

3A Synchronous Step Down DC/DC Converter

■ FEATURES

- 3A Output Current
- Wide 4.75V to 24V Operating Input Range
- Integrated 100mΩ Power MOSFET Switches
- Output Adjustable from 0.925V to 20V
- Up to 95% Efficiency
- Programmable Soft-Start
- Stable with Low ESR Ceramic Output Capacitors
- Fixed 400KHz Frequency
- Cycle-by-Cycle Over Current Protection
- Input Under Voltage Lockout
- SOP8L-EP Package

■ TYPICAL APPLICATION

- Distributed Power Systems
- Networking Systems
- FPGA, DSP, ASIC Power Supplies
- LCD TV / Monitor
- Notebook Computers

■ GENERAL DESCRIPTION

The ZYG1663 is a monolithic synchronous buck regulator. The device integrates 100mΩ MOSFETS that provide 3A continuous load current over a wide operating input voltage of 4.75V to 24V. Current mode control provides fast transient response and cycle-by-cycle current limit.

An adjustable soft-start prevents inrush current at turn on. In shutdown mode, the supply current drops below 1μA.

This device, available in an SOP8L-EP package, provides a very compact system solution with minimal reliance on external components.

ABSOLUTE MAXIMUM RATINGS ⁽¹⁾

Supply Voltage (V_{IN})	.....-0.3V to 28V
Switch Voltage (V_{SW})	.....-1V to $V_{IN} + 0.3V$
Bootstrap Voltage (V_{BS}) $V_{SW}-0.3V$ to $V_{SW} + 6V$
Enable/UVLO Voltage (V_{EN})	.....-0.3V to +6V
Comp Voltage (V_{COMP})	.....-0.3V to +6V
Feedback Voltage (V_{FB})	.....-0.3V to +6V
Junction Temperature	..... +150C
Lead Temperature	..... +270C
Storage Temperature	..... -55°C to +150C

Recommended Operating Conditions ⁽²⁾

Input Voltage (V_{IN})	..... 4.75V to 24V
Output Voltage (V_{SW})	..... 0.925 to 20V
Operating Temperature-20C to +85C

Thermal Resistance ⁽³⁾ θ_{JA} θ_{JC}

SOIC8N50.... 10... °C/W
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(Note: Exceeding these limits may damage the device. Exposure to absolute maximum rating conditions for long periods may affect device reliability.)

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Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{IN}	Input Voltage	4.75	24	V
T_J	Operating Junction Temperature Range	-20	85	°C

ELECTRICAL CHARACTERISTICS

($V_{IN} = 12V$, $T_A = 25^\circ C$ unless otherwise specified.)

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Input Operating Voltage	V_{IN}	$V_{OUT} = 1.0V$, $I_{LOAD} = 0A$ to $3A$	4.75		24	V
Input Holdup Voltage		$V_{OUT} = 1.0V$, $I_{LOAD} = 0A$ to $3A$		4.5		V
Feedback Voltage	V_{FB}	$4.5V \leq V_{IN} \leq 20V$	0.900	0.925	0.950	V
Feedback Overvoltage Threshold				1.1		V
High-Side Switch-On Resistance				100		mΩ
Low-Side Switch-On Resistance				100		mΩ
High-Side Switch Leakage		$V_{EN} = 0V$, $V_{SW} = 0V$		1	10	μA
Upper Switch Current Limit				3.5	4.0	A
Lower Switch Current Limit				0.9		A
COMP to Current Limit Transconductance	G_{COMP}			4.0		A/V
Error Amplifier Transconductance	G_{EA}	$\Delta I_{COMP} = \pm 10\mu A$		800		μA/V
Error Amplifier DC Gain	A_{VEA}			480		V/V
Switching Frequency	f_{SW}		350	400	450	kHz
Short Circuit Switching Frequency		$V_{FB} = 0$		150		kHz
Maximum Duty Cycle	D_{MAX}	$V_{FB} = 0.8V$		90		%
Minimum On Time				220		nS
EN Shutdown Threshold Voltage		V_{EN} Rising	1.1	1.3	1.5	V
EN Shutdown Threshold Voltage Hys-terisis				200		mV
EN Lockout Threshold Voltage			2.2	2.5	2.7	V
EN Lockout Hysteresis				210		mV
Supply Current in Shutdown		$V_{EN} = 0$		0.3	3.0	μA
IC Supply Current in Operation		$V_{EN} = 3V$, $V_{FB} = 1.0V$		1.4	1.5	mA
Input UVLO Threshold Rising	UVLO	V_{EN} Rising	3.80	4.05	4.40	V
Input UVLO Threshold Hysteresis				210		mV
Soft-start Current		$V_{SS} = 0V$		6		μA
Soft-start Period		$CSS = 0.1\mu F$		15		mS
Thermal Shutdown Temperature		Hysteresis = $10^\circ C$		160		°C

3A Synchronous Step Down DC/DC Converter

FUNCTIONAL DESCRIPTION

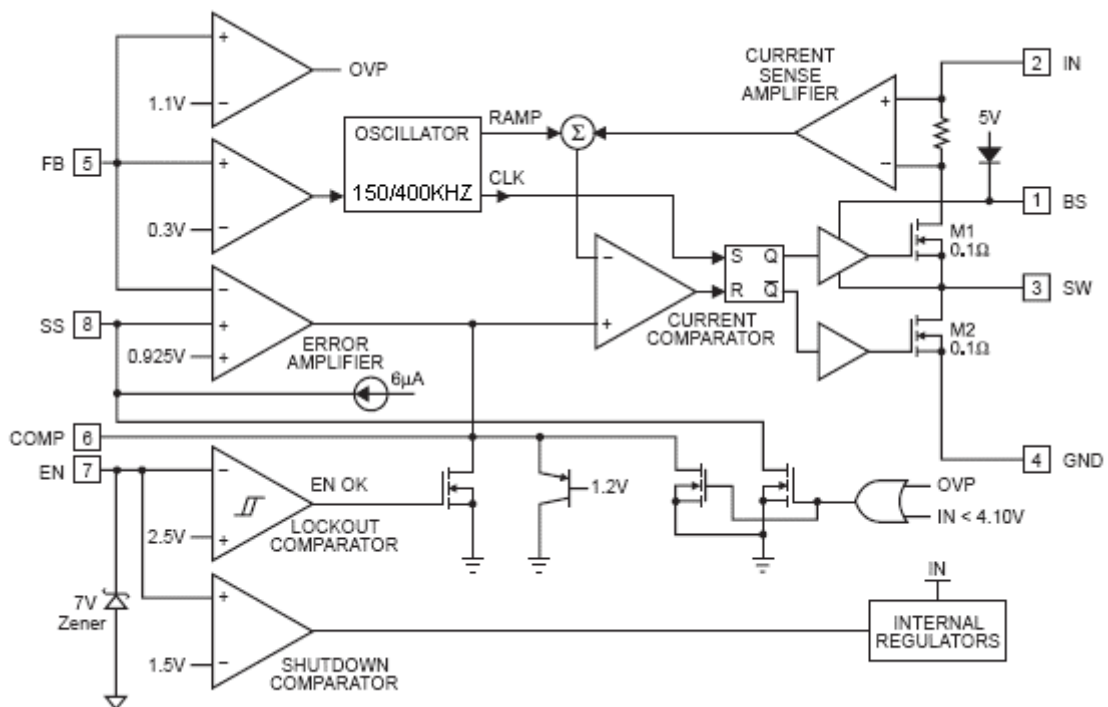
The ZYG1663 is a synchronous rectified, current-mode, step-down regulator. It regulates input voltages from 4.75V to 23V down to an output voltage as low as 0.925V, and supplies up to 3A of load current.

The ZYG1663 uses current-mode control to regulate the output voltage. The output voltage is measured at FB through a resistive voltage divider and amplified through the internal trans-conductance error amplifier. The voltage at the COMP pin is compared to the switch current measured internally to control the output voltage.

The converter uses internal N-Channel MOSFET switches to step-down the input voltage to the regulated output voltage. Since the high side MOSFET requires a gate voltage greater than the input voltage, a boost capacitor connected between SW and BS is needed to drive the high side gate. The boost capacitor is charged from the internal 5V rail when SW is low.

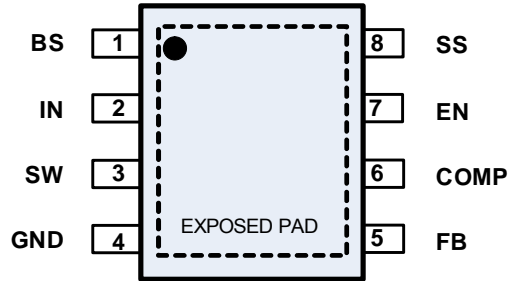
When the ZYG1663 FB pin exceeds 20% of the nominal regulation voltage of 0.925V, the over-voltage comparator is tripped and the COMP pin and the SS pin are discharged to GND, forcing the high-side switch off.

FUNCTIONAL BLOCK DIAGRAM



Top View

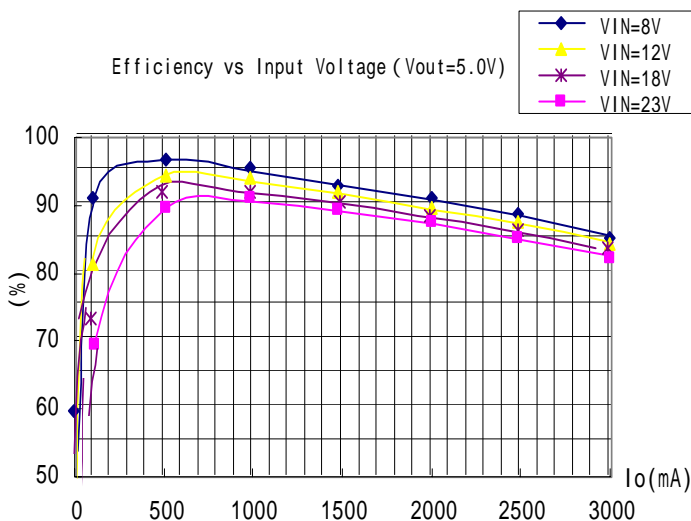
■ PIN ASSIGNMENT



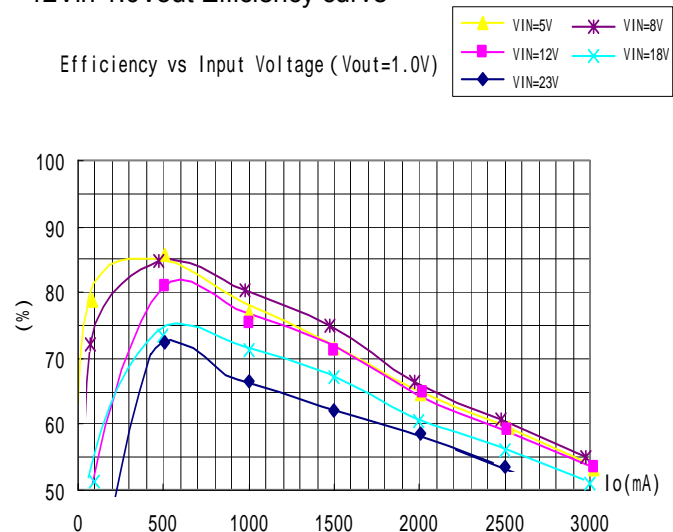
■ PIN DESCRIPTION

Name	No.	Description
BS	1	Bootstrap. This pin acts as the positive rail for the high-side switch's gate driver. Connect a 0.1 μ F capacitor between BS and SW.
IN	2	Input Supply. Bypass this pin to G with a low ESR capacitor. See Input Capacitor in the Application Information section.
SW	3	Switch Output. Connect this pin to the switching end of the inductor.
GND	4	Ground.
FB	5	Feedback Input. The voltage at this pin is regulated to 0.925V. Connect to the resistor divider between output and ground to set output voltage.
COMP	6	Compensation Pin. See Stability Compensation in the Application Information section.
EN	7	Enable Input. When higher than 2.5V, this pin turns the IC on. When lower than 1.3V, this pin turns the IC off. Output voltage is discharged when the IC is off. This pin should not be left open.
SS	8	Soft-Start Control Input. SS controls the soft-start period. Connect a capacitor from SS to GND to set the soft-start period. A 0.1 μ F capacitor sets the soft-start period to 15ms. To disable the soft-start feature, leave SS unconnected.

12Vin 5.0Vout Efficiency curve



12Vin 1.0Vout Efficiency curve



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APPLICATION INFORMATION

Output Voltage Setting

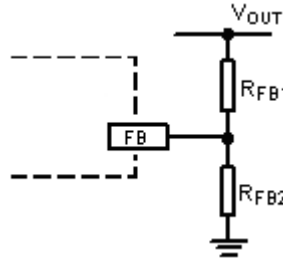


Figure1. Output Voltage Setting

Figure 1 shows the connections for setting the output voltage. Select the proper ratio of the two feedback resistors RFB1 and RFB2 based on the output voltage. Typically, use RFB2 ≈ 10kΩ and determine RFB1 from the following equation:

$$R_{FB1} = R_{FB2} \left(\frac{V_{OUT}}{0.925V} - 1 \right) \quad (1)$$

Table 1—Recommended Resistance Values

VOUT	RFB1	RFB2
1.0V	1.0kΩ	12kΩ
1.2V	3.0kΩ	10kΩ
1.8V	9.53kΩ	10kΩ
2.5V	16.9kΩ	10kΩ
3.3V	26.1kΩ	10kΩ
5V	44.2kΩ	10kΩ
12V	121kΩ	10kΩ

Inductor Selection

The inductor maintains a continuous current to the output load. This inductor current has a ripple that is dependent on the inductance value: higher inductance reduces the peak-to-peak ripple current. The trade off for high inductance value is the increase in inductor core size and series resistance, and the reduction in current handling capability. In general, select an inductance value L based on the ripple current requirement:

$$L = \frac{V_{OUT} \cdot (V_{IN} - V_{OUT})}{V_{IN} f_{SW} I_{OUTMAX} K_{RIPPLE}} \quad (2)$$

where V_{IN} is the input voltage, V_{OUT} is the output voltage, f_{SW} is the switching frequency, I_{OUTMAX} is the maximum output current, and K_{RIPPLE} is the ripple factor. Typically, choose $K_{RIPPLE} = 30\%$ to correspond to the peak-to-peak ripple current being 30% of the maximum output current.

With this inductor value, the peak inductor current is $I_{OUT} \cdot (1 + K_{RIPPLE} / 2)$. Make sure that this peak inductor current is less than the 4A current limit. Finally, select the inductor core size so that it does not saturate at 4A. Typical inductor values for various output voltages are shown in Table 1.

V _{OUT}	1.0V	1.2V	1.5V	1.8V	2.5V	3.3V	5V
L	4.7uH	4.7uH	4.7uH	4.7uH	6.8uH	6.8uH	10uH

Table 1. Typical Inductor Values

Input Capacitor

The input capacitor needs to be carefully selected to maintain sufficiently low ripple at the supply input of the converter. A low ESR capacitor is highly recommended. Since large current flows in and out of this capacitor during switching, its ESR also affects efficiency.

The input capacitance needs to be higher than 10μF. The best choice is the ceramic type; however, low ESR tantalum or electrolytic types may also be used provided that the RMS ripple current rating is higher than 50% of the output current. The input capacitor should be placed close to the IN and G pins of the IC, with the shortest traces possible. In the case of tantalum or electrolytic types, they can be further away if a small parallel 0.1μF ceramic capacitor is placed right next to the IC.

3A Synchronous Step Down DC/DC Converter

Output Capacitor

The output capacitor also needs to have low ESR to keep low output voltage ripple. The output ripple voltage is:

$$V_{RIPPLE} = I_{OUTMAX} K_{RIPPLE} R_{ESR} + \frac{V_{IN}}{8 \cdot f_{SW}^2 L C_{OUT}} \quad (3)$$

where I_{OUTMAX} is the maximum output current, K_{RIPPLE} is the ripple factor, R_{ESR} is the ESR of the output capacitor, f_{SW} is the switching frequency, L is the inductor value, and C_{OUT} is the output capacitance. In the case of ceramic output capacitors, R_{ESR} is very small and does not contribute to the ripple. Therefore, a lower capacitance value can be used for ceramic capacitors. In the case of tantalum or electrolytic capacitors, the ripple is dominated by R_{ESR} multiplied by the ripple current. In that case, the output capacitor is chosen to have sufficiently low ESR.

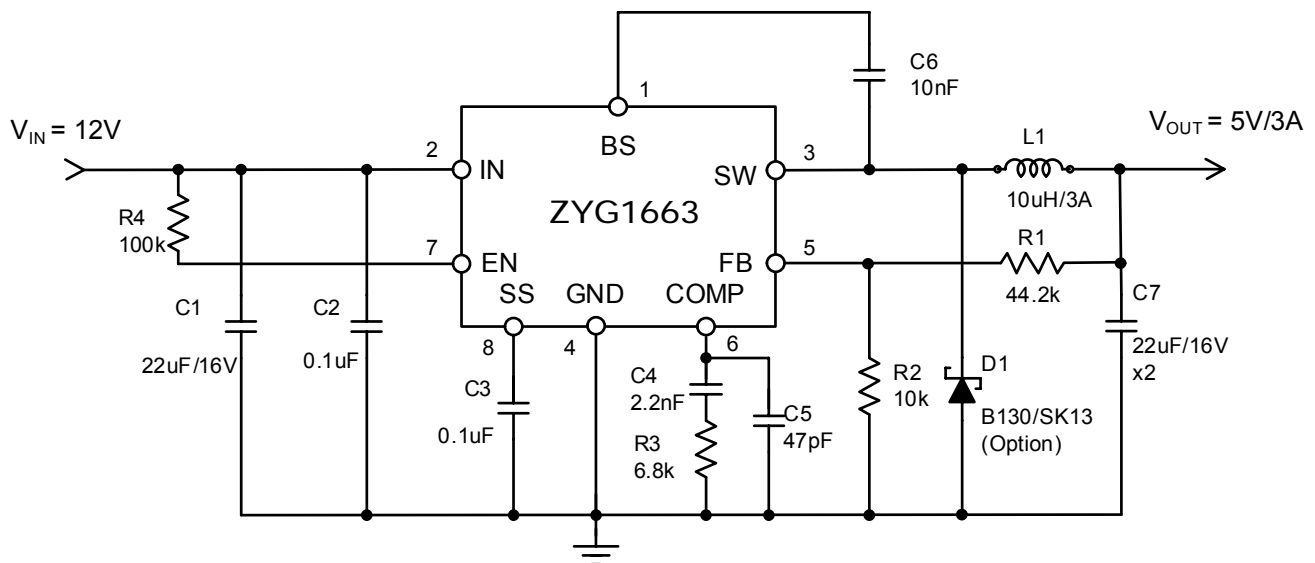
For ceramic output capacitors, typically choose a capacitance of about 22 μ F. For tantalum or electrolytic capacitors, choose a capacitor with less than 50m Ω ESR.

Optional Schottky Diode

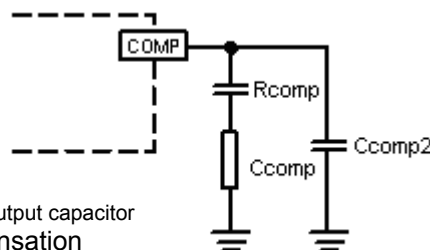
During the transition between high-side switch and low-side switch, the body diode of the low side power MOSFET conducts the inductor current. The forward voltage of this body diode is high. An optional Schottky diode may be paralleled between the SW pin and GND pin to improve overall efficiency. Table 2 lists example Schottky diodes and their Manufacturers.

Table 2—Diode Selection Guide

Part Number	Voltage/Current Rating	Vendor
B130	30V, 1A	Diodes, Inc.
SK13	30V, 1A	Diodes, Inc.
MBRS130	30V, 1A	International Rectifier



Stability Compensation



C_{COMP2} is needed only for high ESR output capacitor
Figure 2. Stability Compensation

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The feedback loop of the IC is stabilized by the components at the COMP pin, as shown in Figure 2. The DC loop gain of the system is determined by the following equation:

$$A_{VDC} = \frac{0.925V}{I_{OUT}} A_{VEA} G_{COMP} \quad (4)$$

The dominant pole P1 is due to C_{COMP} :

$$f_{P1} = \frac{G_{EA}}{2\pi A_{VEA} C_{COMP}} \quad (5)$$

The second pole P2 is the output pole:

$$f_{P2} = \frac{I_{OUT}}{2\pi V_{OUT} C_{OUT}} \quad (6)$$

The first zero Z1 is due to R_{COMP} and C_{COMP} :

$$f_{Z1} = \frac{1}{2\pi R_{COMP} C_{COMP}} \quad (7)$$

And finally, the third pole is due to R_{COMP} and C_{COMP2} (if C_{COMP2} is used):

$$f_{P3} = \frac{1}{2\pi R_{COMP} C_{COMP2}} \quad (8)$$

The following steps should be used to compensate the IC:

STEP1. Set the crossover frequency at 1/10 of the switching frequency via R_{COMP} :

$$R_{COMP} = \frac{2\pi V_{OUT} C_{OUT} f_{SW}}{10 G_{EA} G_{COMP} \cdot 0.925V} \quad (9)$$

but limit R_{COMP} to 10k Ω maximum.

STEP2. Set the zero f_{Z1} at 1/4 of the crossover frequency. If R_{COMP} is less than 10k Ω , the equation for C_{COMP} is:

$$C_{COMP} = \frac{1.8 \times 10^{-5}}{R_{COMP}} \quad (F) \quad (10)$$

If R_{COMP} is limited to 10k Ω , then the actual crossover frequency is 10/ ($V_{OUT} C_{OUT}$). Therefore:

$$C_{COMP} = 1.2 \times 10^{-5} V_{OUT} C_{OUT} \quad (F) \quad (11)$$

STEP3. If the output capacitor's ESR is high enough to cause a zero at lower than 4 times the crossover frequency, an additional compensation capacitor C_{COMP2} is required. The condition for using C_{COMP2} is:

$$R_{ESRCOUT} \geq \text{Min} \left(\frac{1.1 \times 10^{-6}}{C_{OUT}}, 0.012 \cdot V_{OUT} \right) \quad (\Omega) \quad (12)$$

And the proper value for C_{COMP2} is:

$$C_{COMP2} = \frac{C_{OUT} R_{ESRCOUT}}{R_{COMP}} \quad (13)$$

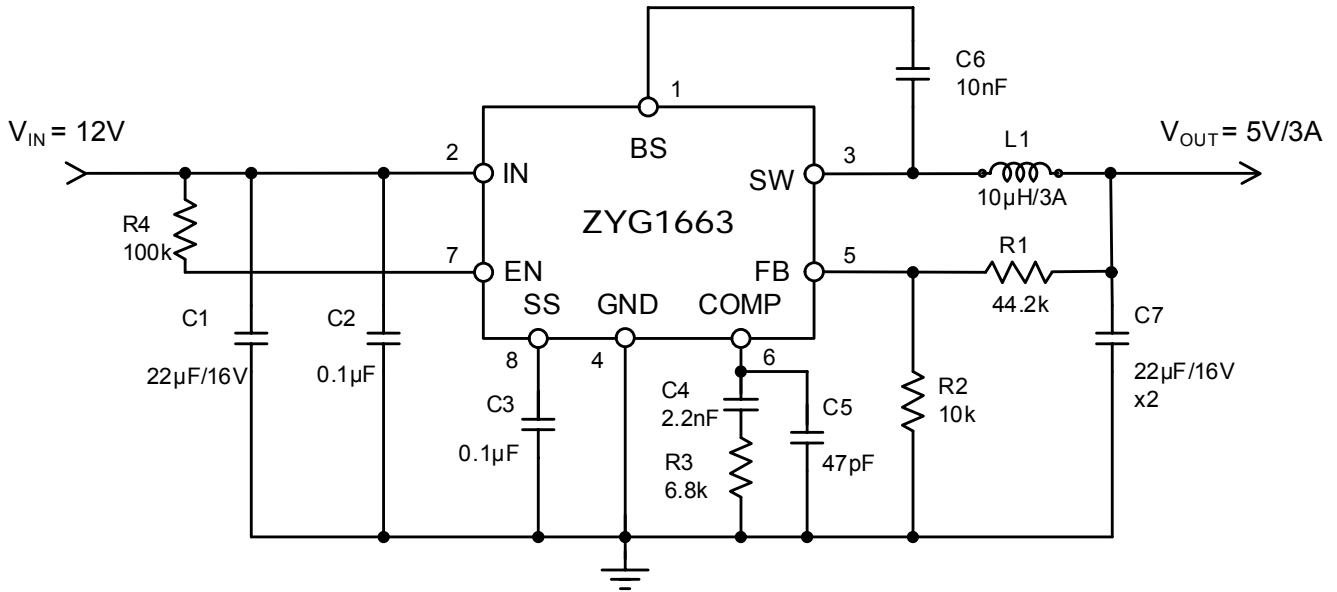


Figure 3 shows a sample ZYG1663 application circuit generating 5V/3A output.

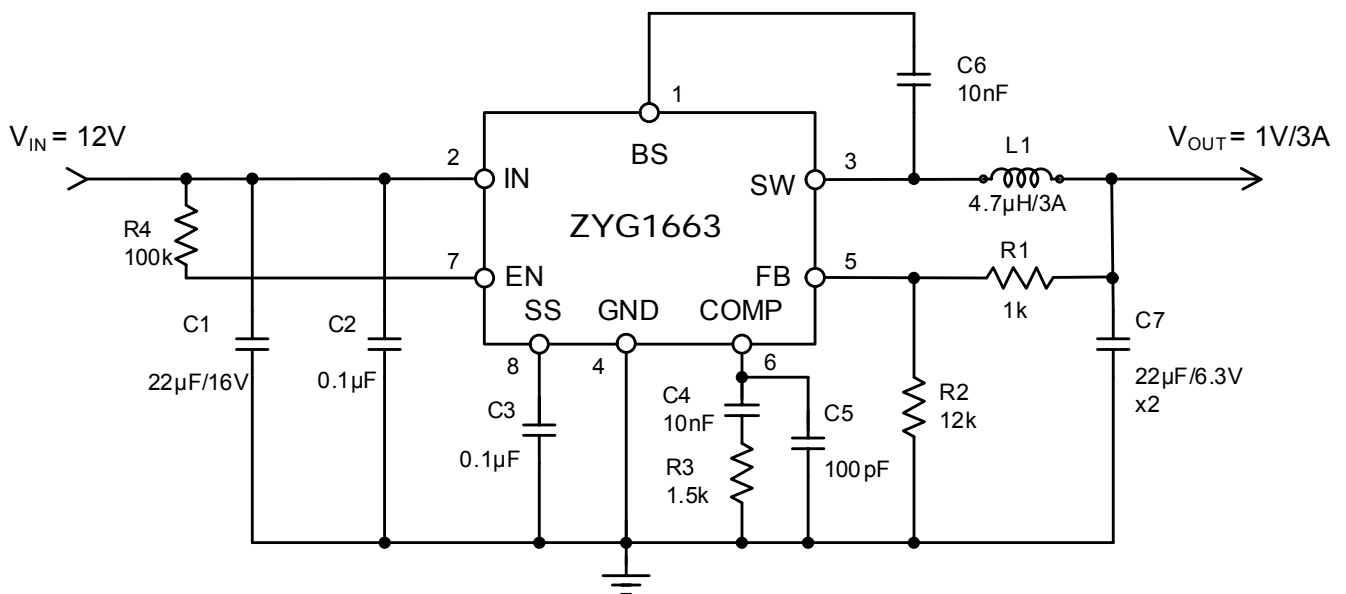
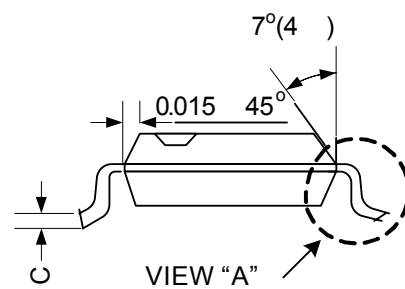
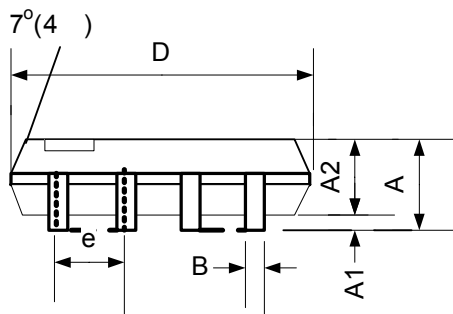
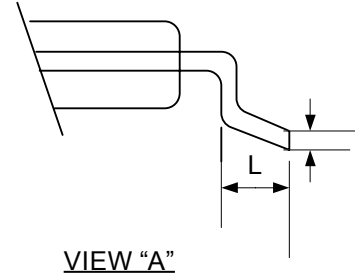
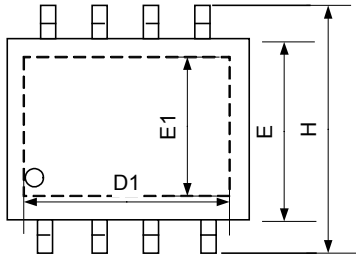


Figure 4 shows a sample ZYG1663 application circuit generating 1.0V/3A output.

3A Synchronous Step Down DC/DC Converter

■ PACKAGE INFORMATION



Symbol	Dimensions In Millimeters			Dimensions In Inches		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	1.35	1.60	1.75	0.053	0.063	0.069
A1	0.05		0.15	0.002		0.006
A2	1.35	1.45	1.55	0.053	0.057	0.061
B	0.33	0.41	0.51	0.013	0.016	0.020
C	0.19	0.20	0.25	0.0075	0.008	0.010
D	4.70	4.90	5.10	0.185	0.196	0.200
D1	3.202		3.402	0.126		0.134
E	3.80	3.90	4.00	0.148	0.154	0.160
E1	2.313		2.513	0.091		0.099
e	1.27TYP.			0.050TYP.		
H	5.80	5.99	6.30	0.228	0.236	0.248
L	0.38	0.71	1.27	0.015	0.028	0.050
θ	0°		8°	0°		8°



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