TC1240/TC1240A

Positive Doubling Charge Pumps with Shutdown in a SOT-23 Package

Features

- Charge Pumps in 6-Pin SOT-23A Package
- >99% Typical Voltage Conversion Efficiency
- Voltage Doubling
- Input Voltage Range, TC1240: +2.5V to +4.0V, TC1240A: +2.5V to +5.5V
- Low Output Resistance, TC1240: 17Ω (Typical) TC1240A: 12Ω (Typical)
- Only Two External Capacitors Required
- Low Supply Current, TC1240: 180µA (Typical) TC1240A: 550µA (Typical)
- Power-Saving Shutdown Mode (1µA Maximum)
- Shutdown Input Fully Compatible with 1.8V Logic Systems

Applications

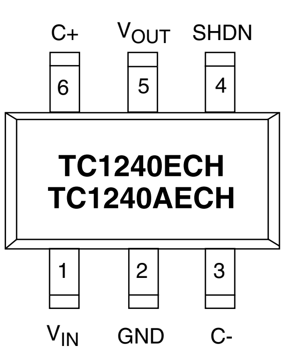
- Cellular Phones
- Pagers
- PDAs, Portable Data Loggers
- Battery Powered Devices
- Handheld Instruments

Device Selection Table

Part Number	Package	Temperature Range
TC1240ECH	6-Pin SOT-23A	-40°C to +85°C
TC1240AECH	6-Pin SOT-23A	-40°C to +85°C

Package Type

6-Pin SOT-23A



NOTE: 6-Pin SOT-23A is equivalent to the EIAJ (SC-74A)

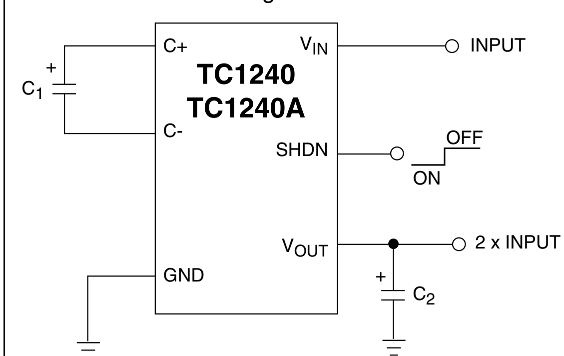
General Description

The TC1240 and TC1240A are doubling CMOS charge pump voltage converters in a small 6-Pin SOT-23A package. The TC1240 doubles an input voltage which can range from +2.5V to +4.0V and the TC1240A doubles an input voltage which can range from +2.5V to +5.5V. Conversion efficiency is typically >99%. Internal oscillator frequency is 160kHz for both devices. The TC1240 and TC1240A have an active high shutdown which limits the current consumption of the devices to less than 1µA.

External component requirement is only two capacitors for standard voltage doubler applications. All other circuitry, including control, oscillator and power MOSFETs, is integrated on-chip. Typical supply current is 180µA for the TC1240 and 550µA for the TC1240A. Both devices are available in a 6-Pin SOT-23A surface mount package.

Typical Application Circuit

Positive Voltage Doubler



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings*

Input Voltage (V_{IN} to GND)
TC1240 .... +4.5V, -0.3V
TC1240A .... +5.8V, -0.3V
Output Voltage (V_{OUT} to GND)
TC1240 .... +9.0V, V_{IN} -0.3V
TC1240A .... +11.6V, V_{IN} -0.3V
Current at V_{OUT} Pin..50mA
Short-Circuit Duration: V_{OUT} to GND ....Indefinite
Thermal Resistance ....210°C/W
Power Dissipation (T_A = +25°C).........................600mW
Operating Temperature Range.............-40°C to +85°C
Storage Temperature (Unbiased) ....-65°C to +150°C

*Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operation sections of the specifications is not implied. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability.

TC1240 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: Typical values apply at T_A = +25°C. Minimum and maximum values apply for T_A = -40° to +85°C, and V_{IN} = +2.8V, C1 = C2 = 3.3µF, SHDN = GND, unless otherwise specified.

Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
I_{DD}	Supply Current	—	180	300	µA	$R_{LOAD} = \infty$
I_{SHDN}	Shutdown Supply Current	—	0.1	1.0	µA	SHDN = V_{IN}
V_{MIN}	Minimum Supply Voltage	2.5	—	—	V	R_{LOAD} = 1.0KΩ
V_{MAX}	Maximum Supply Voltage	—	—	5.5	V	R_{LOAD} = 1.0KΩ
F_{OSC}	Oscillator Frequency	—	160	—	kHz	T_A = -40°C to +85°C
F_{SW}	Switching Frequency **(Note 1)**	40	80	125	kHz	T_A = -40°C to +85°C
V_{IH}	Shutdown Input Logic High	1.4	—	—	V	$V_{IN} = V_{MIN}$ to V_{MAX}
V_{IL}	Shutdown Input Logic Low	—	—	0.4	V	$V_{IN} = V_{MIN}$ to V_{MAX}
P_{EFF}	Power Efficiency	86	93	—	%	R_{LOAD} = 1.0KΩ
V_{EFF}	Voltage Conversion Efficiency	97.5	99.96	—	%	$R_{LOAD} = \infty$
R_{OUT}	Output Resistance **(Note 2)**	— —	17 —	— 30	Ω	R_{LOAD} = 1.0KΩ T_A = -40°C to +85°C

Note 1: Switching frequency is one-half internal oscillator frequency.
2: Capacitor contribution is approximately 26% of the output impedance [ESR = 1 / pump frequency x capacitance].

TC1240A ELECTRICAL SPECIFICATIONS

Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
Electrical Characteristics: Typical values apply at T_A = +25°C. Minimum and maximum values apply for T_A = -40° to +85°C, and V_{IN} = +2.8V, C1 = C2 = 3.3µF, SHDN = GND, unless otherwise specified.						
I_{DD}	Supply Current	—	550	900	µA	$R_{LOAD} = \infty$
I_{SHDN}	Shutdown Supply Current	—	0.01	1.0	µA	SHDN = V_{IN}
V_{MIN}	Minimum Supply Voltage	2.5	—	—	V	
V_{MAX}	Maximum Supply Voltage	—	—	5.5	V	
I_{LOAD}	Ouput Current	20	—	—	mA	
R_{SW}	Sum of the $R_{DS(ON)}$ of the Internal MOSFET Switches	—	4	8	Ω	I_{LOAD} = 20mA
F_{OSC}	Oscillator Frequency	—	160	—	kHz	T_A = -40°C to +85°C
F_{SW}	Switching Frequency **(Note 1)**	40	80	125	kHz	T_A = -40°C to +85°C
V_{IH}	Shutdown Input Logic High	1.4	—	—	V	$V_{IN} = V_{MIN}$ to V_{MAX}
V_{IL}	Shutdown Input Logic Low	—	—	0.4	V	$V_{IN} = V_{MIN}$ to V_{MAX}
P_{EFF}	Power Efficiency	86	94	—	%	I_{LOAD} = 5mA
V_{EFF}	Voltage Conversion Efficiency	99	99.96	—	%	$R_{LOAD} = \infty$
R_{OUT}	Output Resistance **(Note 2)**	— —	12 —	— 25	Ω	I_{LOAD} = 20mA T_A = -40°C to +85°C

Note 1: Switching frequency is one-half internal oscillator frequency.
2: Capacitor contribution is approximately 26% of the output impedance [ESR = 1 / pump frequency x capacitance].

2.0 PIN DESCRIPTION

The description of the pins are listed in Table 2-1.

TABLE 2-1: PIN FUNCTION TABLE

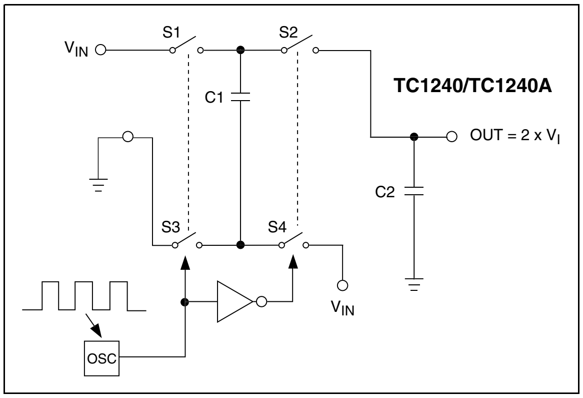
Pin No. (6-Pin SOT-23A)	Symbol	Description
1	V_{IN}	Power supply input.
2	GND	Ground.
3	C-	Commutation capacitor negative terminal.
4	SHDN	Shutdown input (active high).
5	V_{OUT}	Doubled output voltage.
6	C+	Commutation capacitor positive terminal.

3.0 DETAILED DESCRIPTION

The TC1240 and TC1240A charge pump converters double the voltage applied to the V_{IN} pin. Conversion consists of a two-phase operation (Figure 3-1). 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.

During this second phase, C1 is level shifted upward by V_{IN} volts. This connects C1 to the reservoir capacitor C2, allowing energy to be delivered to the output as needed. The actual voltage is slightly lower than 2 x V_{IN} since the four switches (S1-S4) have a non-resistance and the load drains charge from reservoir capacitor C2.

FIGURE 3-1: IDEAL SWITCHED CAPACITOR CHARGE PUMP DOUBLER



4.0 TYPICAL APPLICATIONS

4.1 Output Voltage Considerations

The TC1240 and TC1240A perform voltage doubling 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 12Ω nominal at +25°C and V_{IN} = +5.0V for the TC1240A and 17Ω nominal at +25°C and V_{IN} = +2.8V for the TC1240. V_{OUT} is approximately +10.0V at light loads for the TC1240A and +5.6V for the TC1240, and droops according to the equation below:

$V_{DROOP} = I_{OUT} \times R_{OUT}$
$V_{OUT} = 2 \times V_{IN} - V_{DROOP}$

4.2 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. 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 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 4-1(b).

EQUATION 4-1:

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

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

The pump frequency in Equation 4-1(b) is defined as one-half the oscillator frequency (i.e., $f_{FSW} = F_{OSC}/2$). The $1/(f_{FSW})(C1)$ term in Equation 4-1(b) is the effective output resistance of an ideal switched capacitor circuit (Figure 4-1 and Figure 4-2).

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

EQUATION 4-2:

$$P_{LOSS(4)} = \left[(0.5)(C1)(V_{IN}^2 - V_{OUT}^2) + (0.5)(C_2)(V_{RIPPLE}^2 - 2V_{OUT}\,V_{RIPPLE})\right] \times f_{OSC}$$

EQUATION 4-3:

$$V_{RIPPLE} = [I_{OUT} / 2 \times (f_{OSC})(C2)] + 2(I_{OUT})(ESR_{C2})$$

FIGURE 4-1: IDEAL SWITCHED CAPACITOR MODEL

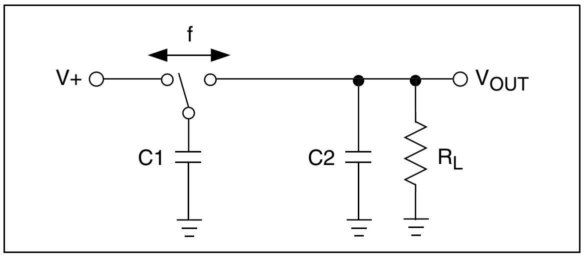
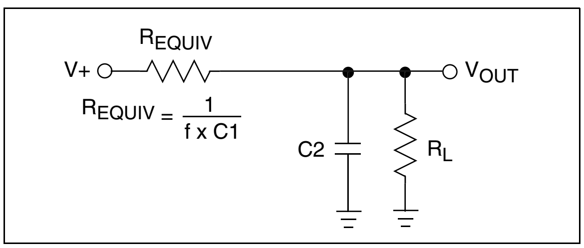


FIGURE 4-2: EQUIVALENT OUTPUT RESISTANCE



4.3 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 4-1(b)).

Table 4-1 shows various values of C1 and the corresponding output resistance values @ +25°C. It assumes a 0.1Ω ESR_{C1} and 0.9Ω R_{SW}. Table 4-2 shows the output voltage ripple for various values of C2. The V_{RIPPLE} values assume 5mA output load current and 0.1Ω ESR_{C2}.

TABLE 4-1: OUTPUT RESISTANCE VS. C1 (ESR = 0.1Ω)

C1 (µF)	TC1240 R_{OUT}(Ω)	TC1240A R_{OUT}(Ω)
0.47	47	35
1	28.5	20.5
2.2	19.5	14
3.3	17	12
4.7	15.5	10.5
10	13.6	9.3
47	12.5	8.3
100	12.2	8.1

TABLE 4-2: OUTPUT VOLTAGE RIPPLE VS. C2 (ESR = 0.1Ω) I_{OUT} 5mA

C1 (µF)	TC1240/TC1240A V_{RIPPLE} (mV)
0.47	142
1	67
2.2	30
3.3	20
4.7	14
10	6.7
47	2.5
100	1.6

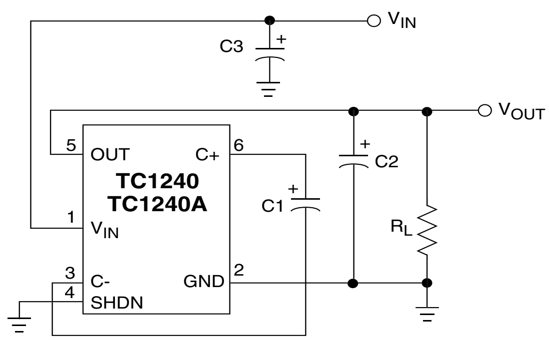
4.4 Input Supply Bypassing

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 should be a large value (at least equal to C1) connected from the input to GND.

4.5 Shutdown Input

The TC1240 and TC1240A are disabled when SHDN is high, and enabled when SHDN is low. This input cannot be allowed to float.

FIGURE 4-3: TEST CIRCUIT



Device	C1	C2	C3
TC1240/A	3.3µF	3.3µF	3.3µF

4.6 Voltage Doubler

The most common application for charge pump devices is the doubler (Figure 4-3). This application uses two external capacitors – C1 and C2 (plus a power supply bypass capacitor, if necessary). The output is equal to 2 x V_{IN} minus any voltage drops due to loading. Refer to Table 4-1 and Table 4-2 for capacitor selection.

4.7 Cascading Devices

Two or more TC1240s or TC1240As can be cascaded to increase output voltage (Figure 4-4). If the output is lightly loaded, it will be close to ((n + 1) 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 the case of the two-stage 'tripler' output resistance can be approximated as $R_{OUT} = 2 \times R_{OUT1} + R_{OUT2}$, where R_{OUT1} is the output resistance of the first stage, and R_{OUT2} is the output resistance of the second stage.

4.8 Paralleling Devices

To reduce the value of R_{OUT}, multiple TC1240s or TC1240As can be connected in parallel (Figure 4-5). The output resistance will be reduced by a factor of N where N is the number of TC1240s or TC1240As. Each device will require its own pump capacitor (C1x), 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 paralled TC1240s or TC1240As, respectively.

4.9 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.

FIGURE 4-4: CASCADING MULTIPLE DEVICES TO INCREASE OUTPUT VOLTAGE

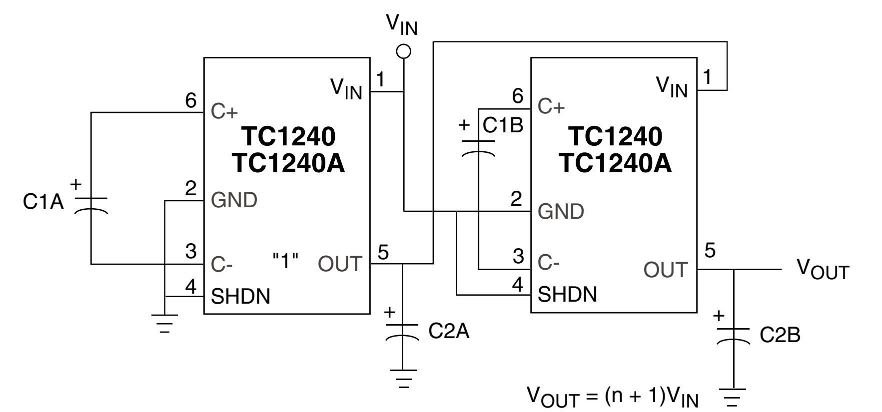
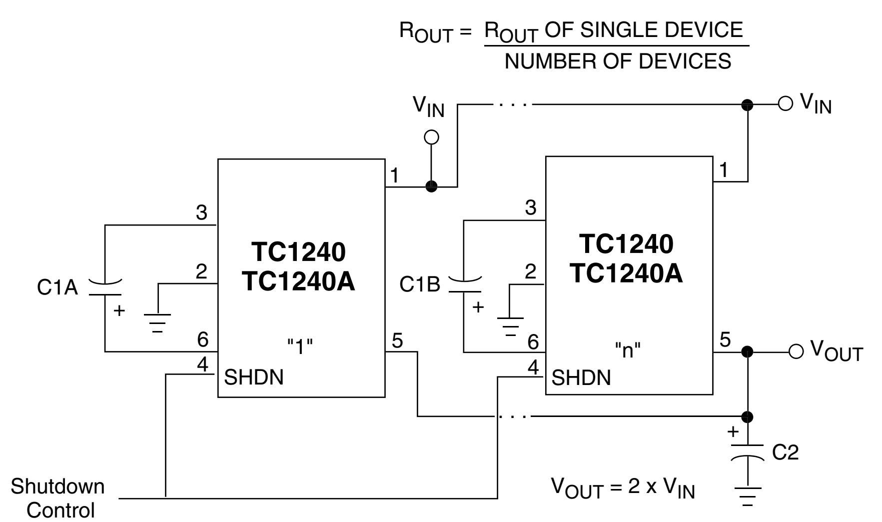
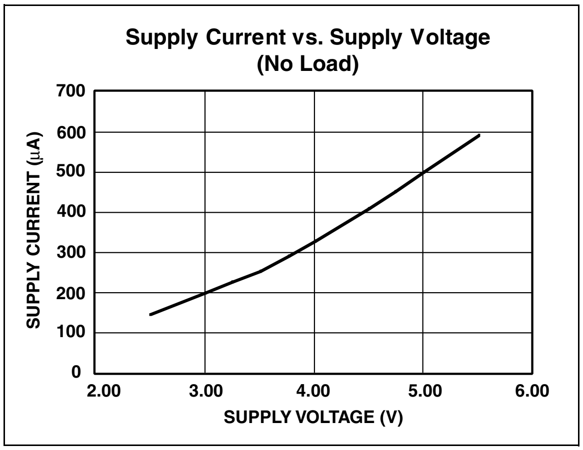


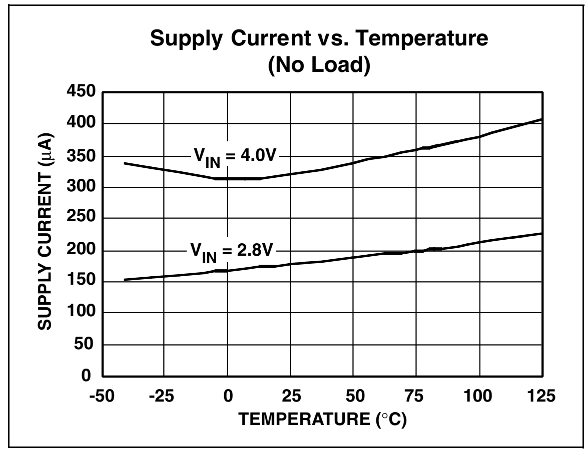
FIGURE 4-5: PARALLELING MULTIPLE DEVICES TO REDUCE OUTPUT RESISTANCE

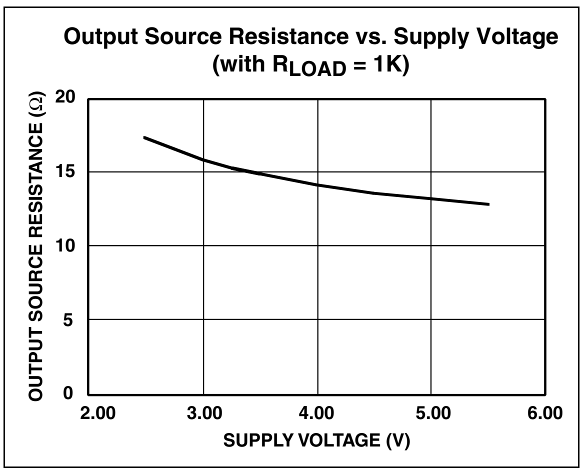


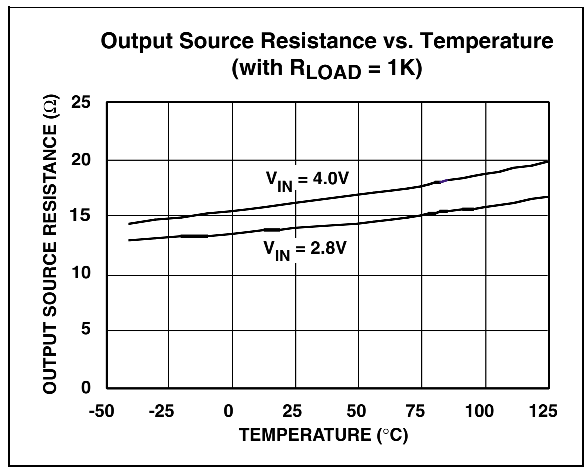
5.0 TYPICAL CHARACTERISTICS

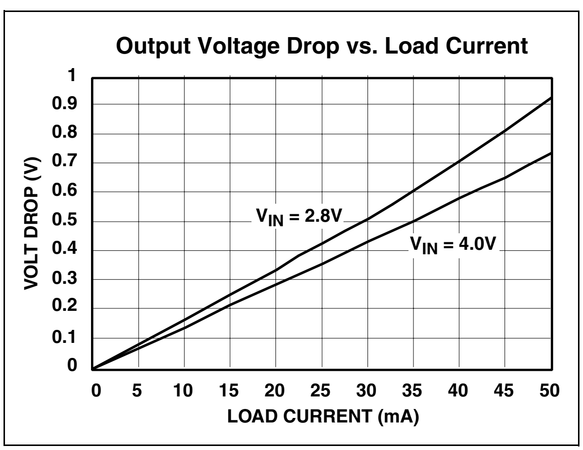
Note:	The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside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

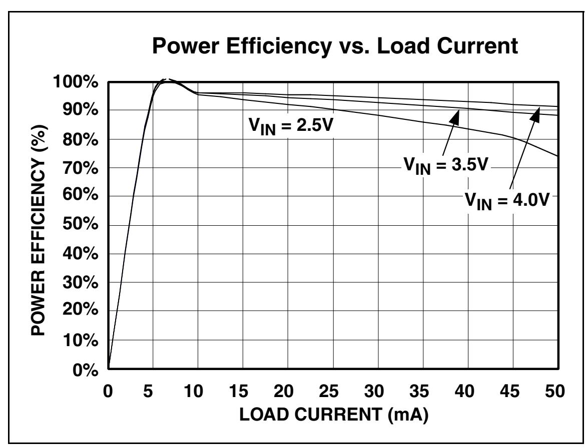




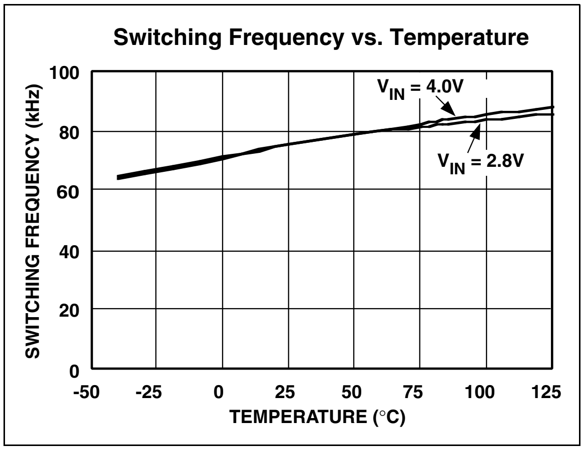






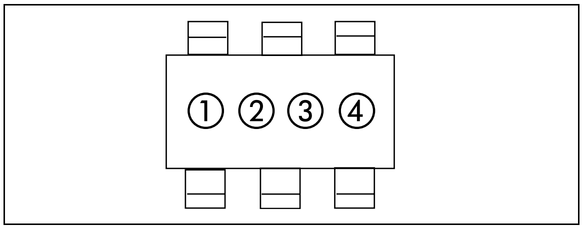


5.0 TYPICAL CHARACTERISTICS (CONTINUED)



6.0 PACKAGING INFORMATION

6.1 Package Marking Information



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

TC1240/TC1240A	**Code**
TC1240ECH	DN
TC1240AECH	EN

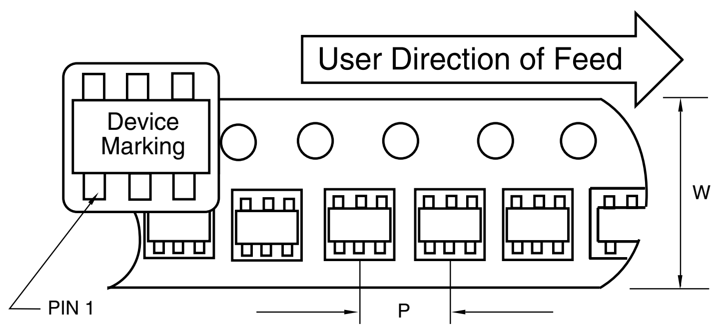
ex: 1240AECH = Ⓔ Ⓝ ◯ ◯

③ represents year and 2-month code

④ represents production lot ID code

6.2 Taping Form

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



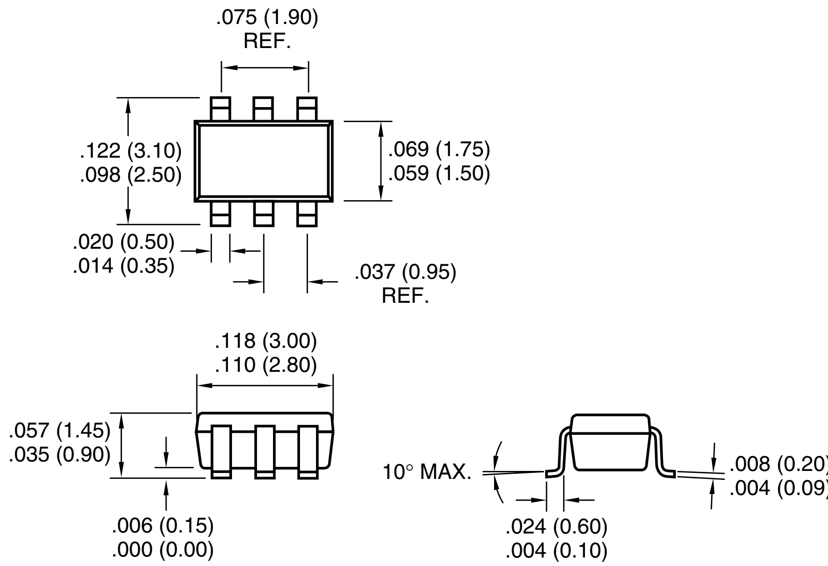
Standard Reel Component Orientation
For TR Suffix Device
(Mark Right Side Up)

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

6.3 Package Dimensions

SOT-23A-6



Dimensions: inches (mm)

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05/01/02