ELM603GC 5V input 1.5A 1.5MHz synchronous step-down DC/DC converter

■General description

ELM603GC is high efficiency 1.5A constant on-time (COT) controlled synchronous step-down DC/DC converter. It can operate with input voltage from 2.5V to 6.0V and provide output range from 0.6V to input level, thanks to its 100% duty cycle operation. The constant on-time control scheme simplifies loop compensation and offers excellent load transient response. ELM603GC operates at fixed 1.5MHz across entire load range. The high gain error amplifier in the control loop provides excellent load and line regulation. ELM603GC has cycle-by-cycle current limit and hiccup mode to protect over-load or short circuit fault conditions.

ELM603GC is available in low profile 6 leads DFN 2mm×2mm packages.

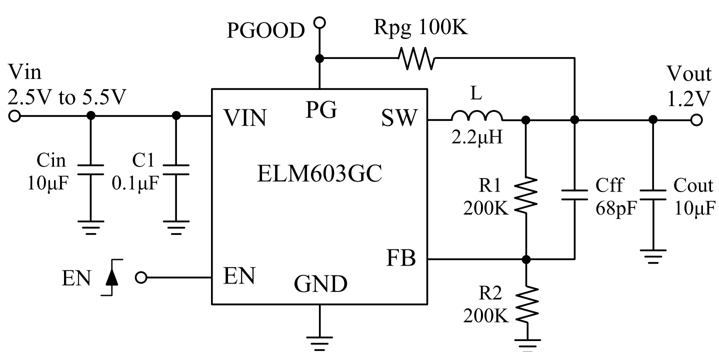
■Features

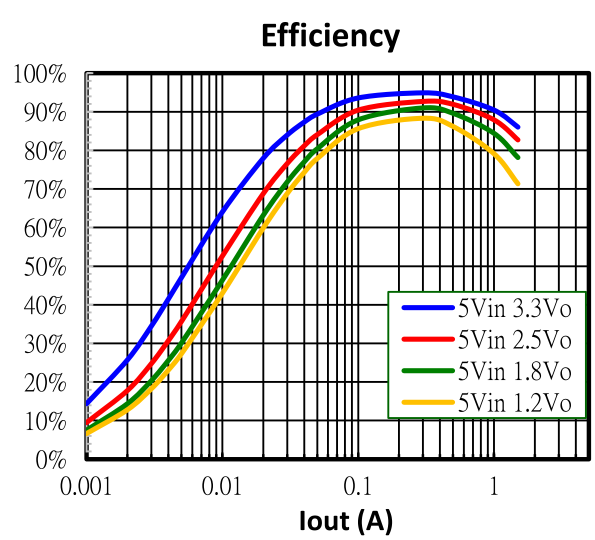
- Proprietary fast transient constant on time architecture stable with low ESR ceramic output capacitors
- Thermal shutdown protection
- Internal 1msec soft-start
- Cycle-by-cycle current limit protection
- Input under/over voltage lockout
- Output discharging function in shutdown
- Hiccup mode for short circuit and over-load protection
- Output current : 1.5A
- Wide input voltage range : 2.5V to 6.0V
- Switching frequency : Fixed 1.5MHz
- Feedback voltage : 0.6V ±2%
- Built-in power switches : 260mΩ/180mΩ
- Maximum duty cycle : 100%
- Package : DFN6-2×2

■Application

- Solid-state and hard disk drives
- WiFi RF modules
- DC/DC micro modules
- Smart phone and tablets

■Typical applications





■Recommended operating conditions

Parameter	Symbol	Limit	Unit
Input voltage	Vin	+2.5 to +6.0	V
Output voltage	Vout	+0.6 to Vin	V
Operating temperature range	Top	-40 to +85	°C

∗ Note: The device is not guaranteed to function outside of the recommended operating conditions.

■Maximum absolute ratings (*1)

Parameter		Symbol	Limit	Unit
Input voltage		Vin	-0.3 to +6.5	V
SW pin voltage		Vsw	-0.3 to Vin+0.3	V
Dynamic Vsw	In 10ns duration		-2.0 to Vin+2.0	V
The other pins		Vother	-0.3 to +6.5	V
Power dissipation at Ta=+25°C (* 2, 3)		Pd	1.3	W
Storage temperature range		Tstg	-65 to +150	°C
Junction temperature range		Tj	-40 to +150	°C
Thermal resistance (* 2, 3)		θja	75	°C/W
Thermal resistance (* 2, 3)		θjc	20	°C/W

∗ : 1. Stress exceeding those listed "Maximum absolute ratings" may damage the device.
2. Measured on JESD51-7, 4-Layer PCB.
3. The maximum allowable power dissipation is a function of the maximum junction temperature TJ_MAX, the junction to ambient thermal resistance θja, and the ambient temperature Ta. The maximum allowable continuous power dissipation at any ambient temperature is calculated by Pd_max= (Tj_max-Ta)/θja. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.

■Selection guide

ELM603GC-N

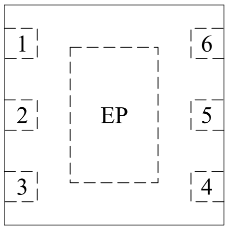
Symbol		
a	Package	G: DFN6-2×2
b	Product version	C
c	Taping direction	N: Refer to PKG file

∗ Taping direction is one way.

ELM603GC - N
↑↑ ↑
a b c

■Pin configuration

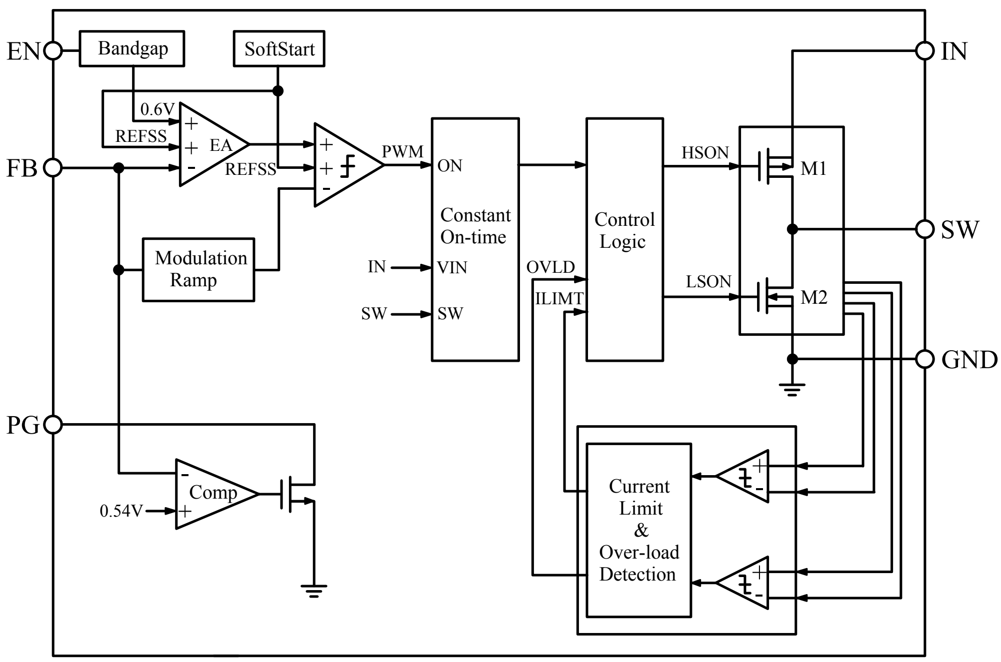
Top view



Exposed pad on backside

Pin No.	Pin name	Description
1	PG	Power good open-drain output. Connect a 100kΩ pull-up resistor to Vin or Vout.
2	EN	Regulator enable control input with accurate 1.21V enable threshold which can be used to build precision R-C turn-on delay and input under-voltage lockout. This pin has a pull-down resistor of typically 1MΩ to GND. • Drive EN above 1.21V to turn on the converter • Drive EN below 1.11V to turn off the converter and discharge output
3	VIN	Input supply voltage
4	SW	Power switch node
5	GND	Ground
6	FB	Voltage feedback input. Connect a resistor divider between output and FB to program the output voltage. VFB is regulated to 0.6V

■Block diagram

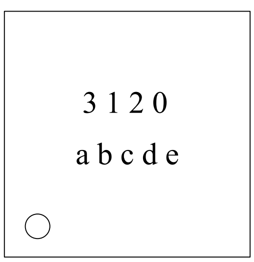


■Electrical characteristics

Top=+25°C, Vin=5V, Unless otherwise noted. Typical values are at Vin=Ven=5V and Vout=1.8V.

Parameter	Symbol	Test conditions	Min.	Typ.	Max.	Unit
Input voltage range	Vin		2.5		6.0	V
Shutdown current	Is	Ven=0V, Vin=5.5V		0.1	1.0	μA
Input under voltage lockout threshold	Vuvlo	Vin Increasing	2.3	2.4	2.5	V
Input under voltage lockout hysteresis	Vhysu			280		mV
Input over voltage lockout threshold	Vovlo		6.4	6.6	6.8	V
Input over voltage lockout hysteresis	Vhyso			400		mV
Quiescent current	Iq	Vfb=0.63V		500	650	μA
Feedback regulation voltage	Vfbref		591	600	609	mV
Feedback current	Ifb			1		nA
HS switch peak current limit	Ilim		2.8	3.5	4.2	A
HS main switch on resistance	Ron_H	Vin=5V		260		mΩ
LS synchronous switch on resistance	Ron_L	Vin=5V		180		mΩ
HS leakage current	Ileak_H	Vin=5.5V, Ven=Vsw=0V		0.1	2.0	μA
LS leakage current	Ileak_L	Vin=Vsw=5.5V, Ven=0V		0.1	2.0	μA
PWM switching frequency	Fsw	Iout=1A		1.5		MHz
EN on threshold	Ven_on	Ven ramp up	1.18	1.21	1.24	V
EN off threshold	Ven_off	Ven ramp down	1.05	1.11	1.17	
EN internal pull down resistor	Ren		700	1000	1300	kΩ
PG output leakage current	Ileak_pg	Vfb=0.63V, Vpg=Vin=5.5V		0.01		μA
PG lower trip threshold	Vpg	Vfb rising, % with respec to Vfbref		-10		%
PG hysteresis	Vpghys	% with respect to Vfbref		5		%
PG delay	tdpg	PG going high to low		20		μs
Thermal shutdown	Tsd			160		°C
Thermal shutdown hysteresis	Tsdhys			30		°C
Output discharge resistance	Rdsc	Ven=0V, Vsw=1V		200		Ω

■Marking



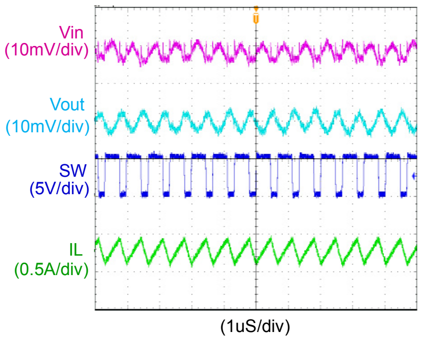
Mark	Content
3120	Product code
a to e	Lot No.

■Typical characteristics

- Cin=10μF, Cout=10μF, L=2.2μH, Top=25°C

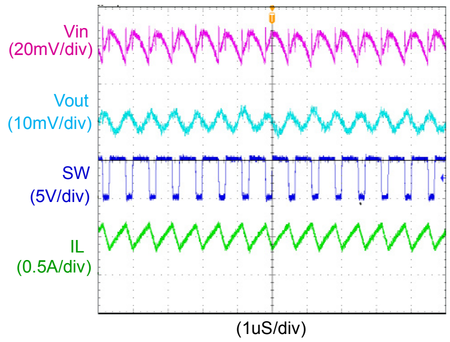
Steady State Test

5Vin 3.3Vo 0mA



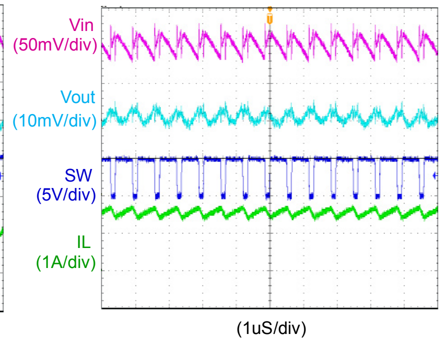
Steady State Test

5Vin 3.3Vo 0.5A



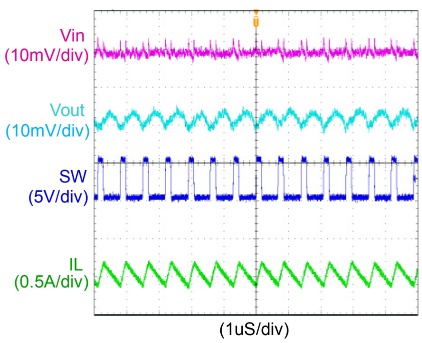
Steady State Test

5Vin 3.3Vo 1.5A



Steady State Test

5Vin 1.2Vo 0mA



Steady State Test

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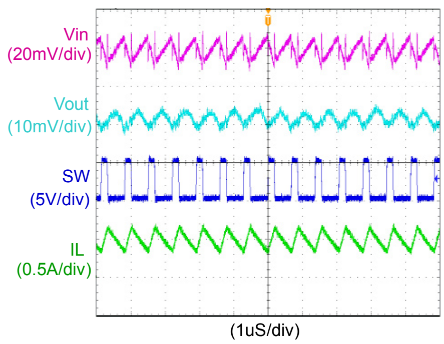
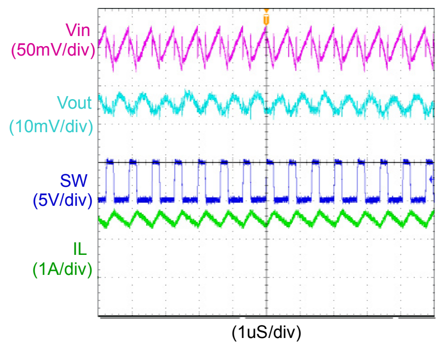


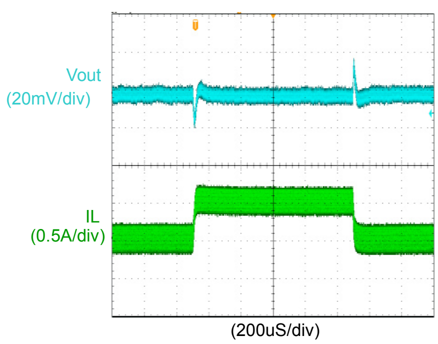
Steady State Test

5Vin 1.2Vo 1.5A



Load Transient Response

5Vin 3.3Vo Io=0A to 0.5A



Load Transient Response

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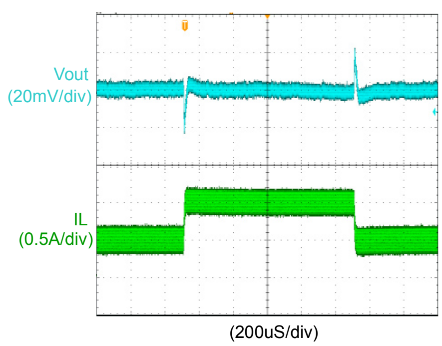
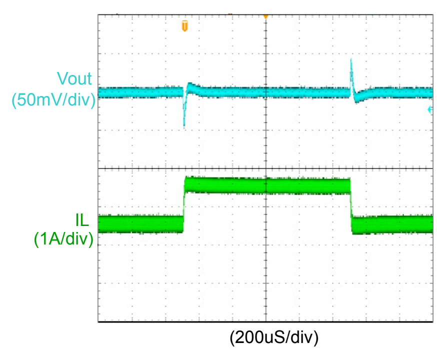


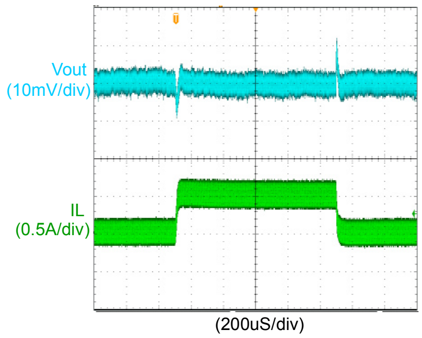
Load Transient Response

5Vin 3.3Vo Io=0.5A to1.5A



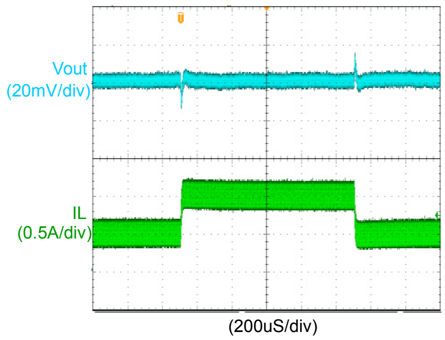
Load Transient Response

5Vin 1.2Vo Io=0A to 0.5A



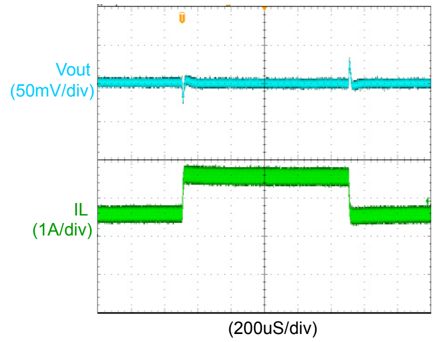
Load Transient Response

5Vin 1.2Vo Io=0.5A to 1A



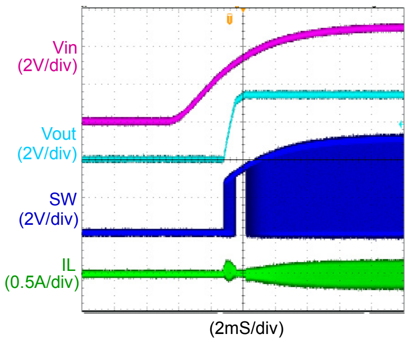
Load Transient Response

5Vin 1.2Vo Io=0.5A to1.5A



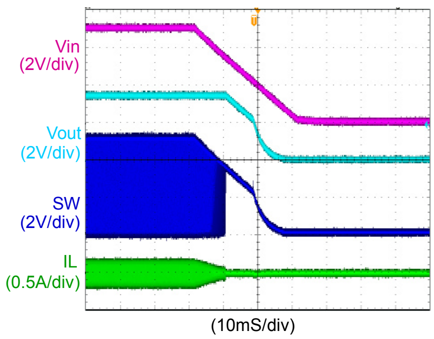
Vin Power On

5Vin 3.3Vo 0A



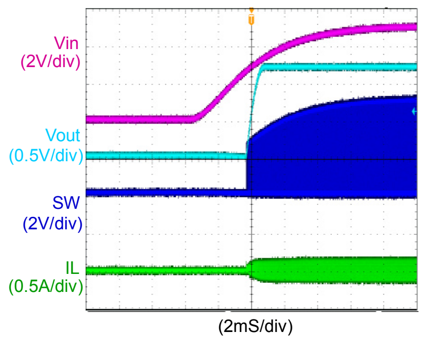
Vin Power Off

5Vin 3.3Vo 0A



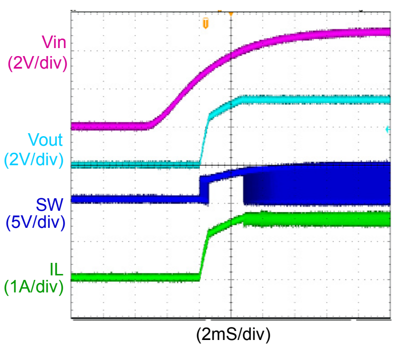
Vin Power On

5Vin 1.2Vo 0A



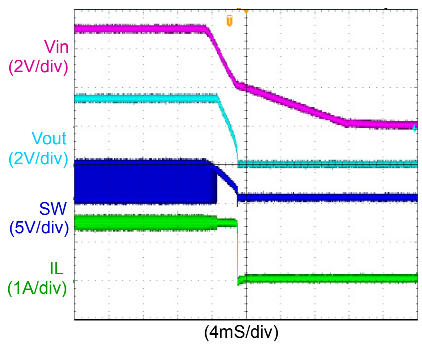
Vin Power On

5Vin 3.3Vo 1.5A



Vin Power Off

5Vin 3.3Vo 1.5A



Vin Power Off

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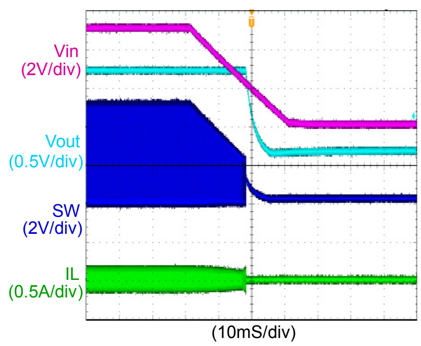
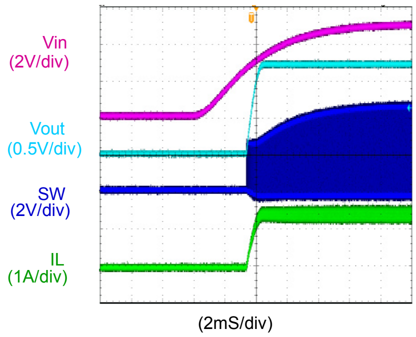


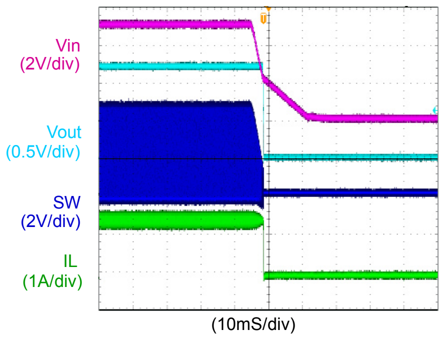
Vin Power On

5Vin 1.2Vo 1.5A

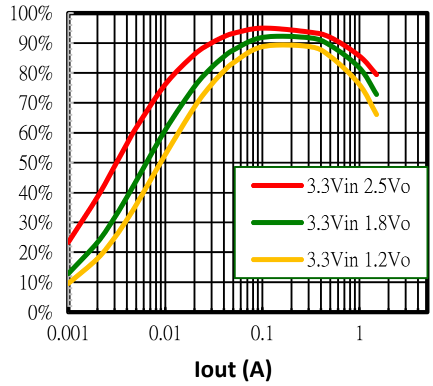


Vin Power Off

5Vin 1.2Vo 1.5A

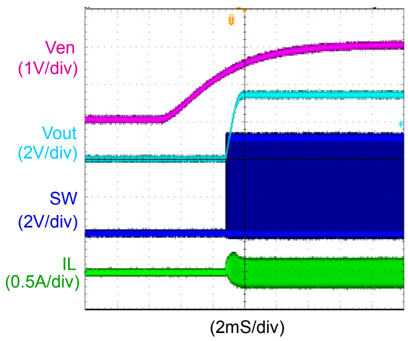


Efficiency



EN On

5Vin 3.3Vo 0A



EN Off

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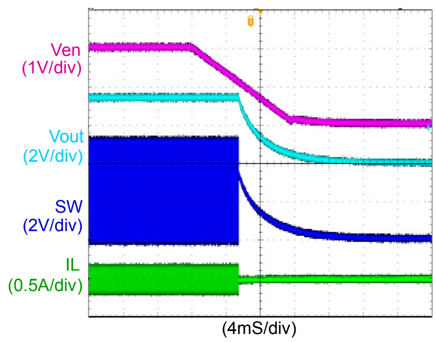

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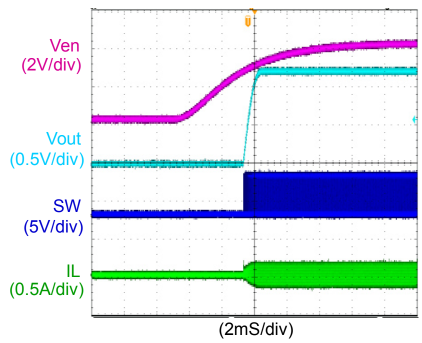

EN On

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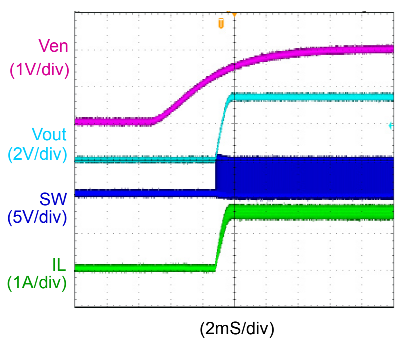

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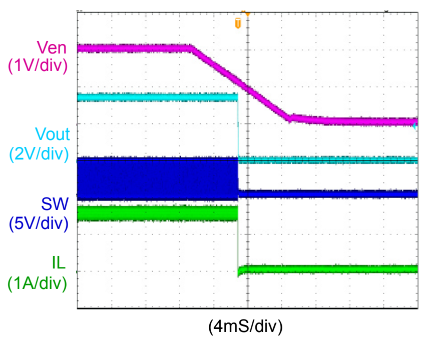

EN Off

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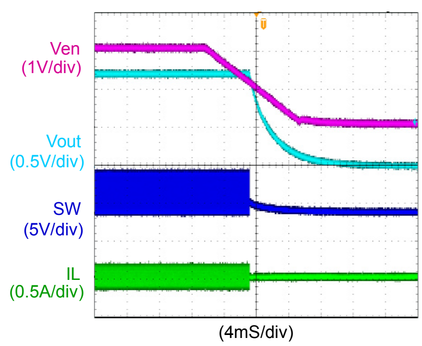
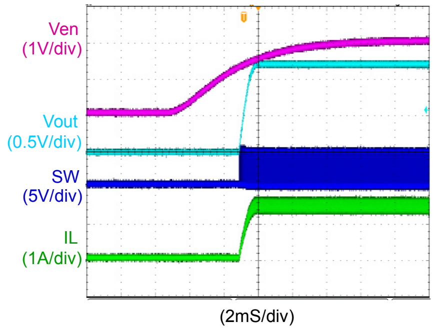


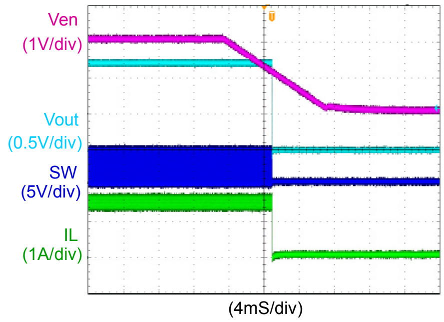
EN On

5Vin 1.2Vo 1.5A



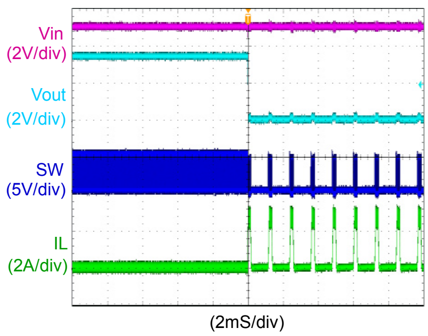
EN Off

5Vin 1.2Vo 1.5A



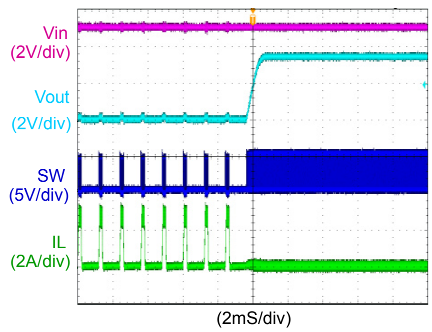
Short Circuit Entry

5Vin 3.3Vo 0A



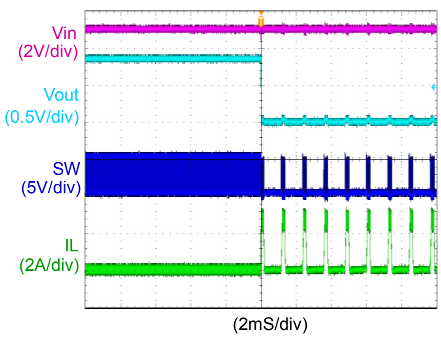
Short Circuit Recovery

5Vin 3.3Vo 0A



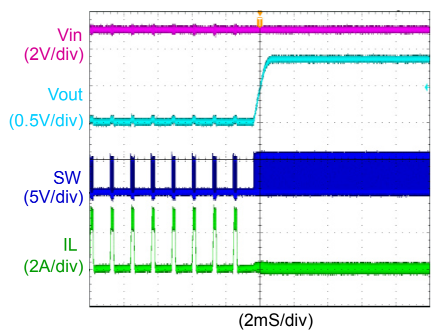
Short Circuit Entry

5Vin 1.2Vo 0A



Short Circuit Recovery

5Vin 1.2Vo 0A



■Theory of operation

ELM603GC is a constant on-time control synchronous step-down DC/DC converter that offers excellent transient response over a wide range of input voltage. It achieves superior light-load efficiency with extremely low quiescent current.

Constant On-time Control

Constant on-time control step-down DC/DC converters turn on HS immediately when FB droops below reference. The HS is turned on for a pre-determined period (on-time) of time to ramp up the inductor current, and then the LS will be turned on to ramp down the inductor current. The cycle repeats itself if FB droops below reference again. ELM603GC uses proprietary technique to take into account the load current impact and adjusts the on-time accordingly to achieve a constant switching frequency over entire load current range.

For ELM603GC, the on-time is approximately:

$$Ton = \frac{Vout}{Vin} \cdot 0.66\mu$$

Due to its immediate response on FB voltage droop and simplified loop compensation, constant on-time offers a superior transient response compare to traditional fixed frequency PWM control step-down converters.

Enable

When input voltage is above the under voltage lock-out threshold, ELM603GC can be enabled by pulling the EN pin to above 1.21V. ELM603GC is disabled if the EN pin is pulled below 1.11V. The enable/disable threshold for EN pin is accurately designed to be 1.21V and 1.11V respectively, so one can also use external resistor divider to program the desired input under-voltage lockout level.

Soft Start

ELM603GC has built-in soft start of 1ms. During the soft start period, output voltage is ramped up linearly to the regulation voltage, independent of the load current level and output capacitor value.

Current Limit and Hiccup Mode

ELM603GC has cycle-by-cycle HS current limit protection to prevent inductor current from running away. Once HS current limit is triggered, ELM603GC will turn on LS and wait for the inductor to drop down to a pre-determined level before the HS can be turned on again. If this current limit condition is repeated for a sustained long period of time, ELM603GC will consider it over-load or short circuit. Either way, ELM603GC will enter hiccup mode, where it stop switching for a pre-determined period of time before automatically re-try to start up again. It always starts up with soft-start to limit inrush current and avoid output overshoot.

■Application information

Setting the output voltage

External feedback resistors are used to set the output voltage. Refer to typical application circuit on page1, the top feedback resistor R1 has some impact on the loop stability, so its recommended range is between 100kΩ~300kΩ. For any chosen R1, the bottom feedback resistor R2 can be calculated as:

$$R2 = \frac{R1}{\frac{Vout}{0.6} - 1}$$

Inductor Selection

The recommended inductor value for ELM603GC is between 1uH to 4.7uH. Usually the inductor value is chosen to satisfy a desired ripple current:

$$L = \frac{Vout \bullet (Vin - Vout)}{Vin \bullet fsw \bullet \Delta I}$$

where ΔI is the inductor ripple current.
With the chosen L , the peak inductor current will be:

$$Ipk = Iload + \frac{1}{2} \bullet \Delta I$$

Input Bypass Capacitor Selection

The input current to the step-down converter is discontinuous with very sharp edges, therefore input bypass ceramic capacitors are required and place them as close to the input pin as possible. For lowest temperature variations, use X5R or X7R dielectric ceramic capacitors.
The RMS current of the input capacitor is approximately:

$$Icin\_rms = Iout \sqrt{D(1 - D)}$$

From the equation, it can be seen that the highest RMS current occurs when D is 0.5:

$$Icin\_rms = \frac{1}{2} Iout$$

Choose the capacitor with RMS current rating higher than 1/2 Iout. The power dissipation on the input capacitor can be estimated with the RMS current and the ESR resistor. Electrolytic or tantalum capacitors can also be used, but due to their significantly higher ESR, a small size ceramic capacitor should be placed as close to the IC as possible.
The voltage ripple on the input capacitor, neglecting the ESR impact, can be calculated as:

$$\Delta Vcin = \frac{Iload}{fsw \bullet Cin} \bullet \frac{Vout}{Vin} \bullet \left(1 - \frac{Vout}{Vin}\right)$$

Output Capacitor Selection

An output capacitor is required to obtain a stable output voltage. To minimize the output voltage ripple, ceramic capacitors should be used, and the ripple voltage can be estimated as:

$$\Delta Vout = \frac{1}{8} \bullet \left(1 - \frac{Vout}{Vin}\right) \bullet \frac{Vout}{L} \bullet \frac{1}{(fsw)^2 \bullet Cout}$$

If electrolytic or tantalum capacitors are used, the ESR will dominate the output voltage ripple:

$$\Delta Vout = \left(1 - \frac{Vout}{Vin}\right) \bullet \frac{Vout}{fsw \bullet L} \bullet Resr$$

PCB Layout recommendation

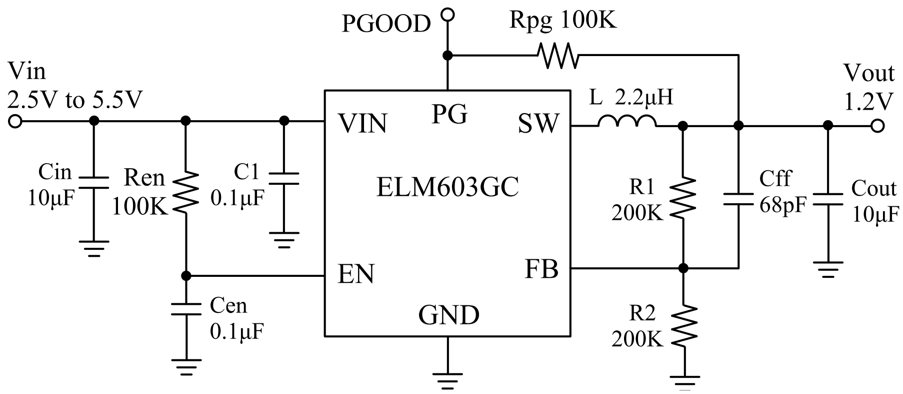
The physical design of the PCB is the final stage in the design of power converter. If designed improperly, the PCB could radiate excessive EMI and contribute instability to the power converter. Therefore, following the PCB layout guidelines below can ensure better performance of ELM603GC.

(1). The loop (Vin-SW-L-Cout-GND) indicates a high current path. The traces within the loop should be kept as wide and short as possible to reduce parasitic inductance and high-frequency loop area. It is also good for efficiency improvement.

(2). Input capacitor as close as possible to the IC Pins (Vin and GND) and the input loop area should be as small as possible to reduce parasitic inductance, input voltage spike and noise emission.

(3). Feedback components (R1, R2 and Cff) should be routed as far away from the inductor and the SW Pin as possible to minimize noise and EMI issue.

■Application schematic



EVB BOM List

Qty	Ref	Value		Description	Package
1	Cin	10μF		Ceramic capacitor, 10V, X5R	0805
1	Cout	10μF		Ceramic capacitor, 10V, X5R	0805
2	C1, Cen	0.1μF		Ceramic capacitor, 10V, X5R	0603
1	Cff	68pF		Ceramic capacitor, 10V, X5R	0603
1	L	2.2μH		Inductor, Rated current 2.25A	0805 SMD
1	R1	Vout=3.3V	200KΩ	Resistor, ±1%	0603
		Vout=2.5V	240KΩ		
		Vout=1.8V	200KΩ		
		Vout=1.2V	200KΩ		
		Vout=1.0V	100KΩ		
1	R2	Vout=3.3V	43KΩ	Resistor, ±1%	0603
		Vout=2.5V	75KΩ		
		Vout=1.8V	100KΩ		
		Vout=1.2V	200KΩ		
		Vout=1.0V	150KΩ		
2	Ren, Rpg	100KΩ		Resistor, ±1%	0603
1	Power IC	ELM603GC		Step-down DC/DC converter	DFN6-2×2