

THREE-TERMINAL VOLTAGE REGULATOR

FEATURES

- Low Dropout Voltage
- Very Low Standby Current (No Load)
- Good Load Regulation
- Internal Thermal Shutdown
- Short Circuit Protection
- 3% Output Voltage Accuracy
- Customized Versions Are Available

APPLICATIONS

- Battery Powered Systems
- Portable Consumer Equipment
- Cordless Telephones
- Personal Communications Equipment
- Portable Instrumentation
- Radio Control Systems
- Toys
- Low Voltage Systems

DESCRIPTION

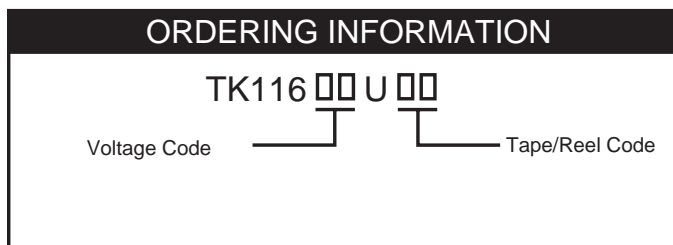
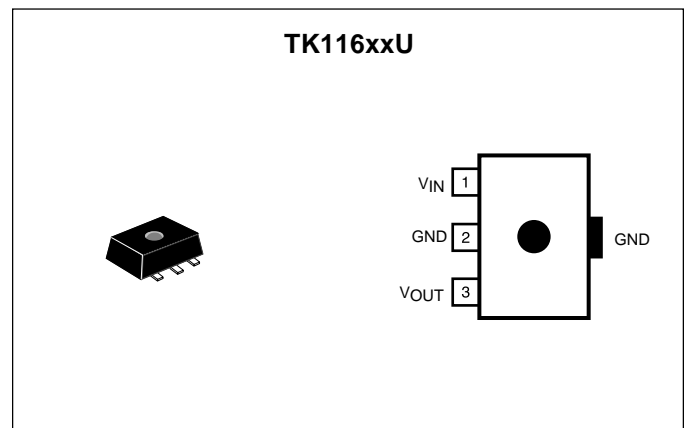
The TK116xxU series devices are low dropout, linear 3-terminal regulators.

An internal PNP pass-transistor is used in order to achieve low dropout voltage (typically 160 mV at 80 mA load current).

The regulated output voltages of 3, 3.3, 5 and 9 V are available. The device has very low (400 μ A) quiescent current with no load and 2 mA with 60 mA load.

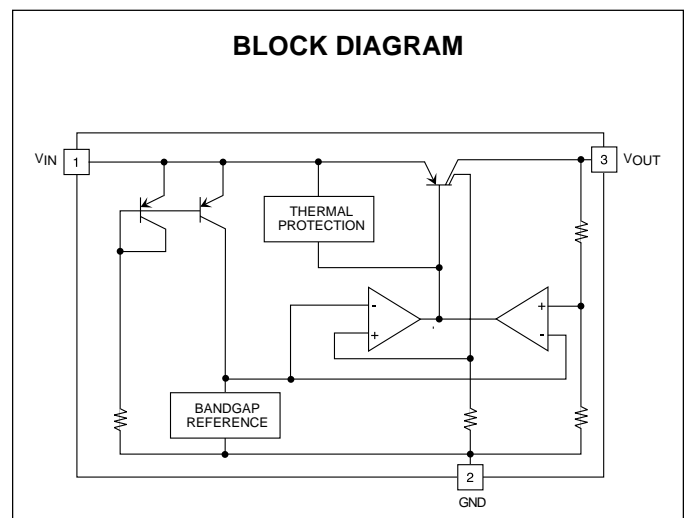
An internal thermal shutdown circuit limits the junction temperature to below 150 °C. The load current is internally monitored and the device will shut down in the presence of a short circuit at the output.

The TK116xxU is available in the SOT-89 surface mount package.



VOLTAGE CODE
 30 = 3.0 V
 33 = 3.3 V
 50 = 5.0 V
 90 = 9.0 V

TAPE/REEL CODE
 TL: Tape Left



TK116xxU

ABSOLUTE MAXIMUM RATINGS

Supply Voltage	18 V	Storage Temperature Range	-55 to +150 °C
Operating Voltage Range	2.5 to 16 V	Operating Temp. Range (Standard)	-30 to +80 °C
Load Current	250 mA	Lead Soldering Temperature (10 s)	235 °C
Power Dissipation (Note 1)	1000 mW	Junction Temperature	150 °C

TK11630U ELECTRICAL CHARACTERISTICS

Test Conditions: $T_A = 25^\circ\text{C}$, $V_{IN} = 4.0\text{ V}$, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
I_Q	Quiescent Current	$V_{IN} = 4.0\text{ V}$, $I_{OUT} = 0\text{ mA}$		400	800	μA
		$V_{IN} = 2.5\text{ V}$, $I_{OUT} = 0\text{ mA}$		0.8	2.0	mA
V_{OUT}	Output Voltage	$V_{IN} = 4.0\text{ V}$, $I_{OUT} = 10\text{ mA}$	2.9	3.0	3.1	V
V_{DROP}	Dropout Voltage	$I_{OUT} = 30\text{ mA}$		80	150	mA
		$I_{OUT} = 100\text{ mA}$		170	330	mV
I_{OUT}	Output Current	$V_{IN} = 4.0\text{ V}$, (Note 2)		190		mA
I_{OR}	Recommended Output Current	$V_{IN} = 4.0\text{ V}$			150	mA
I_{GND}	Ground Current (Note 3)	$V_{IN} = 4.0\text{ V}$, $I_{OUT} = 60\text{ mA}$		2.0	4.5	mA
Line Reg	Line Regulation	$V_{IN} = 4.0\text{ to }9.0\text{ V}$		2.0	30	mV
Load Reg	Load Regulation	$V_{IN} = 4.0\text{ V}$, $I_{OUT} = 0\text{ to }30\text{ mA}$		15	60	mV
		$V_{IN} = 4.0\text{ V}$, $I_{OUT} = 0\text{ to }100\text{ mA}$		40	140	mV
		$V_{IN} = 4.0\text{ V}$, $I_{OUT} = 0\text{ to }150\text{ mA}$		120	220	mV
RR	Ripple Rejection	$V_{IN} = 4.5\text{ V}$, $I_{OUT} = 10\text{ mA}$, $f = 400\text{ Hz}$, 100 mVrms		55		dB
$\Delta V_{OUT} / \Delta T$	Temperature Coefficient	$V_{IN} = 4.5\text{ V}$, $I_{OUT} = 10\text{ mA}$, $-30^\circ\text{C} \leq T_A \leq +80^\circ\text{C}$		± 0.35		$\text{mV}/^\circ\text{C}$

Note 1: Power dissipation is 600 mW in free air. Derate at 4.8 mW/°C for operation above 25°C. Power dissipation is 1 W when mounted as recommended. Derate at 8 mW/°C for operation above 25 °C.

Note 2: I_{OUT} (Load Current) is current when V_{OUT} drops down 0.4 V from V_{OUT} at $I_{OUT} = 10\text{ mA}$.

Note 3: Refer to "Definition of Terms."

TK11633U ELECTRICAL CHARACTERISTICSTest Conditions: $T_A = 25^\circ\text{C}$, $V_{IN} = 4.3\text{ V}$, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
I_Q	Quiescent Current	$V_{IN} = 4.3\text{ V}$, $I_{OUT} = 0\text{ mA}$		400	800	μA
		$V_{IN} = 3.0\text{ V}$, $I_{OUT} = 0\text{ mA}$		0.8	2.0	mA
V_{OUT}	Output Voltage	$V_{IN} = 4.3\text{ V}$, $I_{OUT} = 10\text{ mA}$	3.2	3.3	3.4	V
V_{DROP}	Dropout Voltage	$I_{OUT} = 30\text{ mA}$		80	150	mA
		$I_{OUT} = 100\text{ mA}$		170	330	mV
I_{OUT}	Output Current	$V_{IN} = 4.3\text{ V}$, (Note 1)		190		mA
I_{OR}	Recommended Output Current	$V_{IN} = 4.3\text{ V}$			150	mA
I_{GND}	Ground Current (Note 2)	$V_{IN} = 4.3\text{ V}$, $I_{OUT} = 60\text{ mA}$		2.0	4.5	mA
Line Reg	Line Regulation	$V_{IN} = 4.3\text{ to }9.3\text{ V}$		2.0	30	mV
Load Reg	Load Regulation	$V_{IN} = 4.3\text{ V}$, $I_{OUT} = 0\text{ to }30\text{ mA}$		15	60	mV
		$V_{IN} = 4.3\text{ V}$, $I_{OUT} = 0\text{ to }100\text{ mA}$		40	140	mV
		$V_{IN} = 4.3\text{ V}$, $I_{OUT} = 0\text{ to }150\text{ mA}$		120	220	mV
RR	Ripple Rejection	$V_{IN} = 4.8\text{ V}$, $I_{OUT} = 10\text{ mA}$, $f = 400\text{ Hz}$, 100 mVrms		55		dB
$\Delta V_{OUT} / \Delta T$	Temperature Coefficient	$V_{IN} = 4.8\text{ V}$, $I_{OUT} = 10\text{ mA}$, $-30^\circ\text{C} \leq T_A \leq +80^\circ\text{C}$		± 0.35		$\text{mV}/^\circ\text{C}$

Note 1: I_{OUT} (Load Current) is current when V_{OUT} drops down 0.4 V from V_{OUT} at $I_{OUT} = 10\text{ mA}$.

Note 2: Refer to "Definition of Terms."

TK116xxU

TK11650U ELECTRICAL CHARACTERISTICS

Test Conditions: $T_A = 25^\circ\text{C}$, $V_{IN} = 6.0\text{ V}$, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
I_Q	Quiescent Current	$V_{IN} = 6.0\text{ V}$, $I_{OUT} = 0\text{ mA}$		400	800	μA
		$V_{IN} = 4.0\text{ V}$, $I_{OUT} = 0\text{ mA}$		0.8	2.0	mA
V_{OUT}	Output Voltage	$V_{IN} = 6.0\text{ V}$, $I_{OUT} = 10\text{ mA}$	4.85	5.00	5.15	V
V_{DROP}	Dropout Voltage	$I_{OUT} = 30\text{ mA}$		80	150	mA
		$I_{OUT} = 100\text{ mA}$		170	330	mV
I_{OUT}	Output Current	$V_{IN} = 6.0\text{ V}$, (Note 1)		190		mA
I_{OR}	Recommended Output Current	$V_{IN} = 6.0\text{ V}$			150	mA
I_{GND}	Ground Current (Note 2)	$V_{IN} = 6.0\text{ V}$, $I_{OUT} = 60\text{ mA}$		2.0	4.5	mA
Line Reg	Line Regulation	$V_{IN} = 6.0\text{ to }11.0\text{ V}$		2.0	30	mV
Load Reg	Load Regulation	$V_{IN} = 6.0\text{ V}$, $I_{OUT} = 0\text{ to }30\text{ mA}$		15	60	mV
		$V_{IN} = 6.0\text{ V}$, $I_{OUT} = 0\text{ to }100\text{ mA}$		40	140	mV
		$V_{IN} = 6.0\text{ V}$, $I_{OUT} = 0\text{ to }150\text{ mA}$		120	220	mV
RR	Ripple Rejection	$V_{IN} = 6.5\text{ V}$, $I_{OUT} = 10\text{ mA}$, $f = 400\text{ Hz}$, 100 mVrms		55		dB
$\Delta V_{OUT} / \Delta T$	Temperature Coefficient	$V_{IN} = 6.5\text{ V}$, $I_{OUT} = 10\text{ mA}$, $-30^\circ\text{ C} \leq T_A \leq +80^\circ\text{ C}$		± 0.35		mV/ $^\circ\text{ C}$

Note 1: I_{OUT} (Load Current) is current when V_{OUT} drops down 0.4 V from V_{OUT} at $I_{OUT} = 10\text{ mA}$.

Note 2: Refer to "Definition of Terms."

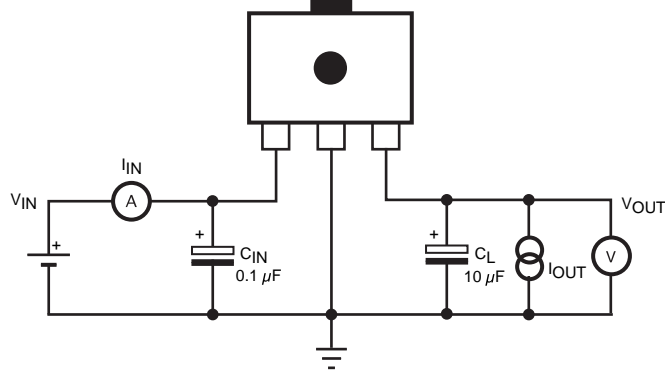
TK11690U ELECTRICAL CHARACTERISTICSTest Conditions: $T_A = 25^\circ\text{C}$, $V_{IN} = 10.0\text{ V}$, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
I_Q	Quiescent Current	$V_{IN} = 10.0\text{ V}$, $I_{OUT} = 0\text{ mA}$		400	800	μA
		$V_{IN} = 8.0\text{ V}$, $I_{OUT} = 0\text{ mA}$		0.8	2.0	mA
V_{OUT}	Output Voltage	$V_{IN} = 10.0\text{ V}$, $I_{OUT} = 10\text{ mA}$	8.73	9.00	9.27	V
V_{DROD}	Dropout Voltage	$I_{OUT} = 30\text{ mA}$		80	150	mA
		$I_{OUT} = 100\text{ mA}$		170	330	mV
I_{OUT}	Output Current	$V_{IN} = 10.0\text{ V}$, (Note 1)		190		mA
I_{OR}	Recommended Output Current	$V_{IN} = 10.0\text{ V}$			150	mA
I_{GND}	Ground Current (Note 2)	$V_{IN} = 10.0\text{ V}$, $I_{OUT} = 60\text{ mA}$		2.0	4.5	mA
Line Reg	Line Regulation	$V_{IN} = 10.0\text{ to }15.0\text{ V}$		2.0	30	mV
Load Reg	Load Regulation	$V_{IN} = 10.0\text{ V}$, $I_{OUT} = 0\text{ to }30\text{ mA}$		15	60	mV
		$V_{IN} = 10.0\text{ V}$, $I_{OUT} = 0\text{ to }100\text{ mA}$		40	140	mV
		$V_{IN} = 10.0\text{ V}$, $I_{OUT} = 0\text{ to }150\text{ mA}$		120	220	mV
RR	Ripple Rejection	$V_{IN} = 10.5\text{ V}$, $I_{OUT} = 10\text{ mA}$, $f = 400\text{ Hz}$, 100 mVrms		55		dB
$\Delta V_{OUT} / \Delta T$	Temperature Coefficient	$V_{IN} = 10.5\text{ V}$, $I_{OUT} = 10\text{ mA}$, $-30^\circ\text{C} \leq T_A \leq +80^\circ\text{C}$		± 0.7		mV/ $^\circ\text{C}$

Note 1: I_{OUT} (Load Current) is current when V_{OUT} drops down 0.4 V from V_{OUT} at $I_{OUT} = 10\text{ mA}$.

Note 2: Refer to "Definition of Terms."

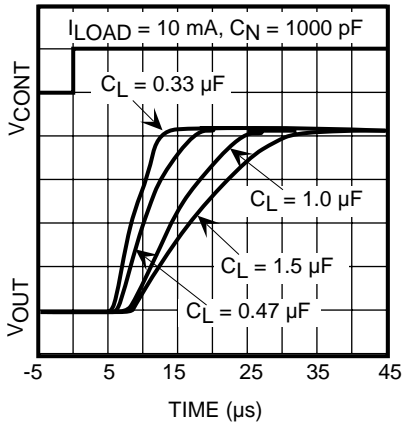
TEST CIRCUIT



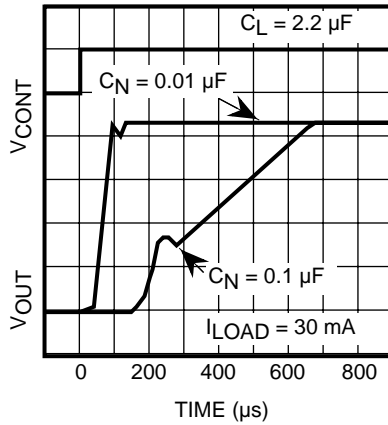
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25 °C, unless otherwise specified.

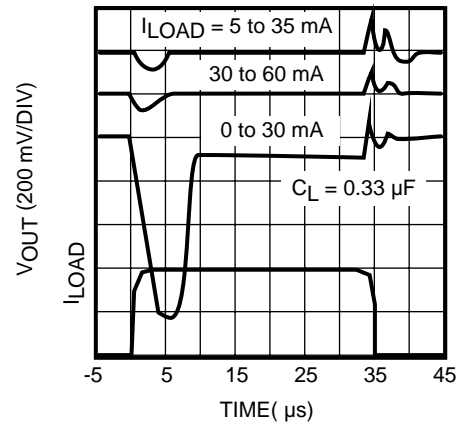
OUTPUT VOLTAGE RESPONSE (OFF→ON)



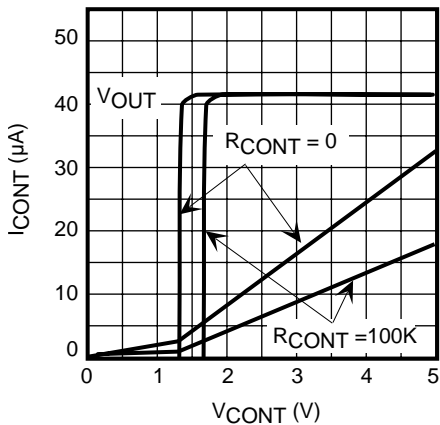
OUTPUT VOLTAGE RESPONSE (OFF→ON)



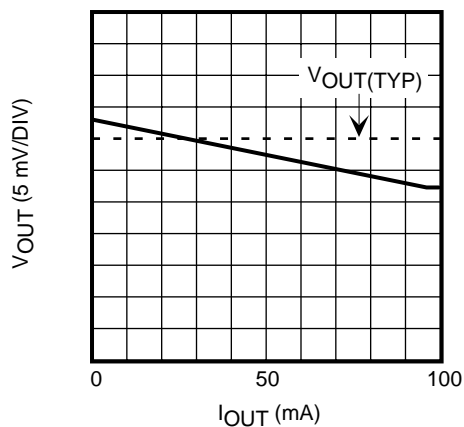
LOAD CURRENT STEP RESPONSE



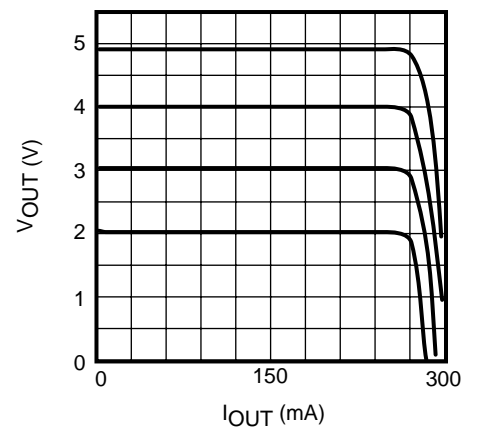
CONTROL PIN CURRENT vs. VOLTAGE



LOAD REGULATION

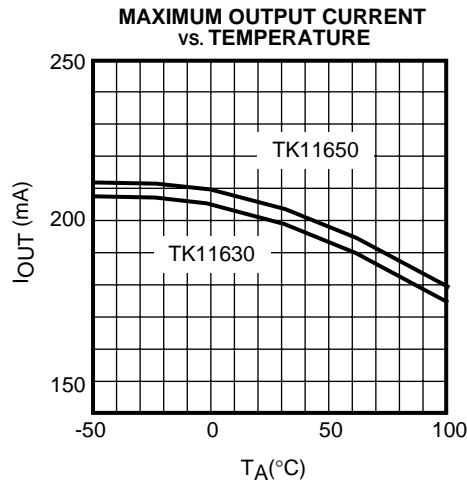
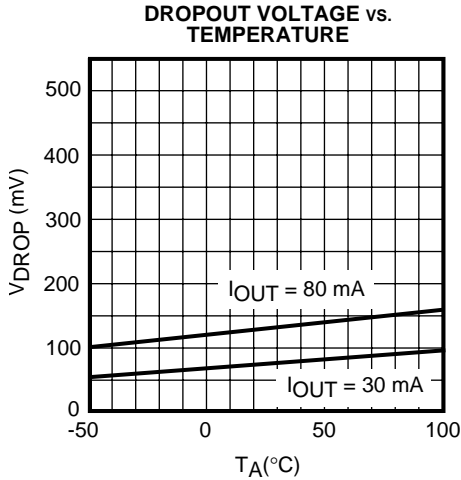


SHORT CIRCUIT CURRENT

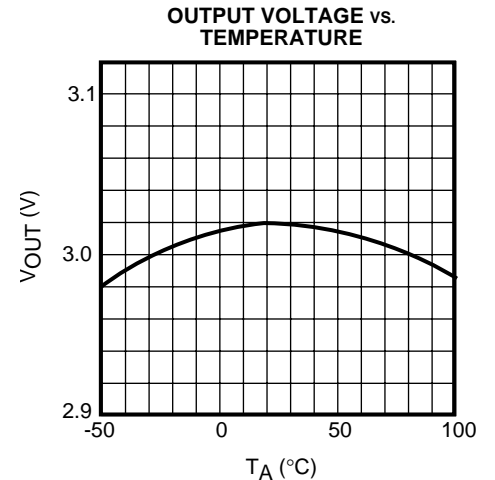
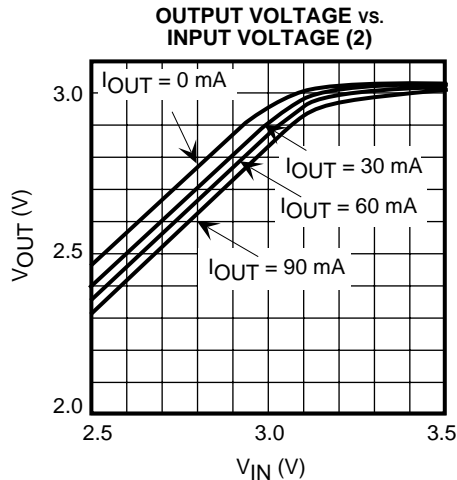
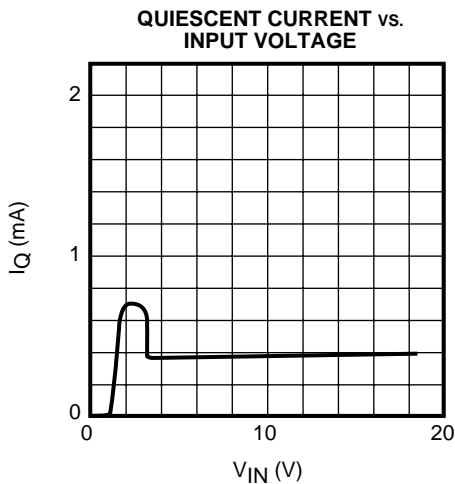
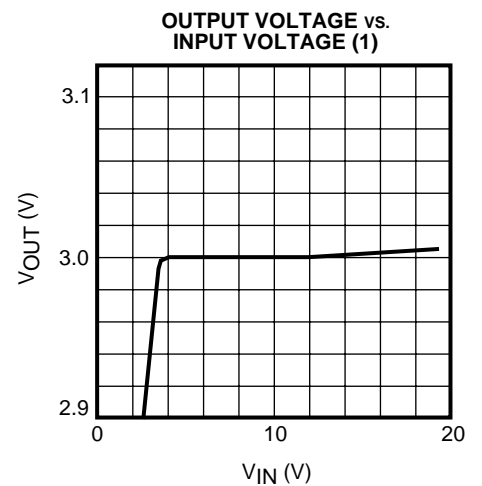
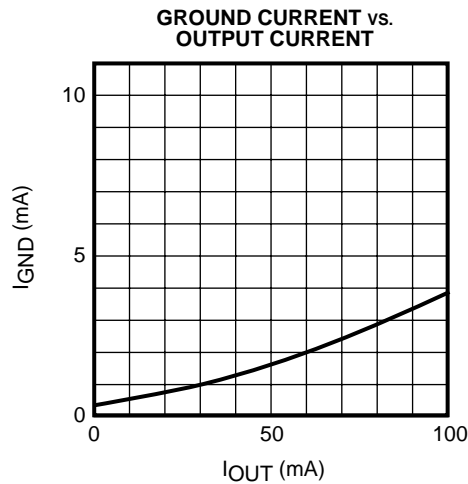
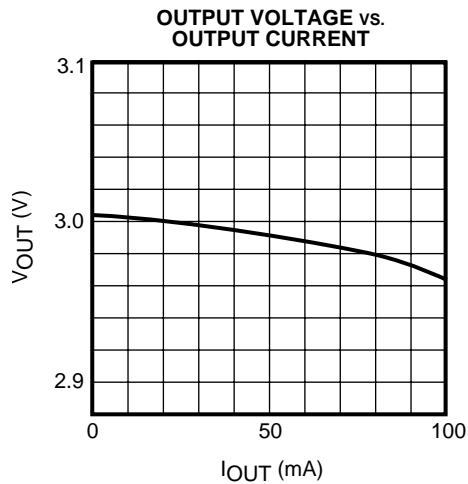


TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

$T_A = 25\text{ }^\circ\text{C}$, unless otherwise specified.



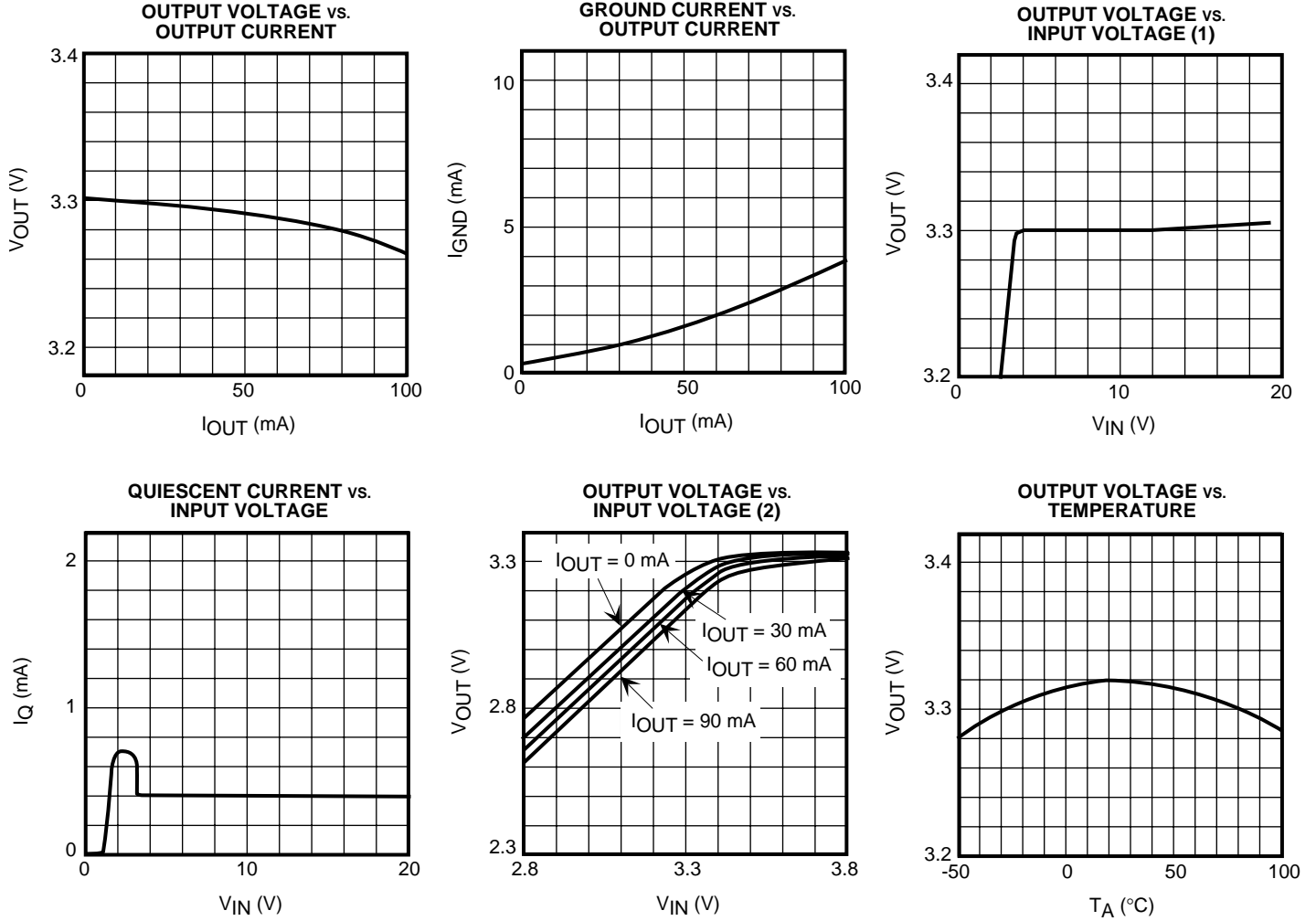
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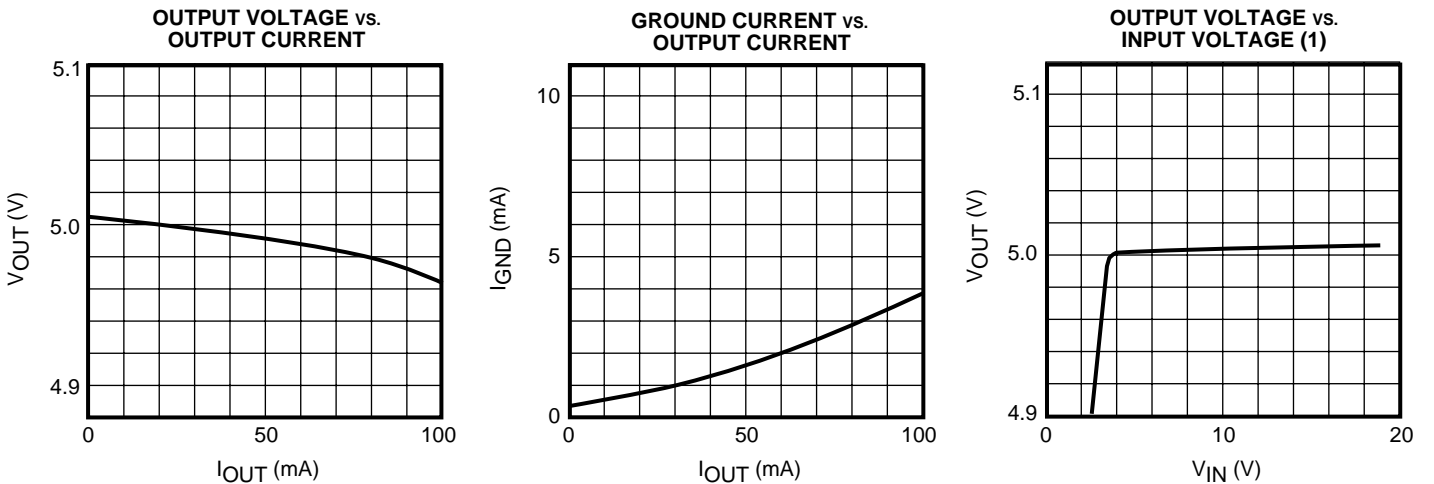
TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

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11633



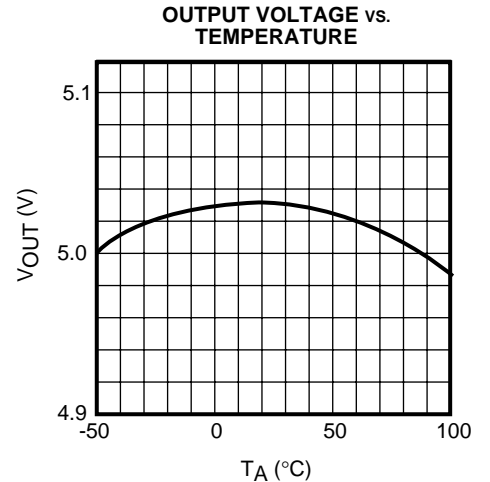
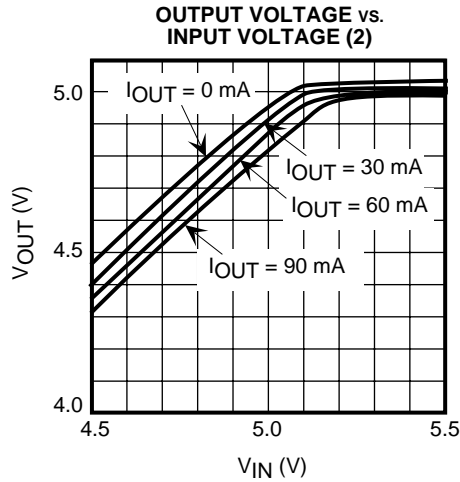
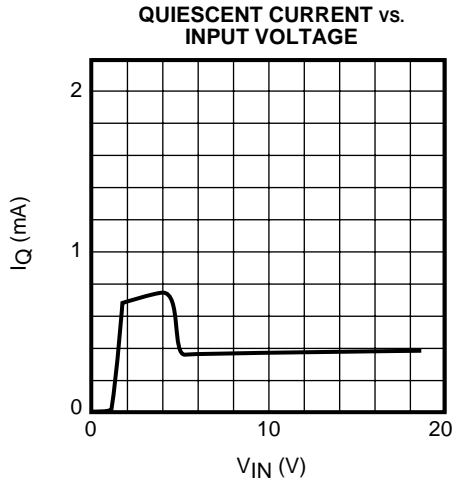
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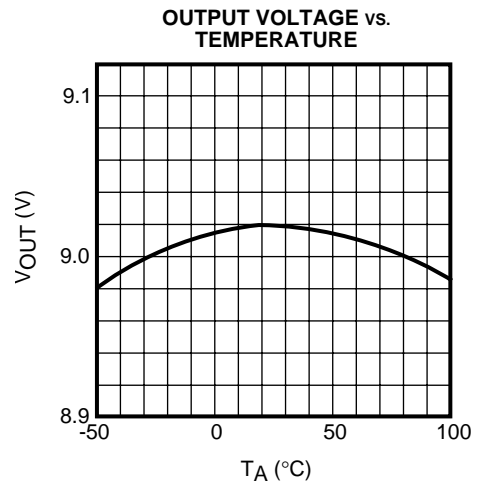
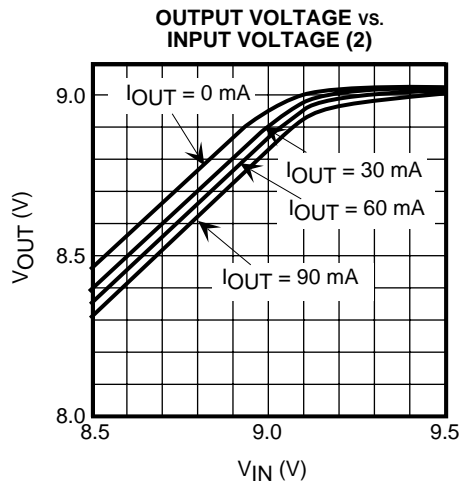
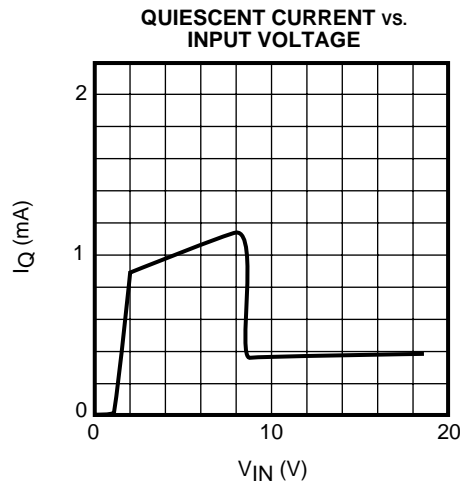
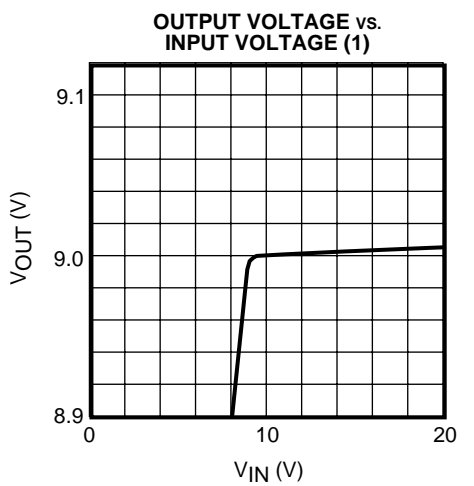
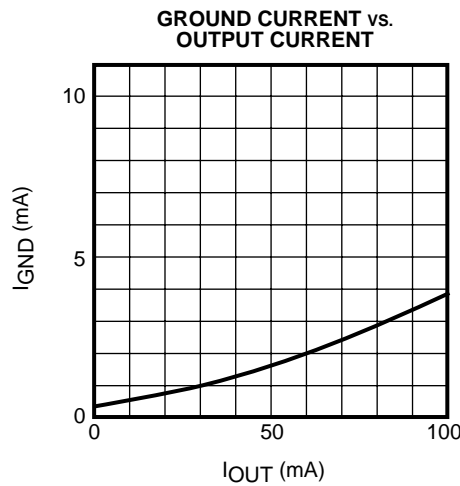
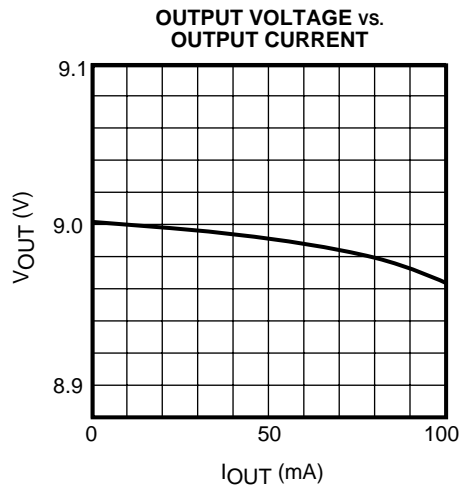
TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

$T_A = 25\text{ }^\circ\text{C}$, unless otherwise specified.

11650 (CONT.)



11690



DEFINITION AND EXPLANATION OF TECHNICAL TERMS

LINE REGULATION (Line Reg)

Line regulation is the ability of the regulator to maintain a constant output voltage as the input voltage changes. The line regulation is specified as the input voltage is changed from $V_{IN} = V_{OUT(TYP)} + 1 \text{ V}$ to $V_{IN} = V_{OUT(TYP)} + 6 \text{ V}$.

LOAD REGULATION (Load Reg)

Load regulation is the ability of the regulator to maintain a constant output voltage as the load current changes. It is a pulsed measurement to minimize temperature effects with the input voltage set to $V_{IN} = V_{OUT(TYP)} + 1 \text{ V}$. The load regulation is specified under three output current step conditions of 0 mA to 30 mA, 0 mA to 100 mA and 0 mA to 150 mA.

DROPOUT VOLTAGE (V_{DROP})

This is a measure of how well the regulator performs as the input voltage decreases. The smaller the number, the further the input voltage can decrease before regulation problems occur. Nominal output voltage is first measured when $V_{IN} = V_{OUT(TYP)} + 1 \text{ V}$ at a chosen load current. When the output voltage has dropped 100 mV from the nominal, $V_{IN} - V_{OUT}$ is the dropout voltage. This voltage is affected by load current and junction temperature.

GROUND CURRENT (I_{GND})

Ground current is the current which flows through the ground pin(s). It is defined as $I_{IN} - I_{OUT}$, excluding control current.

OUTPUT NOISE VOLTAGE

This is the effective AC voltage that occurs on the output voltage under the condition where the input noise is low and with a given load, filter capacitor, and frequency range.

THERMAL PROTECTION

This is an internal feature which turns the regulator off when the junction temperature rises above 150 °C. After the regulator turns off, the temperature drops and the regulator output turns back on. Under certain conditions, the output waveform may appear to be an oscillation as the output turns off and on and back again in succession.

PACKAGE POWER DISSIPATION (P_D)

This is the power dissipation level at which the thermal sensor is activated. The IC contains an internal thermal sensor which monitors the junction temperature. When the junction temperature exceeds the monitor threshold of 150 °C, the IC is shut down. The junction temperature rises as the difference between the input power ($V_{IN} \times I_{IN}$) and the output power ($V_{OUT} \times I_{OUT}$) increases. The rate of temperature is greatly affected by the mounting pad configuration on the PCB, the board material and the ambient temperature. When the IC mounting has good thermal conductivity, the junction temperature will be low, even if the power dissipation is great. When the radiation of heat is good, the device temperature will be low, even if the power loss is great. When mounted on the recommended mounting pad, the power dissipation of the SOT-89 package is 1000 mW. Derate the power dissipation at 8 mW/°C for operation above 25 °C. To determine the power dissipation for shutdown when mounted, attach the device on the actual PCB and deliberately increase the output current (or raise the input voltage) until the thermal protection circuit is activated. Calculate the power dissipation of the device by subtracting the output power from the input power. The measurements should allow for the ambient temperature of the PCB. The value obtained from $P_D / (150 \text{ °C} - T_A)$ is the derating factor. The PCB mounting pad should provide maximum thermal conductivity in order to maintain low device temperatures. As a general rule, the lower the temperature, the better the reliability of the device. The thermal resistance when mounted is expressed as follows:

$$T_j = \Theta_{jA} \times P_D + T_A$$

For Toko ICs, the internal limit for junction temperature is 150 °C. If the ambient temperature (T_A) is 25 °C, then:

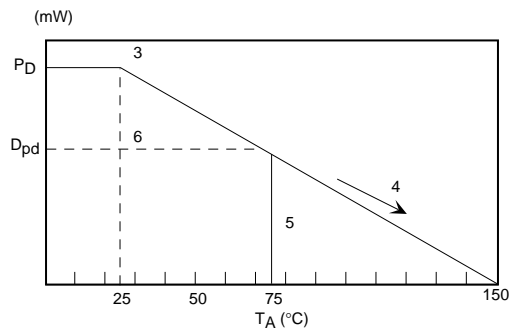
$$150 \text{ °C} = \Theta_{jA} \times P_D + 25 \text{ °C}$$

$$\Theta_{jA} = 125 \text{ °C}/P_D$$

P_D is the value when the thermal sensor is activated. A simple way to determine P_D is to calculate $V_{IN} \times I_{IN}$ when the output side is shorted. Input current gradually falls as temperature rises. You should use the value when the

DEFINITION AND EXPLANATION OF TECHNICAL TERMS (CONT.)

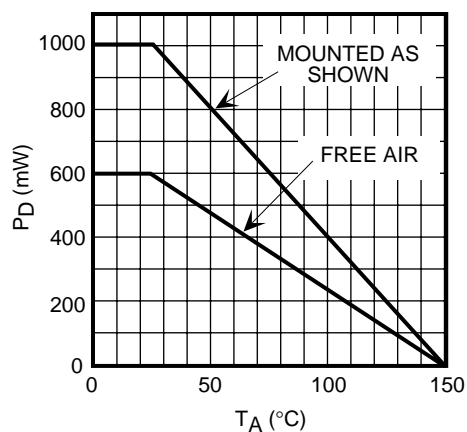
thermal equilibrium is reached. The range of usable currents can also be found from the graph below:



Procedure:

- 1) Find P_D
- 2) P_{D1} is taken to be $P_D \times (\sim 0.8 - 0.9)$
- 3) Plot P_{D1} against 25°C .
- 4) Connect P_{D1} to the point corresponding to the 150°C with a straight line.
- 5) In design, take a vertical line from the maximum operating temperature (e.g., 75°C .) to the derating curve.
- 6) Read off the value of P_D against the point at which the
The maximum operating current is:

$$I_{\text{OUT}} = (D_{\text{PD}} / (V_{\text{IN(MAX)}} - V_{\text{OUT}}))$$



SOT-89 POWER DISSIPATION CURVE

APPLICATION INFORMATION

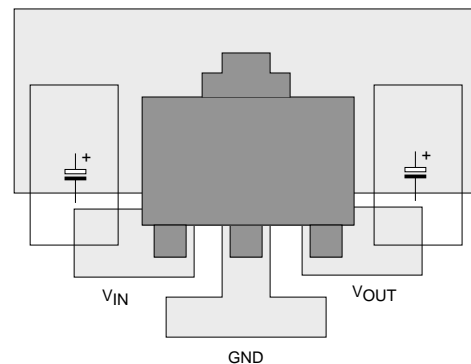
INPUT/OUTPUT DECOUPLING CAPACITOR CONSIDERATIONS

Voltage regulators require input and output decoupling capacitors. The required value of these capacitors vary with application. Capacitors made by different manufacturers can have different characteristics, particularly with regard to high frequencies and Equivalent Series Resistance (ESR) over temperature. The type of capacitor is also important. For example, a $4.7\mu\text{F}$ aluminum electrolytic may be required for a certain application. If a tantalum capacitor is used, a lower value of $2.2\mu\text{F}$ would be adequate. It is important to consider the temperature characteristics of the decoupling capacitors. While Toko regulators are designed to operate as low as $-30\text{ }^\circ\text{C}$, many capacitors will not operate properly at this temperature. The capacitance of aluminum electrolytic capacitors may decrease to 0 at low temperatures. This may cause oscillation on the output of the regulator since some capacitance is required to guarantee stability. Thus, it is important to consider the characteristics of the capacitor over temperature when selection decoupling capacitors.

The ESR is another important parameter. The ESR will increase with temperature but low ESR capacitors are often larger and more costly. In general, tantalum capacitors offer lower ESR than aluminum electrolytic, but new low ESR aluminum electrolytic capacitors are now available from several manufacturers. Usually a bench test is sufficient to determine the minimum capacitance required for a particular application. After taking thermal characteristics and tolerance into account, the minimum capacitance value should be approximately two times this value. Please note that linear regulators with a low dropout voltage have high internal loop gains which require care in guarding against oscillation caused by insufficient decoupling capacitance. The use of high quality decoupling capacitors suited for your application will guarantee proper operation of the circuit.

BOARD LAYOUT

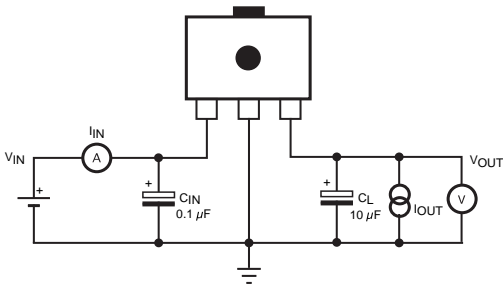
Copper pattern should be as large as possible. Power dissipation is 1000 mW for SOT-89. A low ESR capacitor is recommended. For low temperature operation, select a capacitor with a low ESR at the lowest operating temperature to prevent oscillation, degradation of ripple rejection and increase in noise. The minimum recommended capacitance is $2.2\mu\text{F}$.



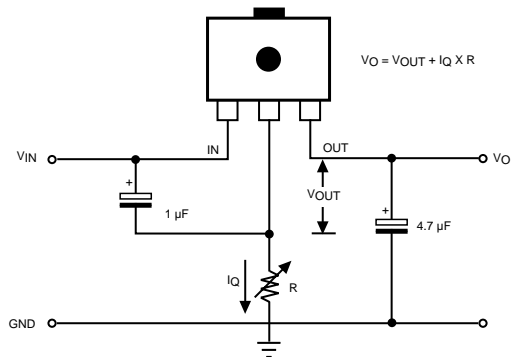
SOT-89 BOARD LAYOUT

TYPICAL APPLICATIONS

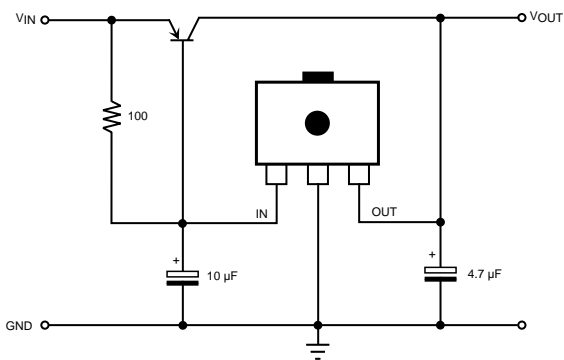
VOLTAGE REGULATOR CIRCUIT



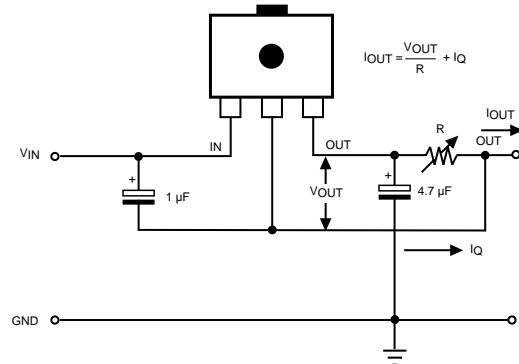
VOLTAGE BOOST CIRCUIT



CURRENT BOOST CIRCUIT



CURRENT REGULATOR CIRCUIT

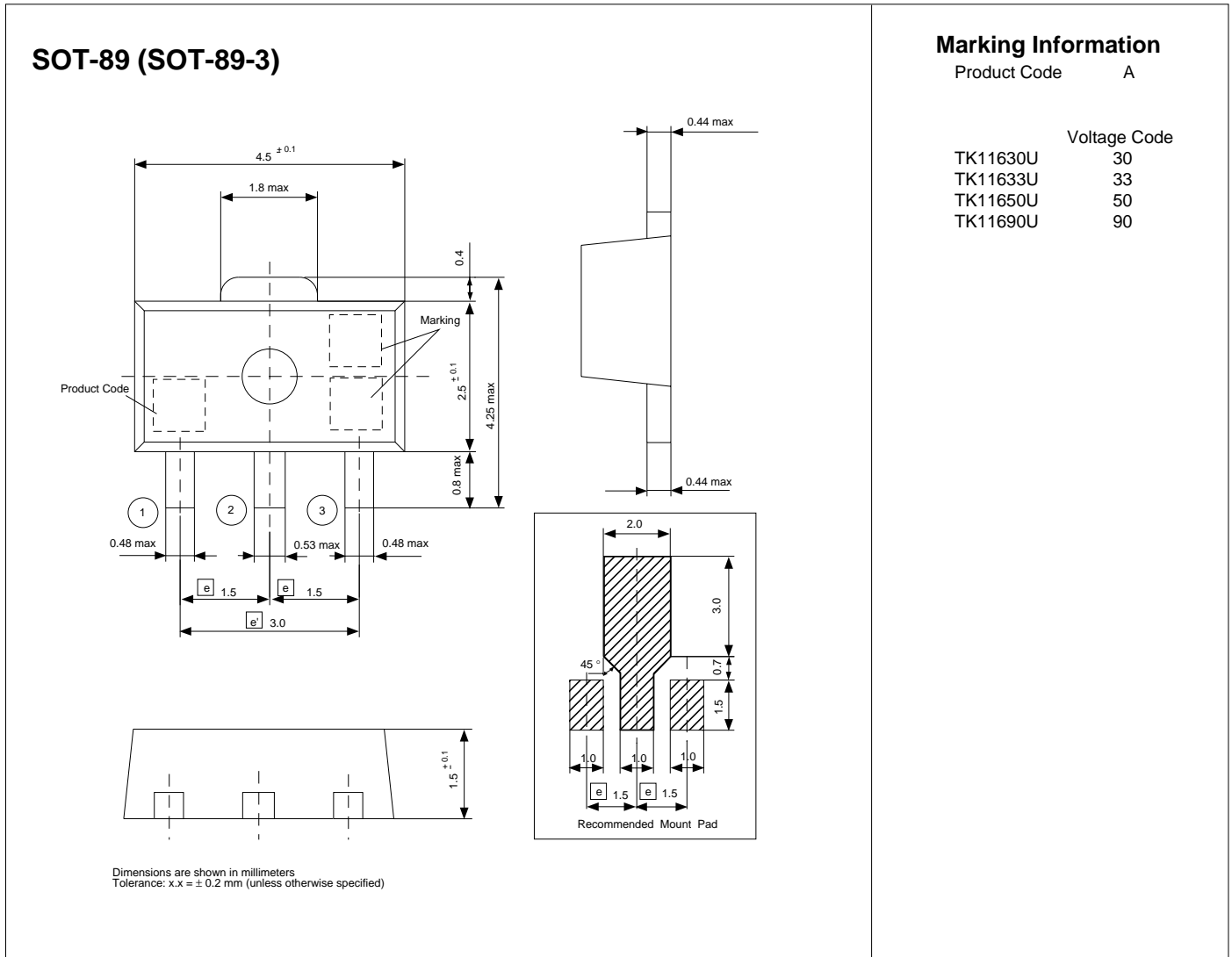


APPLICATION NOTES

Maximize copper foil area connecting to all IC pins for optimum heat conduction. Place input and output bypass capacitors close to the GND pin.

For best transient behavior and lowest output impedance, use as large a capacitor value as possible. The temperature coefficient of the capacitance and Equivalent Series Resistance (ESR) should be taken into account. These parameters can influence power supply noise and ripple rejection. In extreme cases, oscillation may occur. In order to maintain stability, the output bypass capacitor value should be minimum 1 μF for tantalum electrolytic or 4.7 μF for aluminum electrolytic at $T_A = 25\text{ }^\circ\text{C}$.

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