ELM613DA 2A, 20V, 550kHz, synchronous step-down DC/DC converter

■General description

ELM613DA is 550KHz fixed frequency PWM synchronous step-down regulator. ELM613DA is operated from 4.75V to 20V, the generated output is adjustable from 0.923V to 18V, and the output current can be up to 2A. The integrated two MOSFET switches is with turn on resistance of 0.085Ω. Current mode control provides fast transient response and cycle-by-cycle over current protection. The shutdown current is 1μA typical. Adjustable soft start prevents inrush current at turn on. ELM613DA is with thermal shutdown.

■Features

- Programmable soft start
- Short circuit protection
- Thermal shutdown protection
- Input voltage : 4.75V to 20V
- Output voltage : 0.923V to 18V
- Output current : 2A
- High efficiency : Max.93%
- Power MOSFET switches : 85mΩ
- Shutdown current : Typ.1μA
- Fixed frequency : Typ.550kHz
- Package : SOP-8

■Application

- Distributed power system
- Network system
- FPGA, DSP, ASIC power supply
- Notebook computer
- Green electronics and appliance

■Maximum absolute ratings

Parameter	Symbol	Limit	Unit
VIN power supply voltage	Vin	-0.3 to +21	V
Apply voltage to SW	Vsw	-0.3 to Vin+0.3	V
Apply voltage to BS	Vbs	Vsw-0.3 to Vsw+6	V
Apply voltage to FB	Vfb	-0.3 to +6	V
Apply voltage to COMP	Vcomp	-0.3 to +6	V
Apply voltage to EN	Ven	-0.3 to +6	V
Apply voltage to SS	Vss	-0.3 to +6	V
Power dissipation	Pd	630	mW
Operating temperature range	Top	-40 to +85	°C
Storage temperature range	Tstg	-65 to +150	°C

Caution:Permanent damage to the device may occur when ratings above maximum absolute ones are used.

■Selection guide

ELM613DA-N

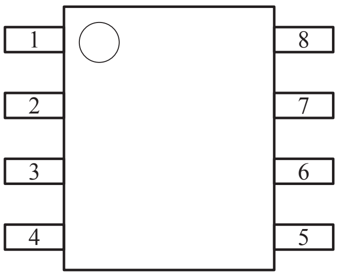
Symbol		
a	Package	D: SOP-8
b	Product version	A
c	Taping direction	N: Refer to PKG file

∗ Taping direction is one way.

ELM613DA - N
↑↑ ↑
a b c

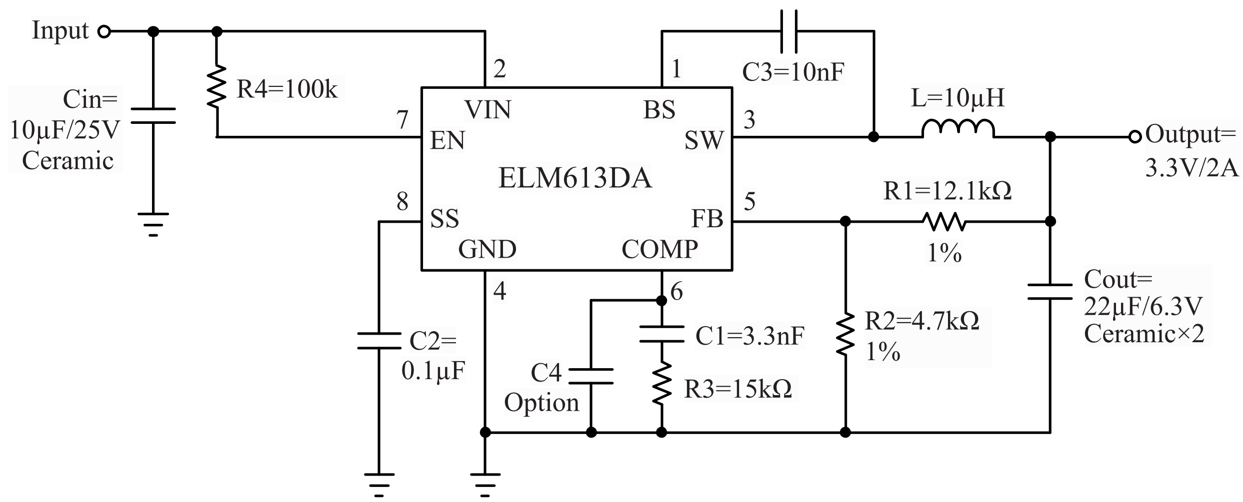
■Pin configuration

SOP-8(TOP VIEW)



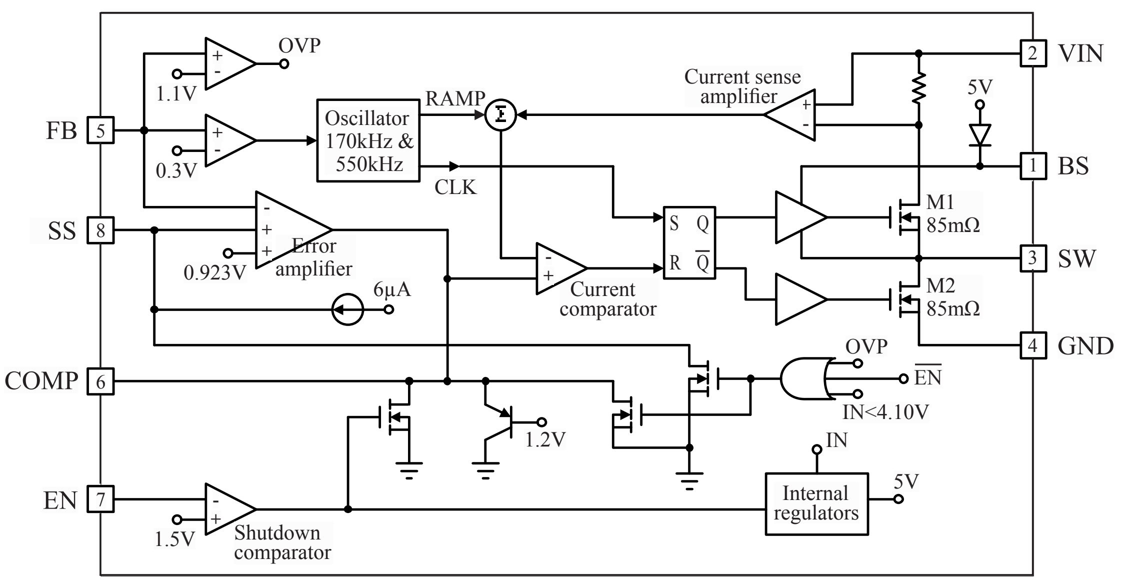
Pin No.	Pin name	Pin description
1	BS	High-side gate drive boost input
2	VIN	Power input
3	SW	Power switching output
4	GND	Ground
5	FB	Feedback input
6	COMP	Compensation node
7	EN	Enable input
8	SS	Soft start control input

■Standard circuit



Note: EN pin is clamped to 5.6V. If EN pin needs to be pulled-up, EN input current has to be lower than 200µA with R4 (about 100kΩ).

■Block diagram



■Electrical characteristics

Vin=+12V, Top=+25°C, unless otherwise noted.

Parameter	Symbol	Test condition	Min.	Typ.	Max.	Unit
Supply voltage	Vin		4.75		20.00	V
Output voltage	Vout		0.923		18.000	V
Output current	Iout				2.0	A
Shutdown current	Is	Ven=0V		1.0	3.0	μA
Supply current	Iss	Ven=2.0V, Vfb=1.0V		1.3	1.5	mA
Feedback voltage	Vfb	4.75V ≤ Vin ≤ 20V	0.900	0.923	0.946	V
Feedback over-voltage threshold	Vfbo-th			1.1		V
Error amplifier voltage gain	Aea			400		V/V
Error amplifier transconductance	Gea	ΔIc = ±10μA		800		μA/V
High-side switch-on resistance	Rds(on)1			85		mΩ
Low-side switch-on resistance	Rds(on)2			85		mΩ
High-side switch leakage current	Ileak	Ven = 0V, Vsw = 0V			10	μA
Upper switch current limit	Ilim_usw	Minimum duty cycle	2.4	4.0		A
Lower switch current limit	Ilim_lsw	From drain to source		1.1		A
COMP to current sense transconductance	Gcs			3.5		A/V
Oscillation frequency	Fosc1		500	550	600	kHz
Short circuit oscillation frequency	Fosc2	Vfb = 0V	120	170	220	kHz
Maximum duty cycle	Dmax	Vfb = 0.78mV		90		%
Minimum on time	To			140		ns
EN shutdown threshold voltage	Vens_th	Ven falling		1.39		V
EN shutdown threshold voltage hysteresis	Vens_hys			210		mV
EN lockout threshold voltage	Venl_th			1.64		V
EN lockout hysteresis	Venl_hys			210		mV
Input under voltage lockout threshold	Vth	Vin rising		4.10		V
Input under voltage lockout threshold hysteresis	Vth_hys			210		mV
Soft-start current	Isoft	Vss = 0V		6		μA
Soft-start period	Psoft	Vss = 0.1μF		15		ms
Thermal shutdown	Tsd			160		°C

■Application notes

ELM613DA is synchronous rectified, current-mode, step-down regulator. It regulates input voltages from 4.75V to 20V down to an output voltage as low as 0.923V, and supplies up to 2A of load current. ELM613DA 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 transconductance 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 ELM613DA FB pin exceeds 20% of the nominal regulation voltage of 0.923V, the over voltage comparator is tripped and the COMP pin and the SS pin are discharged to GND, forcing the high-side switch off.

1. Pin description

BS: High side gate drive boost input

BS supplies the drive for the high-side N-Channel MOSFET switch. Connect a 0.01μF or greater capacitor from SW to BS to power the high side switch.

VIN: Power input

VIN supplies the power to the IC, as well as the step-down converter switches. Drive VIN with a 4.75V to 20V power source. Bypass VIN to GND with a suitably large capacitor to eliminate noise on the input to the IC.

SW: Power switch output

SW is the switching node that supplies power to the output. Connect the output LC filter from SW to the output load. Note that a capacitor is required from SW to BS to power the high-side switch.

GND: Ground

Connect to PCB wiring which is lower than high frequency impedance.

FB: Feedback Input

FB senses the output voltage to regulate that voltage. Drive FB with a resistive voltage divider from the output voltage. The feedback threshold is 0.923V.

COMP: Compensation node

COMP is used to compensate the regulation control loop. Connect a series RC network from COMP to GND to compensate the regulation control loop. In some cases, an additional capacitor from COMP to GND is required.

EN: Enable input

EN is a digital input that turns the regulator on or off. Drive EN high to turn on the regulator, drive it low to turn it off. If EN pin needs to be pulled-up, EN input current has to be lower than 200μA with R4 (about 100kΩ).

SS: Soft-start control input

SS controls the soft start period. Connect a capacitor from SS to GND to set the soft-start period. A 0.1μF capacitor sets the soft-start period to 15ms. To disable the soft-start feature, leave SS unconnected.

2. Setting output voltage

The output voltage is set using a resistive voltage divider from the output voltage to FB pin. The voltage divider divides the output voltage down to the feedback voltage by the ratio:

$$Vfb = Vout \times R2 / (R1 + R2)$$

Where Vfb is the feedback voltage and Vout is the output voltage. Thus the output voltage is:

$$Vout = 0.923 \times (R1 + R2) / R2$$

R2 can be as high as 100kΩ, but a typical value is 10kΩ. Using the typical value for R2, R1 is determined by:

$$R1 = 10.83 \times (Vout - 0.923)\ (k\Omega)$$

3. Inductor

The inductor is required to supply constant current to the output load while being driven by the switched input voltage. A larger value inductor will result in less ripple current that will result in lower output ripple voltage. However, the larger value inductor will have a larger physical size, higher series resistance, and/or lower saturation current. A good rule for determining the inductance to use is to allow the peak-to-peak ripple current in the inductor to be approximately 30% of the maximum switch current limit. Also, make sure that the peak inductor current is below the maximum switch current limit. The inductance value can be calculated by:

$$L = [\ Vout / (fs \times \Delta Il)\ ] \times (1 - Vout/Vin)$$

Where Vout is the output voltage, Vin is the input voltage, fs is the switching frequency, and ΔIl is the peak-to-peak inductor ripple current.

Choose an inductor that will not saturate under the maximum inductor peak current. The peak inductor current can be calculated by:

$$Ilp = Iload + [\ Vout / (2 \times fs \times L)\ ] \times (1 - Vout/Vin)$$

Where Iload is the load current.

The choice of which style inductor to use mainly depends on the price vs. size requirements and any EMI requirements.

4. 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 1 lists example Schottky diodes and their Manufacturers.

Part number	Voltage and current rating	Vendor
B130	30V, 1A	Diodes Inc.
SK13	30V, 1A	Diodes Inc.
MBRS130	30V, 1A	International Rectifier

Table 1: Diode selection guide.

5. Input capacitor

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors may also suffice. Choose X5R or X7R dielectrics when using ceramic capacitors. Since the input capacitor (Cin) absorbs the input switching current it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated by:

$$Icin = Iload \times [\ (Vout/Vin) \times (1 - Vout/Vin)\ ]^{1/2}$$

The worst-case condition occurs at Vin = 2Vout, where Icin = Iload/2. For simplification, choose the input capacitor whose RMS current rating greater than half of the maximum load current.

The input capacitor can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, a small, high quality ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple for low ESR capacitors can be estimated by:

$$\Delta Vin = [\ Iload/(Cin \times fs)\ ] \times (Vout/Vin) \times (1 - Vout/Vin)$$

Where Cin is the input capacitance value.

6. Output capacitor

The output capacitor is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta Vout = [\ Vout/(fs \times L)\ ] \times (1 - Vout/Vin) \times [\ Resr + 1 / (8 \times fs \times Cout)\ ]$$

Where Cout is the output capacitance value and Resr is the equivalent series resistance (ESR) value of the output capacitor.

In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance. The output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated by:

$$\Delta Vout = [\ Vout/(8 \times fs^2 \times L \times Cout)\ ] \times (1 - Vout/Vin)$$

In the case of tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated to:

$$\Delta Vout = [\ Vout/(fs \times L)\ ] \times (1 - Vout/Vin) \times Resr$$

The characteristics of the output capacitor also affect the stability of the regulation system. ELM613DA can be optimized for a wide range of capacitance and ESR values.

7. Compensation components

ELM613DA employs current mode control for easy compensation and fast transient response. The system stability and transient response are controlled through the COMP pin. COMP pin is the output of the internal transconductance error amplifier. A series capacitor and resistor combination sets a pole-zero combination to control the characteristics of the control system.

The DC gain of the voltage feedback loop is given by:

$$Avdc = Rload \times Gcs \times Aea \times Vfb/Vout$$

Where Aea is the error amplifier voltage gain; Gcs is the current sense transconductance and Rload is the load resistor value.

The system has two poles of importance. One is due to the compensation capacitor (C1) and the output resistor of the error amplifier, and the other is due to the output capacitor and the load resistor. These poles are located at:

$$fp1 = Gea / (2\pi \times C1 \times Aea), \quad fp2 = 1 / (2\pi \times Cout \times Rload)$$

Where Gea is the error amplifier transconductance.

The system has one zero of importance, due to the compensation capacitor (C1) and the compensation resistor (R3). This zero is located at:

$$fz1 = 1 / (2\pi \times C1 \times R3)$$

The system may have another zero of importance, if the output capacitor has a large capacitance and/or a high ESR value. The zero, due to the ESR and capacitance of the output capacitor, is located at:

$$fesr = 1 / (2\pi \times Cout \times Resr)$$

In this case, a third pole set by the compensation capacitor (C4) and the compensation resistor (R3) is used to compensate the effect of the ESR zero on the loop gain. This pole is located at:

$$fp3 = 1 / (2\pi \times C4 \times R3)$$

The goal of compensation design is to shape the converter transfer function to get a desired loop gain. The system crossover frequency where the feedback loop has the unity gain is important. Lower crossover frequencies result in slower line and load transient responses, while higher crossover frequencies could cause system instability. A good rule of thumb is to set the crossover frequency below one-tenth of the switching frequency.

To optimize the compensation components, the following procedure can be used.

1) Choose the compensation resistor (R3) to set the desired crossover frequency.

Determine the R3 value by the following equation:

$$R3 = [\ (2\pi \times Cout \times fc) / (Gea \times Gcs)\ ] \times (Vout/Vfb) < [\ (2\pi \times Cout \times 0.1 \times fs) / (Gea \times Gcs)\ ] \times (Vout/Vfb)$$

Where fC is the desired crossover frequency which is typically below one tenth of the switching frequency.

2) Choose the compensation capacitor (C1) to achieve the desired phase margin. For applications with typical inductor values, setting the compensation zero, fz1, below one-forth of the crossover frequency provides sufficient phase margin. Determine the C1 value by the following equation:

$$C1 > 4 / (2\pi \times R3 \times fc)$$

Where R3 is the compensation resistor.

3) Determine if the second compensation capacitor (C4) is required. It is required if the ESR zero of the output capacitor is located at less than half of the switching frequency, or the following relationship is valid:

$$1 / (2\pi \times Cout \times Resr) < fs/2$$

If this is the case, then add the second compensation capacitor (C4) to set the pole fP3 at the location of the ESR zero. Determine the C4 value by the equation:

$$C4 = (Cout \times Resr) / R3$$

8. External bootstrap diode

An external bootstrap diode may enhance the efficiency of the regulator, the applicable conditions of external BS diode are:

$$Vout = 5V \text{ or } 3.3V, \text{ and duty cycle is high: } D = Vout/Vin > 65\%$$

In these cases, an external BS diode is recommended from the output of the voltage regulator to BS pin, as shown in Figure 1.

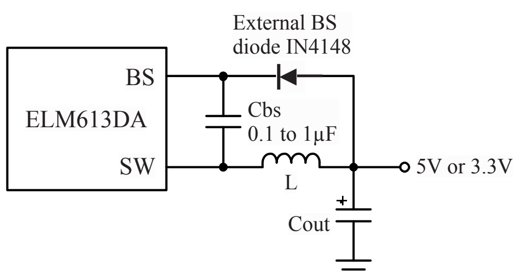


Figure 1. Add optional external bootstrap diode to enhance efficiency.

The recommended external BS diode is IN4148, and the BS capacitor is 0.1 to 1μF.

when Vin≤ 6V, for the purpose of promote the efficiency, it can add an external Schottky diode between IN and BS pins, as shown in Figure 2.

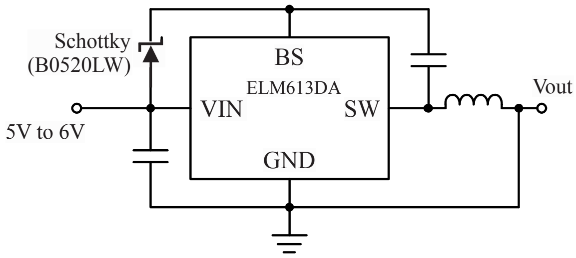


Figure 2: Add a Schottky diode to promote efficiency when Vin ≤ 6V.

9. PCB layout guide

PCB layout is very important to achieve stable operation. Please follow the guidelines below.

1) Keep the path of switching current short and minimize the loop area formed by Input capacitor, high-side MOSFET and low-side MOSFET.
2) Bypass ceramic capacitors are suggested to be put close to the VIN Pin.
3) Ensure all feedback connections are short and direct. Place the feedback resistors and compensation components as close to the chip as possible.
4) Rout SW away from sensitive analog areas such as FB.
5) Connect IN, SW, and especially GND respectively to a large copper area to cool the chip to improve thermal performance and long-term reliability.

Table2 : BOM of ELM613DA

	L	R1		R2	R3	Cout	C1
Vout=5.0V	10µH	15K	15K	6.8K	16K	22µF	3.3nF
Vout=3.3V	10µH	12K	100	4.7K	15K	22µF	3.3nF
Vout=2.5V	10µH	9.1K	470	5.6K	13K	22µF	3.3nF
Vout=1.8V	10µH	6.8K	1K	8.2K	6.8K	22µF	3.3nF
Vout=1.2V	4.7µH	1.5K	1.5K	10K	5.1K	22µF	3.3nF
Vout=1.0V	3.3µH	1K	1K	24K	4.7K	22µF	3.3nF

■Marking

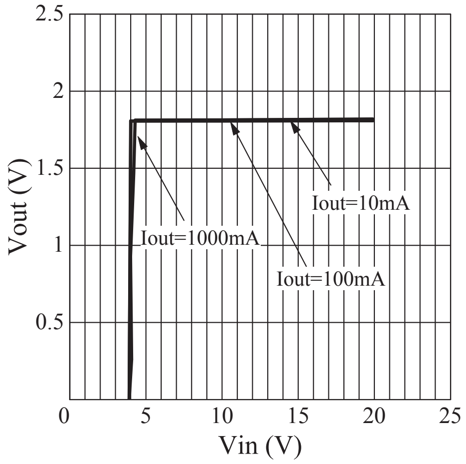
SOP-8

Mark	Content
LV1482SN	Product ID
a to k	Assembly lot No.: 0 to 9 & A to Z repeated

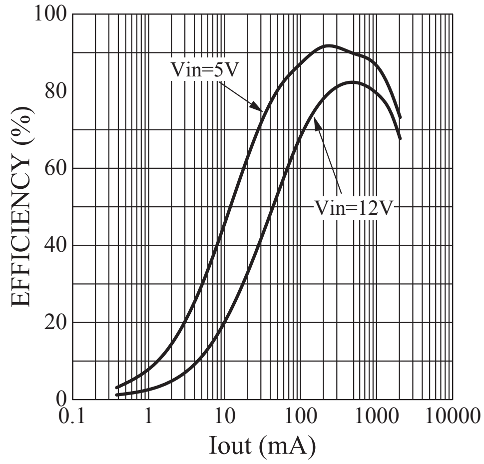
■Typical characteristics

- Vout=1.8V : Cin=10μF, Cout=22μF, L=10μH, R1=9.5k, R2=10k, R3=15k
  C1=3.3nF, C2=0.1μF, C3=10nF, Top=25°C

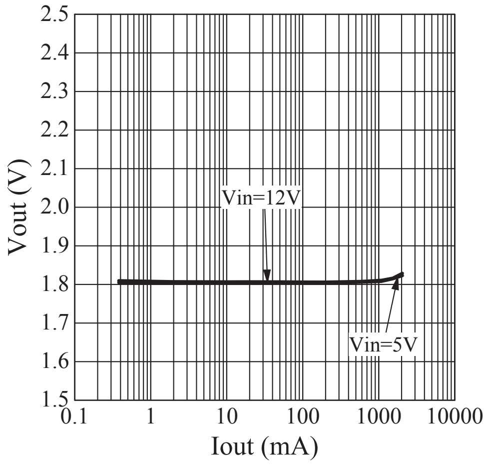
Vout-Vin



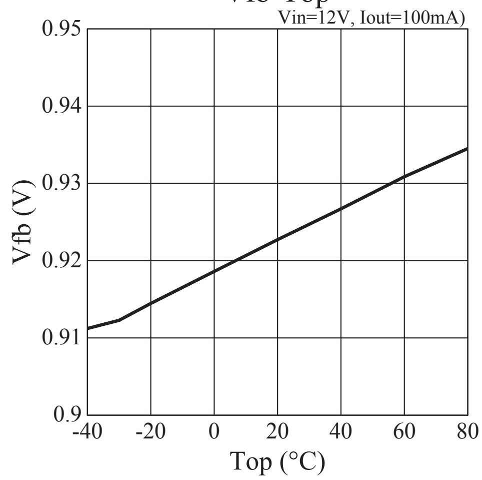
EFFICIENCY-Iout



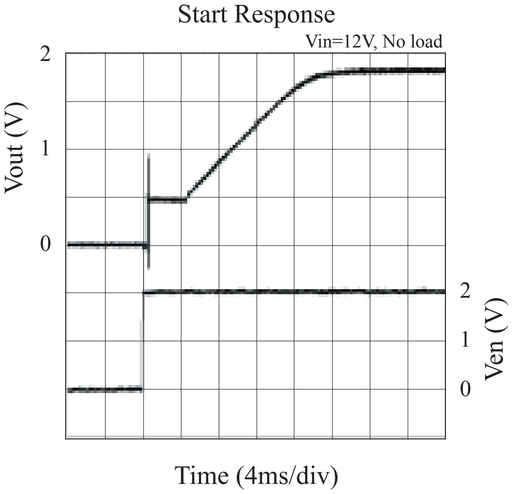
Vout-Iout



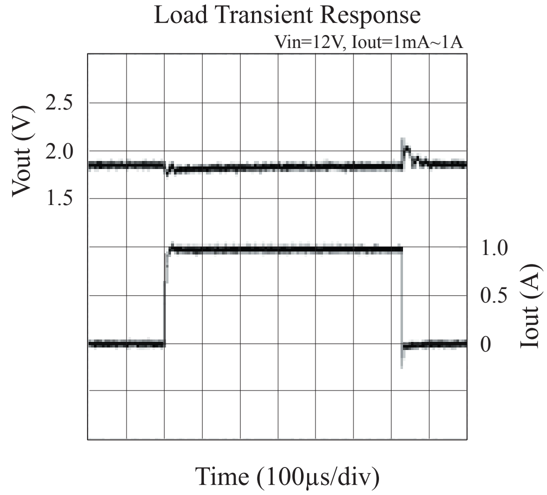
Vfb-Top



Start Response

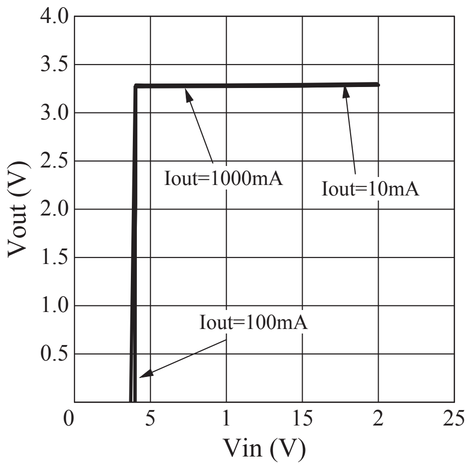


Load Transient Response

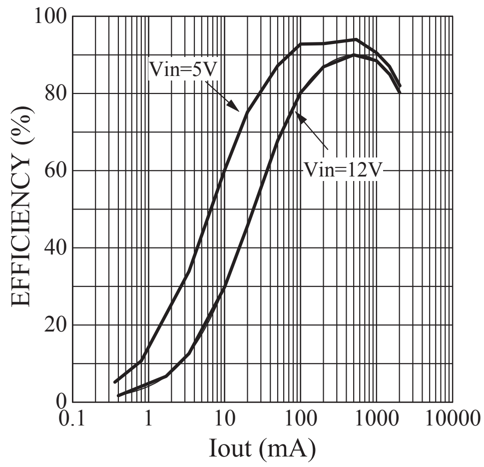


- Vout=3.3V : Cin=10µF, Cout=22µF, L=10µH, R1=12k, R2=4.7k, R3=15k
  C1=3.3nF, C2=0.1µF, C3=10nF, Top=25°C

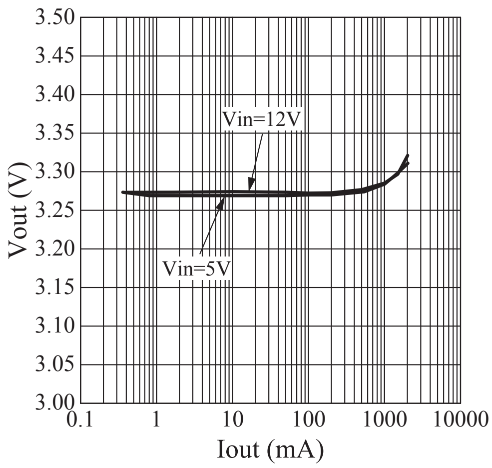
Vout-Vin



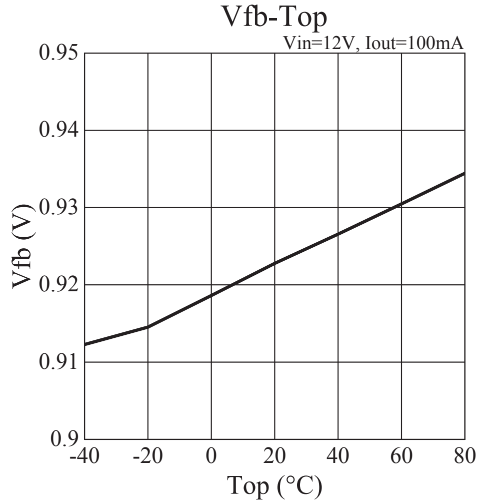
EFFICIENCY-Iout



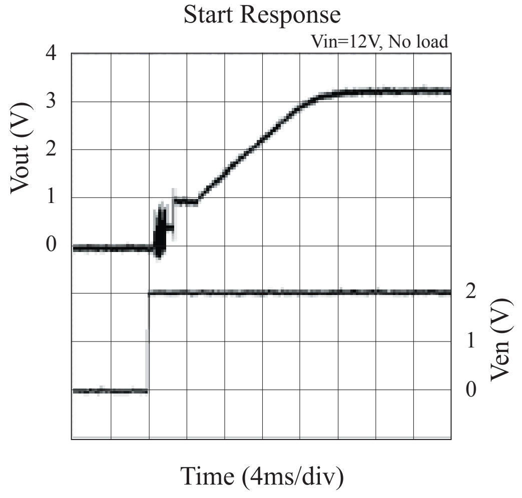
Vout-Iout



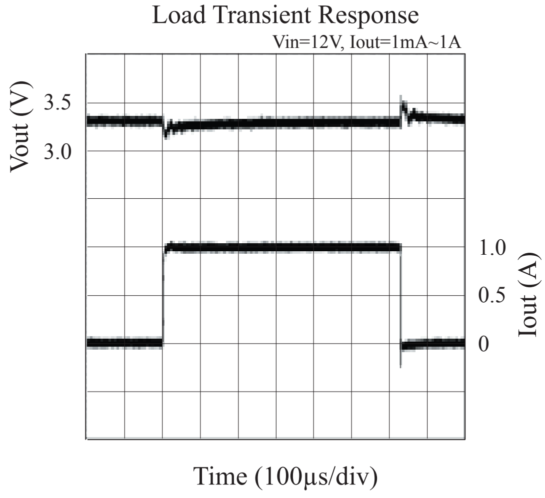
Vfb-Top



Start Response



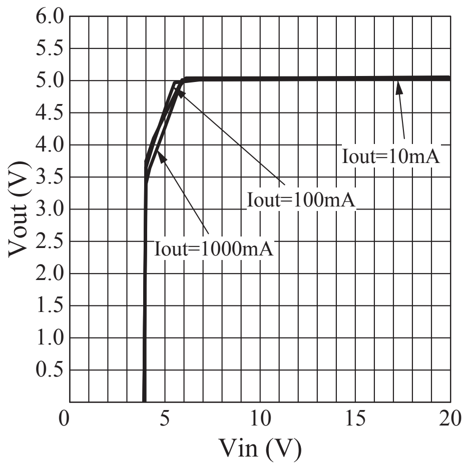
Load Transient Response



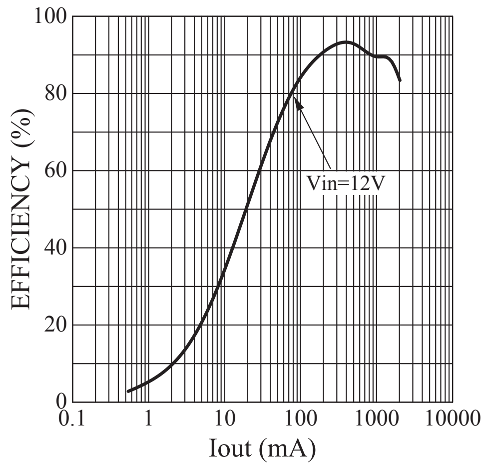
ELM613DA 2A, 20V, 550kHz, synchronous step-down DC/DC converter

- Vout=5.0V : Cin=10μF, Cout=22μF, L=10μH, R1=30K R2=6.8K R3=15K
  C1=3.3nF, C2=0.1μF, C3=10nF, Top=25°C

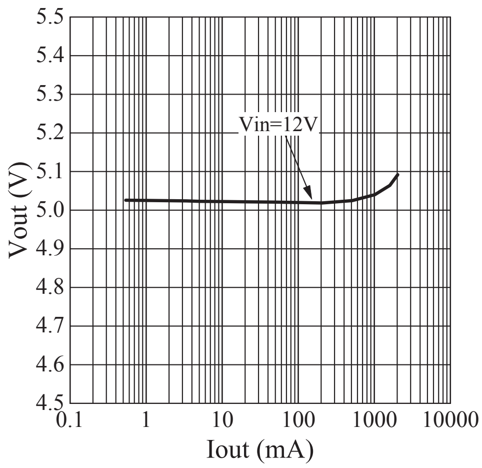
Vout-Vin



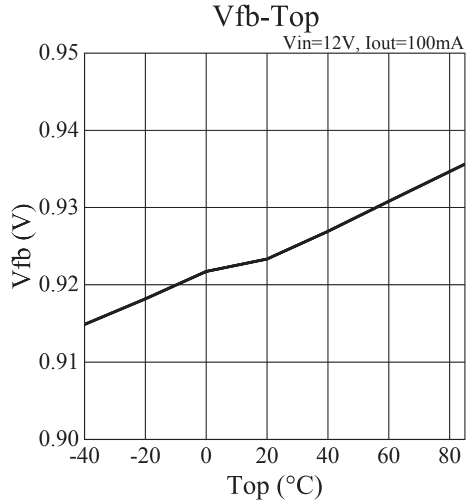
EFFICIENCY-Iout



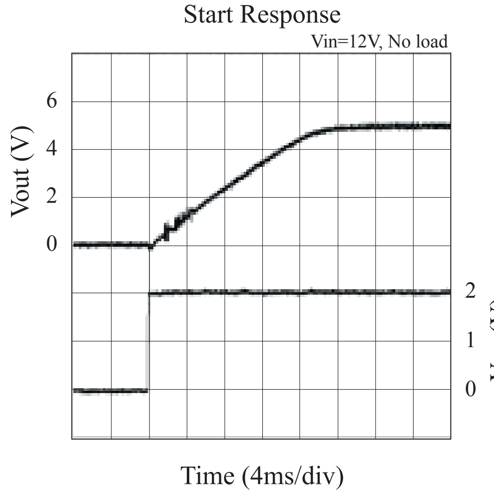
Vout-Iout



Vfb-Top



Start Response



Load Transient Response