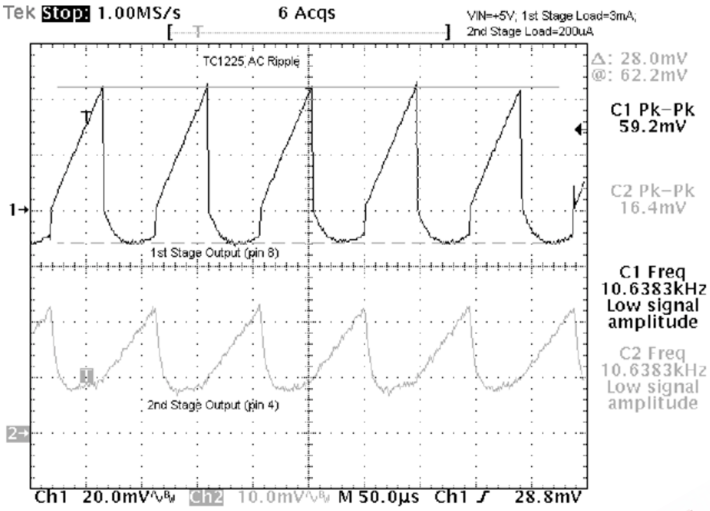
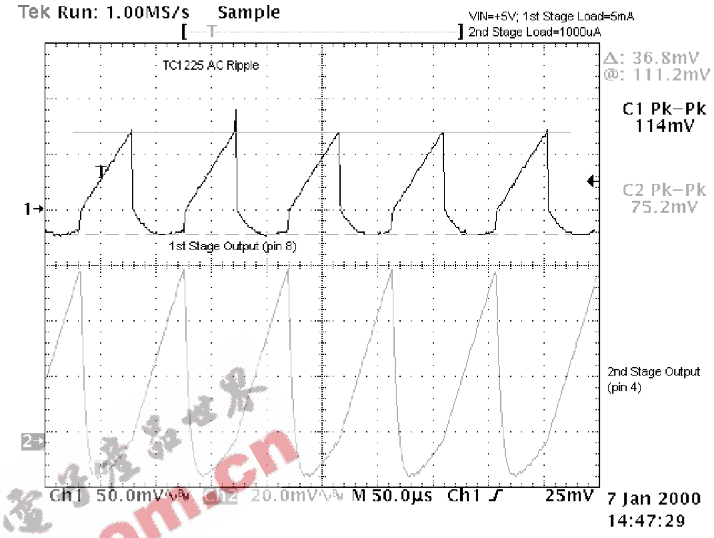
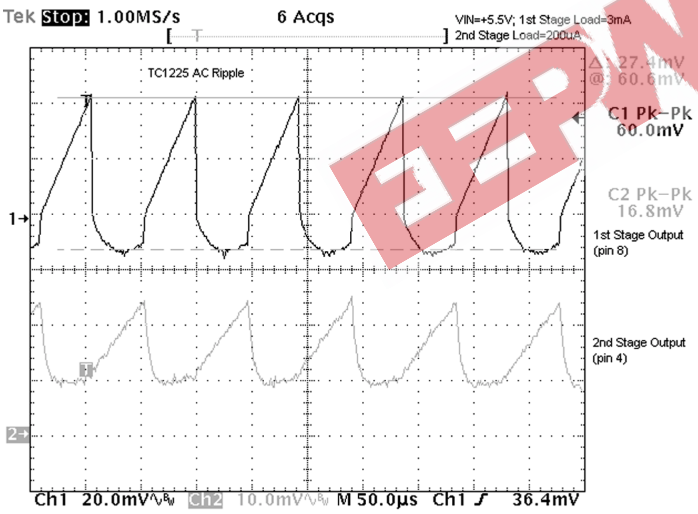


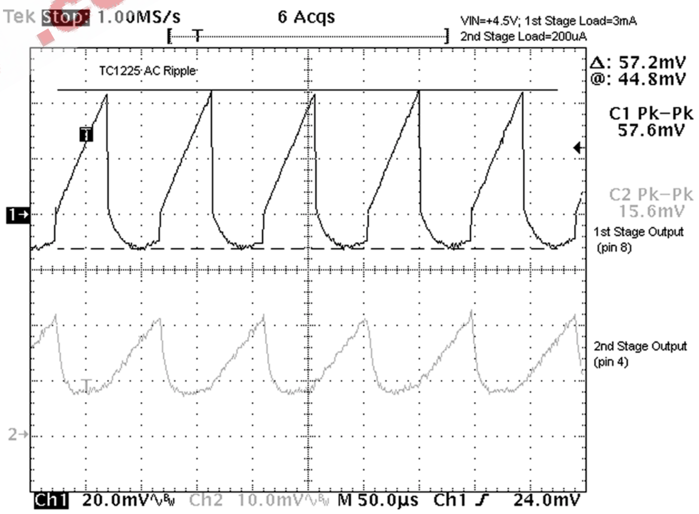
Figure 4. TC1225 DEMO Card Assembly Drawing and Artwork

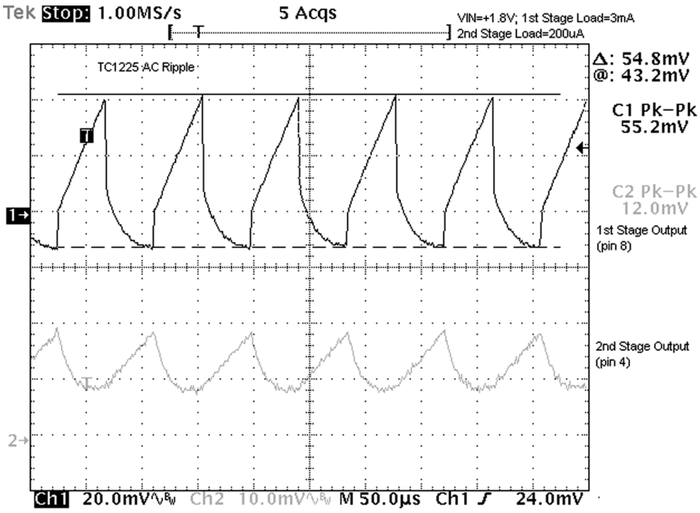
TYPICAL RIPPLE WAVEFORMS





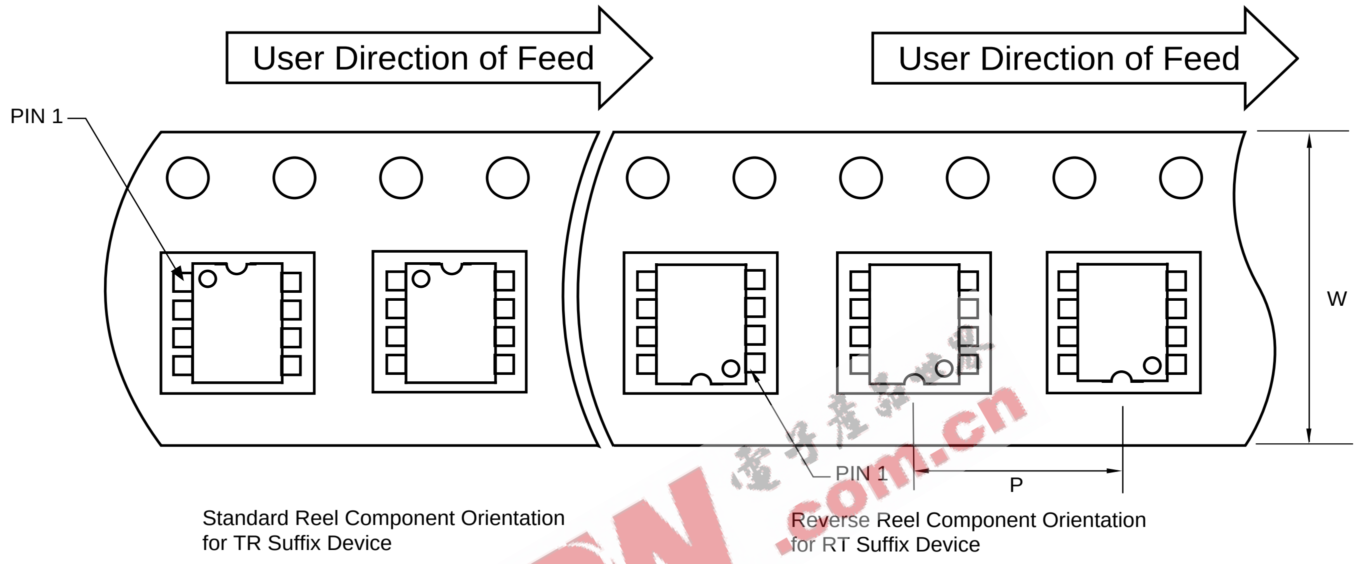






TAPING FORM

Component Taping Orientation for 8-Pin MSOP Devices

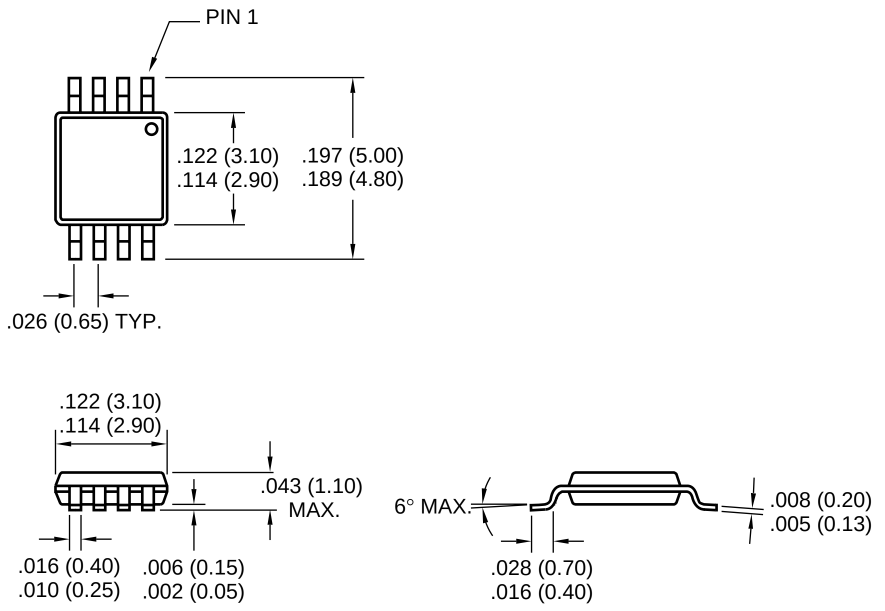


Carrier Tape, Number of Components Per Reel and Reel Size

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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