ELM611DA 2A 23V
high efficiency synchronous PWM step down DC/DC converter

■General description

ELM611DA is 350kHz fixed frequency PWM synchronous step-down regulator, whose input voltage can be set within the range from 4.75V to 23V and output one is adjustable within the range from 0.923V to 18V; maximum output current of ELM611DA can reach 2A. ELM611DA includes 2 switching MOSFETs whose ON resistance is 85mΩ. Current mode control of ELM611DA makes it possible to provide fast transient response and current protection of cycle-by-cycle. Shutdown current is Typ.1μA. Soft start is programmable by external capacitor during start and limits inrush current to the appropriate value. ELM611DA is equipped with thermal shutdown protection.

■Features

- Programmable soft start
- Short circuit protection
- Thermal shutdown protection
- Input voltage : 4.75V to 23V
- Output voltage : 0.923V to 18V
- Output current : 2A
- High efficiency : Max.93%
- Power MOSFET switches : 85mΩ
- Shutdown current : Typ.1μA
- Fixed frequency : Typ.350kHz
- Package : SOP-8

■Application

- Distributed power system
- Network system
- FPGA, DSP, ASIC power supply
- Laptop
- Domestic appliance

■Maximum absolute ratings

Parameter	Symbol	Limit	Unit
VIN power supply voltage	Vin	-0.3 to +24	V
Apply voltage to SW	Vsw	GND-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 Vin+0.3	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

ELM611DA-N

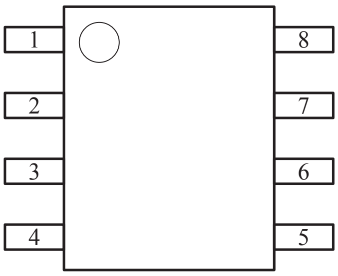
Symbol		
a	Package	D: SOP-8
b	Product version	A
c	Taping direction	N: Refer to PKG file

＊ Taping direction is one way.

ELM611DA - N
↑↑ ↑
a b c

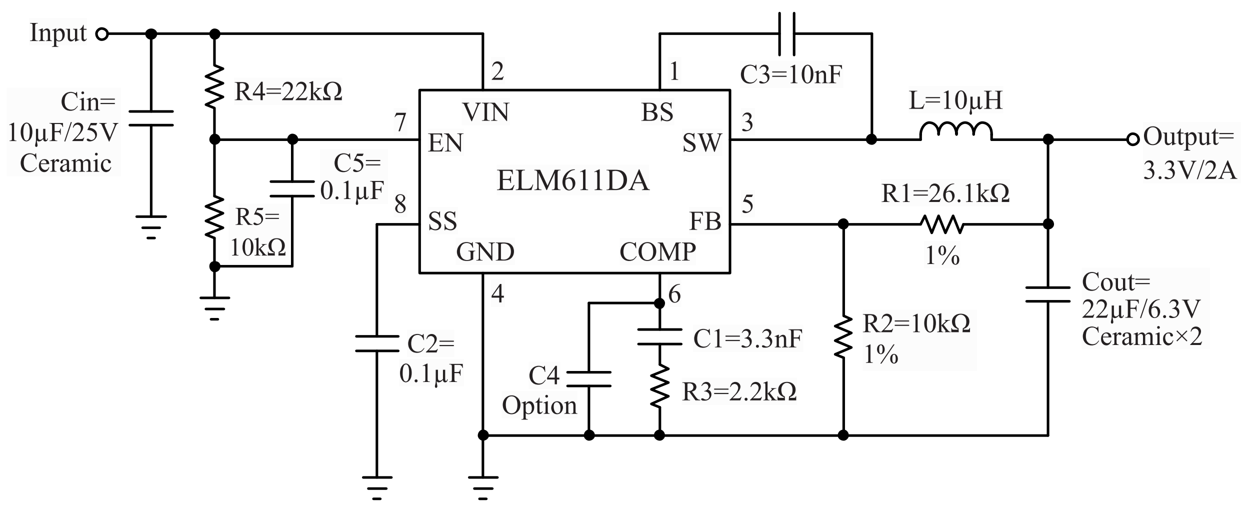
■Pin configuration

SOP-8(TOP VIEW)



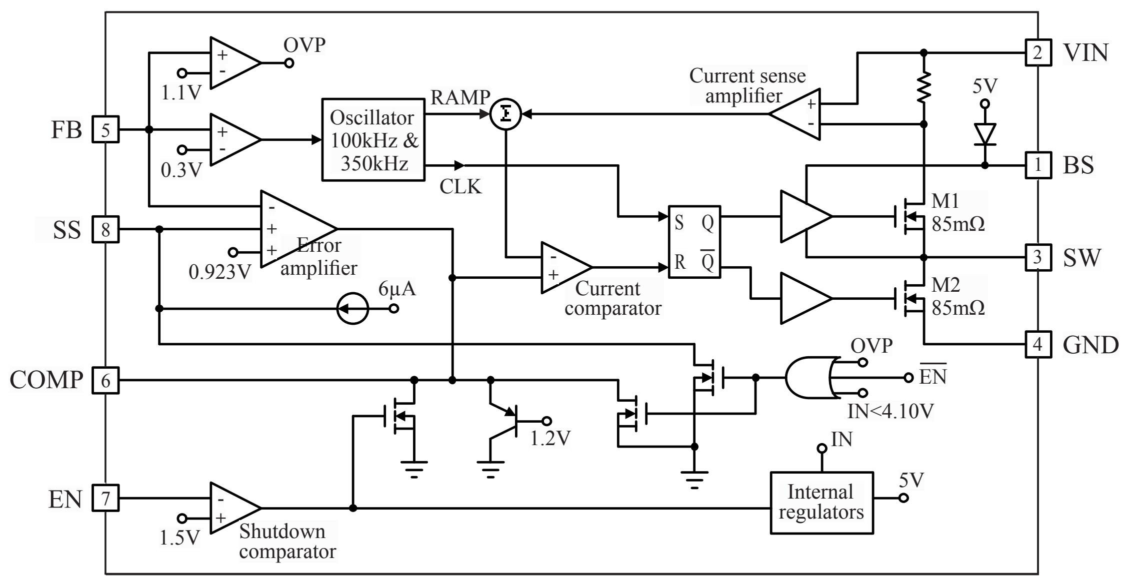
Pin No.	Pin name	Pin description
1	BS	High-side gate drive boost input
2	VIN	Power input
3	SW	Power switching output
4	GND	Ground
5	FB	Feedback input
6	COMP	Compensation node
7	EN	Enable input
8	SS	Soft start control input

■Standard circuit



Note: EN is 5V logic input. When Vin=12V, R4=22kΩ, R5=10kΩ is required; value of R5/R4= 1/2.2

■Block diagram

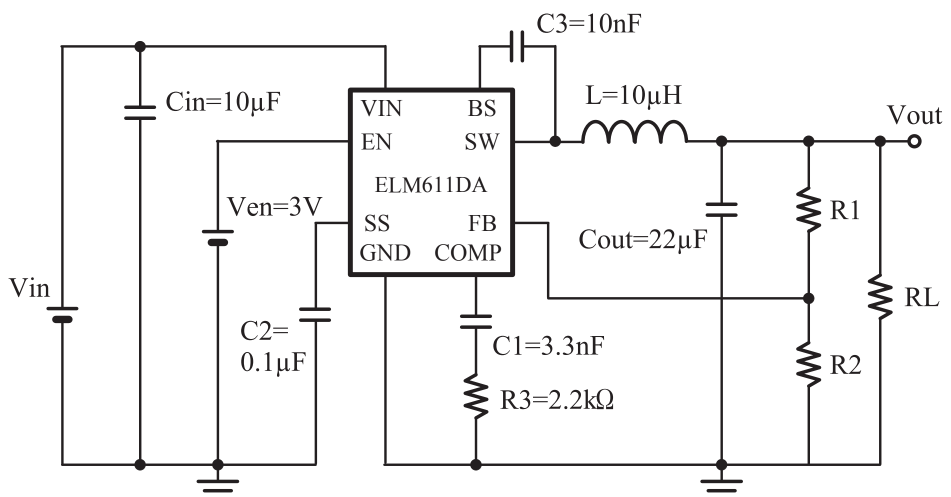


■Electrical characteristics

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

Parameter	Symbol	Test condition	Min.	Typ.	Max.	Unit
Supply voltage	Vin		4.75		23.00	V
Output voltage	Vout		0.923		18.000	V
Shutdown current	Is	Ven = 0V		1	3	μA
Supply current	Iss	Ven = 2.0V, Vfb = 1.0V		1.3	1.5	mA
Feedback voltage	Vfb	4.75V ≤ Vin ≤ 23V	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	3.4		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			350		kHz
Short circuit oscillation frequency	Fosc2	Vfb = 0V		100		kHz
Maximum duty cycle	Dmax	Vfb = 1.0V		90		%
Minimum on time	To			220		ns
EN shutdown threshold voltage	Vens_th	Ven rising	1.3	1.6	1.9	V
EN shutdown threshold voltage hysteresis	Vens_hys			10		mV
Input under voltage lockout threshold	Vth	Vin rising	3.80	4.10	4.40	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

■Test circuits



■Application notes

ELM611DA is 350kHz fixed frequency PWM synchronous step-down regulator, whose input voltage can be set within the range from 4.75V to 23V and output one is adjustable within the range from 0.923V to 18V; maximum output current of ELM611DA can reach 2A. ELM611DA adopts current-mode control to regulate output voltage; error between voltage divided by resistive voltage divider from output voltage is input to FB and internal standard voltage is controlled by internal transconductance error amplifier. CR circuit, which corrects the transmission function of error amplifier to ensure stable operation, is connected to COMP. ELM611DA includes 2 N-channel MOSFETs which works as switches; it is required that gate voltage is higher than the input one in order to turn the NMOS switch of power side on and this voltage can be generated by internal boost strap circuit. A boost capacitor between SW and BS to drive the high side gate. The boost capacitor is charged by the internal 5V line when SW is low. If FB voltage of ELM611DA is higher than 0.923V by 20% or more under monitoring, the over voltage comparator will activate, COMP and SS are discharged to GND, and forces MOS switch to be off. In order to activate internal circuit under 5V, ELM does not recommend adding voltage higher than 5V to FB, COMP, EV and SS.

1. Pin description

BS: High side gate drive boost input

BS supplies the drive for the high-side N-channel MOSFET switch. Connect a capacitor of 0.01μF or greater between SW and BS to power the high side switch.

VIN: Power input

ELM611DA is powered by VIN and input range is 4.75V to 23V. To absorb switch noise, connect the capacitor of suitable value between VIN and GND.

SW: Power switch output

SW powers output by switching inductor current. Connect LC filter between SW and output load. A capacitor between SW and BS is required.

GND: Ground

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

FB: Control voltage feedback

FB regulates voltage by detecting output voltage. Feedback threshold is 0.923V. FB is connected through resistive voltage divider network between output and GND.

COMP: Compensation node

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

EN: Enable input

EN is digital input that turns the regulator on/off. The regulator works when it’s high input by high enable and becomes standby when it’s low input. Automatic startup would activate with pullup by 100kΩ resistor.

EN threshold is 1.6V(typ.). It is possible to adjust automatic startup voltage using register divider (R4, R5) between Vin and GND.

SS: Soft-start control input

SS controls soft start period. By connecting to a 0.15μF capacitor, soft-start period can be set to 15ms. Soft-start function would be disabled when SS is open.

2. Setting output voltage

It is possible to set output voltage by using a resistive voltage divider which divides output voltage and returns it to FB. The The relationship between Vout and voltage of FB can be formulated as follows:

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

When Vfb is 0.923V:

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

ELM recommends using resistor of 10kΩ; maximum value of R2 can be as high as 100kΩ. When using 10kΩ resistor, the value of R2 would be determined by R1 by following formula:

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

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 would generate less ripple current thus results in smaller output ripple voltage. However, inductor with large value are usually with bigger size, higher series resistance, and/or lower saturation current. ELM recommends determining the value of inductor by setting 30% of maximum switch current limit to be peak-to-peak ripple current. A maximum current of the inductor is required to be smaller than a maximum switch current of ELM611DA.

The value of inductor can be calculated as follows:

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

Vout=output voltage; Vin=input voltage; fs=switching frequency; ΔIl=peak-to-peak inductor ripple current.

The peak current of inductor can be calculated as follows:

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

Iload=load current; ELM recommends choosing the shape of inductor by its price, size and EMI requirements.

4. Adding schottky diode

Body diode of MOS switch of GND would be conducted by inductor current during the transition from on to off of MOS switches of power and GND. The forward voltage of this body diode is high and would result in power loss. By connecting an additional Schottky diode between SW and GND in parallel arrangement, the low forward voltage would bypass the inductor current and improve the ovrall efficiency. Table 1 are some Schottky diodes recommended by ELM.

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

Because the input current to step-down converter is discontinuous, a capacitor is required to supply AC current to step-down converter while maintaining DC input voltage. For best performance, ELM recommends using low ESR capacitors, such as ceramic ones. Tantalum or low-ESR electrolytic capacitors may also be used. Due to dielectric characteristic, it requires when using ceramic capacitors; make sure to confirm temperature and voltage characteristics in advance. X5R or X7R are preferable ceramic capacitors. Adequate ripple voltage rating is necessary since the input switching current is absorbed by input capacitor (Cin). RMS of input current can be calculated by following formula:

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

In worst case, when Vin = 2Vout, Icin = Iload/2. It is necessary to select capacitors which tolerate RMS ripple current that is half of maximum load current. For input capacitors, ELM recommends using electrolytic, tantalum or ceramic ones. When using electrolytic or tantalum capacitors, please connect the 0.1μF one which is high quality with high frequency to the IC as close as possible. When using ceramic capacitors, it is necessary to provide sufficient capacity to prevent ripple voltage of input . Input voltage ripple for low ESR capacitors can be calculated by following formula:

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

Cin=input capacitance value.

6. Capacitor

Capacitors are used to ensure output voltage of DC; ELM recommends using ceramic, tantalum, or low ESR electrolytic ones. To keep output voltage ripple low, low ESR capacitors are preferable. Output voltage ripple can be calculated by following formula:

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

Cout=output capacitance value; Resr=equivalent series resistance (ESR) value of the output capacitor.

When using ceramic capacitors, please select by the high frequency impedance capacitance of switching frequency; output voltage ripple is mainly determined by capacitance. Output voltage ripple can be calculated by following formula:

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

When using tantalum or electrolytic capacitors, please select by ESR, which is mainly determined by impedance of switching frequency. Output ripple can be calculated by following formula:

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

Stability of DC/DC converter would be effected by capacitance of output capacitor. ELM611DA is designed to provide wide range of capacitance and stable operation of ESR.

7. Compensation components

ELM611DA realizes simple compensation and fast transient response by adopting current mode control; COMP, which is output of internal transconductance error amplifier, controls system stability and transient response. A capacitor and a resistor in series connection sets a pole-zero combination for compensation. DC gain of voltage feedback loop can be calculated by following formula:

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

Aea=error amplifier voltage gain; Gcs=current sense transconductance; Rload=load resistor value

The control loop has two important poles; one is the product of compensation capacitor (C1) and output resistor of error amplifier, and the other one is the product of output capacitor and load resistor.

These poles are located at:

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

Gea=error amplifier transconductance

Control system is produced by compensation capacitor (C1) and compensation resistor (R3), and has one zero. This zero is located at:

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

There is another important zero which is produced by output capacitance and ESR when output capacitor is with large capacitance with high ESR.
This zero is located at:

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

Under this situation, a third pole is produced by compensation capacitor (C4) and compensation resistor (R3) which are used to compensate the effect of ESR zero.
This pole is located at:

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

The purpose of compensation is to stabilize transfer function of DC/DC converter.
For crossover frequency, feedback loop with unity gain is important. Low crossover frequency slows the response of line and load regulation, whereas high crossover frequency may result in unstableness of control system. To set cross frequency to be 1/10 of switching one is the easiest way.
For best solution of compensation, please follow these steps:
1) Select compensation resistor (R3) based upon the desired crossover frequency. The value of R3 can be calculated by following formula:

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

fc = desired crossover frequency, which is usually set to be 1/10 of switching frequency.
2) Select compensation capacitor (C1) based upon the desired phase margin. For typical inductor values, set fz1 to be 1/10 of switching frequency so that fz1 is able to acquire sufficient phase margin to produce compensation zero. C1 can be calculated by following formula:

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

R3 = compensation resistor.
3) Select the second compensation capacitor (C4) if it is required. If ESR zero is located in half of switching frequency because of output capacitor, or when the following relationship is satisfied:

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

the second compensation capacitor, C4 can be calculated by following formula:

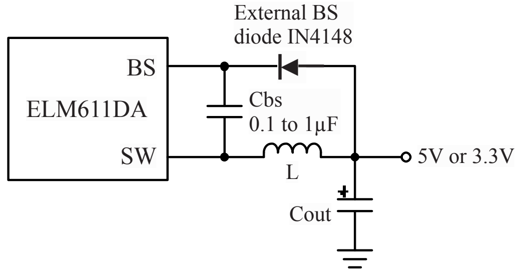
$$C4 = (Cout \times Resr) / R3$$

8. External bootstrap diode

An external bootstrap diode may enhance the efficiency of DC/DC converter, applicable conditions of external BS diode are:

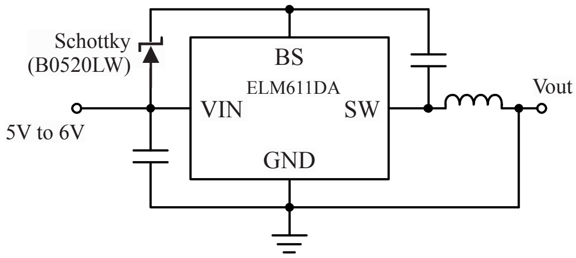
Vout = 5V or 3.3V, and duty cycle is high: D = Vout/Vin > 65%

Under this situation, ELM recommends using an additional external BS diode for better solution.



∗ Add external bootstrap diode to enhance efficiency.

For external BS diode, ELM recommends IN4148; BS capacitors between 0.1 to 1μF are preferable.
To improve efficiency when Vin is ≤ 6V, it is possible to add an external Schottky diode between IN and BS.



∗ Add a Schottky diode to improve efficiency when Vin is ≤ 6V.

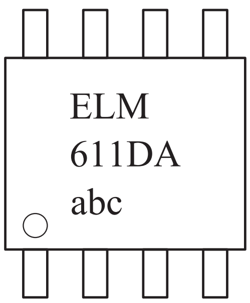
9. PCB layout guide

To stabilize the operation, PCB layout is very important. Please take the following guidelines as reference.

1) Keep the path of switching current as short as possible; minimize the loop area which is connected to input capacitor, high-side and low-side MOSFETs.
2) Bypass ceramic capacitors are recommended to be connected as close to VIN as possible.
3) Please connect all feedback loop wire in the shortest way. Locate feedback resistors and compensation components as close to the chip as possible.
4) Locate wire of SW away from sensitive analog areas such as FB.
5) To cool down the operation temperature of the chip and gain higher long-term reliability, please connect VIN, SW, and especially GND respectively to a large copper area.

■Marking

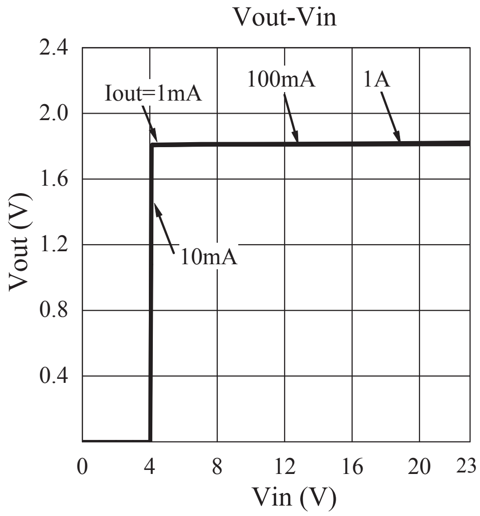
SOP-8

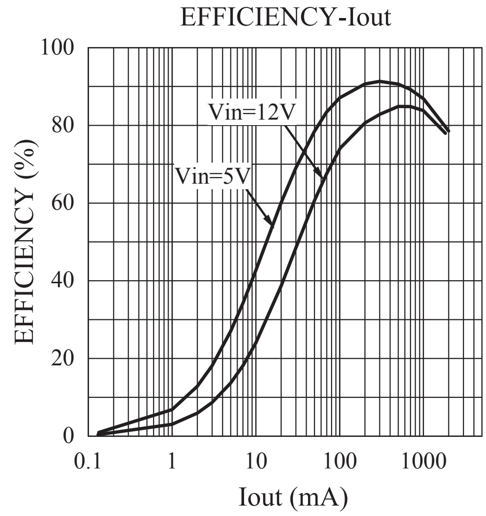


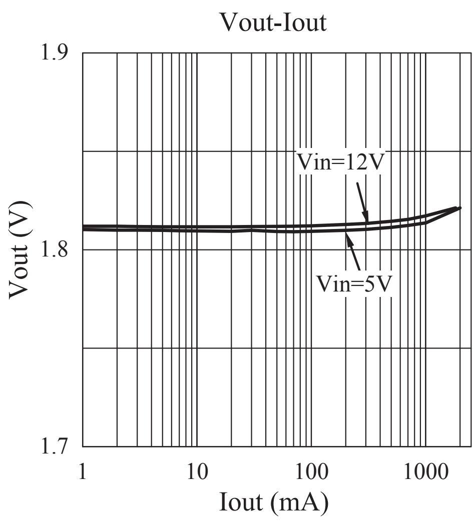
Mark	Content
ELM611DA	Product name
abc	Assembly lot No.: 000 to 999 repeated

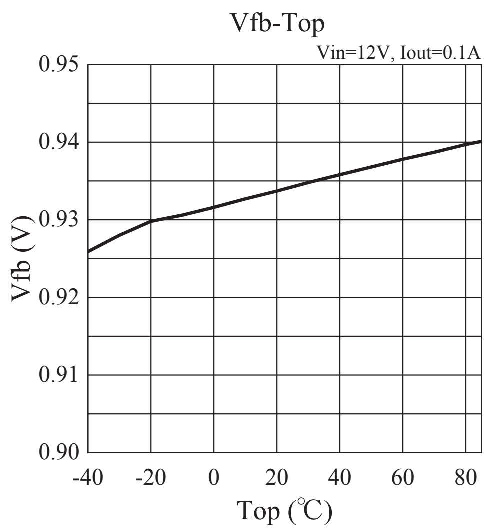
■Typical characteristics

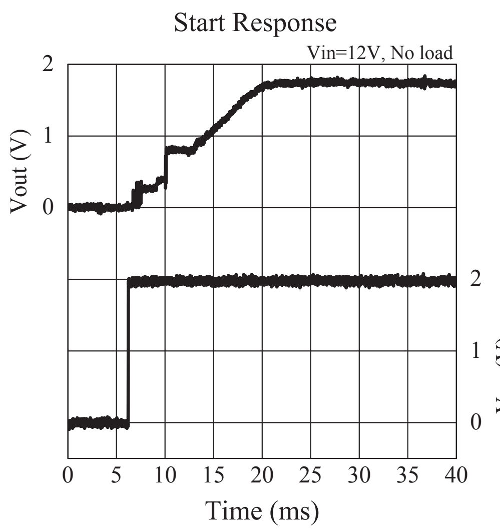
- Vout=1.8V : Cin=10μF, Cout=22μF, L=10μH, R1=13.8kΩ, R2=14.7kΩ, Top=25°C

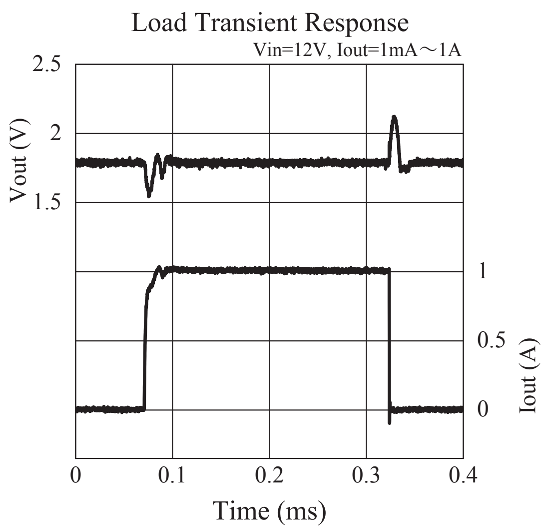






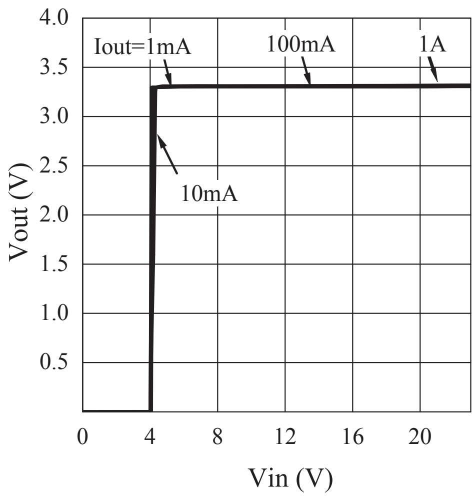




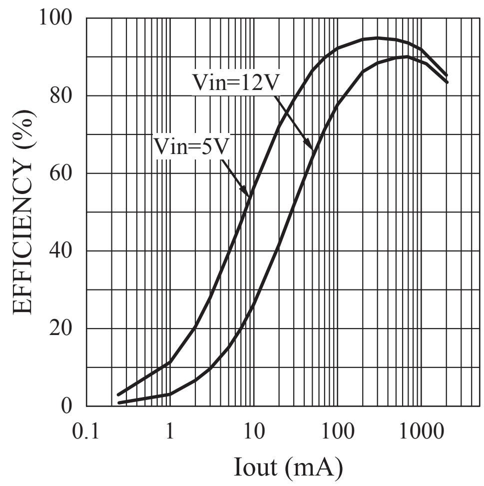


- Vout=3.3V : Cin=10μF, Cout=22μF, L=10μH, R1=38.3kΩ, R2=15.2kΩ, Top=25°C

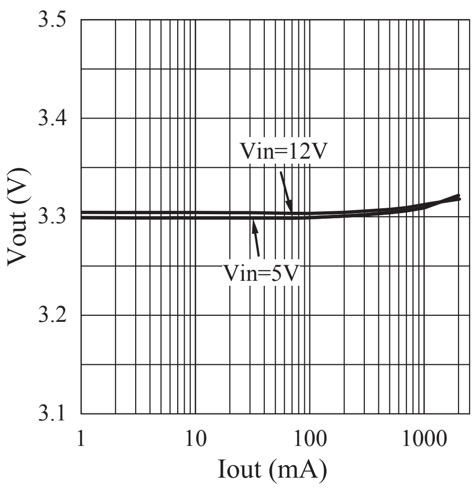
Vout-Vin



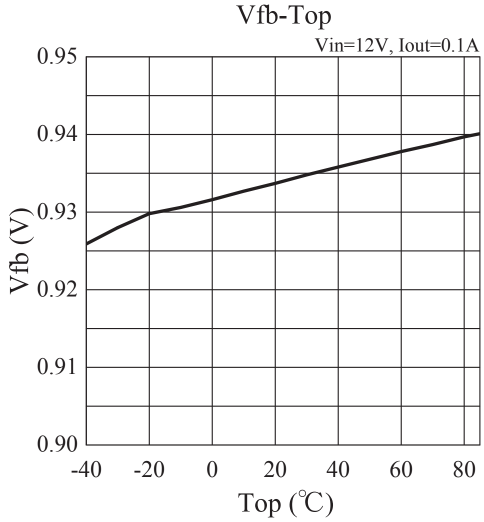
EFFICIENCY-Iout



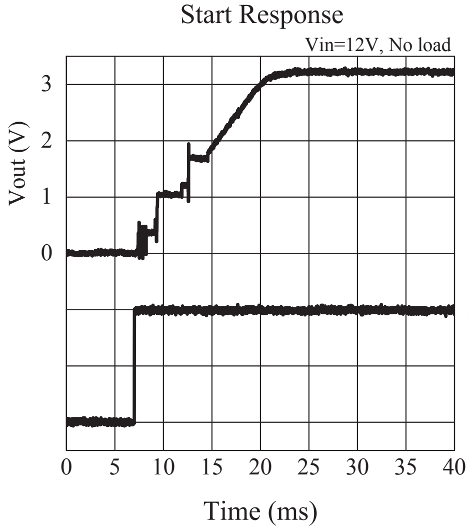
Vout-Iout



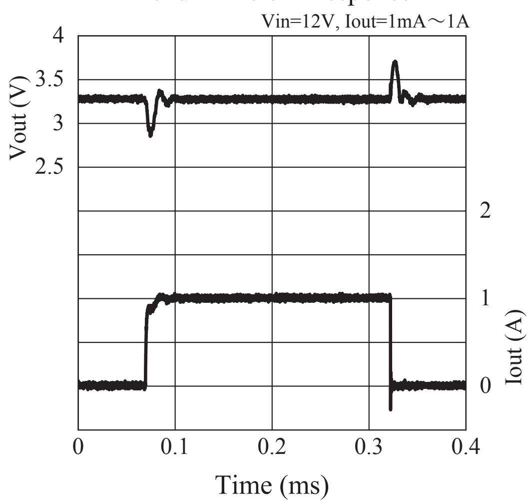
Vfb-Top



Start Response

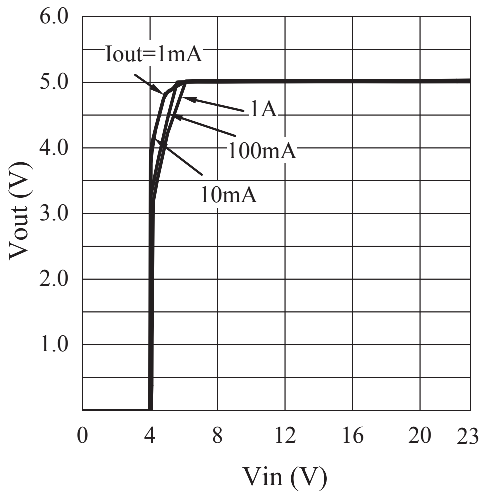


Load Transient Response

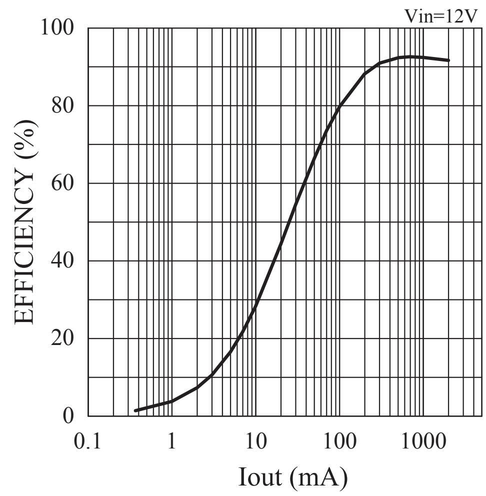


• Vout=5.0V : Cin=10μF, Cout=22μF, L=10μH, R1=6.4kΩ, R2=1.47kΩ, Top=25°C

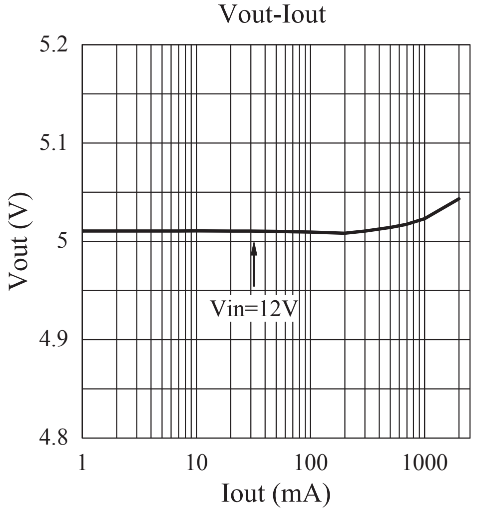
Vout-Vin



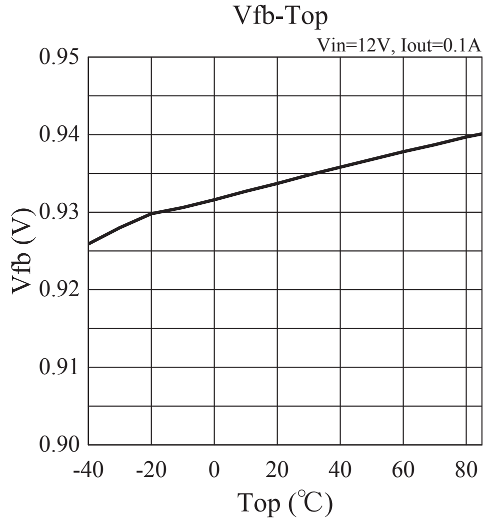
EFFICIENCY-Iout



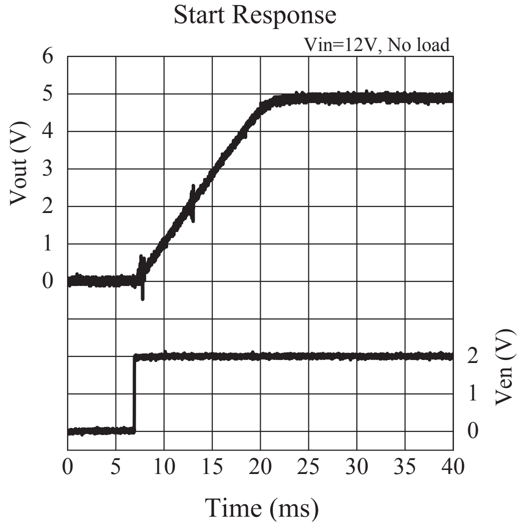
Vout-Iout



Vfb-Top



Start Response



Load Transient Response