Switched-Capacitor Voltage Inverters with Shutdown

Features

- **Inverts Input Supply Voltage**
- **25mA Output Current with A Voltage Drop of 250mV**
- **0.45mA Quiescent Current at 3.3V Supply**
- **99% Voltage Conversion Efficiency**
- **1.8V to 5V operating range**
- **Require Only Two Capacitors**
- **Over-Temperature Protected**
- **2KV ESD Rating**
- **8-Pin SOP Package**

Applications

- **Cell Phone**
- **Small LCD Panels**
- **Portable Equipment**
- **Handy-Terminals, PDAs**
- **Battery-Operated Equipment**

General Description

The G5931 is an unregulated charge-pump voltage inverter which may be used to generate a negative supply from positive input. Input voltages ranging from +1.8V to +5V can be inverted into a -1.8V to -5V output supply. The devices is ideal for both battery- powered and board level voltage conversion applications with a typical operating current of 0.45mA at 3.3V supply.

The G5931 can deliver 25mA output current with a voltage drop of 250mV. The parts are over -temperature protected.

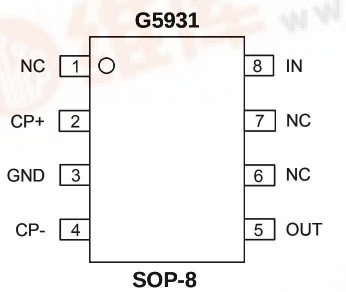
Applications include cell phones, PDAs, and other portable equipment. The devices is available in 8-pin SOP Package.

Ordering Information

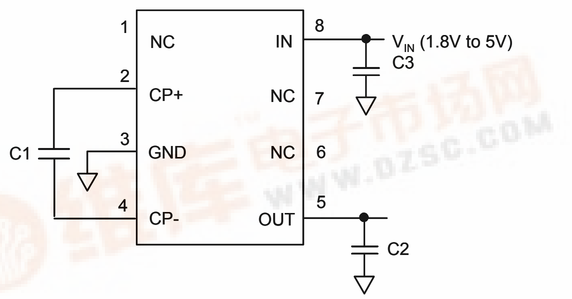
ORDER NUMBER	MARKING	TEMP. RANGE	PACKAGE (Pb free)
G5931P1U	G5931	-40°C to 85°C	SOP-8

Note: P1 : SOP-8
U: Tape & Reel

Pin Configuration



Typical Operating Circuit



Absolute Maximum Ratings

IN to GND Voltage Range……………..…..-0.3V to +5.5V
OUT to GND Voltage Range…………..…-5.5V to +0.3V
C1+ to GND Voltage Range……..…-0.3V to (V_{IN}+0.3V)
C1- to GND Voltage Range……...(V_{OUT} -0.3V) to +0.3V
OUT Output Current………………………………100mA
Operating Temperature Range…..………-40°C to 85°C
OUT Short Circuit to GND……….………………Indifinite

Storage Temperature……………………-65°C to 150°C
Junction Temperature……………………………..…150°C
Reflow Temperature (Soldering, 10sec)…..……260°C
Thermal Resistance
SOIC (θ_{JA})…………………………………...……160°C/W
ESD Rating HBM……………………….…………2000V

Note: Human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin.

Electrical Characteristics

(V_{IN}=+3.3V, C1 = C2 = C3= 1µF, T_A= -40 to 85°C unless otherwise noted. Typical values is at T_A=25°C.)

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Input Voltage, V_{IN}	R_{LOAD}=10kΩ	1.8	---	5	V
Supply Current, I_Q	T_A=25°C	---	0.45	0.5	mA
Charge Pump Frequency, F_{SW}	V_{IN}=5V	255	295	330	KHz
Output Resistance(Note)	I_{LOAD}=5mA	---	8.3	9.6	Ω
Output Ripple	I_{LOAD}=5mA	---	14	---	mV p-p
	I_{LOAD}=25mA	---	56	---	mV p-p
Voltage Conversion Efficiency	No Load	99	---	---	%
Power Efficiency	I_{LOAD}=5mA	---	93	---	%

Electrical Characteristics

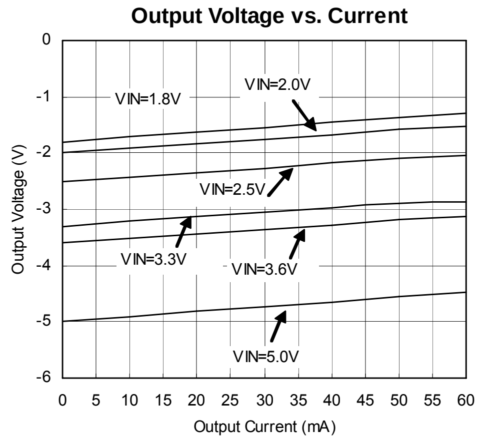
(V_{IN}=+5V, C1 = C2 = C3= 1µF, T_A= -40 to 85°C unless otherwise noted. Typical values is at T_A=25°C.)

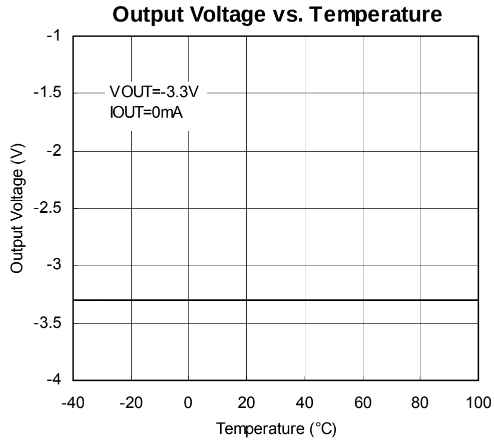
PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Input Voltage, V_{IN}	R_{LOAD}=10kΩ	1.8	---	5	V
Supply Current, I_Q	T_A=25°C	---	0.92	---	mA
Charge Pump Frequency, F_{SW}	V_{IN}=5V	---	290	---	KHz
Output Resistance(Note)	I_{LOAD}=5mA	---	8.8	---	Ω
Output Ripple	I_{LOAD}=5mA	---	25	---	mV p-p
	I_{LOAD}=25mA	---	100	---	mV p-p
Voltage Conversion Efficiency	No Load	99	---	---	%
Power Efficiency	I_{LOAD}=10mA	---	90	---	%

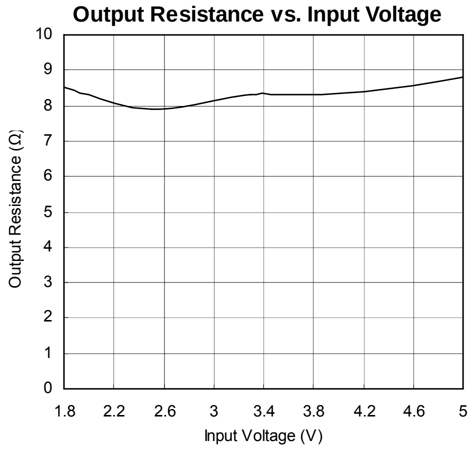
Note: Capacitor contribution (ESR component plus ($1/F_{SW}$)・C) is approximately 20% of output.

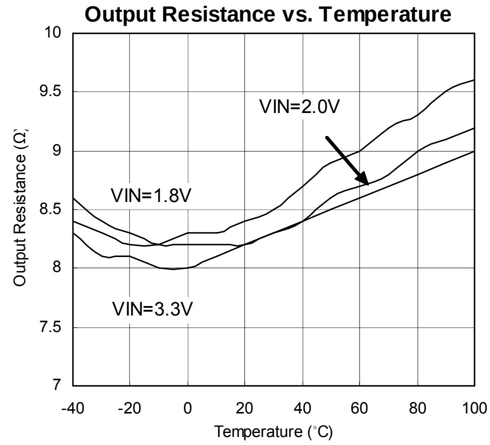
Typical Performance Characteristics

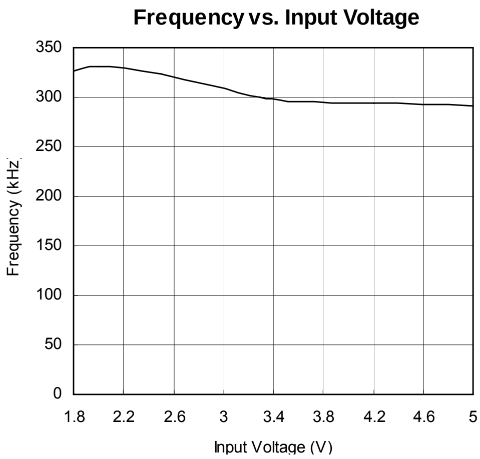
(V_{IN}=3.3V, C_1=C_2=C_3=1µF, T_A=25°C, unless otherwise noted.)

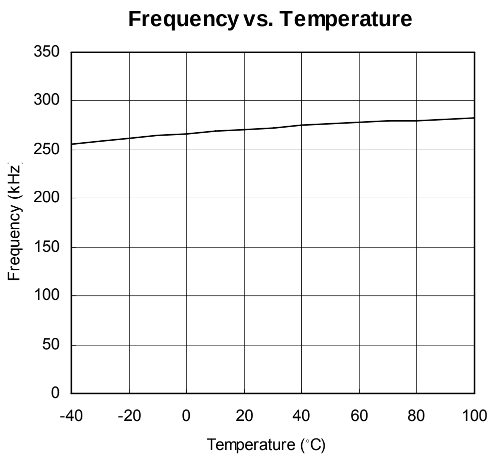






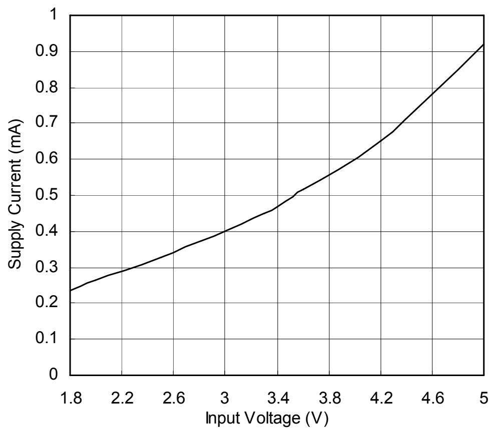




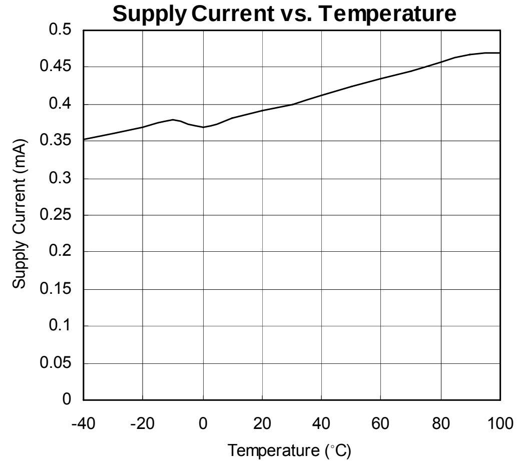


Typical Performance Characteristics (continued)

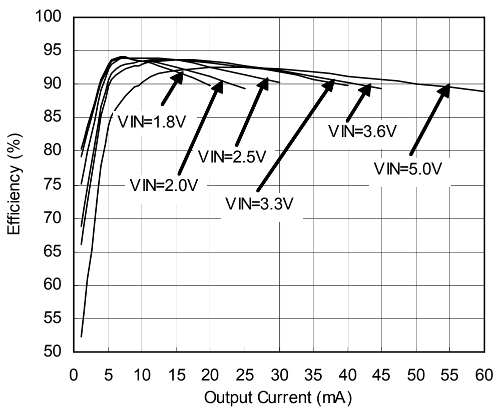
Supply Current vs. Input Voltage



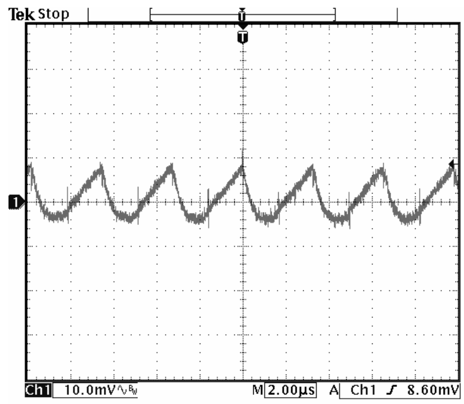
Supply Current vs. Temperature



Efficiency vs. Output Current



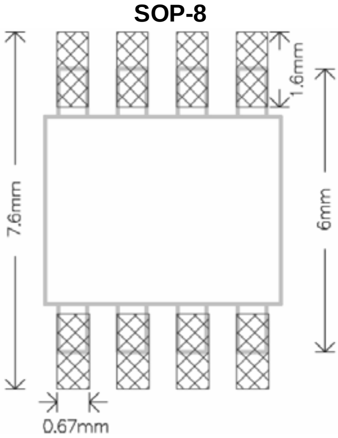
Output Ripple Waveform



VIN=3.3V, IOUT=5mA, AC Coupled

Recommended Minimum Footprint

SOP-8



Pin Descriptions

PIN	NAME	FUNCTION
1,6,7	NC	Not Internally Connected
2	C1+	Flying Capacitor's Positive Terminal
3	GND	Ground
4	C1-	Flying Capacitor's Negative Terminal
5	OUT	Inverting Charge-Pump Output
8	IN	Power-Supply Positive Voltage Input

Detailed Description

The G5931 contains four large switches which are switched in a sequence to inverter the input supply voltage. Energy transfer and storage are provided by external capacitors. Fig. 1 illustrates the voltage conversion scheme. When S1 and S3 are closed, C1 charges to the supply voltage $V_{IN.}$ During this time interval, switches S2 and S4 are open. In the second time interval, S1 and S3 are open; at the same time, S2 and S4 are closed, C1 is charging C2. After a number of cycles, the voltage across C2 will be pumped to V_{IN}. Since the anode of C2 is connected to ground, the output at the cathode of C2 equals -(V_{IN}) when there are no load current.

The main application of G5931 is to generate a negative supply voltage. The range of the input supply voltage is 1.8V to 5V. The output characteristics of this circuit can be approximated by an ideal voltage source in series with a resistance. The voltage source equals -(V_{IN}). The output resistance, Rout, is a function of the ON resistance of the internal MOSFET switches, the oscillator frequency, the capacitance and the ESR of both C_1 and C_2. Since the switching current charging and discharging C_1 is approximately twice as the output current, the effect of the ESR of the pumping capacitor C_1 will be multiplied by four in the output resistance. The output capacitor C_2 is charging and discharging at a current approximately equal to the output current, therefore, this ESR term only counts once in the output resistance. A good approximation of R_{out} is:

$$R_{OUT} \cong 2R_{SW} + \frac{2}{f_{OSC} x C_1} + 4ESR_{C1} + ESR_{C2}$$

Where R_{SW} is the sum of the ON resistance of the internal MOSFET switches shown in Figure 1.
High capacitance, low ESR capacitors will reduce the output resistance.

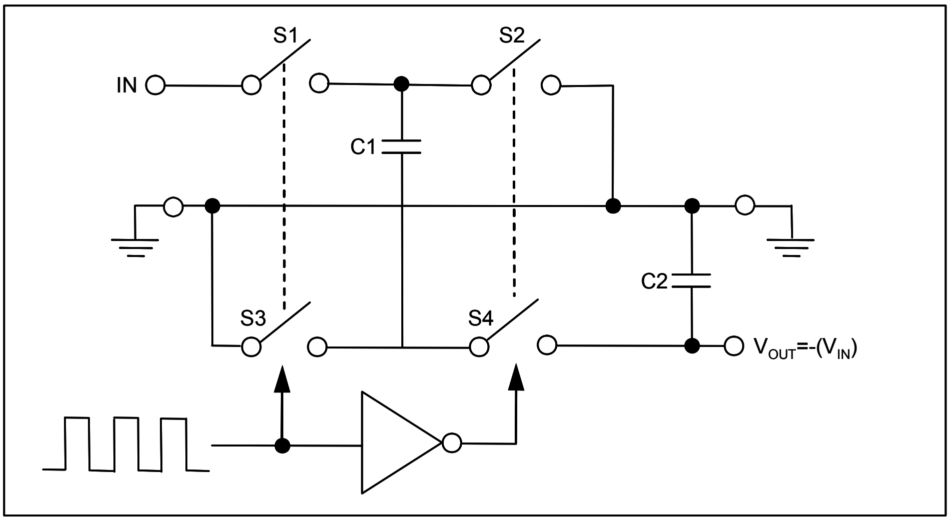


Figure 1. Ideal Voltage Inverter

Application Information

Table 1. Low-ESR Capacitor Manufacturers

PRODUCTION METHOD	MANUFACTURER	SERIES
Surface-Mount Ceramic	AVX	X7R
	Matsuo	X7R

Capacitor Selection

To maintain the lowest output resistance, use capacitors with low ESR (Table 1). The charge-pump output resistance is a function of C1's and C2's ESR. Therefore, minimizing the charge-pump capacitor's ESR minimizes the total output resistance.

Flying Capacitor (C1)

Increasing the flying capacitor's value reduces the output resistance. Above a certain point, increasing C1's capacitance has a negligible effect because the output resistance becomes dominated by the internal switch resistance and capacitor ESR.

Output Capacitor (C2)

Increasing the output capacitor's value reduces the output ripple voltage. Decreasing its ESR reduces both output resistance and ripple. Lower capacitance values can be used with light loads if higher output ripple can be tolerated. Use the following equation to calculate the peak-to-peak ripple:

$$V_{RIPPLE} = \frac{I_L}{f_{OSC} \times C2} + 2xI_L + ESR_{C2}$$

The output resistance is dependent on the capacitance and ESR values of the external capacitors. The output voltage drop is the load current times the output resistance, and the power efficiency is

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{I_L{}^2 R_L}{I_L{}^2 R_L + I_L{}^2 R_{OUT} + I_Q(V_{IN})}$$

Where $I_Q(V_{IN})$ is the quiescent power loss of the IC device,and $I_L{}^2R_{out}$ is the conversion loss associated with the switch on-resistance, the two external capacitors and their ESRs.

Input Bypass Capacitor (C3)

Bypass the incoming supply to reduce its AC impedance and the impact of the G5931's switching noise. A bypass capacitor with a value equal to that of C1 is recommended.

Voltage Inverter

The most common application for these devices is a charge-pump voltage inverter (Figure 2). This application requires only two external components— capacitors C1 and C2—plus a bypass capacitor, if necessary.

Layout and Grounding

Good layout is important, primarily for good noise performance. To ensure good layout, mount all components as close together as possible, keep traces short to minimize parasitic inductance and capacitance, and use a ground plane.

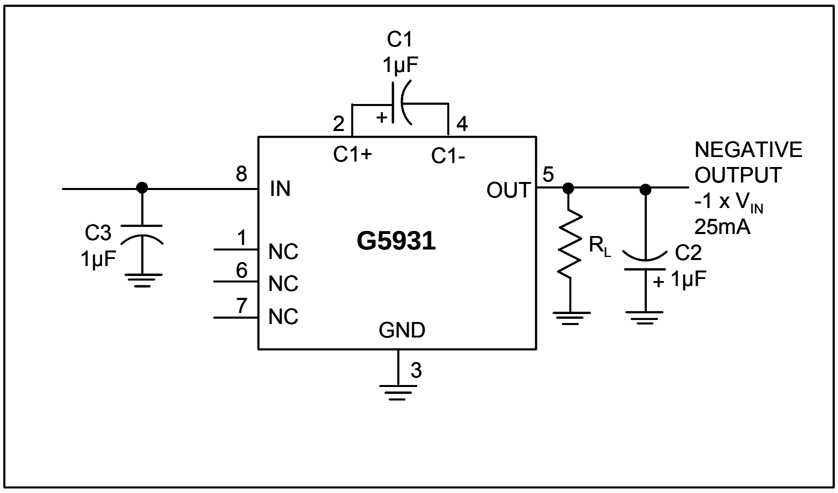
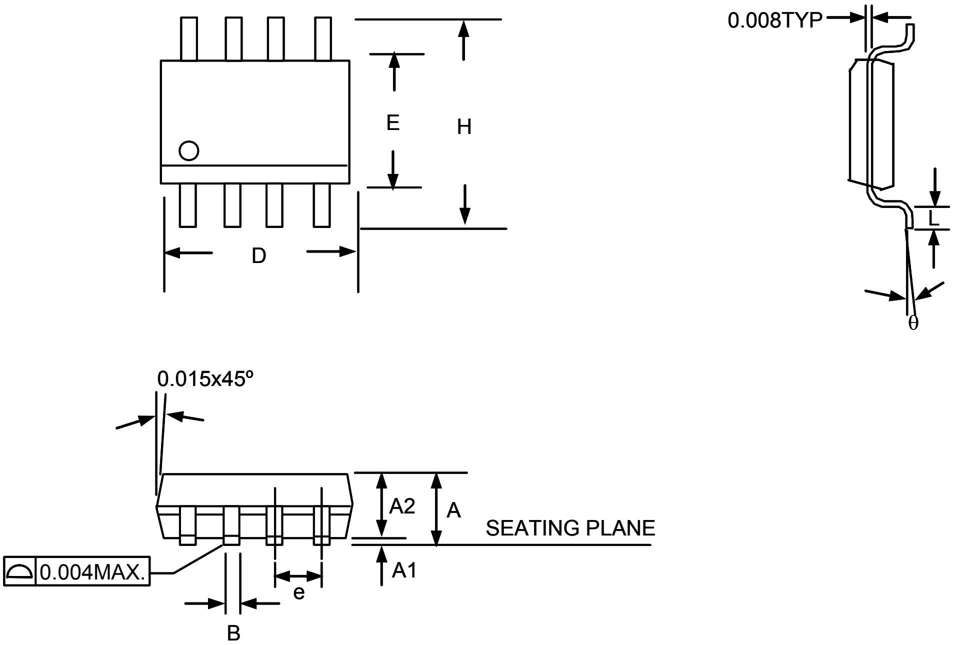


Figure 2. Typical Application Circuit

Package Information



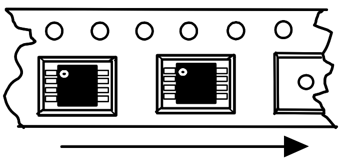
SOP-8 Package

Note:

1. JEDEC Outline: MS-012 AA/E.P. Version: N/A
2. Dimension “D” does not include mold flash, protrusions or gate burrs. Mold flash, protrusions and gate burrs shall not exceed .15mm (.006in) per side.
3. Dimensions “E” does not include inter-lead flash, or protrusions inter-lead flash and protrusions shall not exceed .25mm (.010in) per side.

SYMBOL	DIMENSION IN MM		DIMENSION IN INCH	
	MIN.	MAX.	MIN.	MAX.
A	1.35	1.75	0.053	0.069
A1	0.00	0.13	0.000	0.005
A2	-----	1.50	-----	0.059
B	0.41TYP		0.016TYP	
D	4.80	4.98	0.189	0.196
E	3.81	3.99	0.150	0.157
e	1.27TYP		0.05TYP	
H	5.80	6.20	0.228	0.244
L	0.41	1.27	0.016	0.050
θ	0º	8º	0º	8º

Taping Specification



Feed Direction

Typical SOP Package Orientation

PACKAGE	Q’TY/REEL
SOP-8	2,500 ea