PFM Step-Up DC/DC Regulators

FEATURES

- **Space-Saving 5-Pin SOT-23A Package**
- **Guaranteed 0.9V Start-Up**
- **PFM (100 KHz Max Operating Frequency)**
- **40 µA Maximum Supply Current (V_{OUT} = 3V @ 30 mA)**
- **0.5 µA Shutdown Mode (TC125)**
- **Voltage Sense Input (TC126)**
- **Requires Only Three External Components**
- **80 mA Maximum Output Current**

TYPICAL APPLICATIONS

- **Palmtops/PDAs**
- **Battery-Powered Systems**
- **Cameras**
- **Portable Communicators**

ORDERING INFORMATION

Part #	Output Voltage	Package	Temp. Range
TC125301ECT	3.0V	5-Pin SOT-23A	–40°C to 85°C
TC125331ECT	3.3V	5-Pin SOT-23A	–40°C to 85°C
TC125501ECT	5.0V	5-Pin SOT-23A	–40°C to 85°C
TC126301ECT	3.0V	5-Pin SOT-23A	–40°C to 85°C
TC126331ECT	3.3V	5-Pin SOT-23A	–40°C to 85°C
TC126501ECT	5.0V	5-Pin SOT-23A	–40°C to 85°C

NOTE: Other output voltages are available. Please contact Microchip Technology Inc. for details.

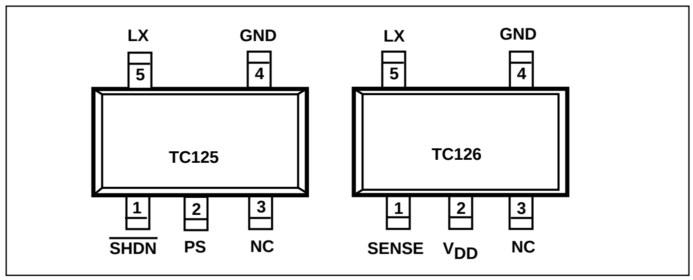
GENERAL DESCRIPTION

The TC125/6 step-up (Boost) switching regulators furnish output currents to a maximum of 80 mA (V_{IN} = 2V, V_{OUT} = 3V) with typical efficiencies above 80%. These devices employ pulse frequency modulation (PFM) for minimum supply current at low loads. They are ideal for battery-operated applications powered from one or more cells. Maximum supply current is less than 70 µA at full output load, and less than 5 µA in standby (V_{OUT} = 3V). Both devices require only an external inductor, diode, and capacitor to implement a complete DC/DC regulator.

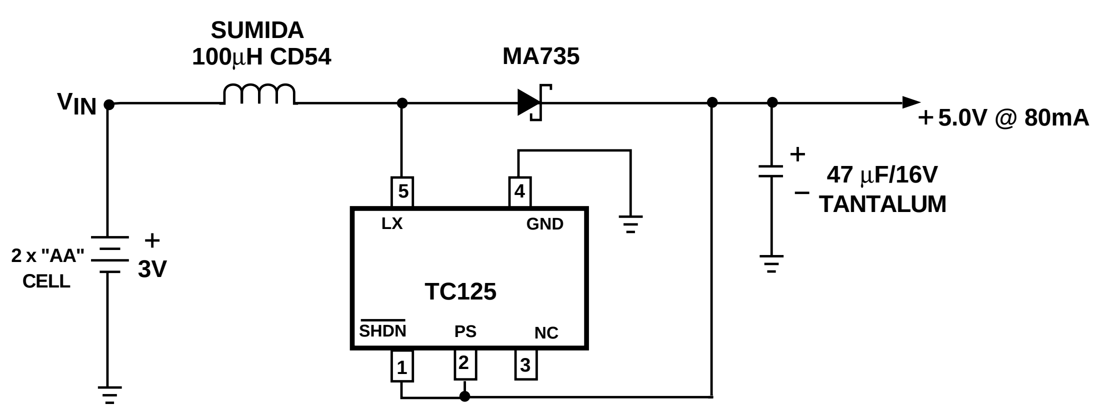
The TC126 has separate output voltage sensing and chip power inputs for greater application flexibility. The TC125 combines the output voltage sensing and chip power inputs onto a single package pin, but adds a power-saving shutdown mode that suspends regulator operation and reduces supply current to less than 0.5 µA when the shutdown control input ($\overline{SHDN}$) is low.

Housed in tiny 5-Pin SOT-23A packages, the TC125/6 occupy minimum board space, and use tiny external components. The TC125 accepts input voltages from 2.0V to 10.0V. The TC126 accepts input voltages from 2.2V to 10V. Both the TC125 and TC126 have a guaranteed start-up voltage of 0.9V at light load.

PIN CONFIGURATIONS



TYPICAL APPLICATION



Two Cell to 5V Boost Regulator

TC125
TC126

ABSOLUTE MAXIMUM RATINGS*

Voltage on V_{DD}, SENSE/V_{DD}, LX, $\overline{SHDN}$ pins . –0.3 to +12V
LX Sink Current .... 400 mA
Power Dissipation .... 150 mW
Operating Temperature .... –40°C to +85°C
Storage Temperature (T_{STG}) .... –40°C to +125°C

*Static-sensitive device. Unused devices must be stored in conductive material. Protect devices from static discharge and static fields. 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 operational sections of the specifications is not implied. Exposure to Absolute Maximum Rating Conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS: $V_{IN} = V_{OUT}$ x 0.6, T_A = 25°C, $\overline{SHDN} = V_{OUT}$ (TC125), unless otherwise noted.

Symbol	Parameter	Test Conditions		Min	Typ	Max	Unit
V_{OUT}	Output Voltage			V_R - 2.5%	V_R ± 0.5%	V_R + 2.5%	V
V_{DD}	Operating Voltage Range	Note 4		0.70	—	10.0	V
V_{START}	Start-Up Voltage	I_{OUT} = 1 mA		—	0.80	0.90	V
I_{DD}	Operating Supply Current	Note 2 TC125	V_{OUT} = 2V, I_{OUT} = 10 mA	—	14	28	µA
		TC125/126	V_{OUT} = 3V, I_{OUT} = 30 mA	—	20	40	
		TC125/126	V_{OUT} = 5V, I_{OUT} = 50 mA	—	32	64	
I_{NL}	No Load Supply Current	I_{OUT} = 0	V_{OUT} = 2V	—	5	9	µA
			V_{OUT} = 3V	—	5	10	
			V_{OUT} = 5V		6	11	
I_{STBY}	Standby Supply Current	$V_{IN} = V_{OUT}$ + 0.5V	V_{IN} = 2V	—	2	4	µA
			V_{IN} = 3V	—	3	5	
			V_{IN} = 5V	—	3	5	
I_{SHDN}	Shutdown Supply Current	Note 2, $\overline{SHDN} = V_{IL}$		–	—	0.5	µA
$R_{LX(ON)}$	LX Pin ON Resistance	Note 2, Note 3, V_{LX} = 0.4V	V_{OUT} = 2V	—	10	14	Ω
			V_{OUT} = 3V	—	6	8	
			V_{OUT} = 5V	—	3	5	
I_{LX}	LX Pin Leakage Current	No External Components, $V_{OUT} = V_{LX}$ = 10V		—	—	1	µA
D_{CYCLE}	Duty Cycle	Note 2, Measured at LX Pin		70	75	80	%
f_{MAX}	Maximum Oscillator Frequency	Note 2		85	100	115	KHz
VLX_{LIM}	LX Pin Limit Voltage	Note 2		0.7	—	1.1	V
η	Efficiency		V_{OUT} = 2V	—	70	—	%
			V_{OUT} = 3V	—	80	—	
			V_{OUT} = 5V	—	85	—	
V_{IH}	$\overline{SHDN}$ Input Logic HIGH			0.75	—	—	V
V_{IL}	$\overline{SHDN}$ Input Logic LOW			—	—	0.20	V
II_{N_H}	$\overline{SHDN}$ Input Current (High)			—	—	0.25	µA
II_{N_L}	$\overline{SHDN}$ Pin Input Current (Low)			–0.25	—	—	µA

NOTES: 1. V_R is the factory output voltage setting.
2. $V_{IN} = V_{OUT}$ x 0.95.
3. V_{DD} input tied to SENSE input for TC126, as shown in Figure 2.
4. The V_{DD} input of the TC126 must be operated between 2.2V and 10.0V for spec compliance.
The V_{PS} input of the TC125 must be operated between 2.0V and 10.0V for spec compliance.

PIN DESCRIPTION

TC125 Pin #	TC126 Pin #	Name	Description
1	—	$\overline{SHDN}$	Shutdown Input. A logic low on this input suspends device operation and reduces supply current to less than 0.5 µA. Device operation resumes when $\overline{SHDN}$ is brought high.
—	1	SENSE	Voltage Sense Input. This input provides feedback voltage sensing to the internal error amplifier. It must be connected to the output voltage node, preferably the single point in the system where tight voltage regulation is most beneficial.
2	—	PS	Power and Voltage Sense Input. This dual function input provides both feedback voltage sensing and internal chip power. It should be connected to the regulator output. (See Figure 1).
—	2	V_{DD}	Power Supply Input.
3	3	NC	Not Connected.
4	4	GND	Ground Terminal.
5	5	LX	Inductor Switch Output. LX is the drain of an internal N-channel switching transistor. This terminal drives the external inductor, which ultimately provides current to the load.

TC125/6 OVERVIEW

The TC125/6 are PFM step-up DC/DC regulators for use in systems operating from two or more cells or in low voltage, line powered applications. Because Pulse Frequency Modulation (PFM) is used, the TC125/6 switching frequency (and therefore supply current) is minimized at low output loads. This is especially important in battery operated applications (such as pagers) that operate in standby mode most of the time. For example, a TC125/6 with a 3V output and no load will consume a maximum supply current of only 10 µA versus a supply current of 40 µA maximum when I_{OUT} = 30 mA. Both devices require only an external inductor, diode, and capacitor to implement a complete DC/DC converter.

The TC125 is recommended for applications requiring shutdown mode as a means of reducing system supply current. The TC125 is powered from the PS input, which must be connected to the regulated output as shown in Figure 1. PS also senses output voltage for closed-loop regulation. Start-up current is furnished through the inductor when input voltage is initially applied. This action starts the oscillator, causing the voltage at the PS input to rise, bootstrapping the regulator into full operation.

The TC126 (Figure 2) is recommended for all applications not requiring shutdown mode. It has separate V_{DD} and SENSE inputs, allowing it to be powered from any source of 2.2V to 10V in the system. The V_{DD} input of the TC126 may be connected to the V_{IN}, V_{OUT}, or an external DC voltage. Lower values of V_{DD} result in lower supply current, but lower efficiency due to higher switch ON resistance. Higher V_{DD} values increase supply current, but drive the internal switching transistor harder (lowering RDS_{ON}), thereby increasing efficiency.

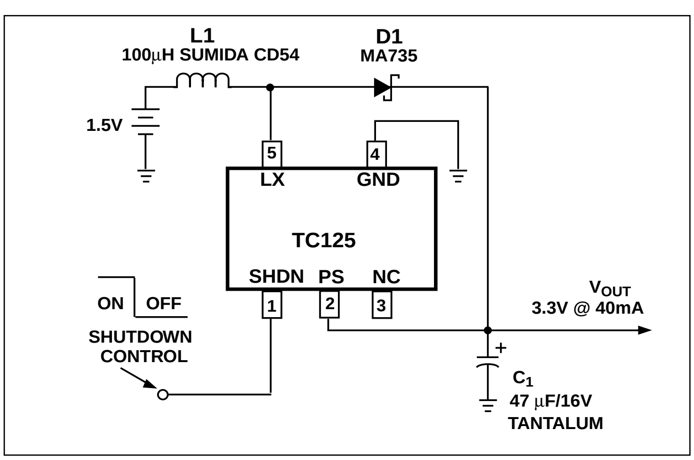


Figure 1.Typical TC125 Circuit

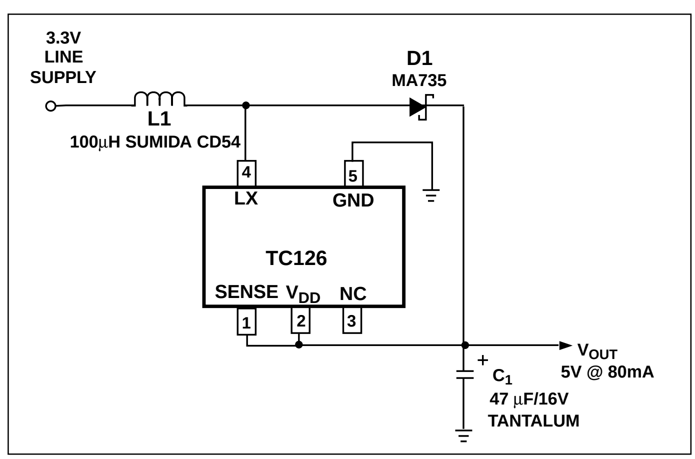


Figure 2. Typical TC126 Circuit

APPLICATIONS

Low Power Shutdown Mode

The TC125 enters a low power shutdown mode when $\overline{SHDN}$ is brought low. While in shutdown, the oscillator is disabled and the internal switch is shut off. Normal regulator operation resumes when $\overline{SHDN}$ is brought high. Because the TC125 uses an external diode, a leakage path between the input voltage and the output node (through the inductor and diode) exists while the regulator is in shutdown. Care must be taken in system design to assure the input supply is isolated from the load during shutdown.

Behavior When V_{IN} is Greater Than the Factory-Programmed OUT Setting

The TC125 and TC126 are designed to operate as step-up regulators only. As such, V_{IN} is assumed to always be less than the factory-programmed output voltage setting (V_R). Operating the TC125/6 with $V_{IN} > V_R$ causes regulating action to be suspended (and corresponding supply current reduction) until V_{IN} is again less than V_R. While regulating action is suspended, V_{IN} is connected to the output voltage node through the series combination of the inductor and Schottky diode. Again, care must be taken to add the appropriate isolation (MOSFET series switch or post LDO with shutdown) during system design if this V_{IN}/V_{OUT} leakage path is problematic.

Input Bypass Capacitors

Adding an input bypass capacitor reduces peak current transients drawn from the input supply and reduces the switching noise generated by the regulator. The source impedance of the input supply determines the size of the capacitor that should be used.

Inductor Selection

Selecting the proper inductor value is a trade-off between physical size and power conversion requirements. Lower value inductors cost less, but result in higher ripple current and core losses. They are also more prone to saturate since the coil current ramps to a higher value. Larger inductor values reduce both ripple current and core losses, but are larger in physical size and tend to increase the start-up time slightly. The recommended inductor value for use with the TC125/6 is 100 µH. Inductors with a ferrite core (or equivalent) are recommended. For highest efficiency, use an inductor with a series resistance less than 20 mΩ.

Internal Transistor Switch Current Limiting

The peak switch current is equal to the input voltage divided by the RDS_{ON} of the internal switch. The internal transistor has absolute maximum current rating of 400 mA with a design limit of 350 mA. A built-in oscillator frequency doubling circuit guards against high switching currents. Should the voltage on the LX pin rise above 1.1V, max while

Table 1. Suggested Components and Manufacturers

Type	Inductors	Capacitors	Diodes
Surface Mount	Sumida CD54 Series CDR125 Series	Matsuo 267 Series Murata GRM200 Series	Nihon EC10 Series
	Coiltronics CTX Series Murata LQN6C Series	Sprague 595D Series Nichicon F93 Series	Matshushita MA735 Series
Through Hole	Sumida RCH855 Series RCH110 Series Renco RL1284-12	Sanyo OS-CON Series Nichicon PL Series	Motorola 1N5817-1N5822

the internal N-channel switch is ON, the oscillator frequency automatically doubles to minimize ON time. Although reduced, switch current still flows because the regulator remains in operation. Therefore, the LX input is not internally current limited and care must be taken never to exceed the 350 mA maximum limit. Failure to observe this will result in damage to the regulator.

Output Diode

For best results, use a Schottky diode such as the MA735, 1N5817, MBR0520L, or equivalent. Connect the diode between the PS and LX pins (TC125) or SENSE and LX pins (TC126) as close to the IC as possible. (Do not use ordinary rectifier diodes since the higher threshold voltages reduce efficiency.)

Output Capacitor

The effective series resistance of the output capacitor directly affects the amplitude of the output voltage ripple. (The product of the peak inductor current and the ESR determines output ripple amplitude.) Therefore, a capacitor with the lowest possible ESR should be selected. Smaller capacitors are acceptable for light loads or in applications where ripple is not a concern. The Sprague 595D series of tantalum capacitors are among the smallest of all low ESR surface mount capacitors available. Table 1 lists suggested component numbers and manufacturers.

Board Layout Guidelines

As with all inductive switching regulators, the TC125/6 generate fast switching waveforms that radiate noise. Interconnecting lead lengths should be minimized to keep stray capacitance, trace resistance, and radiated noise as low as possible. In addition, the GND pin, input bypass capacitor, and output filter capacitor ground leads should be connected to a single point. The input capacitor should be placed as close to power and ground pins of the TC125/6 as possible.

TC125/6 DEMO Card

The TC125/6 DEMO Card can be used to evaluate this series of products. It is a pre-etched and drilled PC card with jumper options to accomodate either device (Figure 3). These cards are available from your local TelCom Semiconductor sales office.

Using the TC125/6 DEMO Board

Mount the TC125/6 on the foil side of the circuit board (Figure 3). The diode, input and output capacitors, and inductor are mounted on the blank side of the board in the locations specified. Jumper locations J1, J2, J3 can be soldered in place as in Table 2, or shorting strips can be installed to facilitate easy reconfiguration. If shorting strips are used, specify 0.1”, single row strip, such as DigiKey S1012 - 36 - ND.

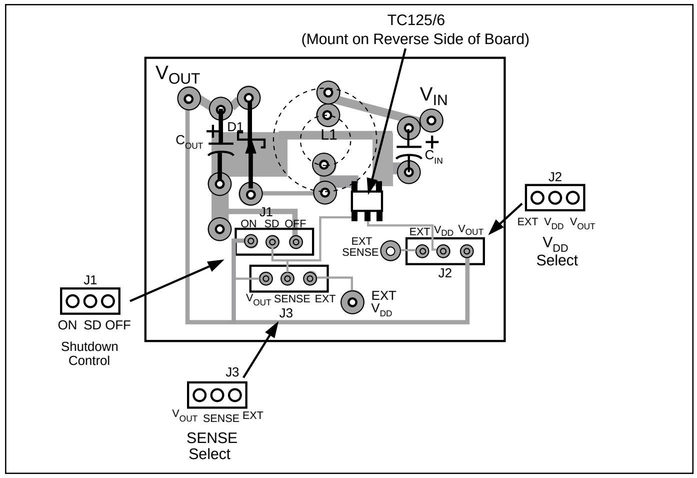


Figure 3. TC125/6 Demo Board Parts

Table 2.

Device	J1	J2	J3
TC125	Short SD to ON	Short V_{DD} to V_{OUT}	Leave OPEN
TC126	Leave OPEN	Short V_{DD} to V_{OUT}	Short SENSE to V_{OUT}

Note that there are two sets of inductor mounting holes to accomodate various sizes of through-hole inductors. Once the components are installed, configure the shorting blocks for normal operation as follows:

The TC125 is placed in shutdown by removing the shorting block (J1) BETWEEN SD and ON and installing it between SD and OFF (J1). The TC126 uses external V_{DD} input when the shorting block between V_{DD} and V_{OUT} is removed from J2 and installed between V_{DD} and EXT. The EXT V_{DD} pad on the board is then wired to desired 2.2V to 10V source. Likewise, external feedback sensing is selected by removing the shorting block between SENSE and V_{OUT} and installing it between V_{OUT} and EXT. The EXT SENSE pad on the board is then wired to the desired location.

Important: Never install shorting blocks on J1 SD to OFF and F3 SENSE to V_{OUT} at the same time. This combination of shorting blocks shorts the input supply!

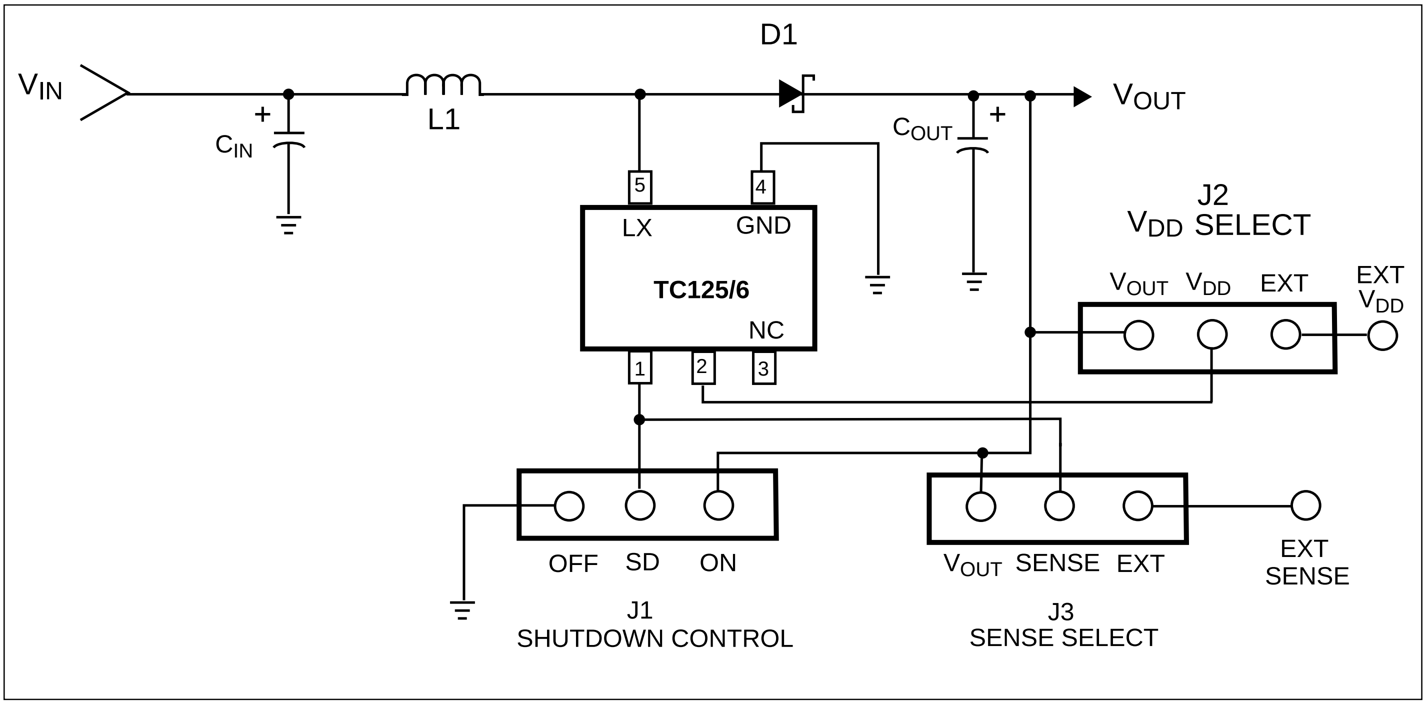


Figure 4. TC125/6 Demo Board Schematic

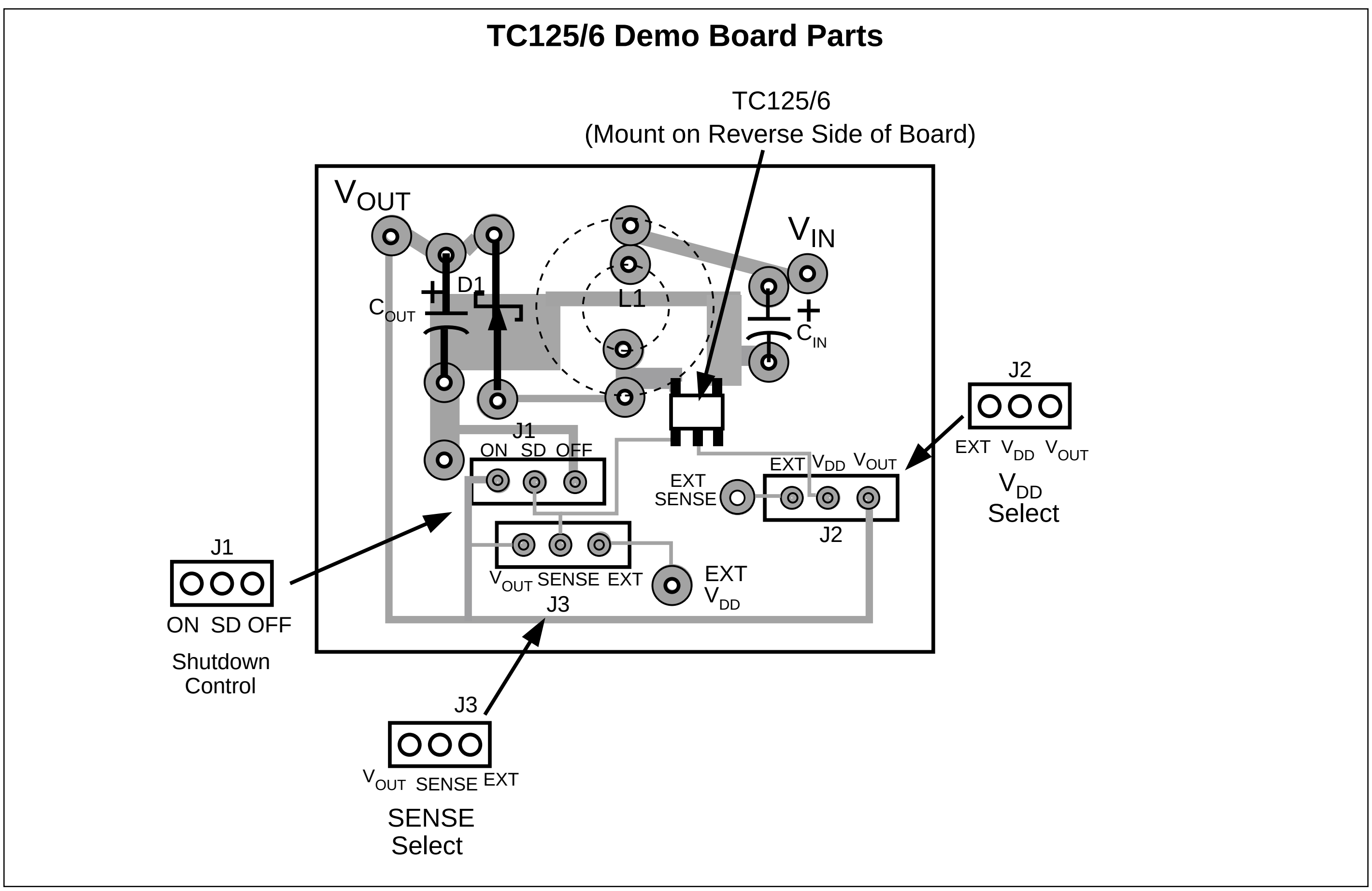
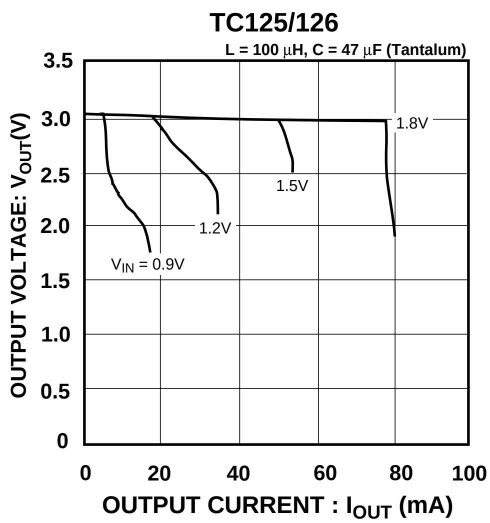
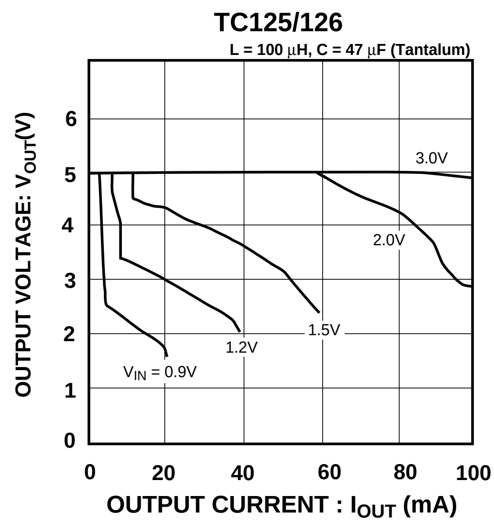


Figure 3. TC125/6 Demo Board Parts

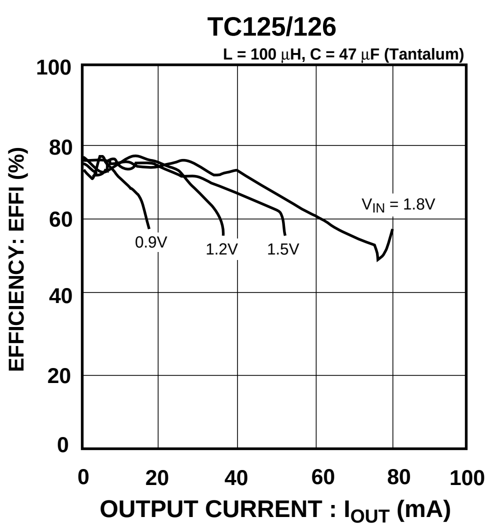
TYPICAL CHARACTERISTICS

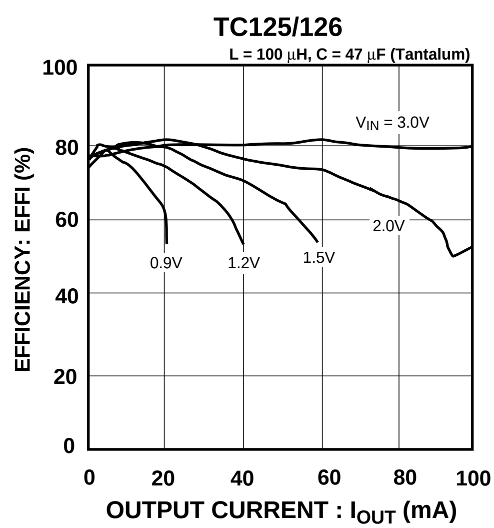
1. OUTPUT VOLTAGE vs. OUTPUT CURRENT





2. EFFICIENCY vs. OUTPUT CURRENT

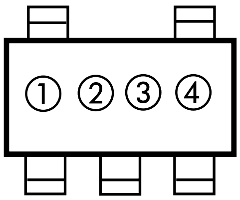




TC125
TC126

MARKINGS

5-Pin SOT-23A



① represents product classification; TC125 = $\overline{L}$
TC126 = $\overline{N}$

② represents integer part of output voltage and frequency

Symbol	
100KHz	**Output Voltage**
1	1
2	2
3	3
4	4
5	5
6	6
7	7

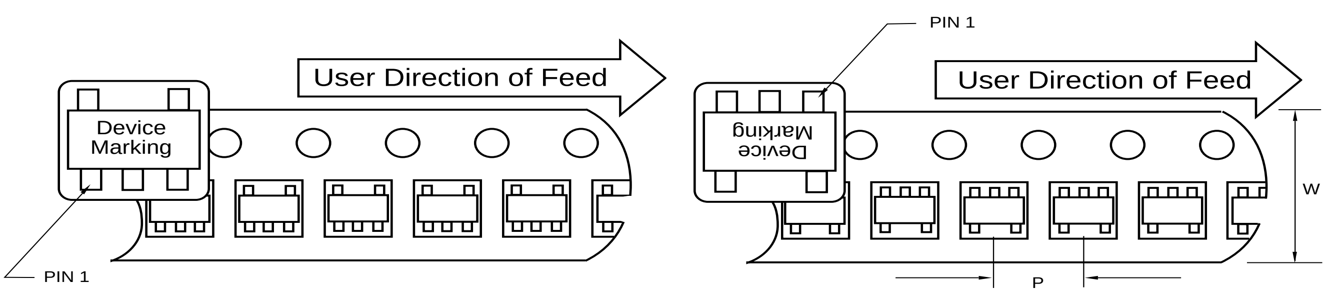
③ represents 1st decimal of output voltage and frequency

Symbol	
100KHz	**Output Voltage**
0	.0
1	.1
2	.2
3	.3
4	.4
5	.5
6	.6
7	.7
8	.8
9	.9

④ represents production lot ID number

TAPING FORM

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



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

Reverse Reel Component Orientation
RT Suffix Device
(Mark Upside Down)

Carrier Tape, Number of Components Per Reel and Reel Size

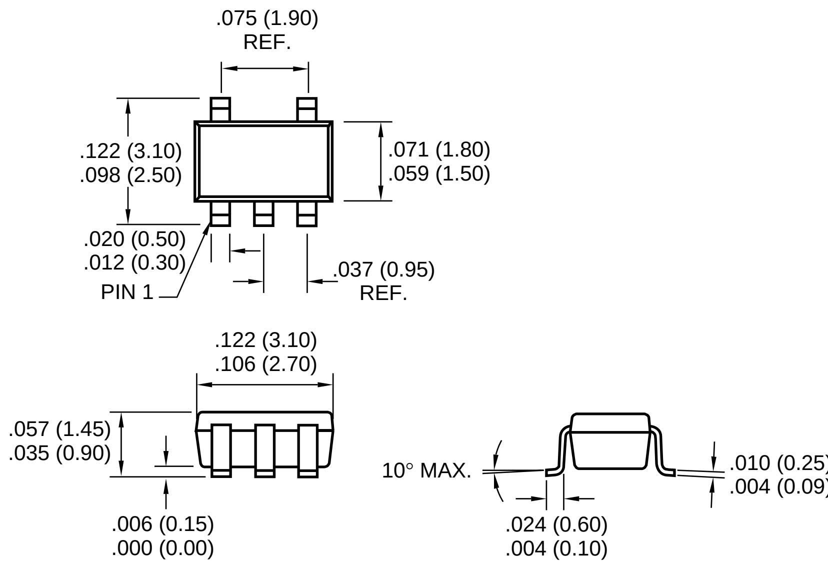
Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
5-Pin SOT-23A	8 mm	4 mm	3000	7 in

Tape and Reel Specifications Table

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

PACKAGE DIMENSIONS

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



Dimensions: inches (mm)

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