POSITIVE-TO-NEGATIVE DC-DC CONVERTER

FEATURES

- **Positive-to-Negative Converter**
- **Adjustable Output Voltage**
- **On/Off Control**
- **Thermal Protection Sensor**
- **Broad Operating Voltage Range**
- **Miniature Package (SOT-23L)**

APPLICATIONS

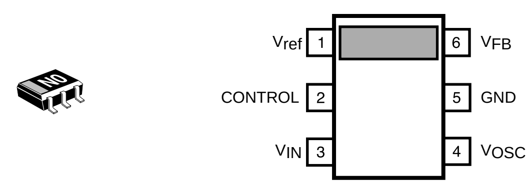
- **Pagers**
- **Cassette Recorders**
- **Cordless Telephones**
- **Portable Instrumentation**
- **Radio Control Systems**
- **Battery Operated Equipment**
- **Local Area Network (LAN) Receivers**

DESCRIPTION

The TK11830 is a positive-to-negative DC-DC converter. This IC converts a positive input voltage into a regulated negative output voltage. This DC-DC converter features an On/Off function with an active low control. The internal voltage reference provides a stable output voltage which can be set from -0.5 to -12.5 V. The thermal protection feature provides oscillator shutdown in the event of an overload condition. The wide input voltage range of 2.5 to 15 V and a 60 mA output current capability allow flexible operation in a large number of applications.

The TK11830 is available in a miniature SOT-23L surface mount package. Optimized Toko inductors are available.

TK11830



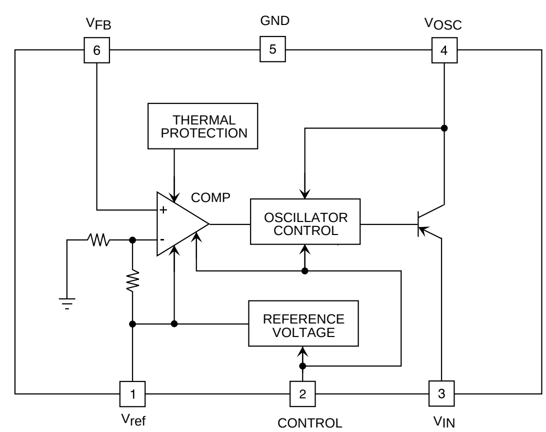
ORDERING INFORMATION

TK11830M □□

Tape/Reel Code

TAPE/REEL CODE
TL: Tape Left

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Supply Voltage .... 16 V
Operating Voltage .... Min. 2.5 V
Power Dissipation (Note 1) .... 400 mW
Storage Temperature Range .... -55 to +150 °C
Operating Temperature Range ....-20 to +75 °C
Junction Temperature .... 150 °C
Lead Soldering Temperature (10 s) .... 235 °C

TK11830 ELECTRICAL CHARACTERISTICS

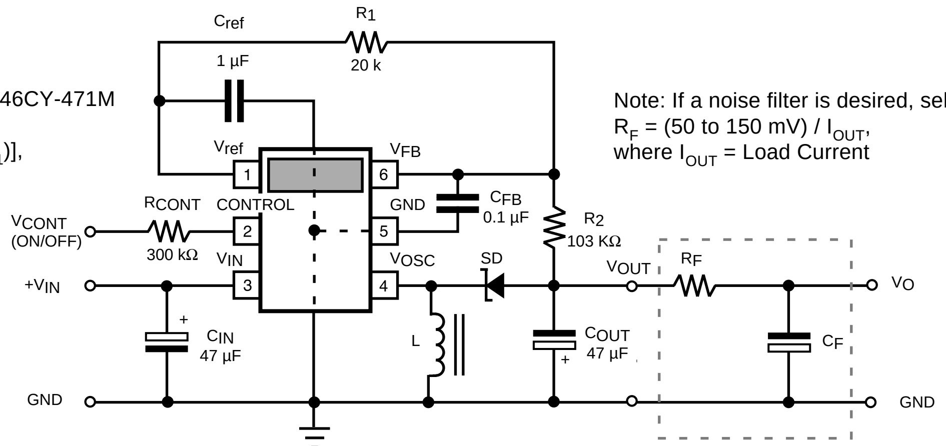
Test Conditions: V_{IN} = 5 V, L = 470 µH, T_A = 25 °C, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
V_{IN}	Input Voltage	V_{IN} + $\|V_{OUT}\|$ ≤16 V	2.5		15	V
V_{ref}	Reference Voltage		1.23	1.28	1.33	V
ΔV_{ref}	Temperature Coefficient of Reference Voltage	T_A = -30 to +80 ° C		±0.1		mV/° C
$I_{IN(OFF)}$	Input Current at Shutdown	R_{CONT} = 300 kΩ, Output OFF, V_{IN} = 5 V		25	100	µA
Line Reg	Line Regulation	V_{IN} = 2.5 to 10 V, V_{OUT} = -5 V, I_{OUT} = 20 mA		10	50	mV
Load Reg	Load Regulation	V_{OUT} = -5 V, I_{OUT} = 1 to 50 mA		20	100	mV
I_{OUT}	Output Current	V_{OUT} = -5 V	50	60		mA
ON/OFF CONTROL TERMINAL						
I_{CONT}	Control Terminal Current	V_{CONT} = 0.4 V, R_{CONT} = 300 kΩ			0.2	µA
		V_{CONT} = 5.0 V, R_{CONT} = 300 kΩ		3.0		µA
$V_{CONT(ON)}$	Control Voltage (ON)	R_{CONT} = 300 kΩ, Output ON			0.4	V
$V_{CONT(OFF)}$	Control Voltage (OFF)	R_{CONT} = 300 kΩ, Output OFF	2.2			V

Note 1: Power dissipation is 400 mW (internally limited) when mounted as recommended. Derate at 3.2 mW/°C for operation above 25 °C.
Gen Note: Output capacitor should have low ESR at reduced temperatures if used below 0 °C.
Gen Note: Parameters with min. or max. values are 100% tested at T_A = 25 °C.

TEST CIRCUIT

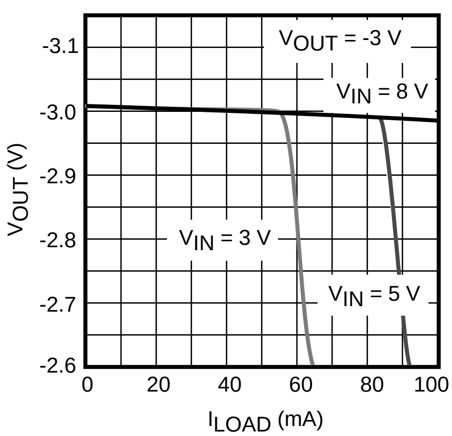
Note: Toko Inductor (470 µH): 646CY-471M or 636CE-471K (D73C)
$V_{OUT} = (V_{ref} / 5) \times [1 - 4 \times (R_2 / R_1)]$,
where V_{ref} = 1.28 V



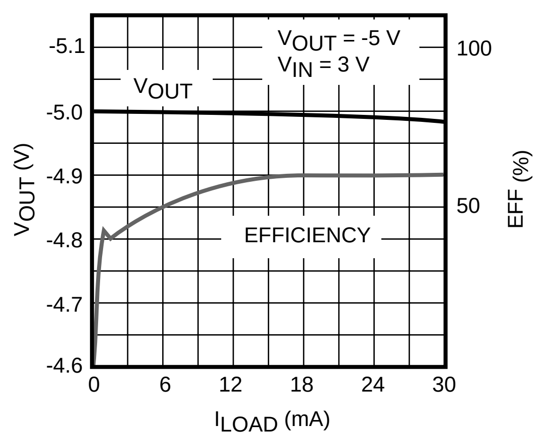
Note: If a noise filter is desired, select:
R_F = (50 to 150 mV) / I_{OUT},
where I_{OUT} = Load Current

TYPICAL PERFORMANCE CHARACTERISTICS

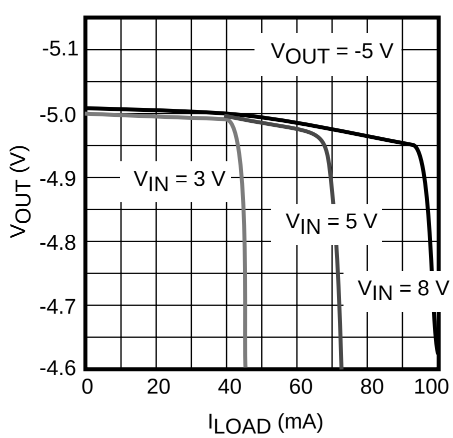
OUTPUT VOLTAGE vs. LOAD CURRENT



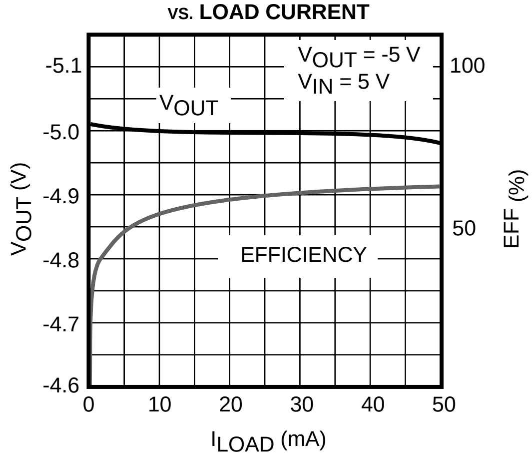
OUTPUT VOLTAGE AND EFFICIENCY vs. LOAD CURRENT



OUTPUT VOLTAGE vs. LOAD CURRENT

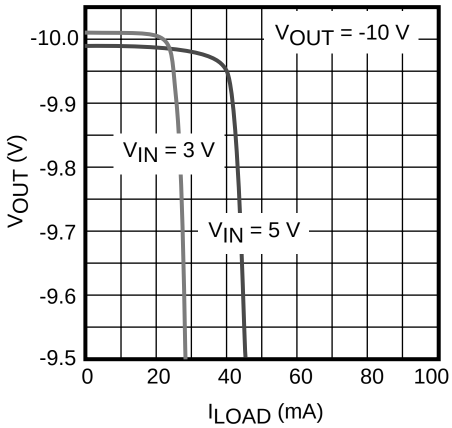


OUTPUT VOLTAGE AND EFFICIENCY vs. LOAD CURRENT

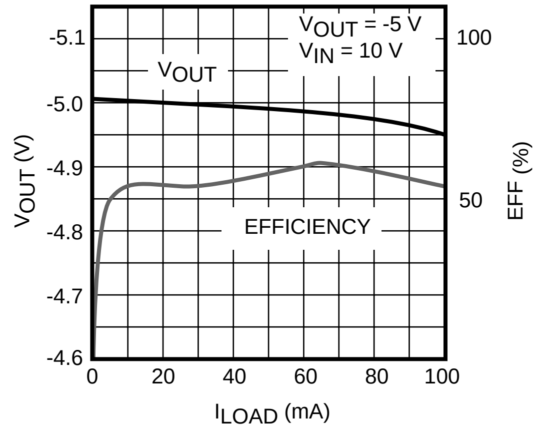


TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

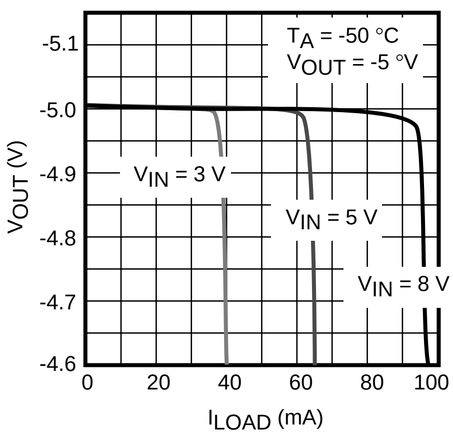
OUTPUT VOLTAGE vs. LOAD CURRENT



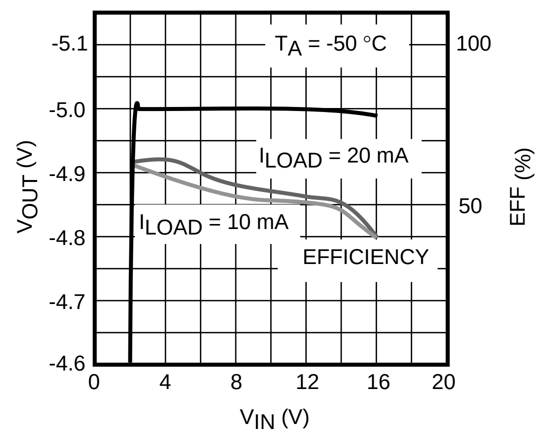
OUTPUT VOLTAGE AND EFFICIENCY vs. LOAD CURRENT



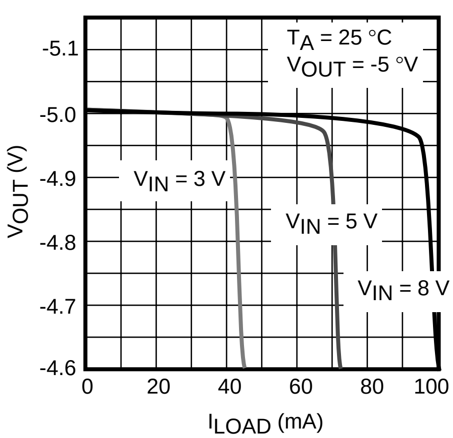
OUTPUT VOLTAGE vs. LOAD CURRENT



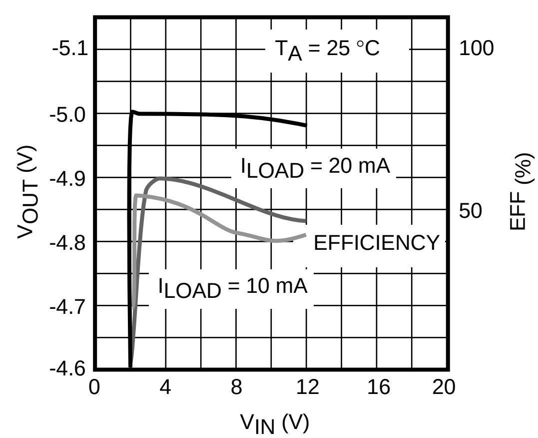
OUTPUT VOLTAGE AND EFFICIENCY vs. INPUT VOLTAGE



OUTPUT VOLTAGE vs. LOAD CURRENT

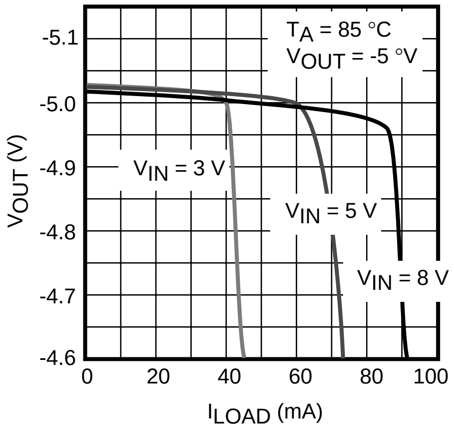


OUTPUT VOLTAGE AND EFFICIENCY vs. INPUT VOLTAGE

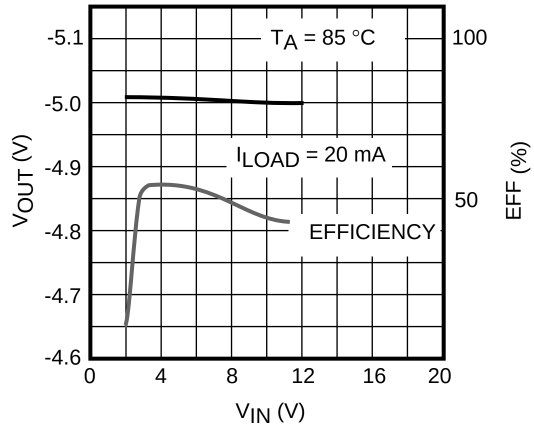


TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

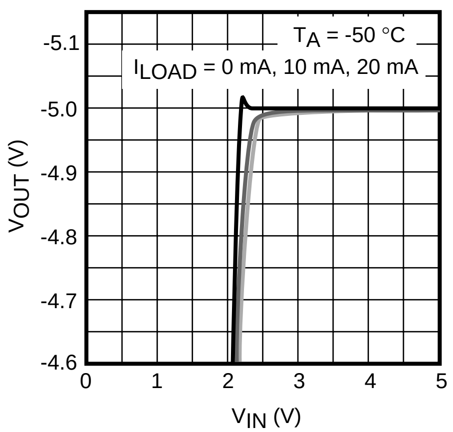
OUTPUT VOLTAGE vs. LOAD CURRENT



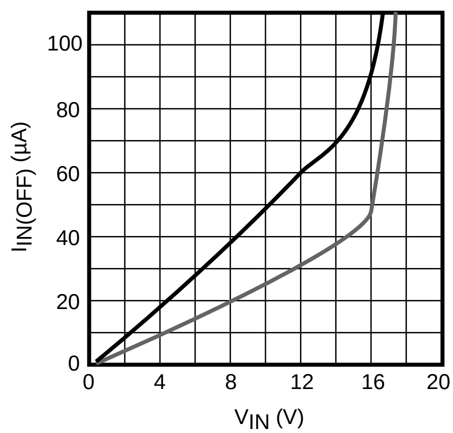
OUTPUT VOLTAGE AND EFFICIENCY vs. INPUT VOLTAGE

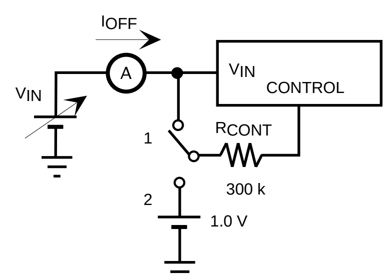


OUTPUT VOLTAGE vs. INPUT VOLTAGE

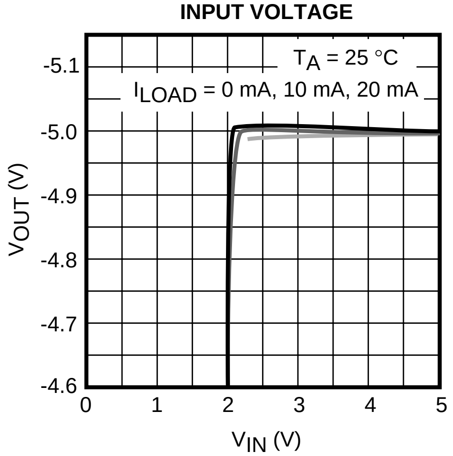


INPUT CURRENT (SHUTDOWN) vs. INPUT VOLTAGE

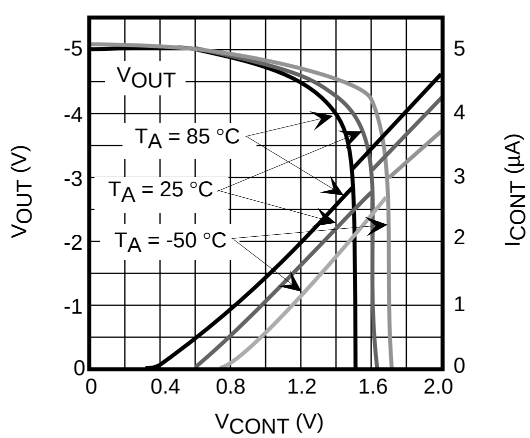


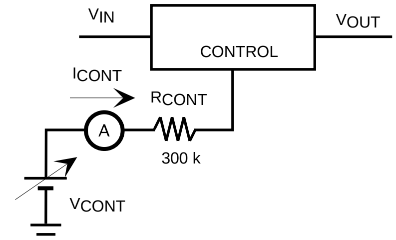


OUTPUT VOLTAGE vs. INPUT VOLTAGE



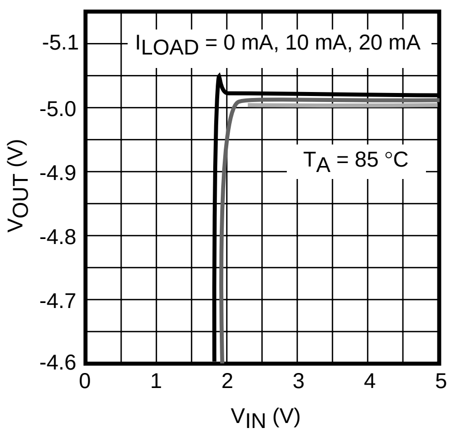
OUTPUT VOLTAGE AND CONTROL CURRENT vs. CONTROL VOLTAGE



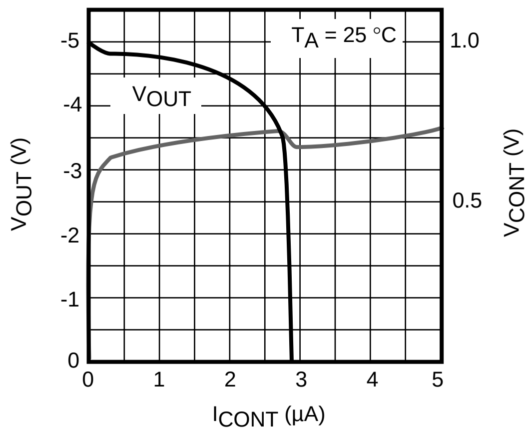


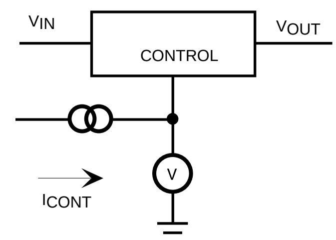
TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

OUTPUT VOLTAGE vs. INPUT VOLTAGE

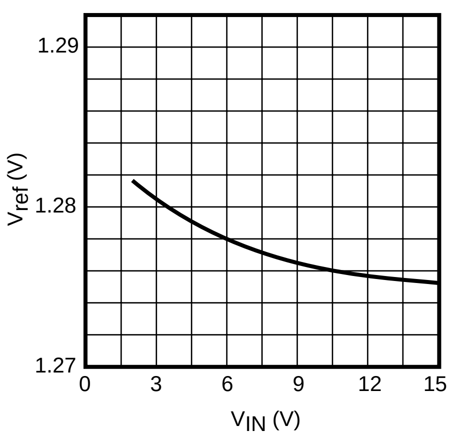


OUTPUT VOLTAGE AMD CONTROL VOLTAGE vs. CONTROL CURRENT

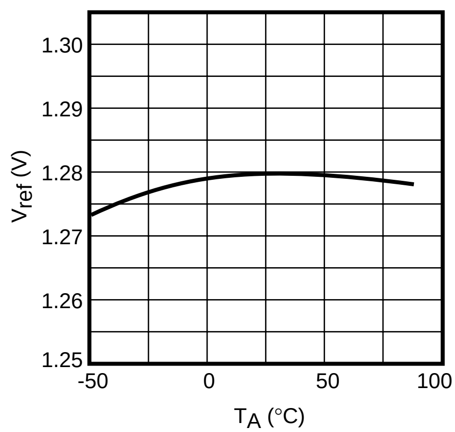




REFERENCE VOLTAGE vs. INPUT VOLTAGE

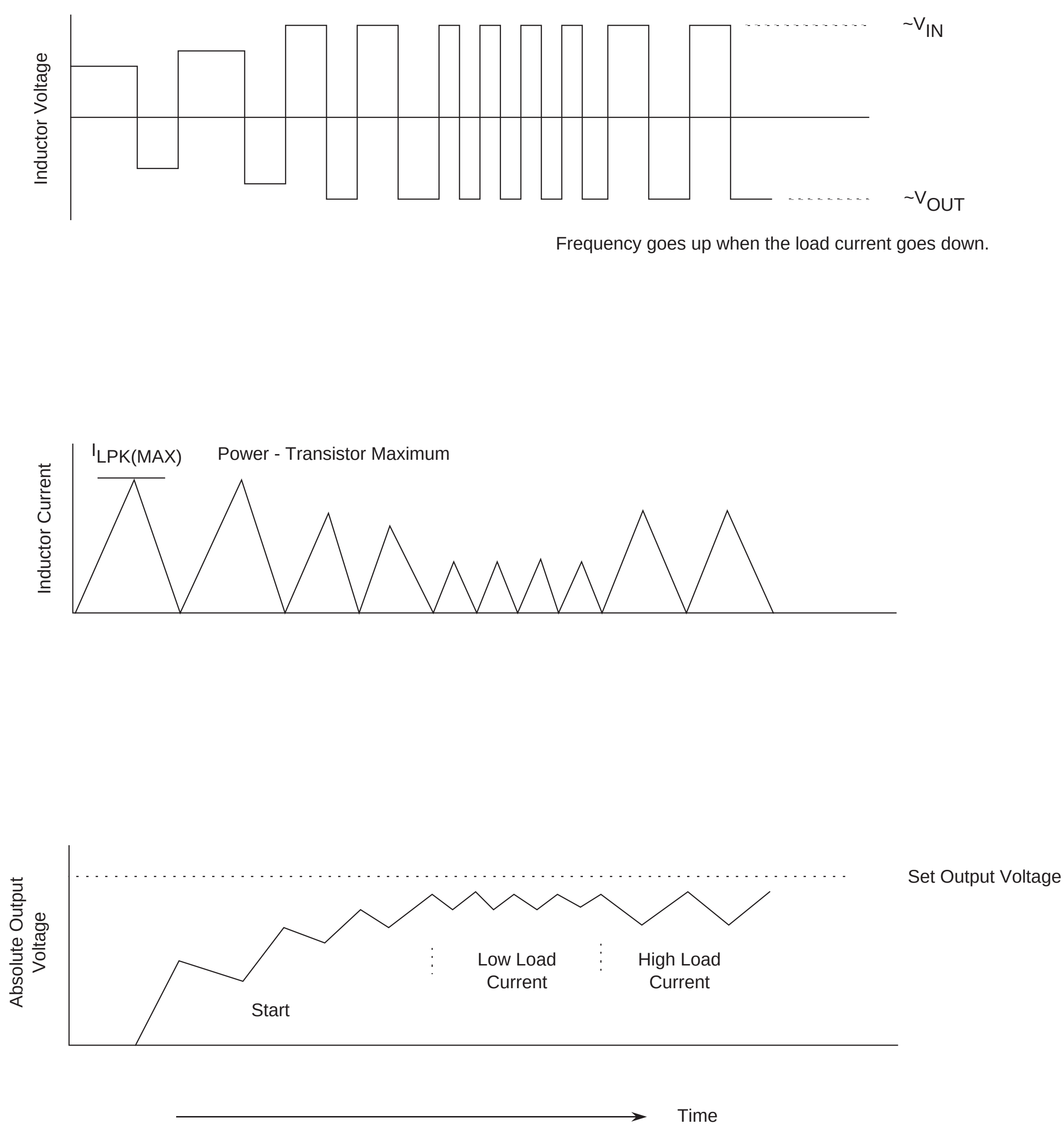


REFERENCE VOLTAGE vs. AMBIENT TEMPERATURE



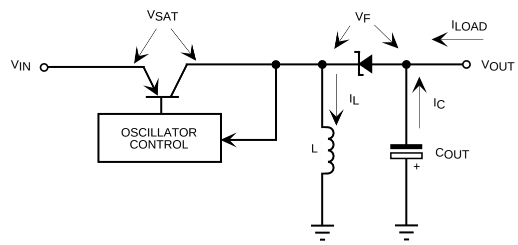
CIRCUIT OPERATION

The TK11830 operates with a continuous mode oscillator. The circuit operates by detecting the difference between the set output voltage and the internal bandgap reference. This is used to vary the oscillator frequency in response to load current. The output voltage is regulated by controlling the power transistor switch current; this maintains a constant charge on the output capacitor.



CIRCUIT OPERATION (CONT.)

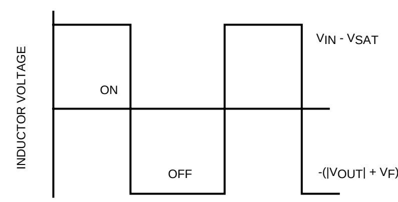
POLARITY-INVERTING OPERATION



V_{SAT}	Power Transistor Saturation Voltage
V_F	Diode Forward Voltage Drop
I_L	Inductor Current
I_C	Capacitor Current
I_{LOAD}	Load Current
V_L	Inductor Voltage

where:

$V_L = L \times (di_L / d_t)$ and V_L = a constant value: $I_L = (V_L / L) \times t$

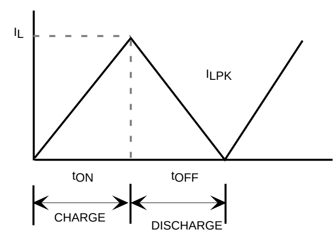


During the charge cycle:

$$I_{LPK} = [(V_{IN} - V_{SAT}) \times t_{ON}] / L \quad (1)$$

During the discharge cycle:

$$I_{LPK} = [(|V_{OFF}| + V_F) \times t_{OFF}] / L$$
$$(I_L = 0 \text{ after } t_{OFF}) \quad (2)$$

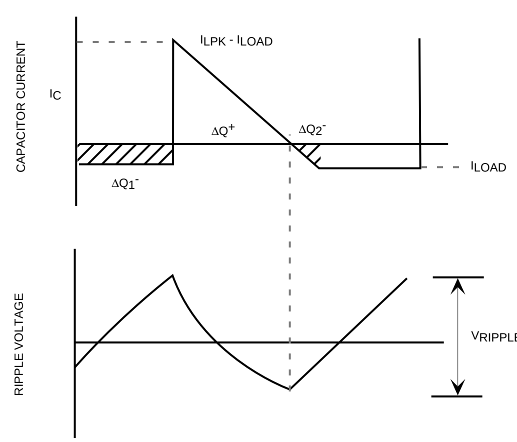


From (1) and (2):

$$t_{ON} / t_{OFF} = (|V_{OUT}| + V_F) / (V_{IN} - V_{SAT}) \quad (3)$$

When $I_L = I_C + I_{LOAD}$ and output voltage are in a steady state, the change of the charge/discharge must be equivalent, so:

$$\Delta Q^+ = \Delta Q_1^- + \Delta Q_2^-$$



And:

$$I_{LPK} = 2 \times I_{LOAD} \times [(t_{ON} / t_{OFF}) + 1] \quad (4)$$

Ripple Voltage:

$$V_{RIPPLE} = \Delta Q^+ / C_{OUT}$$
$$= (I_{LPK} - I_{LOAD})^2 \times t_{OFF} / 2C_{OUT} \times I_{LPK}$$
$$\sim I_{LOAD} \times t_{ON} / C_{OUT} \quad (5)$$

CIRCUIT OPERATION (CONT.)

Oscillator Frequency:

$$f = 1/(t_{ON} + t_{OFF})$$

Where:

$$t_{ON} = L \times [I_{LPK} / (V_{IN} - V_{SAT})]$$

And:

$$t_{OFF} = L \times [I_{LPK} / (|V_{OUT}| + V_F)]$$

Therefore:

$$f = \frac{1}{I_{LPK} L \times \left(\frac{1}{V_{IN} - V_{SAT}} + \frac{1}{|V_{OUT}| + V_F} \right)}$$

$$= \frac{(V_{IN} - V_{SAT})^2 (|V_{OUT}| + V_F)}{2 I_{LOAD} (V_{IN} - V_{SAT} + |V_{OUT}| + V_F)^2} \times \frac{1}{L}$$

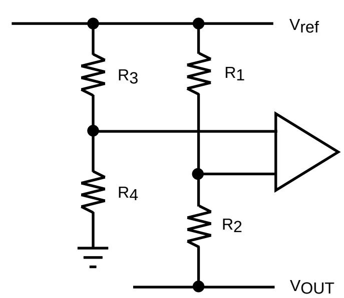
t_{ON} / t_{OFF}	$(\lvert V_{OUT}\rvert + V_F) / (V_{IN} - V_{SAT})$
I_{LPK}	$2 \times I_{LOAD} \times [(t_{ON} / t_{OFF}) + 1]$
f	$\frac{(V_{IN} - V_{SAT})^2 (\lvert V_{OUT}\rvert + V_F)}{2 I_{LOAD} (V_{IN} - V_{SAT} + \lvert V_{OUT}\rvert + V_F)^2} \bullet \frac{1}{L}$
C_{OUT}	$(I_{LOAD} \times t_{ON}) / V_{RIPPLE}$

The ESR of the capacitor and the effect of the input voltage difference for the comparator function are added to V_{RIPPLE}. The maximum inductor current is limited by the power transistor switch capacity: $I_{LPK(MAX)}$ ~ 300 mA.

Output Voltage is as follows:

$$V_{OUT} = (V_{ref} / 5) \times (1 - 4 \times R_2 / R_1)$$

where: V_{ref} = 1.28 V
R_3, R_4: IC Internal
$R_4 / R_3 = 1 / 4$
R_1, R_2 : External Resistor



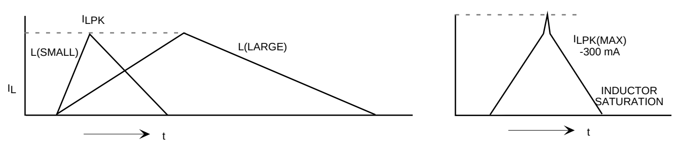
APPLICATION INFORMATION

COMPONENT REQUIREMENTS

Inductor

DC resistance of the inductor must be less than 5 Ω. For optimal performance and efficiency, an inductor with a DC resistance of less than 1 Ω is recommended. The oscillator frequency is inversely proportional to inductance. The inductance should be greater than 300 µH to prevent loss of efficiency at high frequencies.

There is a large peak current (up to I_{LPK} = 300mA) when the inductor is saturated.



C_{FB}, C_{REF}, C_{IN}, C_{OUT}

The filtered output ripple is fed back to the feedback pin. To ensure continuous operation, C_{FB} should be connected between the feedback pin and ground. If a large voltage is fed back to the feedback pin, the power transistor switch drive will be intermittent. This causes a large ripple voltage since I_{LPK} becomes larger. The value of C_{FB} is determined by the value of the output capacitor, $C_{OUT,}$ and the feedback resistance, R_2. The feedback capacitor must be larger when the ripple voltage is high due to the lower C_{OUT}. C_{REF} is used to prevent oscillation of the band gap reference and to stabilize the feedback loop. The input capacitor, C_{IN}, is used to reduce supply impedance and to provide sufficient input current during switching for stable circuit operation.

Recommended values:

C_{REF} > 0.1 µF

C_{FB} > 0.01 µF

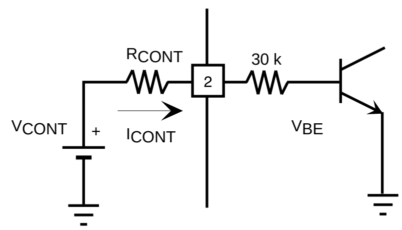
C_{IN} > 22 µF

C_{OUT} > 22 µF

Note: C_{OUT} should be sufficiently large and have a low ESR to minimize ripple voltage.

Control Pin Resistor (R_{CONT})

Input requirements of the Control pin are as follows:



When V_{CONT} is high (above 2.2 V), the circuit operation is stopped. When V_{CONT} is low (below 0.4 V), operation is resumed.

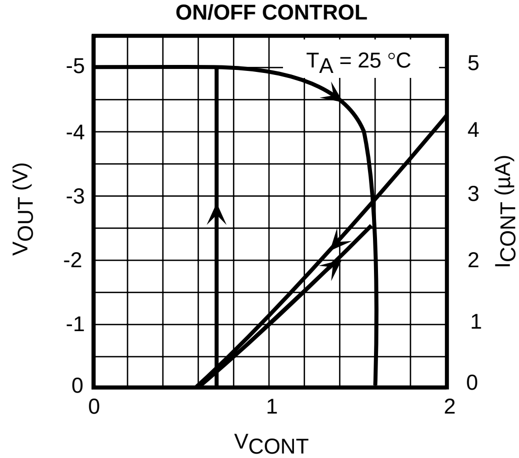
A control current of 3 µA (typ.) is required for shutdown. Shutdown voltage, V_{CONT}, is related to the resistance R_{CONT} as shown below. V_{CONT} changes when R_{CONT} is changed.

$$V_{CONT} \sim R_{CONT} \times I_{CONT} + V_{BE}$$

$$V_{CONT} \sim (300\ k\Omega) \times (3\ \mu A) + 0.7\ V = 1.60\ V \text{ at}$$

$$R_{SD} = 300\ k\Omega \text{ and } V_{BE} \sim 0.7\ V$$

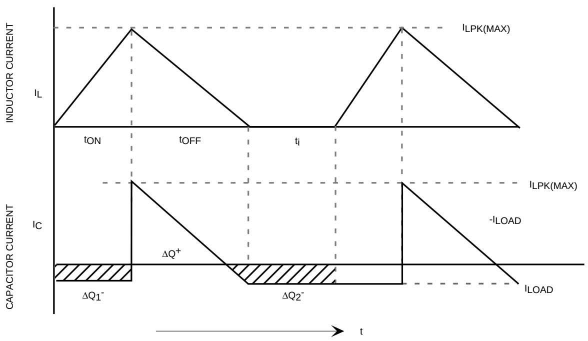
ON/OFF CONTROL



APPLICATION INFORMATION (CONT.)

INTERMITTENT OSCILLATION

When the ripple voltage applied to the feedback pin is large and C_{FB} is small, the power transistor switch drive is large and the output voltage exceeds the desired value. This causes the oscillator to stop for a period of t_i. When the ripple voltage is large and the power transistor is driven at maximum capacity, a current up to $I_{LPK(MAX)}$ goes through the inductor.



Note: $t_{ON}/t_{OFF} = (|V_{OUT}| + V_F) / (V_{IN} - V_{SAT})$

$t_{ON} = [I_{LPK(MAX)} / (V_{IN} - V_{SAT})] \times L$

$t_{OFF} = [I_{LPK(MAX)} / (|V_{OUT}| + V_F)] \times L$

Since the charge of the capacitor is equivalent to the discharge ($\Delta Q^+ = \Delta Q_1^- + \Delta Q_2^-$):

$$I_{LPK(MAX)} = 2 \times I_{LOAD} \times [(t_{ON} / t_{OFF}) + 1] + 2 \times I_{LOAD} \times (t_i / t_{OFF})$$

$$t_i = ([I_{LPK(MAX)} / (2 \times I_{LOAD})] \times t_{OFF}) - (t_{ON} + t_{OFF})$$

$$f = 1 / (t_{ON} + t_{OFF} + t_i)$$

When load current increases, t_i becomes shorter.

As in the case above, if the load current is too small, the power transistor becomes overdriven and intermittent oscillation will occur.

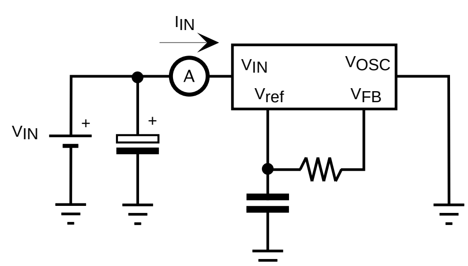
PACKAGE POWER DISSIPATION

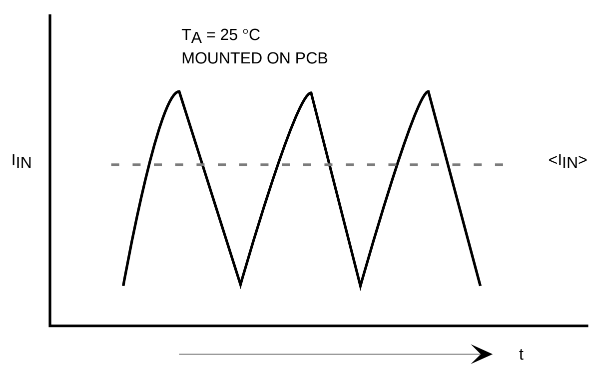
The internal thermal protection circuit will operate when T_j is approximately 150 °C. When thermal protection operates, the power transistor switch will cycle between on and off to keep $T_j \leq 150$ °C. Thermal resistance $\Theta_j a$ is determined by mounting. The package power dissipation curve on a printed circuit board is estimated as follows:

When Pin 4 is connected to GND (Power transistor switch is at maximum conductance), all input power is dissipated by the IC at T_A = room temperature. In this state T_j goes up to 150 °C and thermal protection operates. Input power is defined as $P_{IN} = V_{IN} \times \langle I_{IN} \rangle$, where $\langle I_{IN} \rangle$ is the average of input current. From $T_j = \Theta_j a \times P + T_A$ and $T_j = 150$ °C. $P = P_{IN}$, T_A = Room temp., $\Theta_j a$ can be found. The power dissipation curve shows the effect of mounting on thermal characteristics.

P_{LOSS}, must be within this curve. The efficiency, E (%), is the ratio between input and output power when the dc-dc converter is operating.

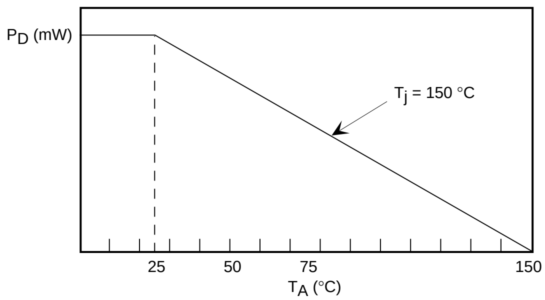
$$\begin{aligned} P_{LOSS} &= P_{IN} - P_{OUT} \\ &= P_{OUT} \times [(100 / E) - 1] \\ &= |V_{OUT}| \times I_{LOAD} \times [(100 / E) - 1] \end{aligned}$$

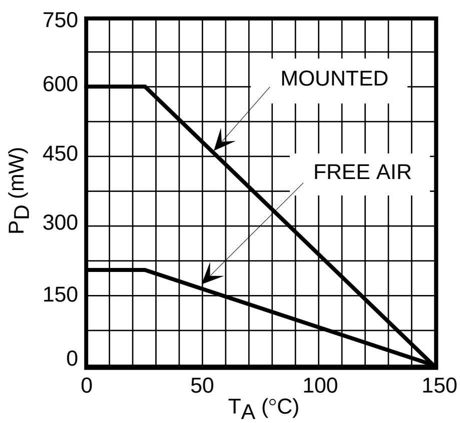


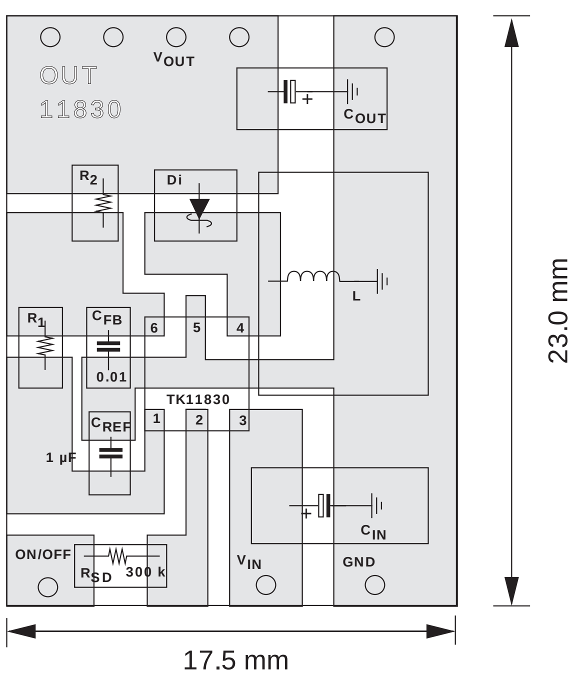


I_{IN} WAVEFORM WHEN THERMAL PROTECTION IS OPERATING

APPLICATION INFORMATION (CONT.)

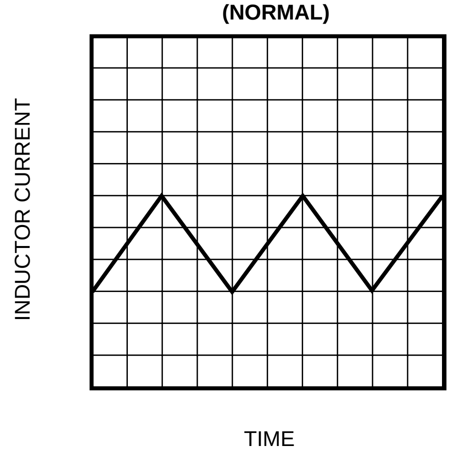




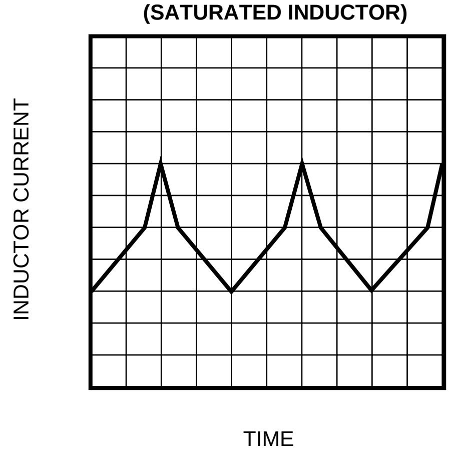


The components shown in the test circuit may be changed for different operating conditions (input/output voltage, output current, inductor type, etc.) The performance of the DC-DC converter depends largely on the coil in use. To optimize efficiency, a coil with a low DC resistance should be used, such as the Toko 646CY471M. Oscillation will begin with an inductor value as low as 100 µH. However, if the Equivalent Series Resistance (ESR) is over 5 Ω, oscillation may not occur. The input and output capacitors should have a low ESR and high capacity since there is a large ripple current present. For operation below 0 °C, the capacitors should be selected for low ESR and good temperature stability at reduced temperatures. This is required to minimize ripple current. For low values of load current, a smaller coil can be used. For higher current, a large coil is needed to prevent saturation. When the coil saturates, the current increases dramatically, resulting in a severe overcurrent through the inductor. Please refer to the following drawings.

INDUCTOR CURRENT WAVEFORM (NORMAL)

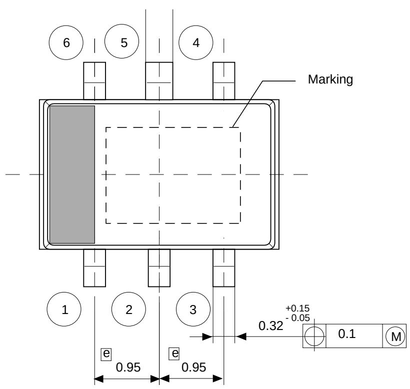


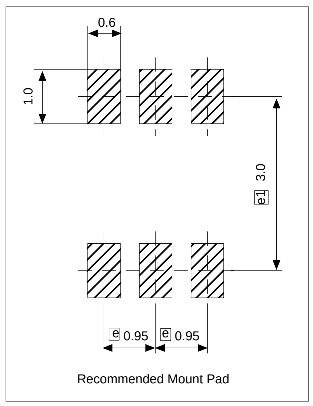
INDUCTOR CURRENT WAVEFORM (SATURATED INDUCTOR)

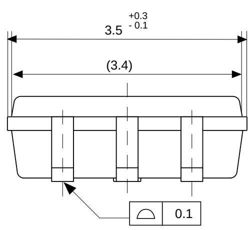


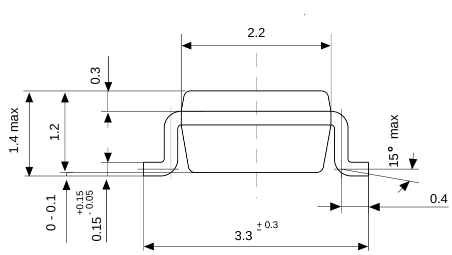
PACKAGE OUTLINE

SOT-23L (SOT-23L-6)









Dimensions are shown in millimeters
Tolerance: x.x = ± 0.2 mm (unless otherwise specified)

Marking Information

	Marking
TK11830	N0

TOKO

Toko America, Inc. Headquarters
1250 Feehanville Drive, Mount Prospect, Illinois 60056
Tel: (847) 297-0070 Fax: (847) 699-7864

TOKO AMERICA REGIONAL OFFICES

Midwest Regional Office
Toko America, Inc.
1250 Feehanville Drive
Mount Prospect, IL 60056
Tel: (847) 297-0070
Fax: (847) 699-7864

Western Regional Office
Toko America, Inc.
2480 North First Street , Suite 260
San Jose, CA 95131
Tel: (408) 432-8281
Fax: (408) 943-9790

Eastern Regional Office
Toko America, Inc.
107 Mill Plain Road
Danbury, CT 06811
Tel: (203) 748-6871
Fax: (203) 797-1223

Semiconductor Technical Support
Toko Design Center
4755 Forge Road
Colorado Springs, CO 80907
Tel: (719) 528-2200
Fax: (719) 528-2375

Visit our Internet site at http://www.tokoam.com

IC-140-TK11830
0798O0.0K

Printed in the USA