TC1221
TC1222

High Frequency Switched Capacitor Voltage Converters with Shutdown in SOT Packages

FEATURES

- Charge Pumps in 6-Pin SOT-23A Package
- 96% Voltage Conversion Efficiency
- Voltage Inversion and/or Doubling
- Operates from +1.8V to +5.5V
- Up to 25 mA Output Current
- Only Two External Capacitors Required
- Power-Saving Shutdown Mode
- Fully Compatible with 1.8V Logic Systems

APPLICATIONS

- LCD Panel Bias
- Cellular Phones
- Pagers
- PDAs, Portable Dataloggers
- Battery-Powered Devices

GENERAL DESCRIPTION

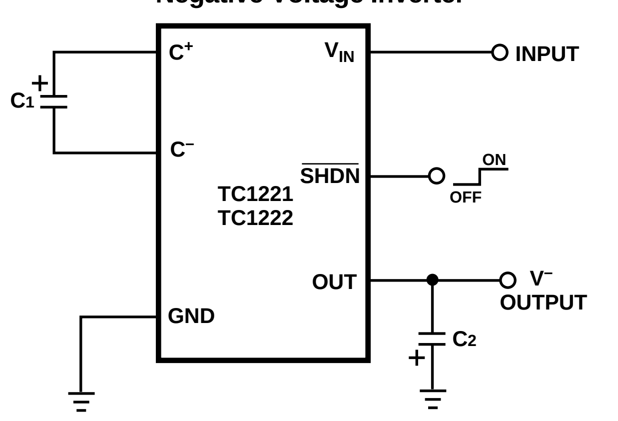
The TC1221/1222 are CMOS “charge-pump” voltage converters in ultra-small 6-Pin SOT-23A packages. They invert and/or double an input voltage which can range from +1.8V to +5.5V. Conversion efficiency is typically 96%. Switching frequency is 125 kHz for the TC1221, 750KHz for the TC1222. When the shutdown pin is held at a logic low, the device goes into a very low power mode of operation, consuming less than 1µA of supply current.

For standard voltage inverter applications, the device requires only two external capacitors. With a few additional components a positive doubler can also be built. All other circuitry, including control, oscillator, power MOSFETs are integrated on-chip. Typical supply currents are 290µA (TC1221) and 1800µA (TC1222).

All devices are available in 6-Pin SOT-23A surface mount packages.

TYPICAL OPERATING CIRCUIT

Negative Voltage Inverter

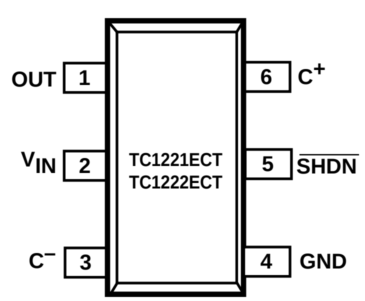


ORDERING INFORMATION

Part No.	Package	Osc. Freq. (KHz)	Temperature Range
TC1221ECH	6-Pin SOT-23A	125	– 40°C to +85°C
TC1222ECH	6-Pin SOT-23A	750	– 40°C to +85°C

PIN CONFIGURATION

6-Pin SOT-23A*



NOTE: * 6-Pin SOT-23A is equivalent to EIAJ SC-74

ABSOLUTE MAXIMUM RATINGS*

Input Voltage (V_{IN} to GND) .... +6.0V, – 0.3V
Output Voltage (OUT to GND) .... –6.0V, + 0.3V
Current at OUT Pin .... 50 mA
Short-Circuit Duration – OUT to GND .... Indefinite
Operating Temperature Range .... – 40°C to +85°C
Power Dissipation ($T_A \le 70°C$)
6-Pin SOT-23A .... 240 mW
Storage Temperature (Unbiased) .... – 65°C to +150°C
Lead Temperature (Soldering, 10 sec) .... +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 = 1µF (TC1221), C1 = C2 = 0.22µF (TC1222), unless otherwise noted. Typical values are at T_A = +25°C.

Symbol	Parameter	Device	Test Conditions	Min	Typ	Max	Unit
I_{DD}	Supply Current	TC1221 TC1222		— —	290 1800	600 2800	µA
I_{SHDN}	Shutdown Supply Current		$\overline{SHDN}$ = GND, V_{IN} = 5V (Note 2)	—	0.01	1.0	µA
V_{MIN}	Minimum Supply Voltage		R_{LOAD} = 1 KΩ:	1.8	—	—	V
V_{MAX}	Maximum Supply Voltage		R_{LOAD} = 1 KΩ	—	—	5.5	V
F_{OSC}	Oscillator Frequency	TC1221 TC1222		81 550	125 750	169 950	KHz
V_{IH}	Shutdown Input Logic High		V_{IN} = V_{MIN} to V_{MAX}	1.4	—	—	V
V_{IL}	Shutdown Input Logic Low		V_{IN} = V_{MIN} to V_{MAX}	—	—	0.4	V
P_{EFF}	Power Efficiency	TC1221 TC1222	R_{LOAD} = 1 KΩ	—	90 70	—	%
V_{EFF}	Voltage Conversion Efficiency		$R_{LOAD} = \infty$	94	96	—	%
R_{OUT}	Output Resistance (Note 1)	TC1221 TC1222	I_{LOAD} = 0.5mA to 25mA	—	25	65	Ω
T_{WK}	Wake-Up Time From Shutdown Mode	TC1221 TC1222	R_{LOAD} = 1KΩ	— —	80 25	— —	µsec

NOTES: 1. Capacitor contribution is approximately 20% of the output impedance [ESR = 1 / pump frequency x capacitance)].
2. V_{IN} is guaranteed to be disconnected from OUT when the converter is in shutdown.

PIN DESCRIPTION

Pin No. (6-Pin SOT-23A)	Symbol	Description
1	OUT	Inverting Charge Pump Output.
2	V_{IN}	Positive Power Supply Input.
3	C^-	Commutation Capacitor Negative Terminal.
4	GND	Ground.
5	$\overline{SHDN}$	Shutdown Input (Active Low).
6	C^+	Commutation Capacitor Positive Terminal.

DETAILED DESCRIPTION

The TC1221/1222 charge pump converters invert the voltage applied to the V_{IN} pin. Conversion consists of a two-phase operation (Figure 1). During the first phase, switches S2 and S4 are opened and S1 and S3 are closed. During this time, C1 charges to the voltage on V_{IN} and load current is supplied from C2. During the second phase, S2 and S4 are closed, and S1 and S3 are opened. This action connects C1 across C2, restoring charge to C2.

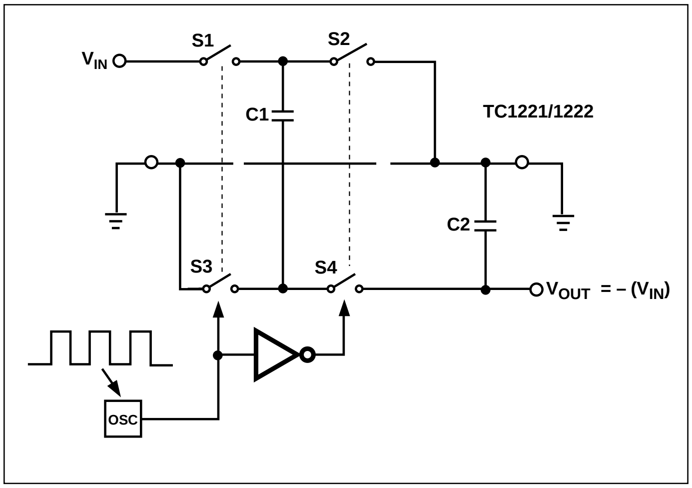


Figure 1. Ideal Switched Capacitor Charge Pump

APPLICATIONS INFORMATION

Output Voltage Considerations

The TC1221/1222 perform voltage conversion but do not provide *regulation*. The output voltage will droop in a linear manner with respect to load current. The value of this equivalent output resistance is approximately 25Ω nominal at +25°C and V_{IN} = +5V. V_{OUT} is approximately – 5V at light loads, and droops according to the equation below:

$$V_{DROP} = I_{OUT} \times R_{OUT}$$
$$V_{OUT} = -(V_{IN} - V_{DROP})$$

Charge Pump Efficiency

The overall power efficiency of the charge pump 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 the 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 factors (2) and (3) above. These losses are given by Equation 1(b).

(a) $P_{LOSS\,(2,\,3)} = I_{OUT}^2 \times R_{OUT}$

(b) Where $R_{OUT} = \left[\frac{1}{f_{OSC}(C1)} + 8R_{SWITCH} + 4ESR_{C1} + ESR_{C2}\right]$

Equation 1.

The $1/(f_{OSC})(C1)$ term in Equation 1(b) is the effective output resistance of an ideal switched capacitor circuit (Figures 2a, 2b). The value of R_{SWITCH} can be approximated at 0.5Ω for the TC1221/1222.

The remaining losses in the circuit are due to factor (4) above, and are shown in Equation 2. The output voltage ripple is given by Equation 3.

$$P_{LOSS\,(4)} = \left[(0.5)(C1)(V_{IN}^2 - V_{OUT}^2) + (0.5)(C2)(V_{RIPPLE}^2 - 2V_{OUT}V_{RIPPLE})\right] \times f_{OSC}$$

Equation 2.

$$V_{RIPPLE} = \frac{I_{OUT}}{(f_{OSC})(C2)} + 2(I_{OUT})(ESR_{C2})$$

Equation 3.

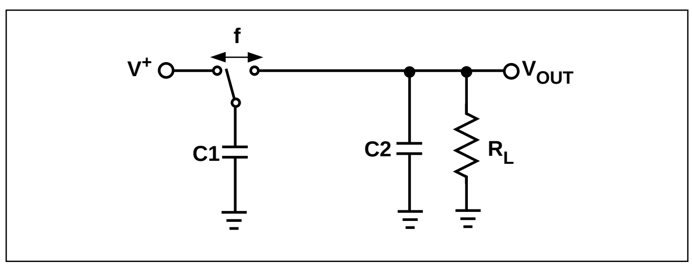


Figure 2a. Ideal Switched Capacitor Model

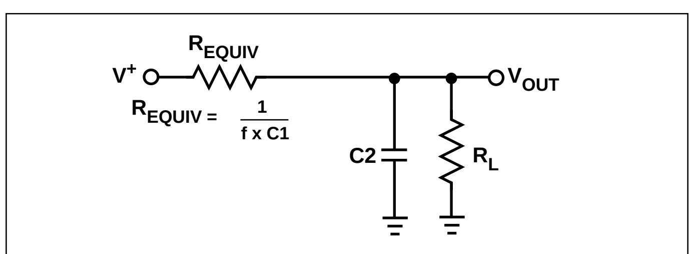


Figure 2b. Equivalent Output Resistance

Capacitor Selection

In order to maintain the lowest output resistance and output voltage ripple, it is recommended that low ESR capacitors be used. Additionally, larger values of C1 will lower the output resistance and larger values of C2 will reduce output ripple. (See Equation 1(b) and Equation 3).

Table 1 shows various values of C1 and the corresponding output resistance values @ +25°C. It assumes a 0.1Ω ESR_{C1} and 2Ω R_{SW}. Table 2 shows the output voltage ripple for various values of C2. The V_{RIPPLE} values assume 10mA output load current and 0.1Ω ESR_{C2}.

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

C1(µF)	TC1221 R_{OUT} (Ω)	TC1222 R_{OUT} (Ω)
0.22	52.9	22.6
0.33	40.8	20.5
0.47	33.5	19.4
1.0	25	17.8

Table 2. Output Voltage Ripple vs. C2 (ESR = 0.1Ω) I_{OUT} 10mA

C2 (µF)	TC1221 V_{RIPPLE} (mV)	TC1222 V_{RIPPLE} (mV)
0.22	366	63
0.33	244	42
0.47	172	30
1.0	82	15

Input Supply Bypassing

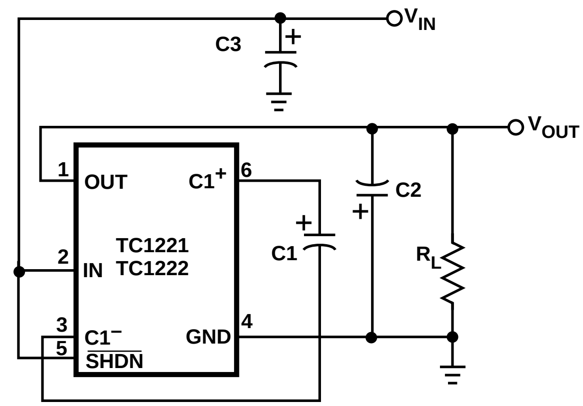
The V_{IN} input should be capacitively bypassed to reduce AC impedance and minimize noise effects due to the internal switching of the device. The recommended capacitor depends on the configuration of the TC1221/1222.

Shutdown Input

The TC1221/1222 is enabled when $\overline{SHDN}$ is high, and disabled when $\overline{SHDN}$ is low. This input cannot be allowed to float. The $\overline{SHDN}$ input should be limited to 0.5V above VIN to avoid significant current flows.

Voltage Inverter

The most common application for charge pump devices is the inverter (Figure 3). This application uses two exterrnal capacitors: C1 and C2 (plus a power supply bypass capacitor, if necessary). The output is equal to $-V_{IN}$ plus any voltage drops due to loading. Refer to Table 1 and Table 2 for capacitor selection.



Device	C1	C2	C3
TC1221	1 F	1 F	1 F
TC1222	0.22 F	0.22 F	0.22 F

Voltage Inverter

Figure 3. Test Circuit

Cascading Devices

Two or more TC1221/1222 can be cascaded to increase output voltage (Figure 4). If the output is lightly loaded, it will be close to (– 2 x V_{IN}) but will droop at least by R_{OUT} of the first device multiplied by the I_Q of the second. It can be seen that the output resistance rises rapidly for multiple cascaded devices.

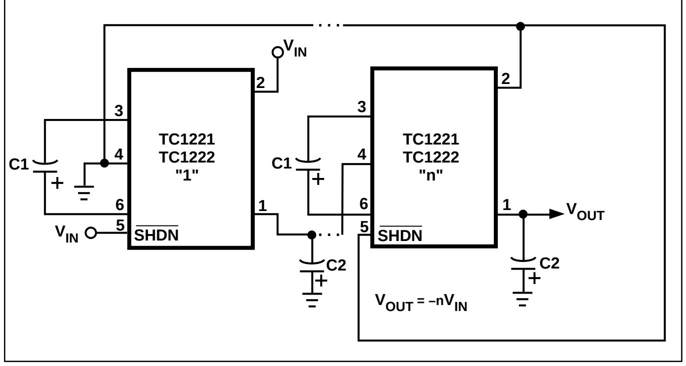


Figure 4. Cascading Multiple Devices to Increase Output Voltage

Paralleling Devices

To reduce the value of R_{OUT}, multiple TC1221/1222's can be connected in parallel (Figure 5). The output resistance will be reduced by a factor of N where N is the number of TC1221/1222. Each device will require its own pump capacitor (C1), but all devices may share one reservoir capacitor (C2). However, to preserve ripple performance the value of C2 should be scaled according to the number of paralleled TC1221/1222.

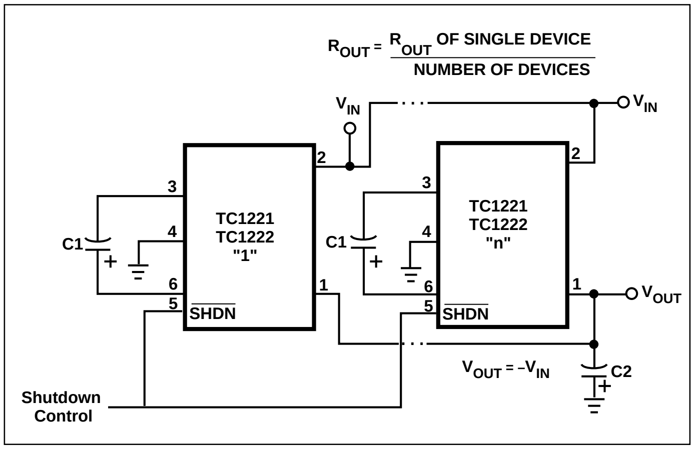


Figure 5. Paralleling Multiple Devices to Reduce Output Resistance

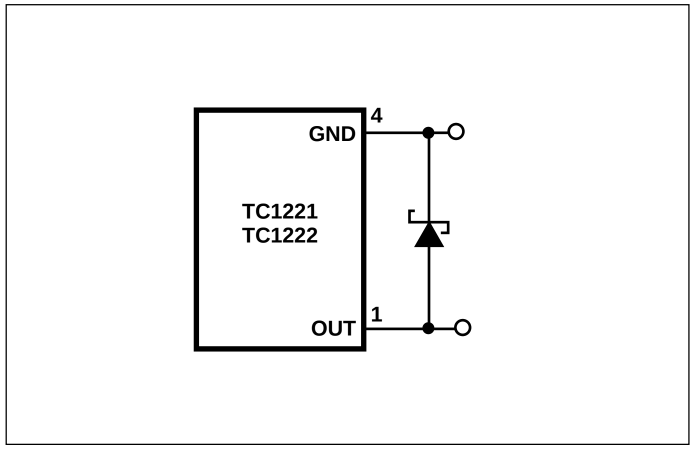


Figure 7. High V^{-} Load Current

Voltage Doubler/Inverter

Another common application of the TC1221/1222 is shown in Figure 6. This circuit performs two functions in combination. C1 and C2 form the standard inverter circuit described above. C3 and C4 plus the two diodes form the voltage doubler circuit. C1 and C3 are the pump capacitors and C2 and C4 are the reservoir capacitors. Because both sub-circuits rely on the same switches if either output is loaded, both will droop toward GND. Make sure that the total current drawn from both the outputs does not total more than 40 mA.

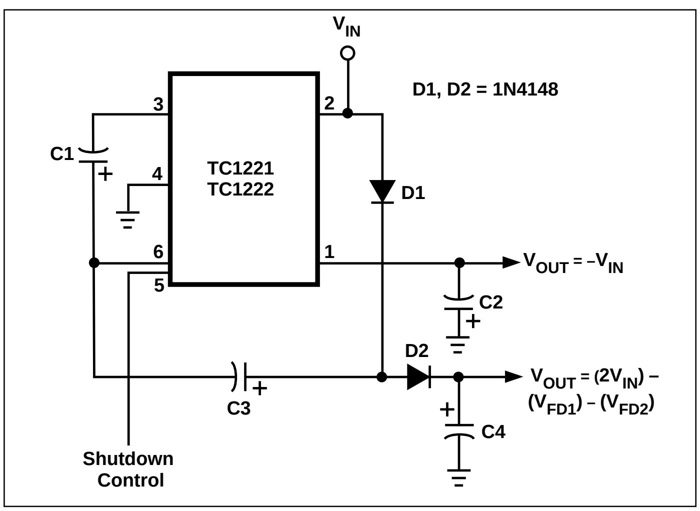


Figure 6. Combined Doubler and Inverter

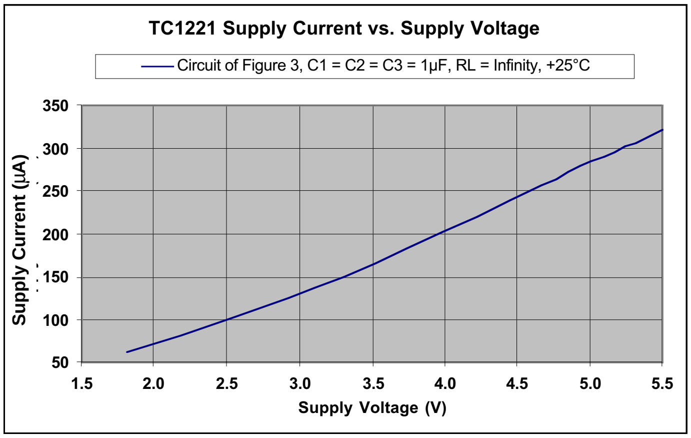
Diode Protection for Heavy Loads

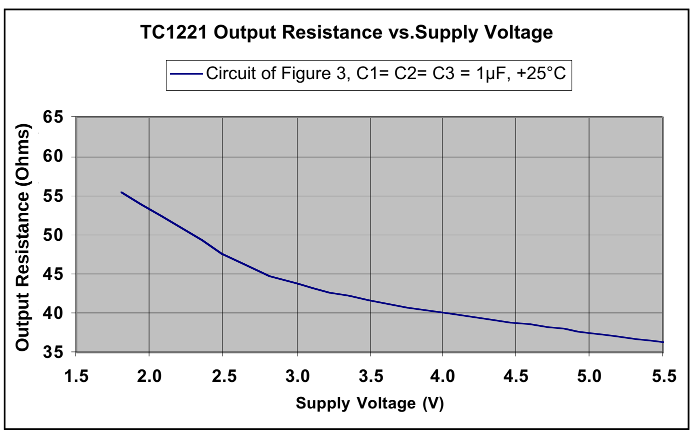
When heavy loads require the OUT pin to sink large currents being delivered by a positive source, diode protection may be needed. The OUT pin should not be allowed to be pulled above ground. This is accomplished by connecting a Schottky diode (1N5817) as shown in Figure 7.

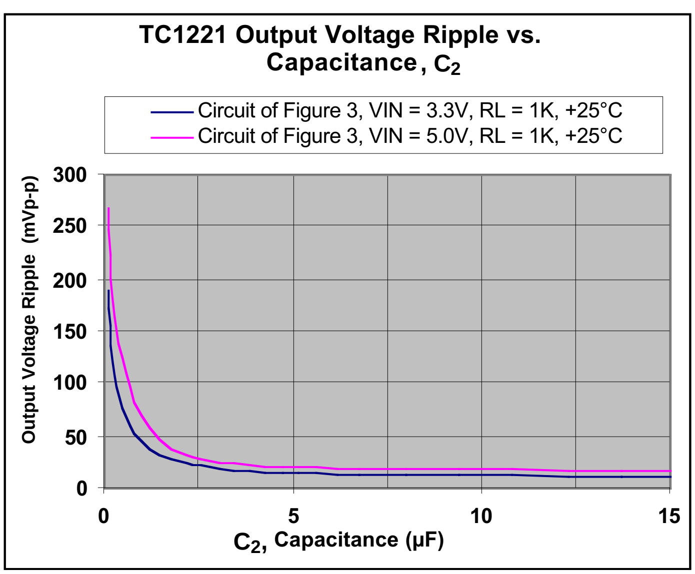
Layout Considerations

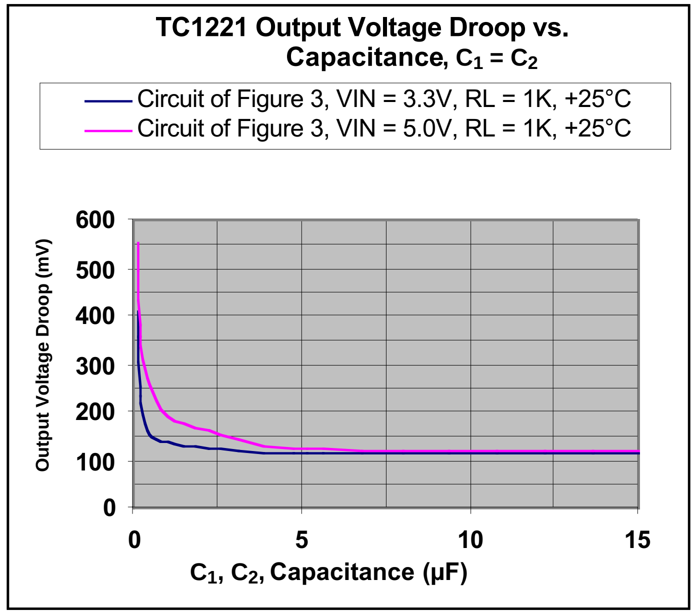
As with any switching power supply circuit, good layout practice is recommended. Mount components as close together as possible to minimize stray inductance and capacitance. Noise leakage into other circuitry can be minimized with the use of a large ground plane.

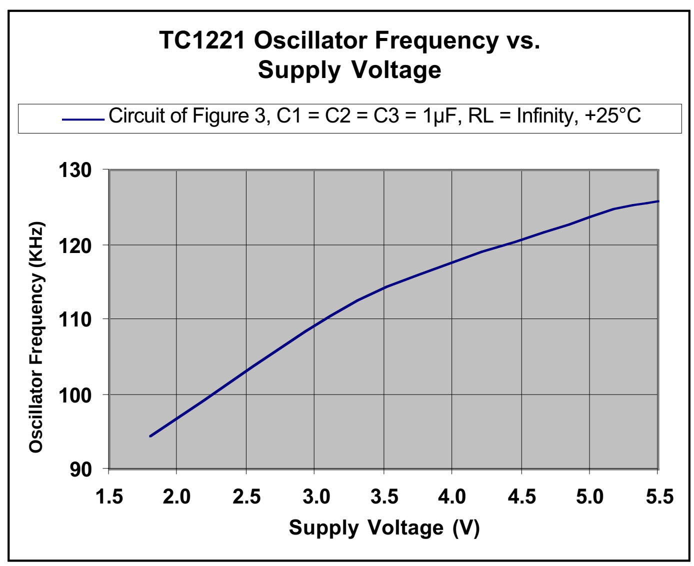
TYPICAL CHARACTERISTICS



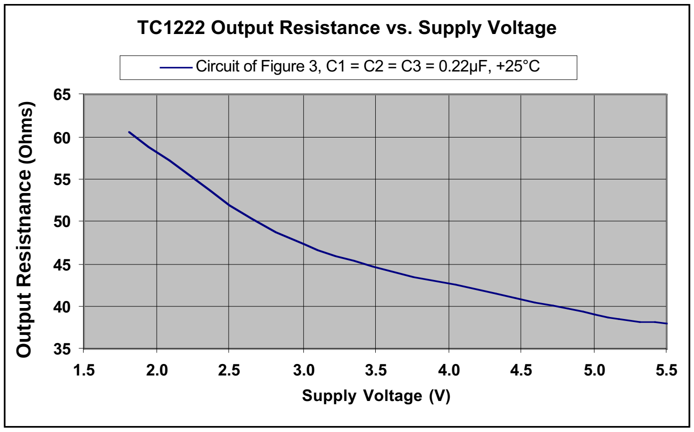


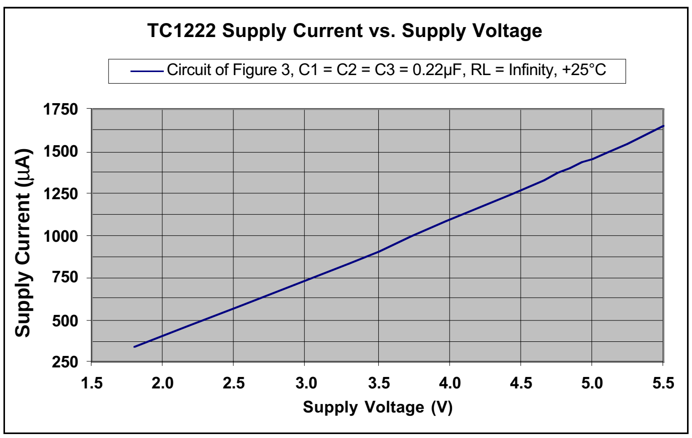


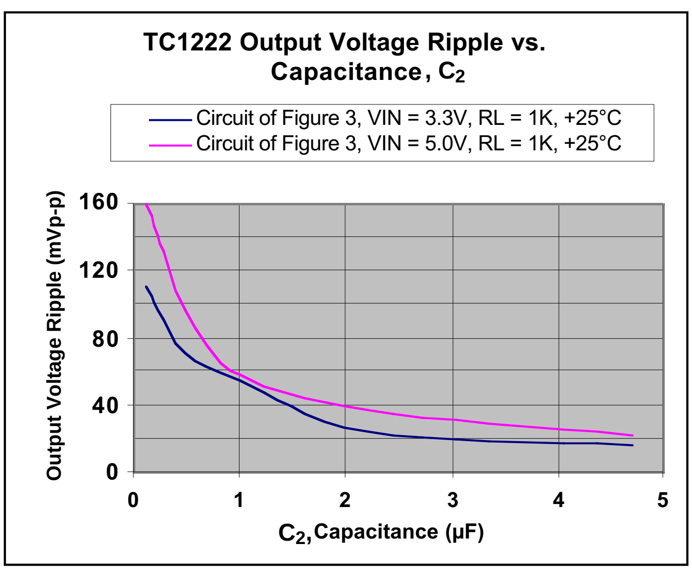


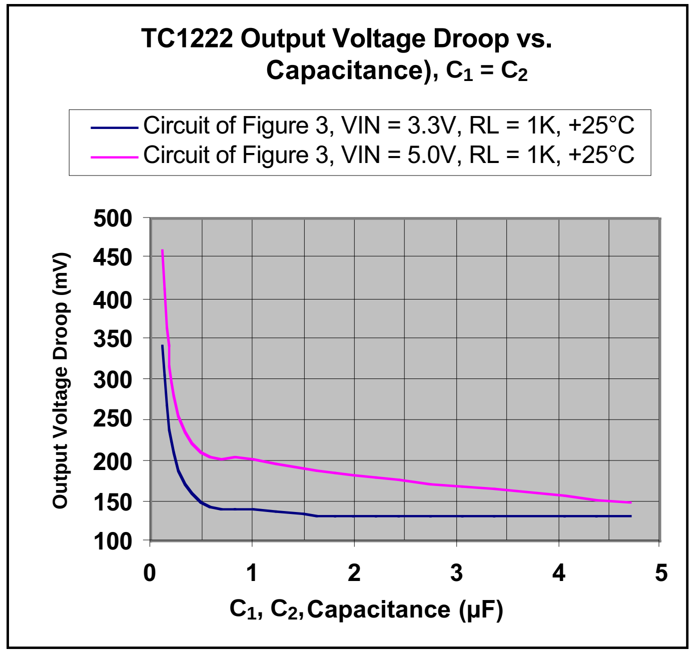


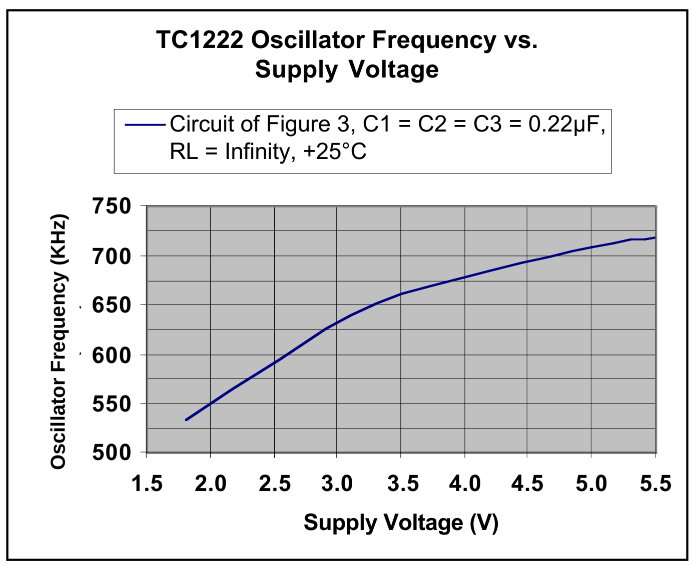
TYPICAL CHARACTERISTICS





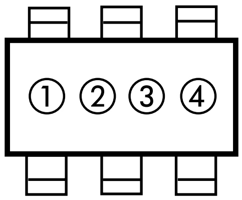






MARKING

6-PIN SOT-23A



Part Numbers and Part Marking

① & ② = part number code + temperature range (two-digit code).

TC1221/1222	Code
TC1221ECH	GA
TC1222ECH	GB

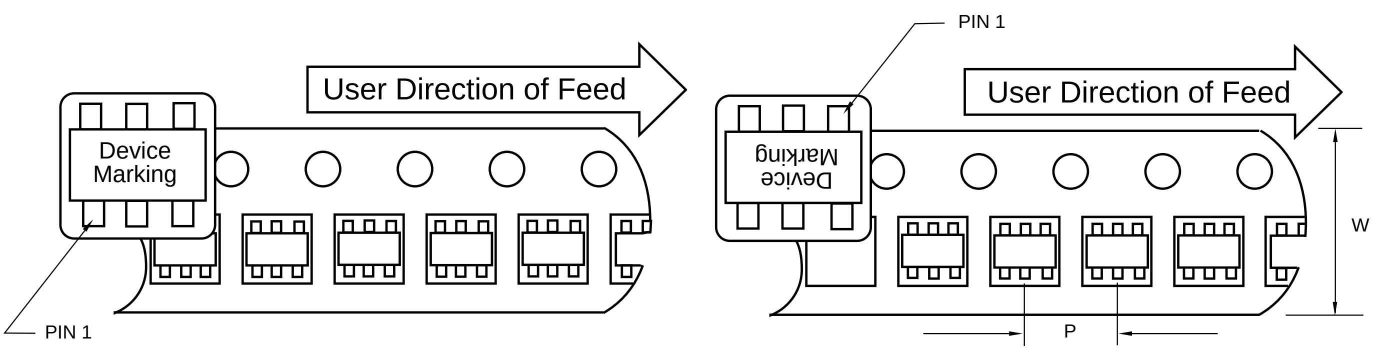
ex: 1221ECH = Ⓖ Ⓐ ◯ ◯
1222ECH = Ⓖ Ⓑ ◯ ◯

③ represents year and 2-month code

④ represents lot ID number

TAPING FORM

Component Taping Orientation for 6-Pin SOT-23A (EIAJ SC-74) Devices



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

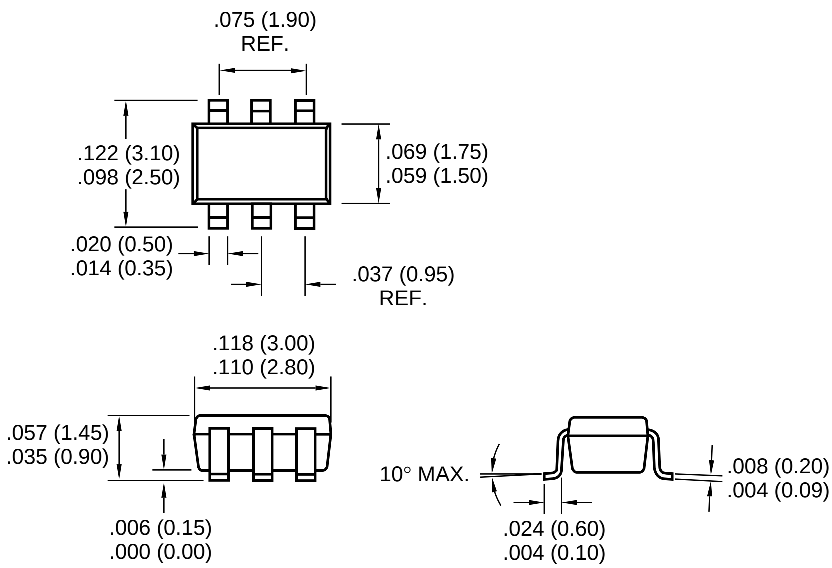
Reverse Reel Component Orientation
For RT Suffix Device
(Mark Upside Down)

Carrier Tape, Number of Components Per Reel and Reel Size

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

TAPING FORM

6-Pin SOT-23A (EIAJ SC-74)



Dimensions: inches (mm)

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