

Switched Capacitor Voltage Converters

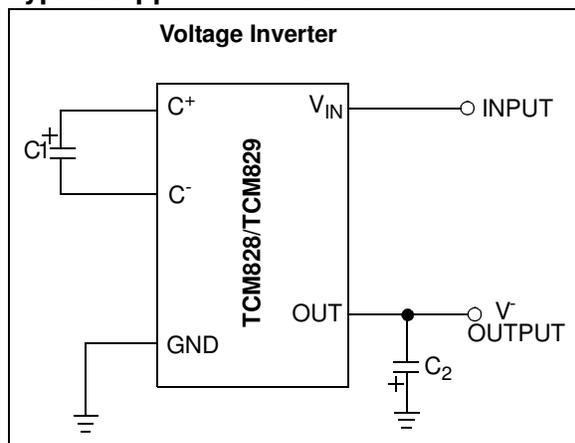
Features

- Charge Pump in 5-Pin SOT-23 Package
- >95% Voltage Conversion Efficiency
- Voltage Inversion and/or Doubling
- Low 50 μA (TCM828) Quiescent Current
- Operates from +1.5V to +5.5V
- Up to 25 mA Output Current
- Only Two External Capacitors Required

Applications

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

Typical Application Circuit



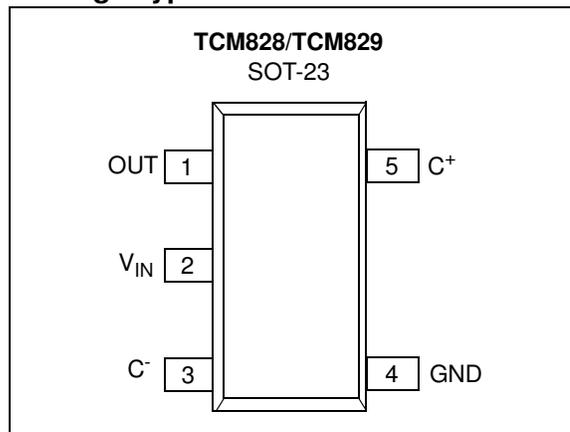
Description

The TCM828/TCM829 devices are CMOS "charge-pump" voltage converters in ultra-small, 5-Pin SOT-23 packages. They invert and/or double an input voltage which can range from +1.5V to +5.5V. Conversion efficiency is typically >95%. Switching frequency is 12 kHz for the TCM828, and 35 kHz for the TCM829.

External component requirement is only two capacitors (3.3 μF nominal) for standard voltage inverter applications. With a few additional components, a positive doubler can also be built. All other circuitry, including control, oscillator and power MOSFETs, are integrated on-chip. Supply current is 50 μA (TCM828) and 115 μA (TCM829).

The TCM828 and TCM829 devices are available in a 5-Pin SOT-23 surface mount package.

Package Type



Ordering Information

Part No.	Package	Temperature Range
TCM828ECT	5-Pin SOT-23	-40°C to +85°C
TCM828VT	5-Pin SOT-23	-40°C to +125°C
TCM829ECT	5-Pin SOT-23	-40°C to +85°C

Note: 5-Pin SOT-23 is equivalent to EIAJ SC-74A.

TCM828/TCM829

NOTES:

1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Input Voltage (V_{IN} to GND)	+30V
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
Variable Temp. Range (TCM828 only)	
.....	-40°C to +125°C
Power Dissipation ($T_A \leq 70^\circ\text{C}$)	240 mW
Storage Temperature (Unbiased).....	-65°C to +150°C
Lead Temperature (Soldering, 10 sec).....	+300°C

† **Notice:** Stresses above those listed under “Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS (0°C TO +85°C)

Electrical Specifications: $T_A = 0^\circ\text{C}$ to $+85^\circ\text{C}$, $V_{IN} = +5\text{V}$, $C1 = C2 = 10 \mu\text{F}$ (TCM828), $C1 = C2 = 3.3 \mu\text{F}$ (TCM829), unless otherwise noted. Typical values are at $T_A = +25^\circ\text{C}$.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Supply Current	I_{DD}	—	50	90	μA	TCM828 , $T_A = +25^\circ\text{C}$
		—	115	260	μA	TCM829 , $T_A = +25^\circ\text{C}$
Minimum Supply Voltage	V^+	1.5	—	—	V	$R_{LOAD} = 10 \text{ k}\Omega$, $T_A = 0^\circ\text{C}$ to $+85^\circ\text{C}$
Maximum Supply Voltage	V^+	—	—	5.5	V	$R_{LOAD} = 10 \text{ k}\Omega$
Oscillator Frequency	F_{OSC}	8.4	12	15.6	kHz	TCM828 , $T_A = +25^\circ\text{C}$
		24.5	35	45.5	kHz	TCM829 , $T_A = +25^\circ\text{C}$
Power Efficiency	P_{EFF}	—	96	—	%	$I_{LOAD} = 3 \text{ mA}$, $T_A = +25^\circ\text{C}$
Voltage Conversion Efficiency	V_{EFF}	95	99.9	—	%	$R_{LOAD} = \infty$
Output Resistance	R_{OUT}	—	25	50	Ω	$I_{OUT} = 5 \text{ mA}$, $T_A = +25^\circ\text{C}$
		—	—	65	Ω	$I_{OUT} = 5 \text{ mA}$, $T_A = 0^\circ\text{C}$ to $+85^\circ\text{C}$

Note 1: Capacitor contribution is approximately 20% of the output impedance [$ESR = 1/\text{pump frequency} \times \text{capacitance}$].

ELECTRICAL CHARACTERISTICS (-40°C TO +85°C)

Electrical Specifications: $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$, $V_{IN} = +5\text{V}$, $C1 = C2 = 10 \mu\text{F}$ (TCM828), $C1 = C2 = 3.3 \mu\text{F}$ (TCM829), unless otherwise noted. Typical values are at $T_A = +25^\circ\text{C}$. (**Note 1**)

Parameters	Sym	Min	Typ	Max	Units	Conditions
Supply Current	I_{DD}	—	—	115	μA	TCM828
		—	—	325	μA	TCM829
Supply Voltage Range	V^+	1.5	—	5.5	V	$R_{LOAD} = 10 \text{ k}\Omega$
Oscillator Frequency	F_{OSC}	6	—	15.6	kHz	TCM828
		19	—	45.5	kHz	TCM829
Output Resistance	R_{OUT}	—	—	65	Ω	$I_{OUT} = 5 \text{ mA}$

Note 1: All -40°C to +85°C specifications above are assured by design.

TCM828/TCM829

NOTES:

2.0 TYPICAL CHARACTERISTICS

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

Note: Circuit of Figure 5-3, $V_{IN} = +5V$, $C1 = C2 = C3$, $T_A = +25^\circ C$, unless otherwise noted.

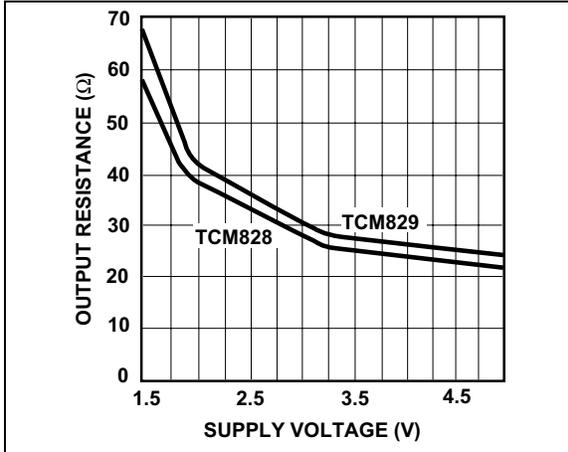


FIGURE 2-1: Output Resistance vs. Supply Voltage.

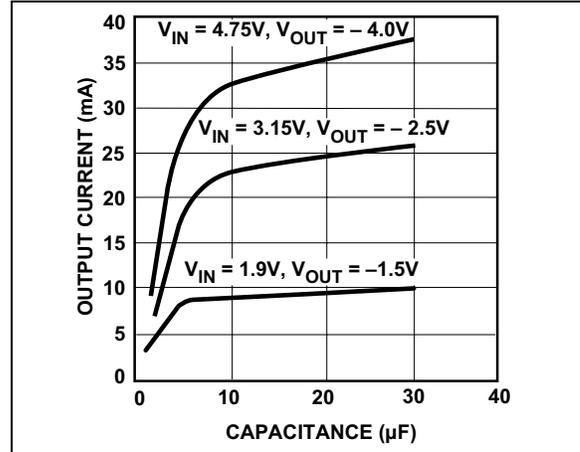


FIGURE 2-3: TCM828 – Output Current vs. Capacitance.

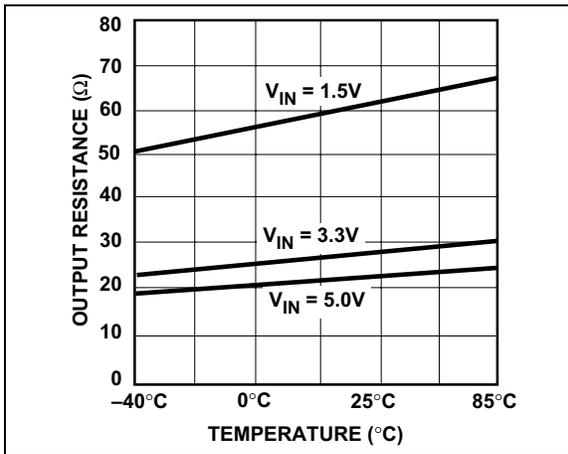


FIGURE 2-2: Output Resistance vs. Temperature.

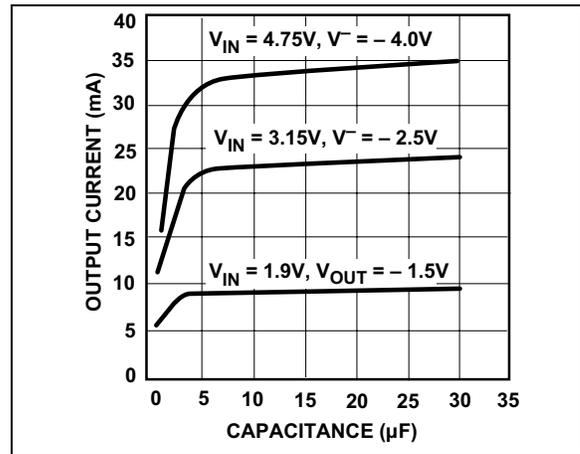


FIGURE 2-4: TCM829 – Output Current vs. Capacitance.

TCM828/TCM829

Note: Circuit of Figure 5-3, $V_{IN} = +5V$, $C1 = C2 = C3$, $T_A = +25^\circ C$, unless otherwise noted.

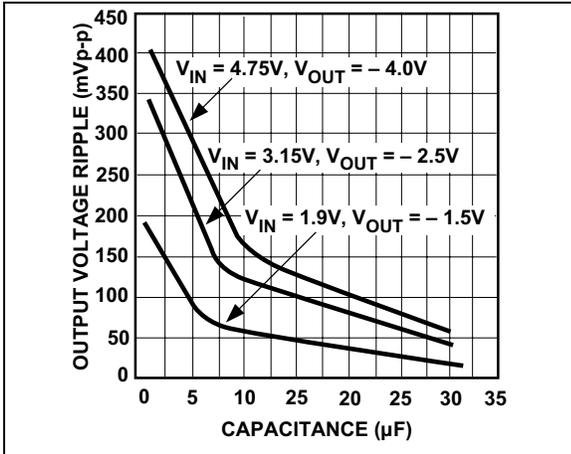


FIGURE 2-5: TCM828 – Output Voltage Ripple vs. Capacitance.

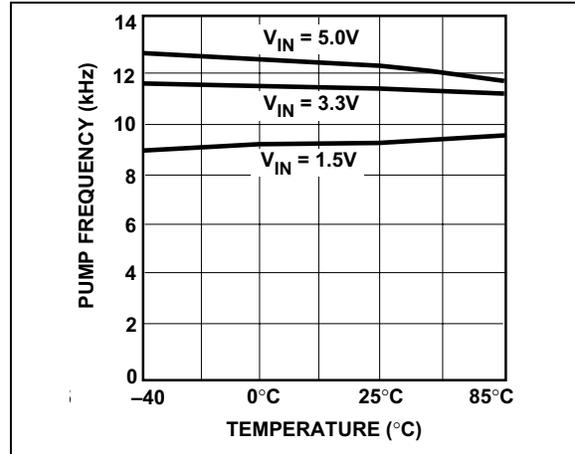


FIGURE 2-8: TCM828 – Pump Frequency vs. Temperature.

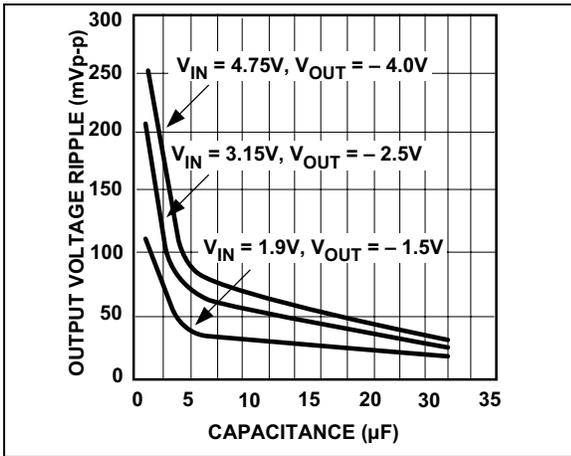


FIGURE 2-6: TCM829 – Output Voltage Ripple vs. Capacitance.

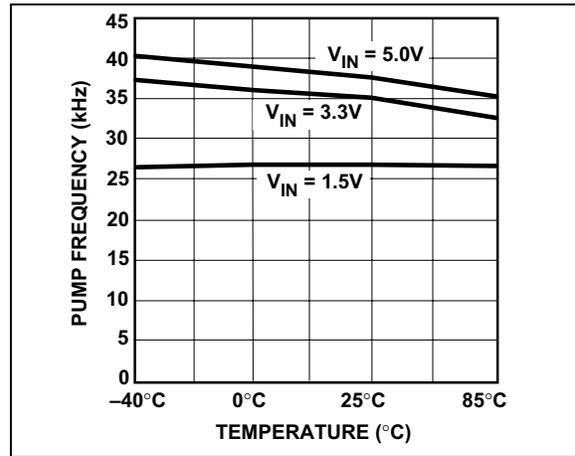


FIGURE 2-9: TCM829 – Pump Frequency vs. Temperature.

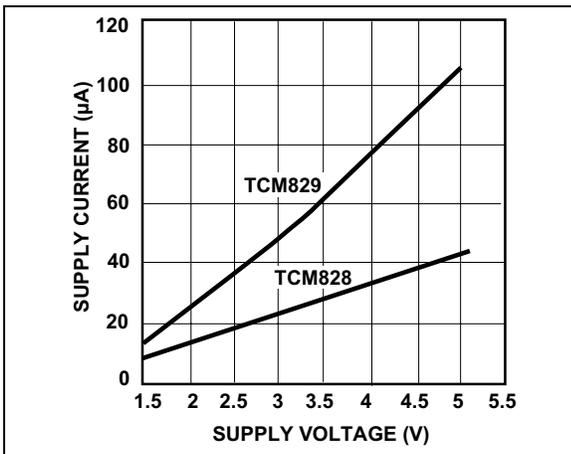


FIGURE 2-7: Supply Current vs. Supply Voltage.

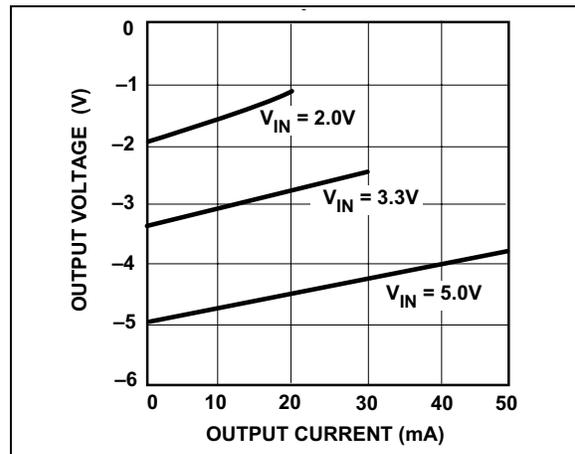


FIGURE 2-10: Output Voltage vs. Output Current.

Note: Circuit of Figure 5-3, $V_{IN} = +5V$, $C1 = C2 = C3$, $T_A = +25^\circ C$, unless otherwise noted.

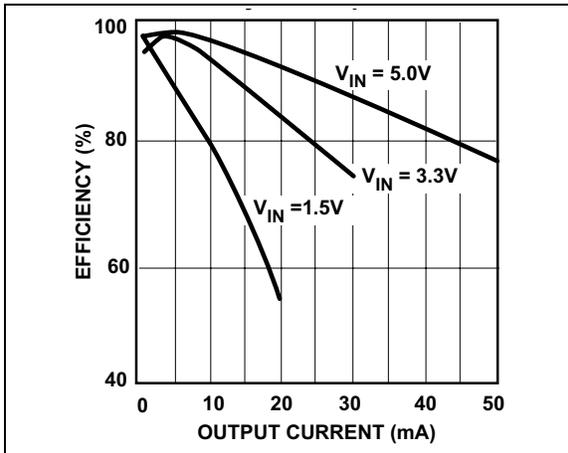


FIGURE 2-11: Efficiency vs. Output Current.

TCM828/TCM829

NOTES:

3.0 PIN DESCRIPTION

The descriptions of the pins are listed in [Table 3-1](#).

TABLE 3-1: PIN FUNCTION TABLE

TCM828/TCM829 SOT-23	Symbol	Function
1	OUT	Inverting charge pump output
2	V _{IN}	Positive power supply input
3	C ₁ ⁻	Commutation capacitor negative terminal
4	GND	Ground
5	C ₁ ⁺	Commutation capacitor positive terminal

TCM828/TCM829

NOTES:

4.0 DETAILED DESCRIPTION

The TCM828/TCM829 charge pump converters invert the voltage applied to the V_{IN} pin. Conversion consists of a two phase operation (Figure 4-1). During the first phase operation, switches S2 and S4 are open, while 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 open. This action connects C1 across C2, restoring charge to C2.

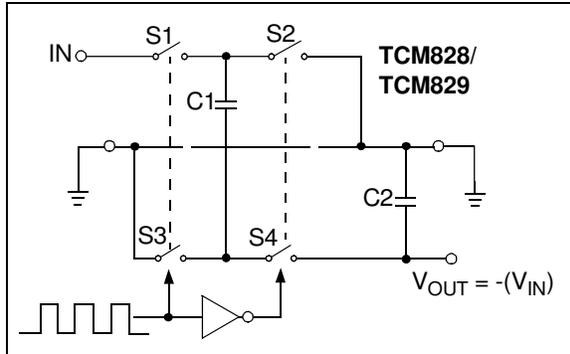


FIGURE 4-1: *Ideal Switched Capacitor Charge Pump.*

TCM828/TCM829

NOTES:

5.0 APPLICATIONS INFORMATION

5.0.1 OUTPUT VOLTAGE CONSIDERATIONS

The TCM828/TCM829 devices 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 VIN = +5V. VOUT is approximately -5V at light loads, and droops according to the equation below:

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

$$V_{OUT} = -(V_{IN} - V_{DROOP})$$

5.0.2 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. I²R 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, 3 and 4 above. These losses are shown in Equation 5-1.

EQUATION 5-1:

$$P_{LOSS(2,3,4)} = I_{OUT}^2 \times R_{OUT}$$

$$\cong I_{OUT}^2 \times \left[\frac{1}{(f_{OSC})C1} + 8R_{SWITCH} + 4ESR_{C1} + ESR_{C2} \right]$$

The 1/(f_{OSC})(C1) term in Equation 5-1 is the effective output resistance of an ideal switched capacitor circuit (Figures 5-1 and 5-2).

The losses in the circuit due to factor 4 above are also shown in Equation 5-2. The output voltage ripple is shown in Equation 5-3.

EQUATION 5-2:

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

EQUATION 5-3:

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

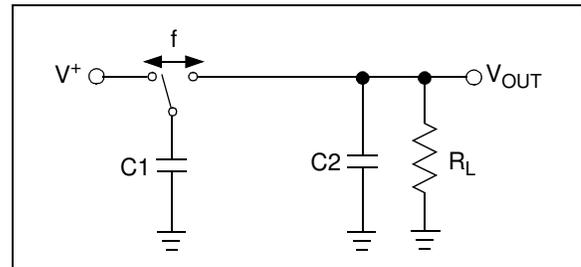


FIGURE 5-1: Ideal Switched Capacitor Model.

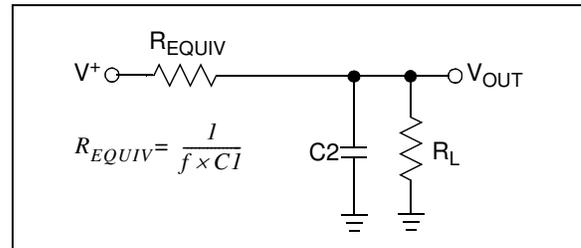


FIGURE 5-2: Equivalent Output Resistance.

TCM828/TCM829

5.0.3 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 will lower the output resistance and larger values of C2 will reduce output ripple. (See Equation 5-1).

Table 5-1 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 5-2 shows the output voltage ripple for various values of C2. The V_{RIPPLE} values assume 10 mA output load current and 0.1Ω ESR_{C2}.

TABLE 5-1: OUTPUT RESISTANCE VS. C1 (ESR = 0.1Ω)

C1 (μF)	TCM828 R _{OUT} (Ω)	TCM829 R _{OUT} (Ω)
0.1	850	302
1	100	45
3.3	42	25
10	25	19
47	18	17
100	17	17

TABLE 5-2: OUTPUT VOLTAGE RIPPLE VS. C2 (ESR = 0.1Ω) I_{OUT} 10MA

C2 (μF)	TCM828 V _{RIPPLE} (mV)	TCM829 R _{OUT} (Ω)
1	835	286
3.3	254	88
10	85	31
47	20	8
100	10	5

5.0.4 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. The recommended capacitor depends on the configuration of the TCM828/TCM829 devices.

If the device is loaded from OUT to GND, it is recommended that a large value capacitor (at least equal to C1) be connected from the input to GND. If the device is loaded from IN to OUT, a small (0.1 μF) capacitor is sufficient.

5.0.5 VOLTAGE INVERTER

The most common application for charge pump devices is the inverter (Figure 5-3). This application uses two external 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 5-1 and Table 5-1 for capacitor selection.

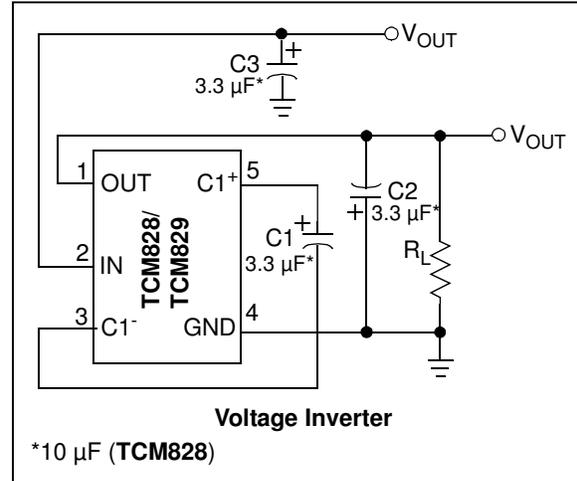


FIGURE 5-3: Test Circuit.

5.0.6 CASCADING DEVICES

Two or more TCM828/829 devices can be cascaded to increase output voltage (Table 5-4). If the output is lightly loaded, it will be close to (-2 x VIN) but will drop at least by R_{OUT} of the first device multiplied by the IQ of the second. It can be seen that the output resistance rises rapidly for multiple cascaded devices. For large negative voltage requirements see the TC682 or TCM680 data sheets.

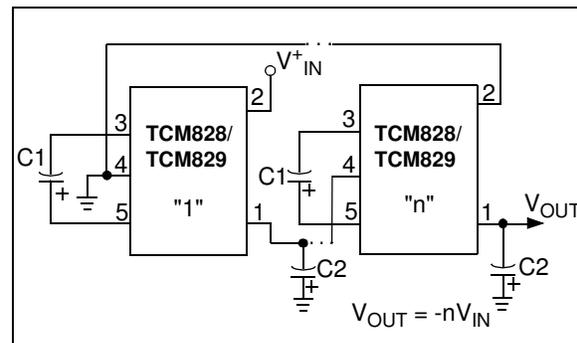


FIGURE 5-4: Cascading TCM828 or TCM829 Devices to Increase Output Voltage.

5.0.7 PARALLELING DEVICES

To reduce the value of R_{OUT} , multiple TCM828/TCM829 devices can be connected in parallel (Figure 5-5). The output resistance will be reduced by a factor of N, where N is the number of TCM828/TCM829 device. 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 TCM828/TCM829 devices.

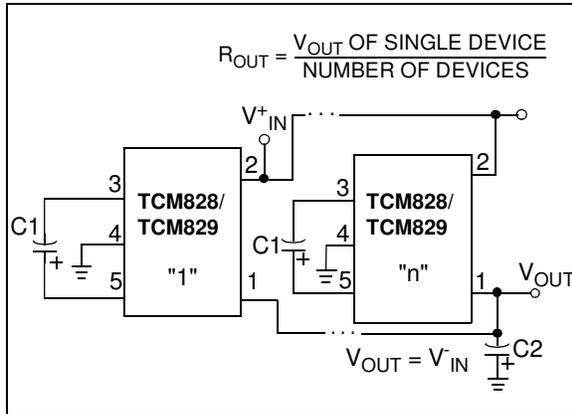


FIGURE 5-5: Paralleling TCM828 or TCM829 Devices to Reduce Output Resistance.

5.0.8 VOLTAGE DOUBLER/INVERTER

Another common application of the TCM828/TCM829 devices is shown in Figure 5-6. 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, while C2 and C4 are the reservoir capacitors. Because both sub-circuits rely on the same switches, if either output is loaded, both will drop toward GND. Make sure that the total current drawn from both the outputs does not total more than 40 mA.

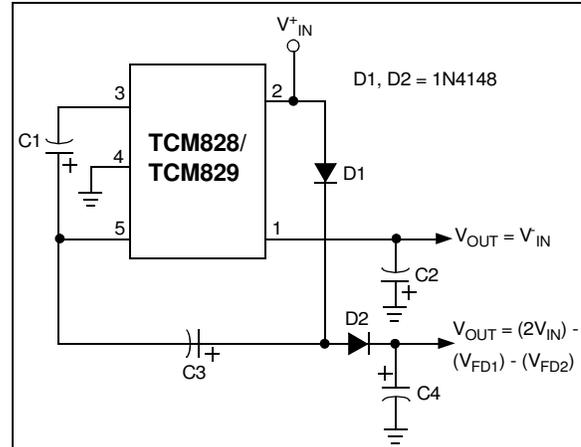


FIGURE 5-6: Combined Doubler and Inverter.

5.0.9 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 5-7.

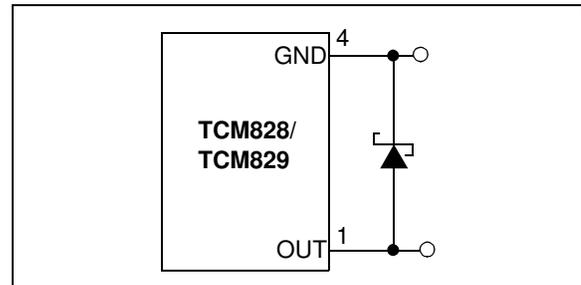


FIGURE 5-7: High V^- Load Current.

5.0.10 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.

TCM828/TCM829

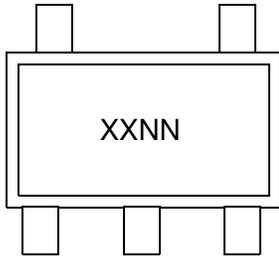
NOTES:

6.0 PACKAGING INFORMATION

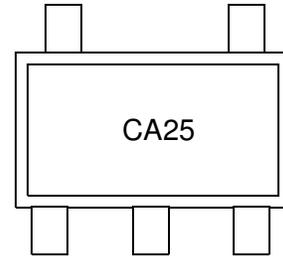
6.1 Package Marking Information

5-Lead SOT-23

Example:



Device	Code
TCM828ECT728	CANN
TCM828VT713	CWNN
TCM829ECT713-GVAO	CBNN



Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

TCM828/TCM829

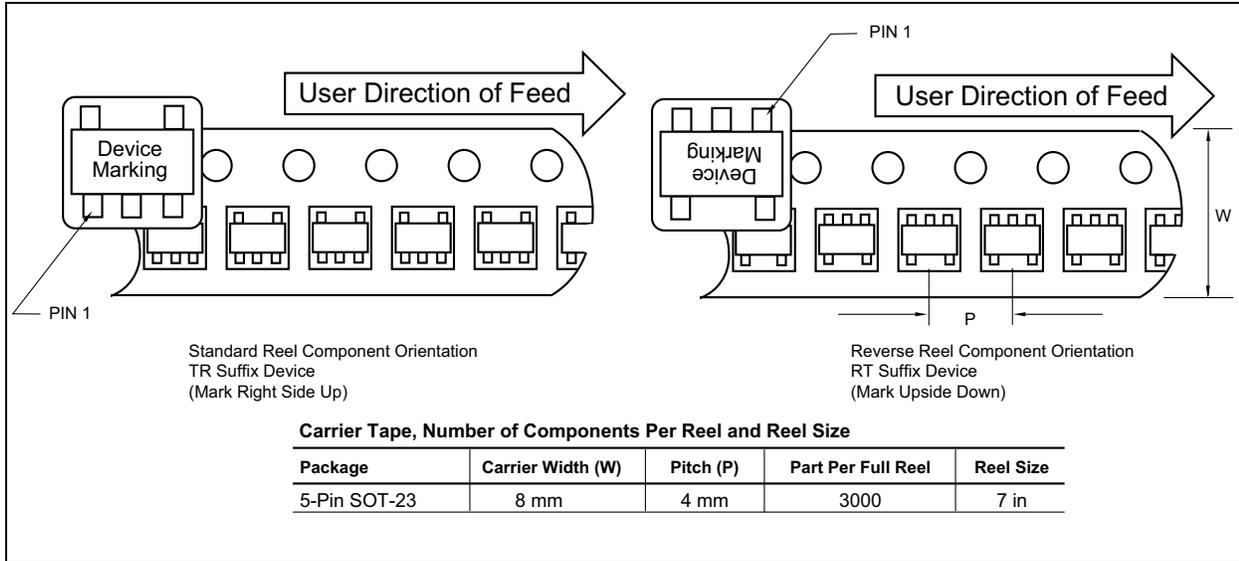
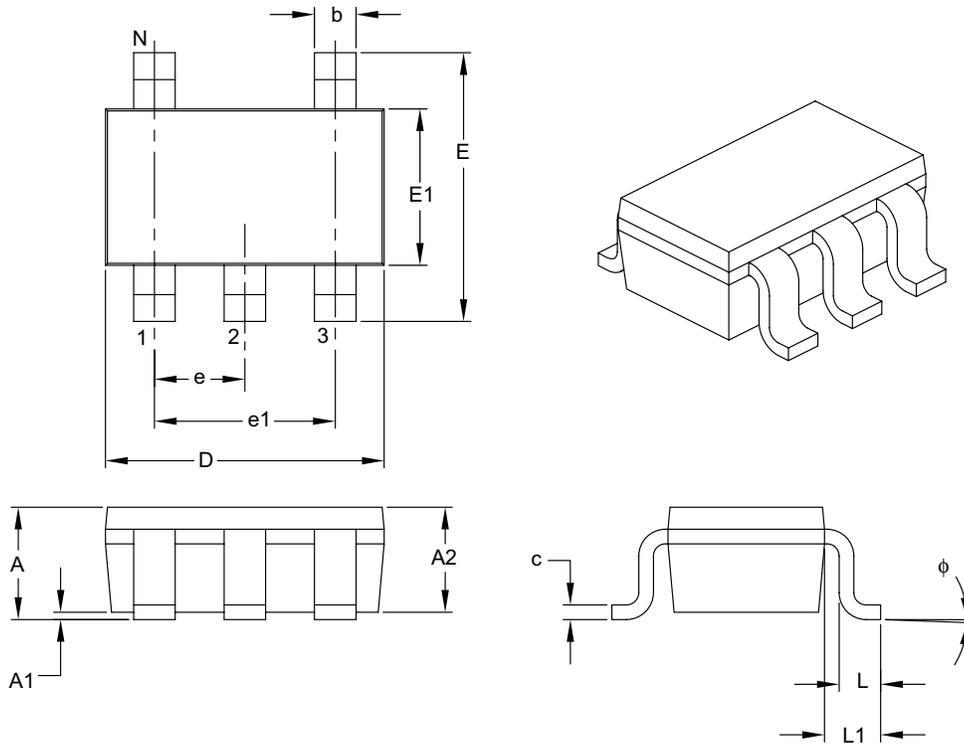


FIGURE 6-1: Component Taping Orientation for 5-Pin SOT-23 (EIAJ SC-74A) Devices.

5-Lead Plastic Small Outline Transistor (CT) [SOT-23]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Dimension Limits	Units	MILLIMETERS		
		MIN	NOM	MAX
Number of Pins	N	5		
Lead Pitch	e	0.95 BSC		
Outside Lead Pitch	e1	1.90 BSC		
Overall Height	A	0.90	–	1.45
Molded Package Thickness	A2	0.89	–	1.30
Standoff	A1	0.00	–	0.15
Overall Width	E	2.20	–	3.20
Molded Package Width	E1	1.30	–	1.80
Overall Length	D	2.70	–	3.10
Foot Length	L	0.10	–	0.60
Footprint	L1	0.35	–	0.80
Foot Angle	ϕ	0°	–	30°
Lead Thickness	c	0.08	–	0.26
Lead Width	b	0.20	–	0.51

Notes:

- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.127 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M.

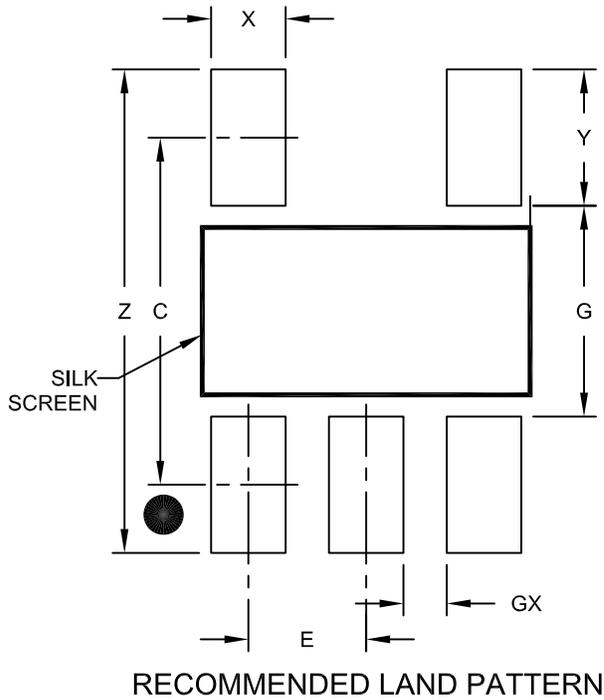
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-091B

TCM828/TCM829

5-Lead Plastic Small Outline Transistor (CT) [SOT-23]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Dimension	Units	MILLIMETERS		
		MIN	NOM	MAX
Contact Pitch	E	0.95 BSC		
Contact Pad Spacing	C		2.80	
Contact Pad Width (X5)	X			0.60
Contact Pad Length (X5)	Y			1.10
Distance Between Pads	G	1.70		
Distance Between Pads	GX	0.35		
Overall Width	Z			3.90

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2091A

APPENDIX A: REVISION HISTORY

Revision B (August 2010)

The following is the list of modifications:

1. Added new operating temperature for TCM828 (TCM828VT).
2. Reformatted the original document.
3. Updated package drawings.

Revision A (March 2001)

- Original Release of this Document.

TCM828/TCM829

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

<u>PART NO.</u>	<u>X</u>	<u>/XX</u>
Device	Temperature Range	Package
Device:	TCM828: CMOS Voltage Converter. TCM829: CMOS Voltage Converter.	
Temperature Range:	E = -40°C to +85°C V = -40°C to +125°C	
Package:	CT = 5-Lead Plastic Small Outline Transistor, SOT-23.	

Examples:

- a) TCM828ECT728: Extended Temp., 5-LD SOT-23 Package.
- b) TCM828VT713: Various Temperature 5-LD SOT-23 Package.
- c) TCM829ECT713-GVAO: Extended Temp., 5-LD SOT-23 Package.

TCM828/TCM829

NOTES:

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
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