TCM828
TCM829

Switched Capacitor Voltage Converters

FEATURES

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

APPLICATIONS

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

GENERAL DESCRIPTION

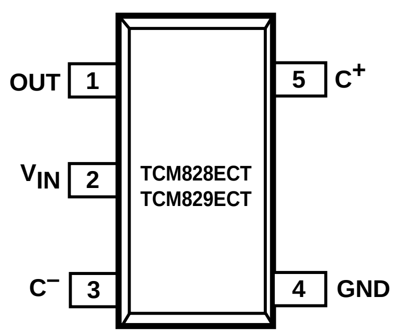
The TCM828/829 are CMOS “charge-pump” voltage converters in ultra-small 5-Pin SOT-23A packages. They invert and/or double an input voltage which can range from +1.5V to +5.5V. Conversion efficiency is typically >95%. Switching frequency is 12kHz for the TCM828 and 35kHz for the TCM829.

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

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

PIN CONFIGURATION

***5-Pin SOT-23A**



NOTE: *5-Pin SOT-23A is equivalent to EIAJ SC-74A

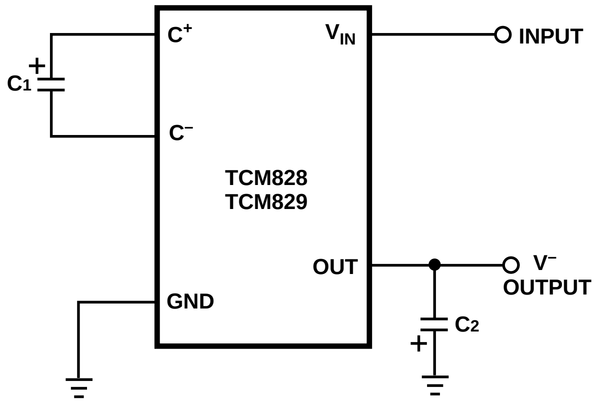
ORDERING INFORMATION

Part No.	Package	Temp. Range
TCM828ECT	5-Pin SOT-23A	– 40°C to +85°C
TCM829ECT	5-Pin SOT-23A	– 40°C to +85°C

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

TYPICAL OPERATING CIRCUIT

Voltage Inverter



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 50mA
Short-Circuit Duration – OUT to GND .... Indefinite
Operating Temperature Range .... – 40°C to +85°C
Power Dissipation ($T_A \leq 70°C$)
5-Pin SOT-23A 240mW
Storage Temperature (Unbiased) .... – 65°C to +150°C
Lead Temperature (Soldering, 10 sec) .... +300°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 = 0°C to +85°C, V_{IN} = +5V, C1 = C2 = 10µF (TCM828), C1 = C2 = 3.3µF (TCM829), unless otherwise noted. Typical values are at T_A = +25°C.

Symbol	Parameter	Device	Test Conditions	Min	Typ	Max	Unit
I_{DD}	Supply Current	TCM828 TCM829	T_A = +25°C	— —	50 115	90 260	µA
V^+	Minimum Supply Voltage		R_{LOAD} = 10kΩ: T_A = 0°C to +85°C	1.5	—	—	V
V^+	Maximum Supply Voltage		R_{LOAD} = 10kΩ	—	—	5.5	V
F_{OSC}	Oscillator Frequency	TCM828 TCM829	T_A = +25°C	8.4 24.5	12 35	15.6 45.5	kHz
P_{EFF}	Power Efficiency		I_{LOAD} = 3mA, T_A = +25°C	—	96	—	%
V_{EFF}	Voltage Conversion Efficiency		R_{LOAD} = ∞	95	99.9	—	%
R_{OUT}	Output Resistance		I_{OUT} = 5mA, T_A = 25°C T_A = 0°C to +85°C	— —	25 —	50 65	Ω

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

ELECTRICAL CHARACTERISTICS: T_A = – 40°C to +85°C, V_{IN} = +5V, C1 = C2 = 10µF (TCM828), C1 = C2 = 3.3µF (TCM829) unless otherwise noted. Typical values are at T_A = +25°C. (Note 2)

Symbol	Parameter	Device	Test Conditions	Min	Typ	Max	Unit
I_{DD}	Supply Current	TCM828 TCM829		— —	— —	115 325	µA
V^+	Supply Voltage Range		R_{LOAD} = 10kΩ	1.5	—	5.5	V
F_{OSC}	Oscillator Frequency	TCM828 TCM829		6 19	— —	20 54.3	kHz
R_{OUT}	Output Resistance		I_{OUT} = 5mA	—	—	65	Ω

NOTE: 2. All – 40°C to +85°C specifications above are guaranteed by design.

PIN DESCRIPTION

Pin No. (5-Pin SOT-23A)	Symbol	Description
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.

DETAILED DESCRIPTION

The TCM828/829 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 open 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 open. This action connects C1 across C2, restoring charge to C2.

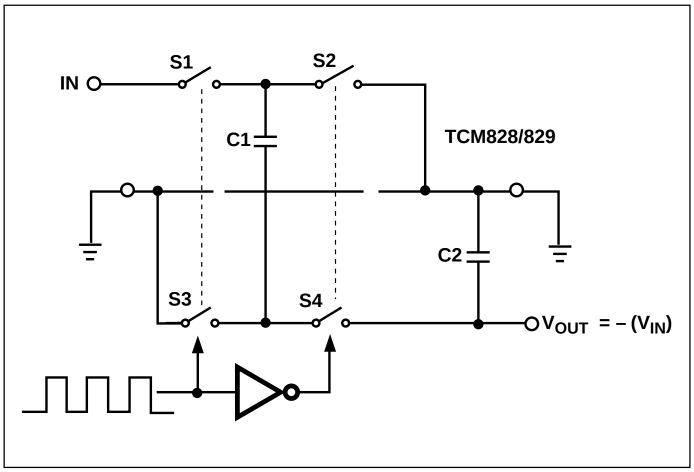


Figure 1. Ideal Switched Capacitor Charge Pump

APPLICATIONS INFORMATION

Output Voltage Considerations

The TCM828/829 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:

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

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), (3) and (4) above. These losses are given by Equation 1.

$$P_{LOSS\,(2,\,3,\,4)} = I_{OUT}^2 \times R_{OUT}$$
$$\cong I_{OUT}^2 \times \left[\frac{1}{(f_{OSC})\,C1} + 8R_{SWITCH} + 4ESR_{C1} + ESR_{C2}\right]$$

Equation 1.

The $1/(f_{OSC})(C1)$ term in Equation 1 is the effective output resistance of an ideal switched capacitor circuit (Figures 2a, 2b).

The losses in the circuit due to factor (4) above are also 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.

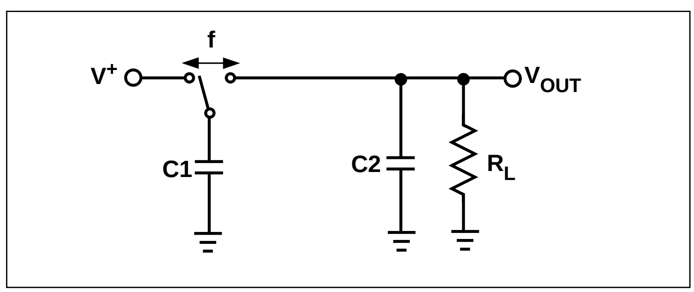


Figure 2a. Ideal Switched Capacitor Model

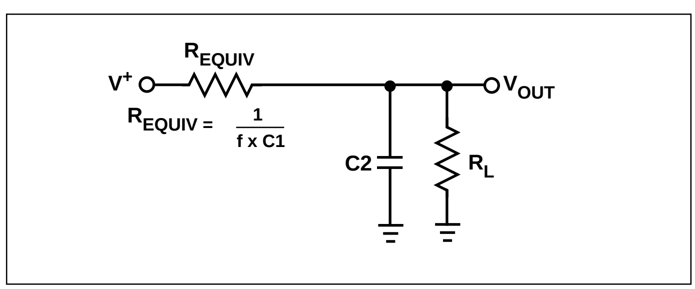


Figure 2b. Equivalent Output Resistance

Capacitor Selection

In order to maintain the lowest output resistance and output 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 1(b)).

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

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

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 TCM828/829.

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 (0.1µF) capacitor from IN to OUT is sufficient.

Voltage Inverter

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

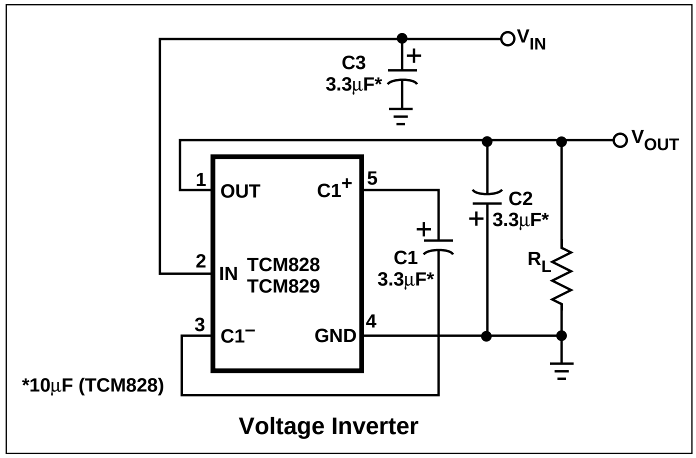


Figure 3. Test Circuit

Cascading Devices

Two or more TCM828/829's 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. For large negative voltage requirements see the TC682 or TCM680 data sheets.

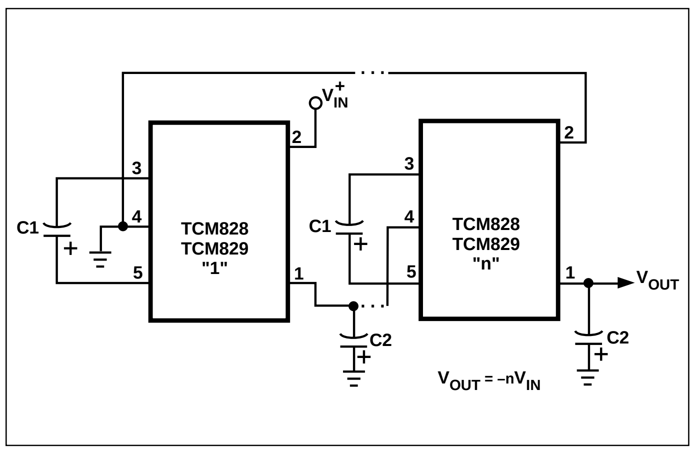


Figure 4. Cascading TCM828s or TCM829s to Increase Output Voltage

Paralleling Devices

To reduce the value of R_{OUT}, multiple TCM828/829s can be connected in parallel (Figure 5). The output resistance will be reduced by a factor of N where N is the number of TCM828/829's. Each device will require it's 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 TCM828/829's.

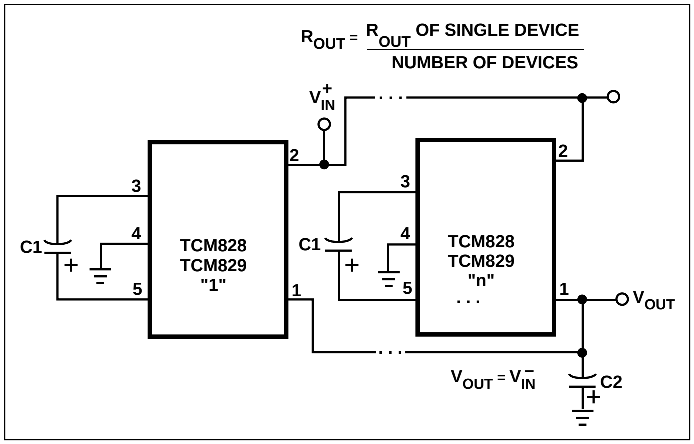


Figure 5. Paralleling TCM828s or TCM829s to Reduce Output Resistance

Voltage Doubler/Inverter

Another common application of the TCM828/829 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 40mA.

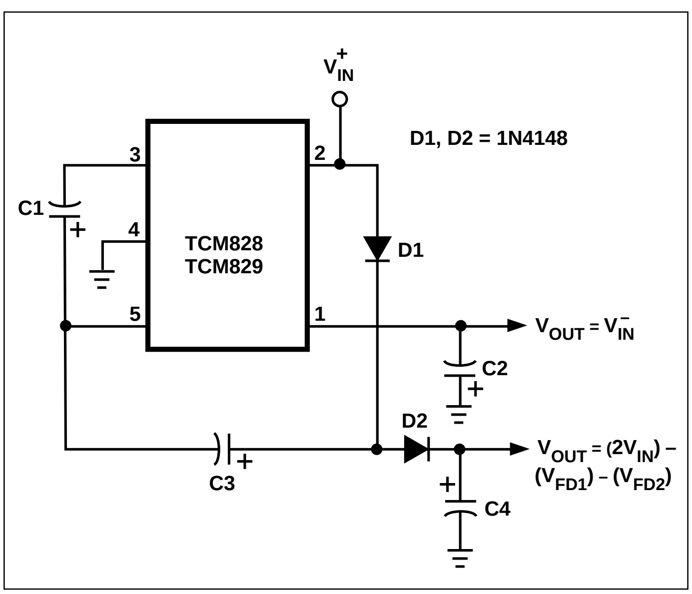


Figure 6. Combined Doubler and Inverter

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.

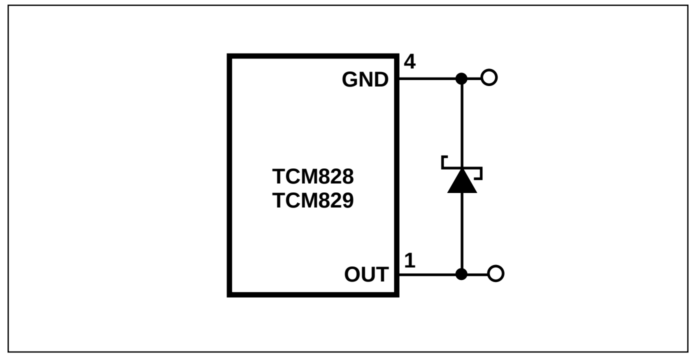


Figure 7. High V^- Load Current

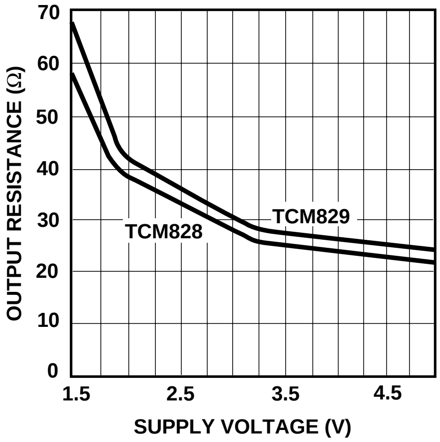
Layout Considerations

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.

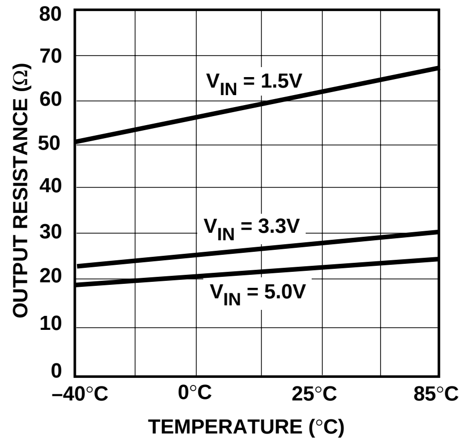
TYPICAL CHARACTERISTICS

Circuit of Figure 3, V_{IN} = +5V, C1 = C2 = C3, T_A = +25°C, unless otherwise noted.

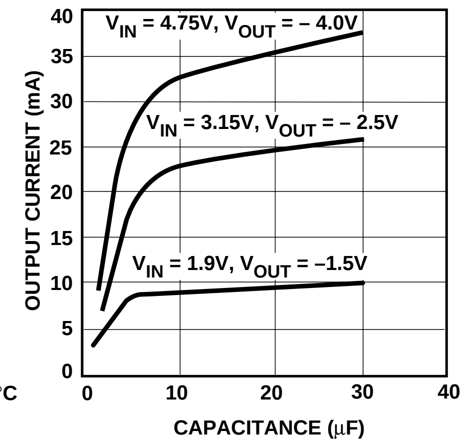
Output Resistance vs. Supply Voltage



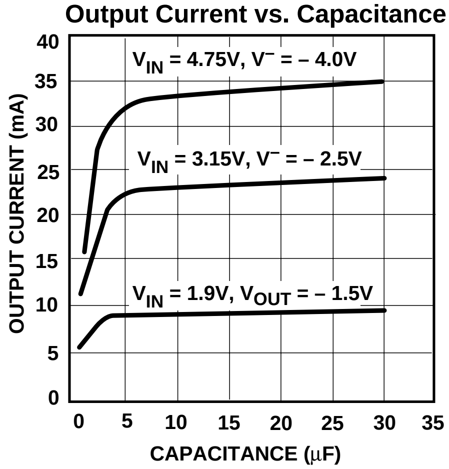
Output Resistance vs. Temperature



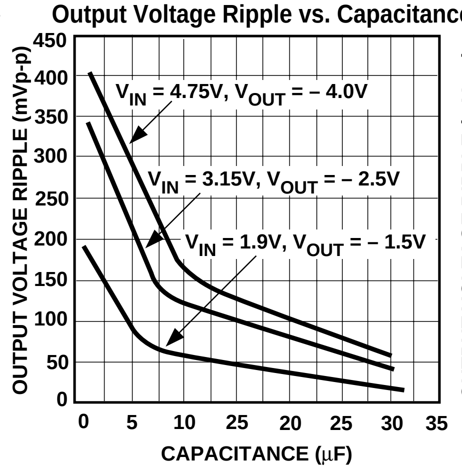
TCM828 Output Current vs. Capacitance



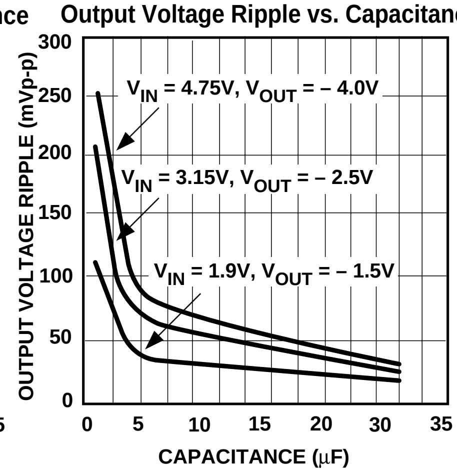
TCM829 Output Current vs. Capacitance



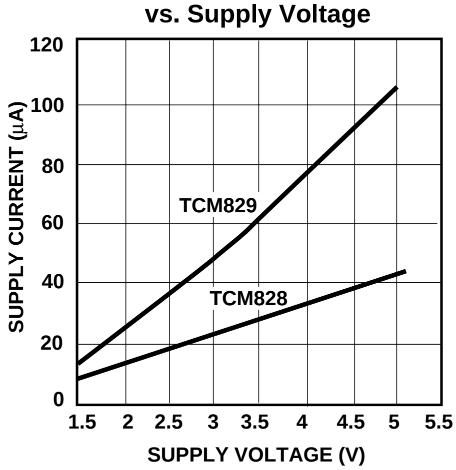
TCM828 Output Voltage Ripple vs. Capacitance



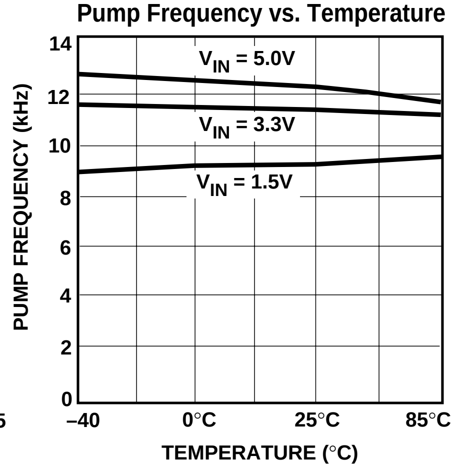
TCM829 Output Voltage Ripple vs. Capacitance



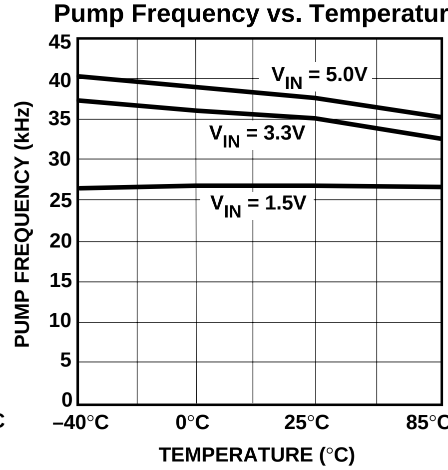
Supply Current vs. Supply Voltage



TCM828 Pump Frequency vs. Temperature



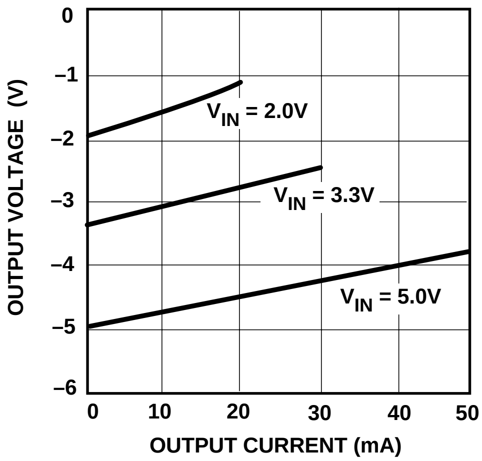
TCM829 Pump Frequency vs. Temperature



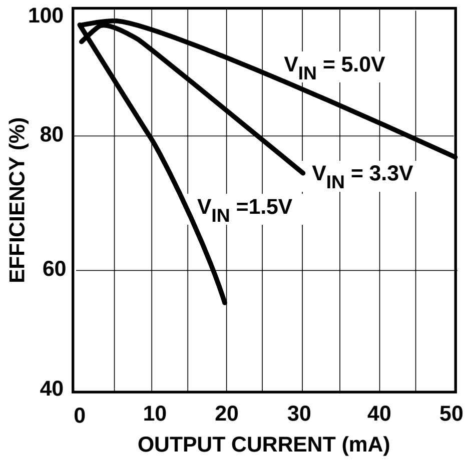
TYPICAL CHARACTERISTICS (Cont.)

Circuit of Figure 3, V_{IN} = +5V, C1 = C2 = C3, T_A = +25°C, unless otherwise noted.

Output Voltage vs. Output Current

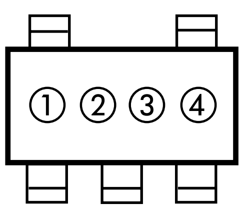


Efficiency vs. Output Current



MARKING

5-PIN SOT-23A



Part Numbers and Part Marking

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

TCM828/829	Code
TCM828ECT	CA
TCM829ECT	CB

ex: TCM828ECT = Ⓒ Ⓐ ◯ ◯

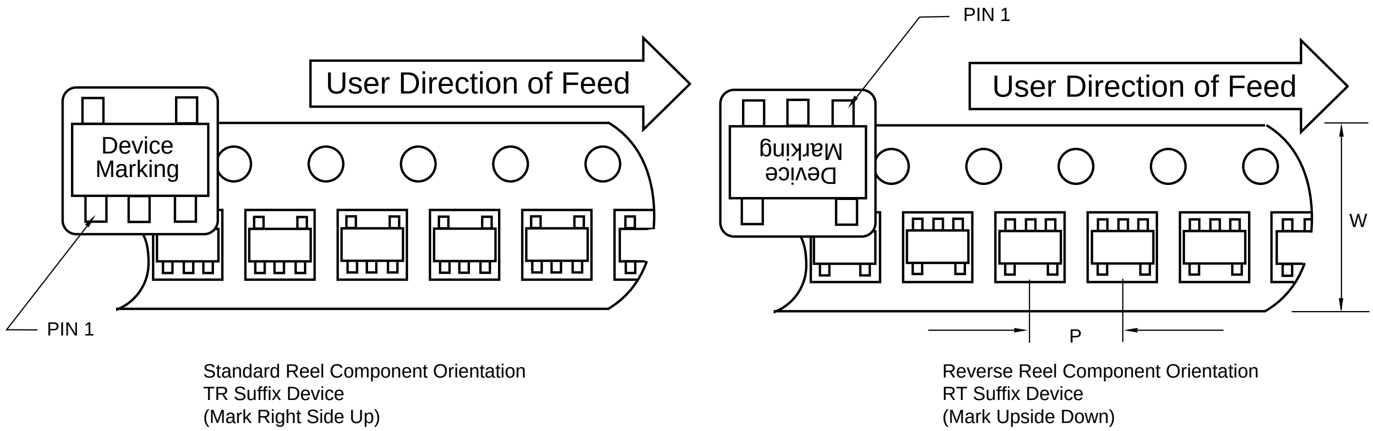
③ represents year and quarter code

④ represents lot ID number

TCM828
TCM829

TAPING FORM

Component Taping Orientation for 5-Pin SOT-23A (EIAJ SC-74A) Devices

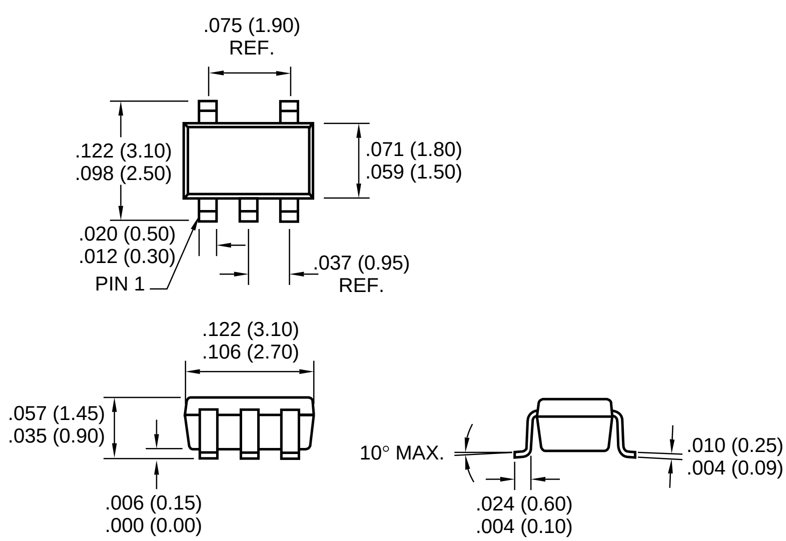


Carrier Tape, Number of Components Per Reel and Reel Size

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

PACKAGE DIMENSIONS

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



Dimensions: inches (mm)

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