24V/3A
Sync. Step-Down Converter

DESCRIPTION

The KA9889 is a monolithic buck switching regulator based on I2 architecture for fast transient response. Operating with an input range of 4V~24V, KA9889 delivers 3A of continuous output current with two integrated N-Channel MOSFETs. The internal synchronous power switches provide high efficiency without the use of an external Schottky diode. At light loads, the regulator operates in low frequency to maintain high efficiency and low output ripples.
KA9889 guarantees robustness with output short protection, thermal protection, current run-away protection, input under voltage lockout.
KA9889 is available in TSOT23-6 packages, which provide a compact solution with minimal external components.

FEATURES

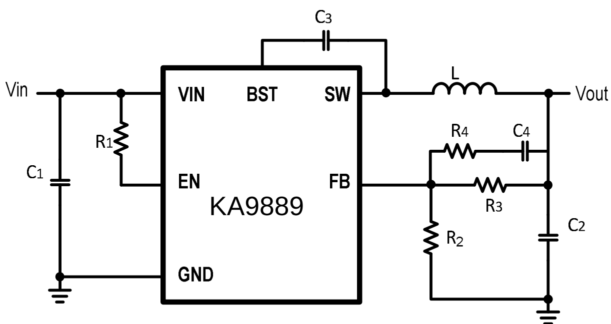
- 4V to 24V operating input range
  3A output current
- Up to 95% efficiency
- High efficiency (>85%) at light load
- 500kHz switching frequency
- Internal soft-start
- Input under voltage lockout
- Current run-away protection
- Output short protection
- Thermal protection
- Available in TSOT23-6

APPLICATIONS

- Distributed Power Systems
- Networking Systems
- FPGA, DSP, ASIC Power Supplies
- Green Electronics/ Appliances
- Notebook Computers

TYPICAL APPLICATION

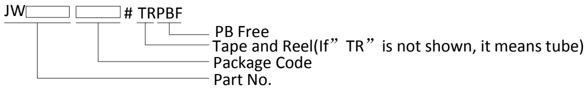
3.3V/3A Step-down Regulator



ORDER INFORMATION

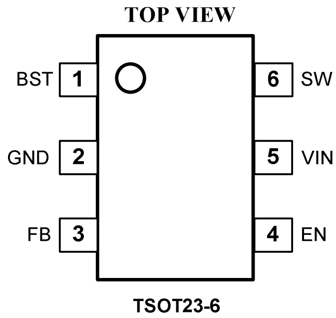
DEVICE[1]	PACKAGE	TOP MARKING[2]
TSOTB#TRPBF	TSOT23-6	J67X

Notes:

1)


2) The first three of top marking mean Part No., and the last letter of top marking means Date Code.

PIN CONFIGURATION



ABSOLUTE MAXIMUM RATING[1)]

VIN, EN, SW Pin .... -0.3V to 25V
BST Pin .... SW-0.3V to SW+5V
All other Pins .... -0.3V to 6V
Junction Temp. [2) 3)] ....150°C
Lead Temperature ....260°C
ESD Susceptibility (Human Body Model) 2kV

RECOMMENDED OPERATING CONDITIONS

Input Voltage VIN .... 4V to 24V
Output Voltage Vout ....0.6V to VIN-3V

THERMAL PERFORMANCE[4)]

θ_{JA} θ_{Jc}

TSOT23-6..110....55°C/W

Note:

1) Exceeding these ratings may damage the device.
2) The KA9889 guarantees robust performance from -40° C to 150°C junction temperature. The junction temperature range specification is assured by design, characterization and correlation with statistical process controls.
3) The KA9889 includes thermal protection that is int ended to protect the device in overload conditions. Thermal protection is active when junction temperature exceeds the maximum operating junction temperature. Continuous operation over the specified absolute maximum operating junction temperature may damage the device.
4) Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

VIN=12V, T_A=25℃，Unless otherwise stated.

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
V_{IN} Under Voltage Lock-out Threshold	V_{IN_MIN}	V_{IN} rising	3.3	3.6	3.8	V
V_{IN} Under voltage Lockout Hysteresis	$V_{IN\_MIN\_HYST}$			200		mV
Shutdown Supply Current	I_{SD}	V_{EN}=0V			1	μA
Supply Current	I_Q	V_{EN}=5V, V_{FB}=1.2V		220		μA
Feedback Voltage	V_{FB}	4V<V_{VIN}<24V		600		mV
Top Switch Resistance[5)]	$R_{DS(ON)T}$			70		mΩ
Bottom Switch Resistance[5)]	$R_{DS(ON)B}$			38		mΩ
Top Switch Leakage Current	I_{LEAK_TOP}	V_{IN}=24V, V_{EN}=0V, V_{SW}=0V			1	μA
Bottom Switch Leakage Current	I_{LEAK_BOT}	V_{IN}=24, V_{EN}=0V, V_{SW}=24V			1	μA
Top Switch Current Limit	I_{LIM_TOP}		5	6	7	A
Minimum On Time[5)]	T_{ON_MIN}			120		ns
Minimum Off Time[5)]	T_{OFF_MIN}	V_{FB}=0.4V		100		ns
EN Rising threshold[5)]	V_{EN_H}	V_{EN} rising	1.9	2.05	2.2	V
EN Hysteresis[5)]	V_{EN_HYS}	V_{EN} Hysteresis		150		mV
Soft-Start Time[5)]	t_{SS}			1.6		ms
Thermal Shutdown[5)]	T_{TSD}			140		°C
Thermal Shutdown hysteresis[5)]	T_{TSD_HYST}			15		°C

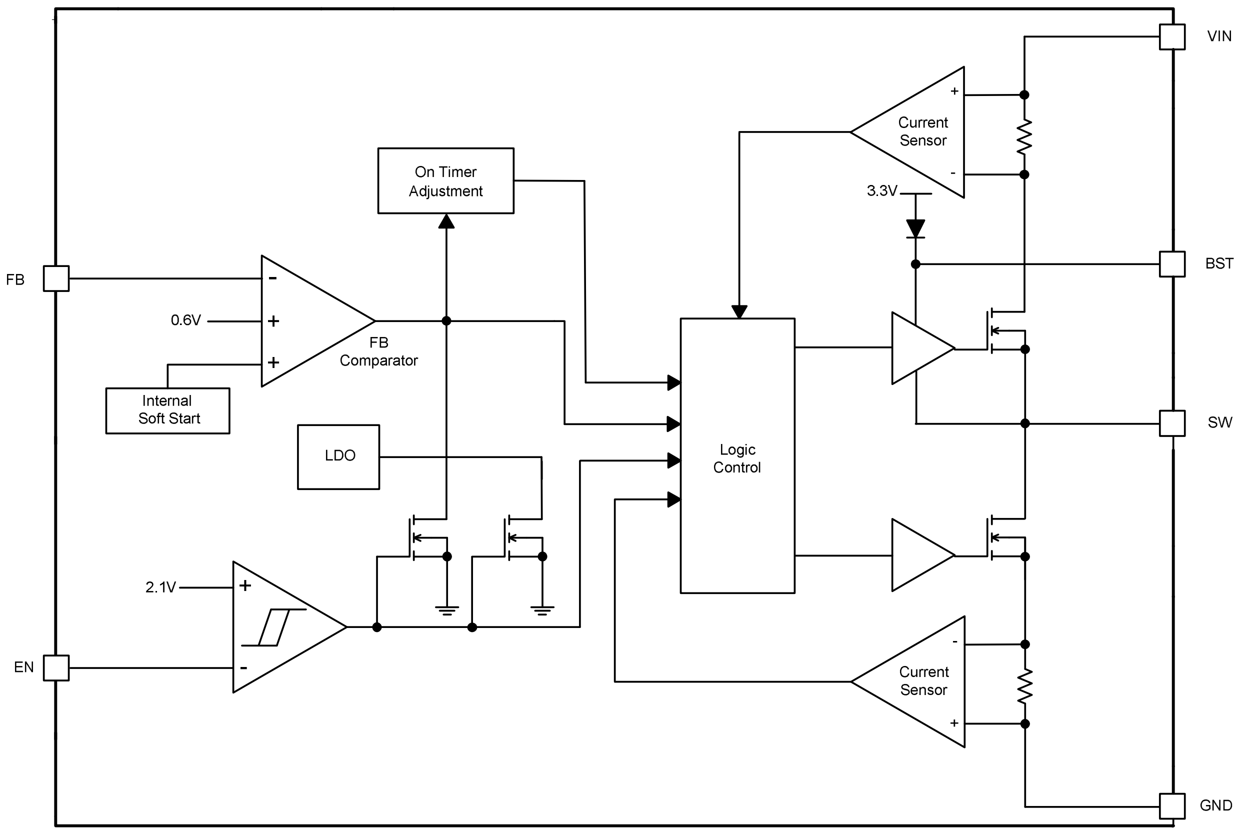
Note：

5) Guaranteed by design.

PIN DESCRIPTION

Pin	Name	Description
2	GND	Ground pin.
6	SW	SW is the switching node that supplies power to the output. Connect the output LC filter from SW to the output load.
5	VIN	Input voltage pin. VIN supplies power to the IC. Connect a 4V to 24V supply to VIN and bypass VIN to GND with a suitably large capacitor to eliminate noise on the input to the IC.
3	FB	Output feedback pin. FB senses the output voltage and is regulated by the control loop to 0.6V. Connect a resistive divider at FB.
4	EN	Drive EN pin high to turn on the regulator and low to turn off the regulator.
1	BST	Connect a 0.1uF capacitor between BST and SW pin to supply current for the top switch driver.

BLOCK DIAGRAM

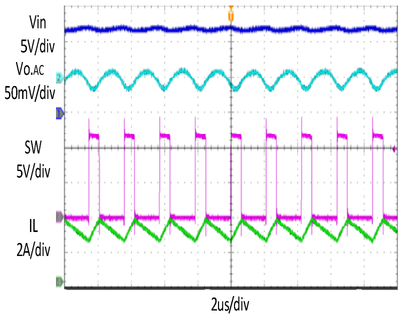


TYPICAL PERFORMANCE CHARACTERISTICS

Vin =12V, Vout = 3.3V, L = 4.7μH, Cout = 22μF, TA = +25°C, unless otherwise noted

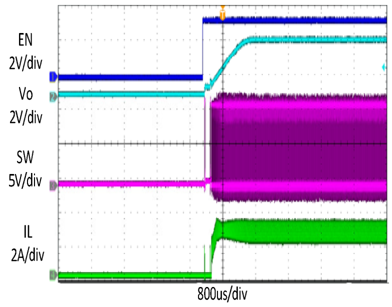
Steady State Test

VIN=12V, Vout=3.3V
Iout=3A



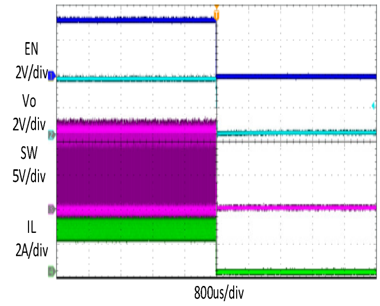
Startup through Enable

VIN=12V, Vout=3.3V
Iout=3A(Resistive load)



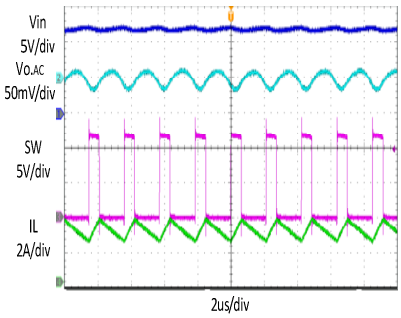
Shutdown through Enable

VIN=12V, Vout=3.3V
Iout=3A (Resistive load)



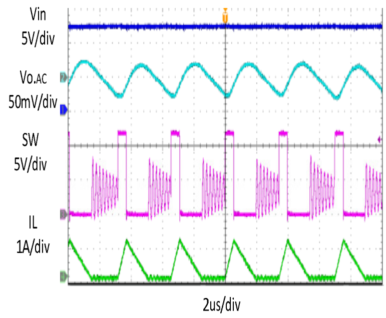
Heavy Load Operation

3A LOAD



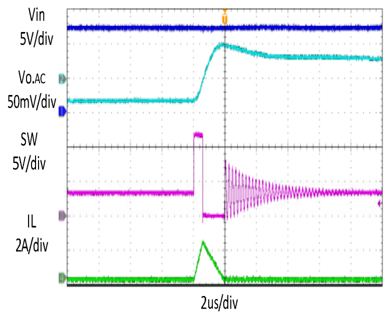
Medium Load Operation

0.3A LOAD



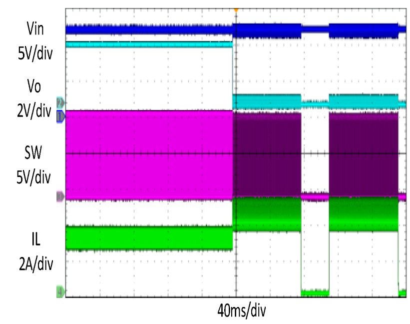
Light Load Operation

0 A LOAD



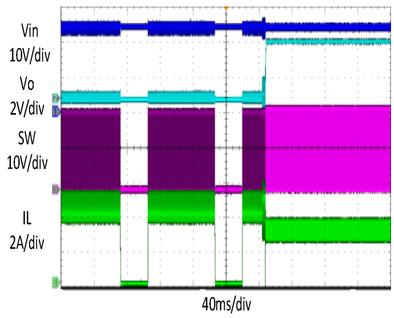
Short Circuit Protection

VIN=12V, Vout=3.3V
Iout=3A- Short



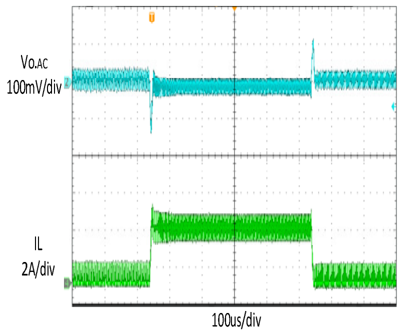
Short Circuit Recovery

VIN=12V, Vout=3.3V
Iout= Short-3A



Load Transient

C4=300pF,R4=1k
0.3A LOAD → 3A LOAD → 0.3A LOAD



TYPICAL PERFORMANCE CHARACTERISTICS

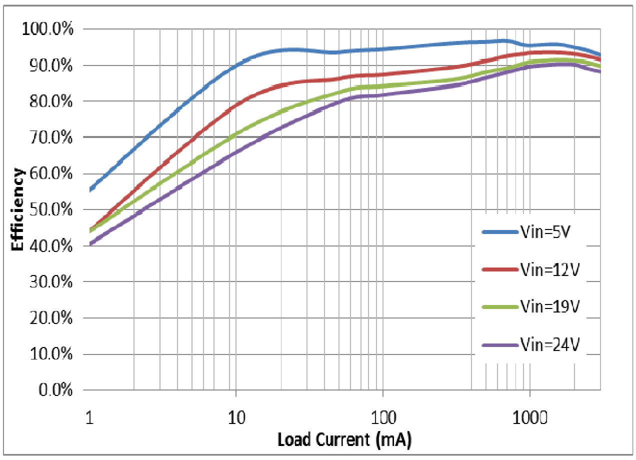


Figure 1. Efficiency vs Load Current

(Vout=3.3V, L=4.7uH)

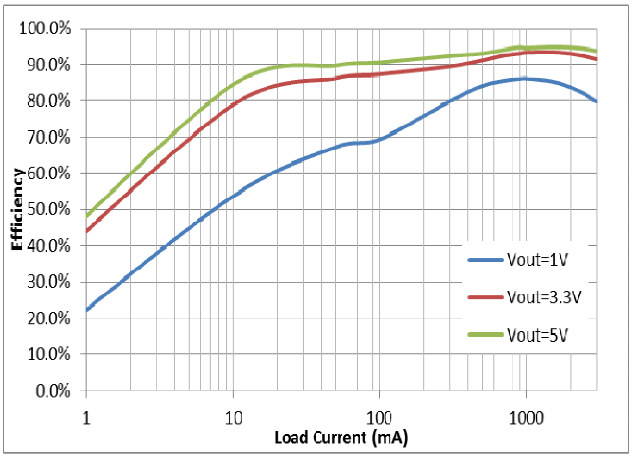


Figure 2. Efficiency vs Load Current

(Vin=12V, L=4.7uH)

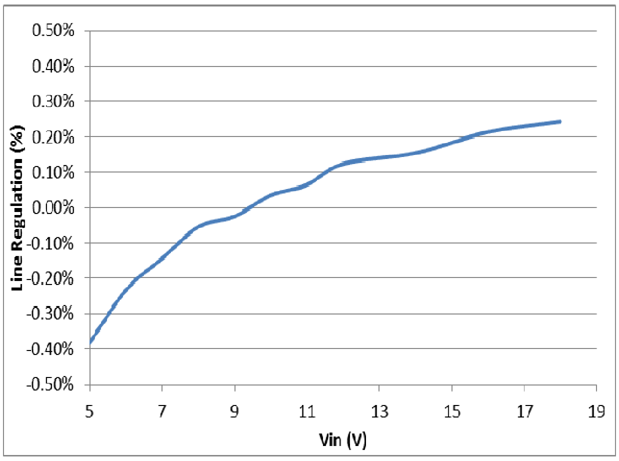


Figure 3. Line Regulation vs Vin

(Vout=3.3V, L=4.7uH)

FUNCTIONAL DESCRIPTION

KA9889 is a synchronous step-down regulator based on I2 control architecture. It regulates input voltages from 4V to 24V down to an output voltage as low as 0.6V, and is capable of supplying up to 3A of load current.

Shut-Down Mode

KA9889 shuts down when voltage at EN pin is driven below 0.3V. The entire regulator is off and the supply current consumed by KA9889 drops below 1uA.

Power Switch

N-Channel MOSFET switches are integrated on the KA9889 to down convert the input voltage to the regulated output voltage. Since the top MOSFET needs a gate voltage great than the input voltage, a boost capacitor connected between BST and SW pins is required to drive the gate of the top switch. The boost capacitor is charged by the internal 3.7V rail when SW is low.

Vin Under-Voltage Protection

A resistive divider can be connected between Vin and ground, with the central tap connected to EN, so that when Vin drops to the pre-set value, EN drops below 2V to trigger input under voltage lockout protection.

Output Current Run-Away Protection

At start-up, due to the high voltage at input and low voltage at output, current inertia of the output inductor can be easily built up, resulting in a large start-up output current.

A valley current limit is designed in KA9889 so that only when output current drops below the valley current limit can the top power switch be turned on. By such control mechanism, the output current at start-up is well controlled.

Output Short Protection

When the output is shorted to ground, the regulator is allowed to switch for 1024 cycles. If the short condition is cleared within this period, then the regulator resumes normal operation. If the short condition is still present after 1024 switching cycles, then no switching is allowed and the regulator enters hiccup mode for 2048 cycles. After the 2048 hiccup cycles, the regulator will try to start-up again. If the short condition still exists after 1024 cycles of switching, the regulator enters hiccup mode. This process of start-up and hiccup iterate itself until the short condition is removed.

Thermal Protection

When the temperature of the KA9889 rises above 140°C, it is forced into thermal shut-down. Only when core temperature drops below 125°C can the regulator becomes active again.

APPLICATION INFORMATION

Output Voltage Set

The output voltage is determined by the resistor divider connected at the FB pin, and the voltage ratio is:

$$V_{FB} = V_{OUT} \cdot \frac{R_2}{R_2 + R_3}$$

where V_{FB} is the feedback voltage and V_{OUT} is the output voltage.

Choose R_2 around 10kΩ~15kΩ, and then R_3 can be calculated by:

$$R_3 = \left(\frac{V_{OUT}}{0.6} - 1\right) \cdot R_2$$

The following table lists the recommended values.

VOUT(V)	R3(kΩ)	R2(kΩ)
2.5	47	15
3.3	49.9	11
5	110	15

Input Capacitor

The input capacitor is used to supply the AC input current to the step-down converter and maintaining the DC input voltage. The ripple current through the input capacitor can be calculated by:

$$I_{C1} = I_{LOAD} \cdot \sqrt{\frac{V_{OUT}}{V_{IN}} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

where I_{LOAD} is the load current, V_{OUT} is the output voltage, V_{IN} is the input voltage.

Thus the input capacitor can be calculated by the following equation when the input ripple voltage is determined.

$$C_1 = \frac{I_{LOAD}}{f_s \cdot \Delta V_{IN}} \cdot \frac{V_{OUT}}{V_{IN}} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

where C_1 is the input capacitance value, f_s is the switching frequency, $\triangle V_{IN}$ is the input ripple voltage.

The input capacitor can be electrolytic, tantalum or ceramic. To minimizing the potential noise, a small X5R or X7R ceramic capacitor, i.e. 0.1uF, should be placed as close to the IC as possible when using electrolytic capacitors.

A 22uF ceramic capacitor is recommended in typical application.

Output Capacitor

The output capacitor is required to maintain the DC output voltage, and the capacitance value determines the output ripple voltage. The output voltage ripple can be calculated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_s \cdot L} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \cdot \left(R_{ESR} + \frac{1}{8 \cdot f_s \cdot C_2}\right)$$

where C_2 is the output capacitance value and R_{ESR} is the equivalent series resistance value of the output capacitor.

The output capacitor can be low ESR electrolytic, tantalum or ceramic, which lower ESR capacitors get lower output ripple voltage.

The output capacitors also affect the system stability and transient response, and a 47uF ceramic capacitor is recommended in typical application.

Inductor

The inductor is used to supply constant current to the output load, and the value determines the ripple current which affect the efficiency and the output voltage ripple. The ripple current is switch current limit, thus the inductance value can be calculated by:

$$L = \frac{V_{OUT}}{f_S \cdot \Delta I_L} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

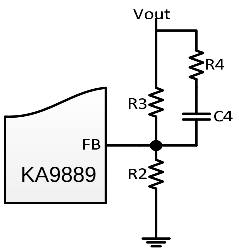
where V_{IN} is the input voltage, V_{OUT} is the output voltage, fs is the switching frequency, and $\triangle I_L$ is the peak-to-peak inductor ripple current.

External Bootstrap Capacitor

A bootstrap capacitor is required to supply voltage to the top switch driver. A 0.1uF low ESR ceramic capacitor is recommended to connected to the BST pin and SW pin.

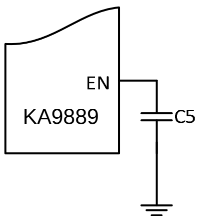
Feedforward Capacitor

In order to minimize the ripple of output voltage at light load, a feedforward capacitor in series with a resistor should be in parallel to the upper divider resistor. Choose R_4 around 1kΩ and C4 around 22pF.



Start up through EN

If KA9889 start up through EN, a 10nF or larger capacitor should be connected between EN pin and GND to eliminate noise.



PCB Layout Note

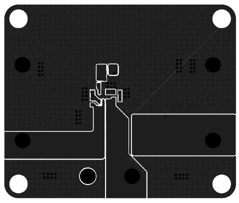
For minimum noise problem and best operating performance, the PCB is preferred to following the guidelines as reference.

1. Place the input decoupling capacitor as close to KA9889 (VIN pin and PGND) as possible to eliminate noise at the input pin. The loop area formed by input capacitor and GND must be minimized.
2. Put the feedback trace as far away from the inductor and noisy power traces as possible.
3. The ground plane on the PCB should be as large as possible for better heat dissipation.

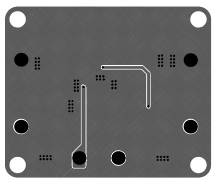
PRINTED CIRCUIT BOARD LAYEROUT

TSOT23-6:

Top Layer



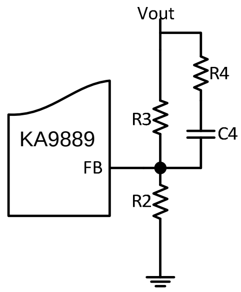
Bottom Layer



Silk Layer

External Components Suggestion:

VOUT(V)	R2 (kΩ)	R3 (kΩ)	R4 (kΩ)	C4 (pF)	L(uH)	Cout(uF)
1	13.3	9	1	180	4.7	54~66
1.2	28	28	1	180	4.7	54~66
1.5	16	24	1	180	4.7	54~66
2.5	15	47	1	22	4.7	22~66
3.3	11	49.9	1	22	4.7	22~66
5	15	110	1	22	4.7	22~66



REFERENCE DESIGN

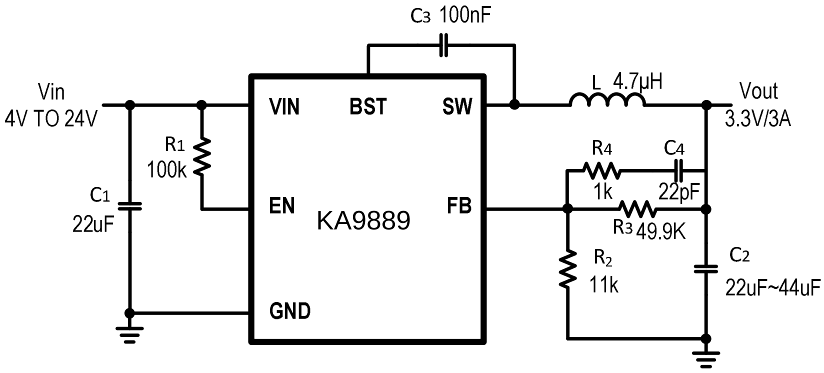
Reference 1:

Vin : 4V~24V

Vout: 3.3V

Iout : 0~3A

TSOT23-6:



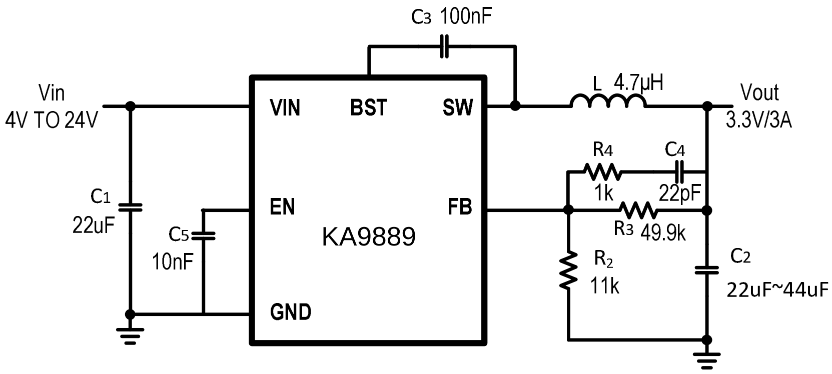
Start up Through EN

Vin : 4V~24V

Vout: 3.3V

Iout : 0~3A

TSOT23-6:



PACKAGE OUTLINE

TSOT23-6	UNIT: mm