SGM3209
High Voltage, Charge Pump DC/DC Converter

GENERAL DESCRIPTION

The SGM3209 is a charge pump voltage converter. It converts a 3V to 18V input to a corresponding -3V to -18V output using the combination of few external components, eliminating inductors and their associated cost, size and EMI. In addition to a wider power supply input range, the SGM3209 can source output currents as high as 100mA. The switching frequency is resistor programmable from 120kHz to 1.25MHz.

The SGM3209 is recommended for designs requiring greater output current and/or lower input/output voltage drop. The SGM3209 enters into shutdown status by external enable control signal to reduce system power dissipation.

The SGM3209 is available in Green TDFN-2×2-8L and SOIC-8 packages. It operates over an ambient temperature range of -40℃ to +85℃.

FEATURES

- **Wide Operating Range: 3V to 18V**
- **Output Current: 100mA**
- **600kΩ Pull-Low Resistor on EN Pin**
- **120kHz to 1.25MHz Programmable Oscillator Frequency**
- **No External Diodes Required**
- **Low Output Impedance: 15Ω (TYP) at I_{OUT} = 20mA**
- **CMOS Construction**
- **-40℃ to +85℃ Operating Temperature Range**
- **Available in Green TDFN-2×2-8L and SOIC-8 Packages**

APPLICATIONS

Laptop Computers
Disk Drives
Process Instrumentation

TYPICAL APPLICATION

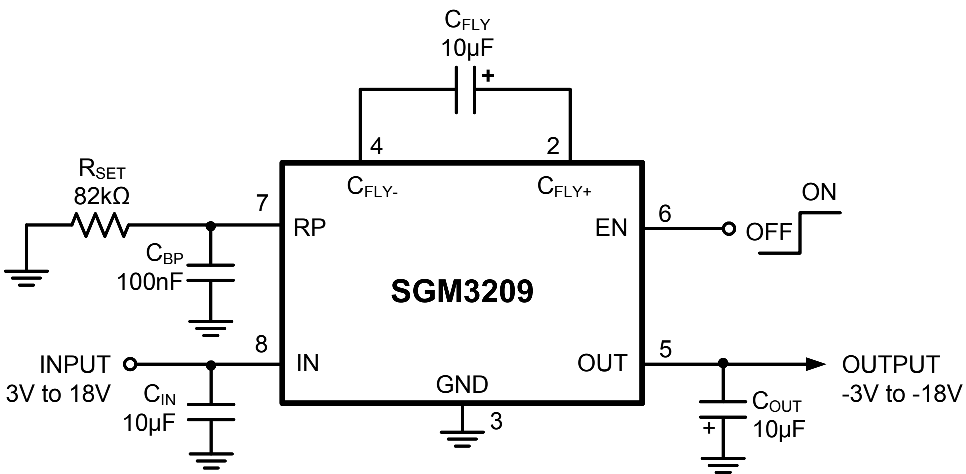


Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM3209	SOIC-8	-40℃ to +85℃	SGM3209YS8G/TR	SGM 3209YS8 XXXXX	Tape and Reel, 2500
	TDFN-2×2-8L	-40℃ to +85℃	SGM3209YTDE8G/TR	3209 XXXX	Tape and Reel, 3000

NOTE: XXXX = Date Code. XXXXX = Date Code and Vendor Code.

Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

ABSOLUTE MAXIMUM RATINGS

IN to GND .... -0.3V to 22V
OUT to GND .... -(V_{IN} + 0.3V) to 0.3V
EN, RP to GND .... -0.3V to 6V
Junction Temperature ....150℃
Storage Temperature Range ....-65℃ to +150℃
Lead Temperature (Soldering, 10sec) ....260℃
ESD Susceptibility
HBM...8000V
MM...400V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Input Voltage Range ....3V to 18V
Operating Temperature Range ....-40℃ to +85℃

OVERSTRESS CAUTION

Stresses beyond those listed may cause permanent damage to the device. Functional operation of the device at these or any other conditions beyond those indicated in the operational section of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

ESD SENSITIVITY CAUTION

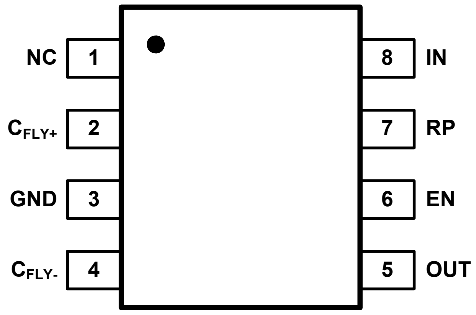
This integrated circuit can be damaged by ESD if you don't pay attention to ESD protection. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, specification or other related things if necessary without notice at any time.

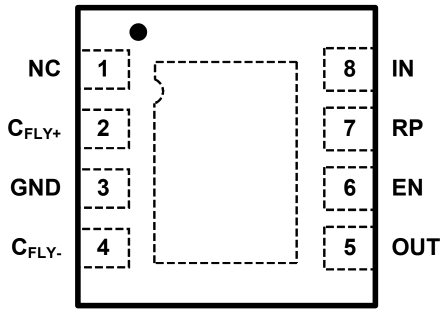
PIN CONFIGURATIONS

SGM3209 (TOP VIEW)



SOIC-8

SGM3209 (TOP VIEW)



TDFN-2×2-8L

PIN DESCRIPTION

PIN		NAME	FUNCTION
TDFN-2×2-8L	SOIC-8		
1	1	NC	No Connection.
2	2	C_{FLY+}	Charge Pump Capacitor Positive Terminal.
3	3	GND	Ground Terminal.
4	4	C_{FLY-}	Charge Pump Capacitor Negative Terminal.
5	5	OUT	Output Voltage.
6	6	EN	Enable Control Pin. Logic HIGH to enable chip and logic LOW to shut down chip.
7	7	RP	Switching Frequency Setting. Connect one resistor (R_{SET}) between RP pin and GND to program switching frequency. The resistor should be located very close to this pin. Frequency range is from 120kHz to 1.25MHz.
8	8	IN	Supply Input.
Exposed Pad	—	NC	No Connection.

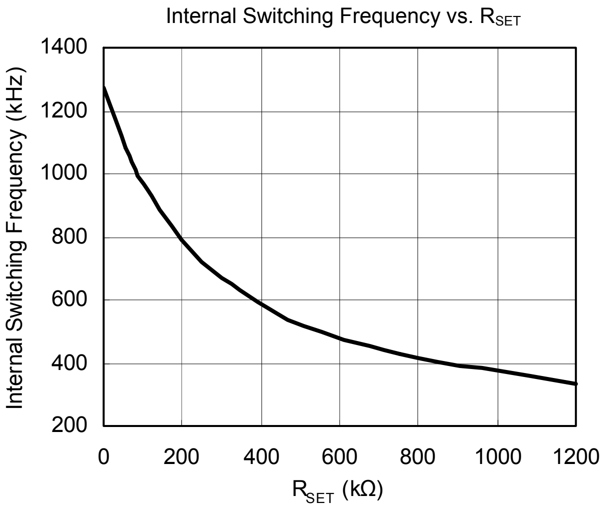
ELECTRICAL CHARACTERISTICS

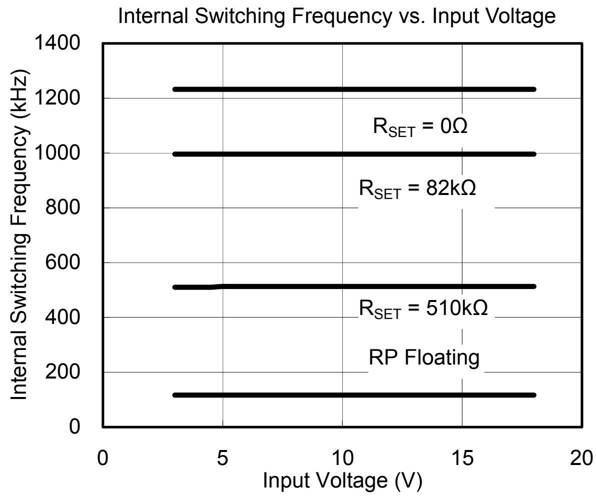
(V_{IN} = 15V, C_{IN} = C_{FLY} = C_{OUT} = 10μF, Full = -40℃ to +85℃. Typical values are at T_A = +25℃, unless otherwise noted.)

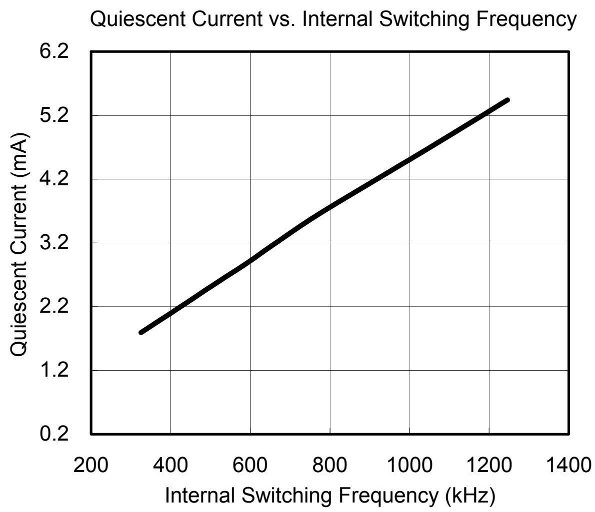
PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}		Full	3		18	V
Maximum Output Current Range at OUT Pin	I_{OUT}		+25℃	100			mA
Output Voltage	V_{OUT}		+25℃		$-V_{IN}$		V
Output Voltage Ripple	V_{PP}	I_{OUT} = 100mA, RP Floating	+25℃		250		mV_{P-P}
		I_{OUT} = 100mA, R_{SET} = 82kΩ	+25℃		40		
		I_{OUT} = 100mA, R_{SET} = 0Ω	+25℃		35		
Quiescent Current	I_Q	RP Floating, I_{OUT} = 0mA	+25℃		0.9	1.4	mA
		R_{SET} = 82kΩ, I_{OUT} = 0mA	+25℃		4.3	5.5	
		R_{SET} = 0Ω, I_{OUT} = 0mA	+25℃		5.3	7.0	
		Shutdown Mode, V_{EN} = 0V	+25℃		0.5	1.2	μA
Internal Switching Frequency	f_{OSC}	RP Floating	+25℃	100	120	145	kHz
		R_{SET} = 82kΩ	+25℃	850	1000	1160	
		R_{SET} = 0Ω	+25℃	1050	1250	1520	
Impedance	R_O	I_{OUT} = 20mA, RP Floating	+25℃		15	19	Ω
		I_{OUT} = 20mA, R_{SET} = 82kΩ	+25℃		23	38	
		I_{OUT} = 20mA, R_{SET} = 0Ω	+25℃		33	57	
EN Logic Level High	V_{IH}	V_{IN} = 3V to 18V	Full	1.4			V
EN Logic Level Low	V_{IL}	V_{IN} = 3V to 18V	Full			0.6	V
EN Internal Pull Low Resistance	$R_{PULL-LOW}$		+25℃		600		kΩ
Thermal Shutdown Temperature	T_{SHDN}				150		℃
Thermal Shutdown Hysteresis	ΔT_{SHDN}				20		℃

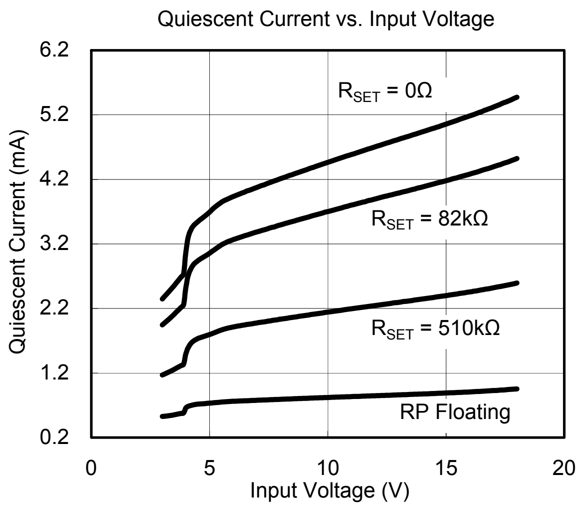
TYPICAL PERFORMANCE CHARACTERISTICS

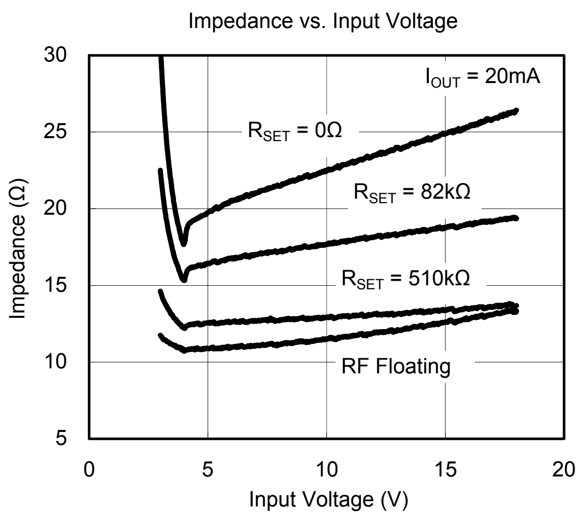
V_{IN} = 15V, C_{IN} = C_{FLY} = C_{OUT} = 10μF, T_A = +25℃, unless otherwise noted.

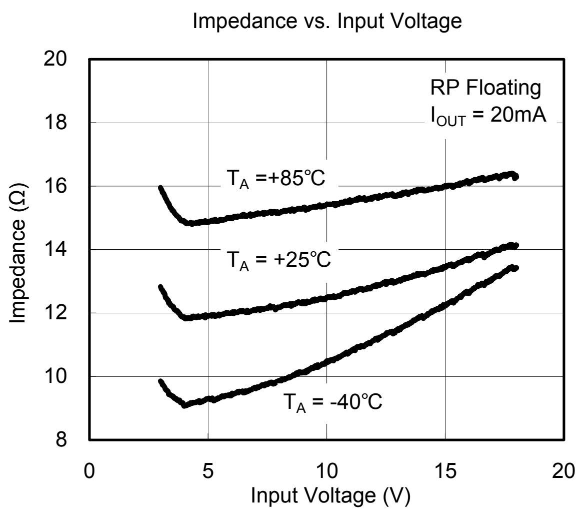












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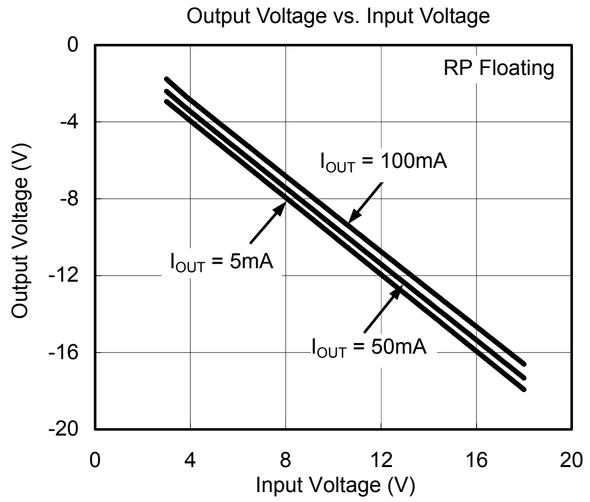

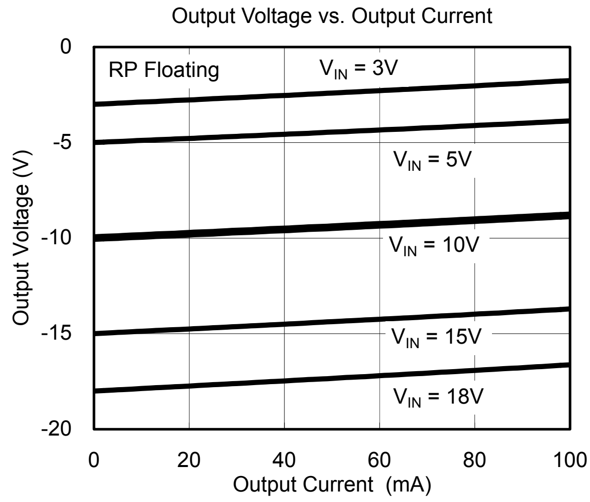

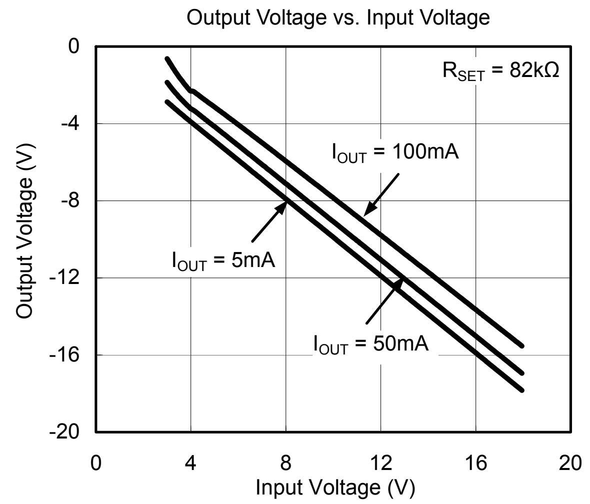

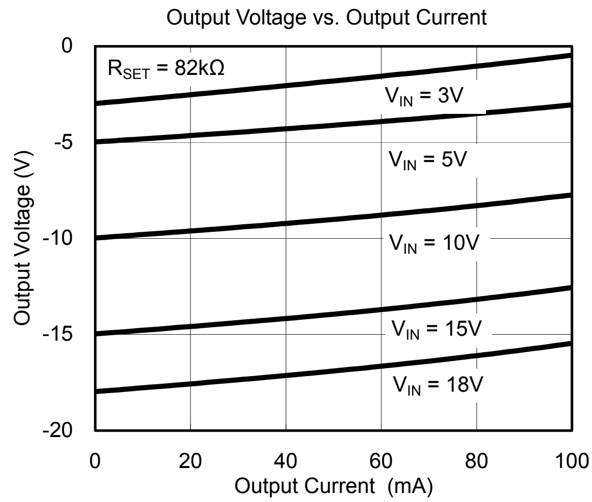

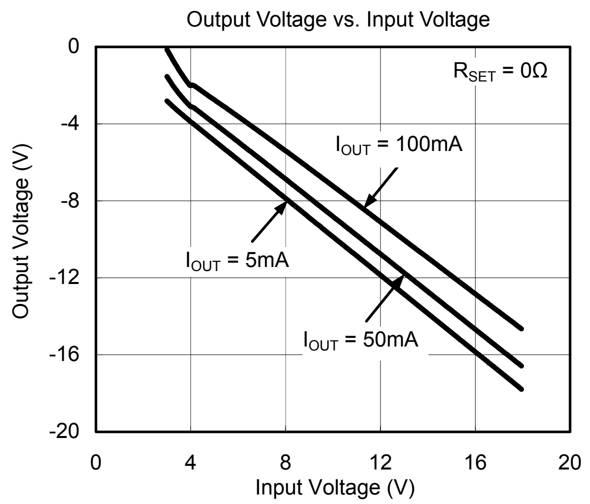

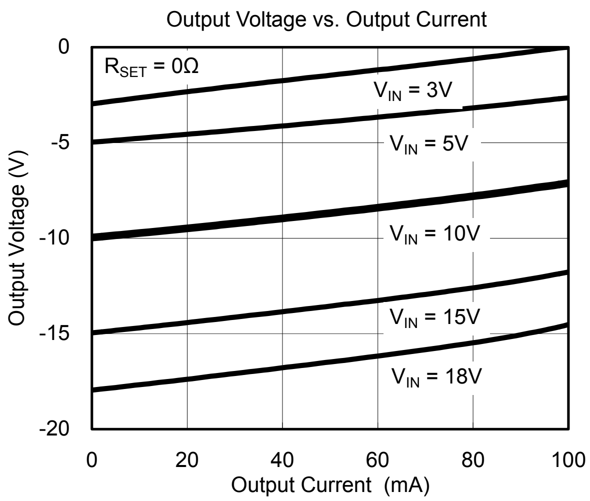

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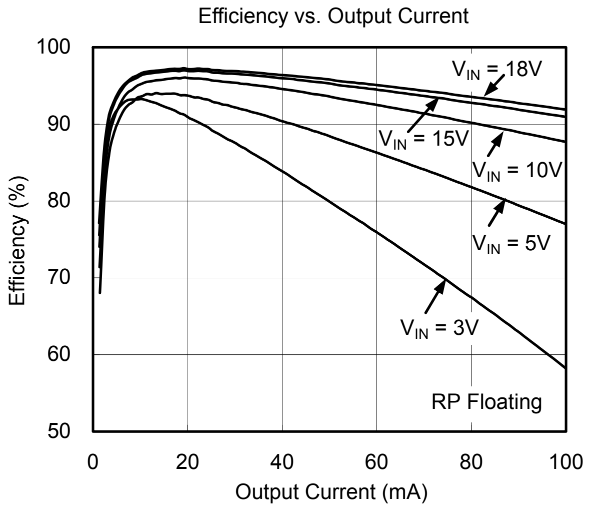

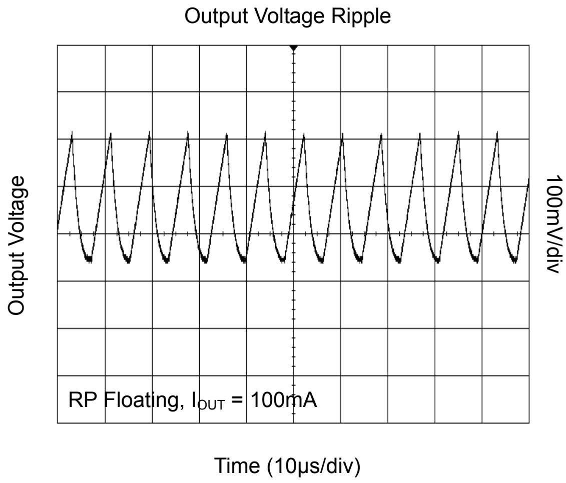

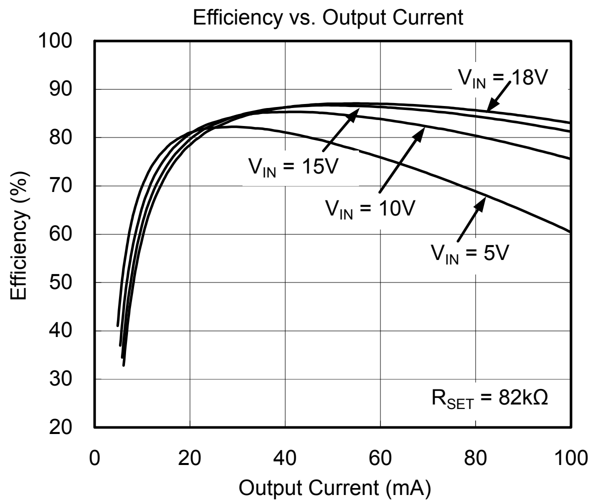

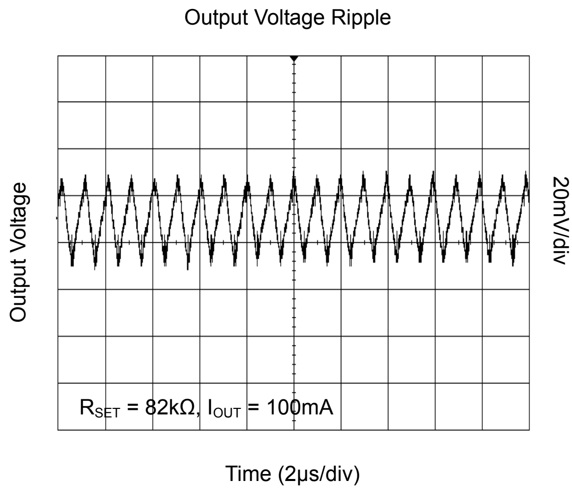

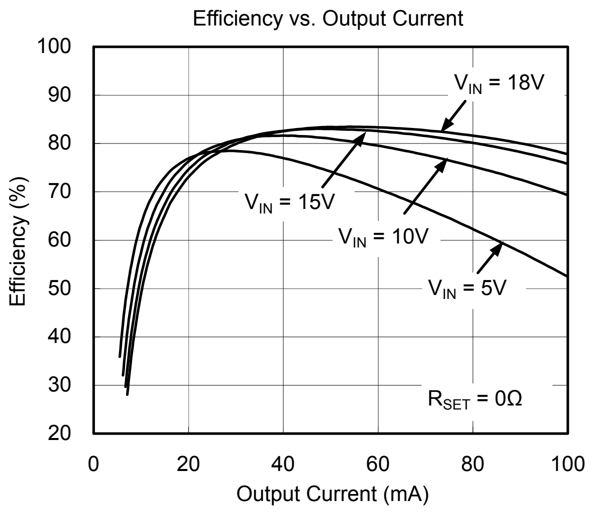

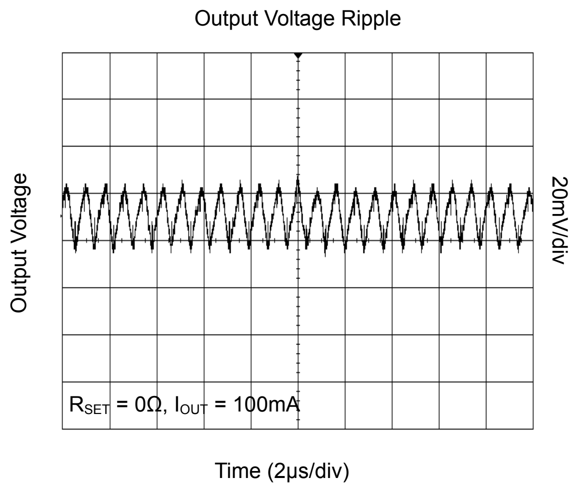

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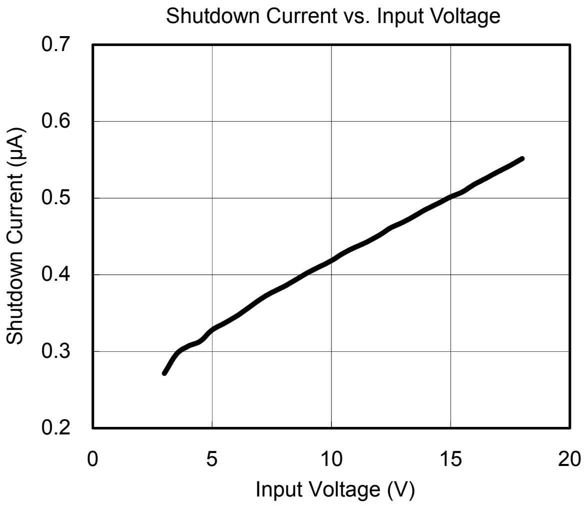


DETAILED DESCRIPTION

Operating Principle

The SGM3209 charge pump inverts the voltage applied to the input. For the best performance, use low equivalent series resistance (ESR) capacitors (e.g., ceramic). During the first half-cycle, switches S2 and S4 open, switches S1 and S3 close, and capacitor C_{FLY} charges to the voltage at V_{IN}. During the second half-cycle, S1 and S3 open and S2 and S4 close. This connects the positive terminal of C_{FLY} to GND and the negative to V_{OUT}. By connecting C_{FLY} in parallel, C_{OUT} is charged negative. The actual voltage at the output is more positive than $-V_{IN}$, since switches S1 - S4 have resistance and the load drains charge from C_{OUT}.

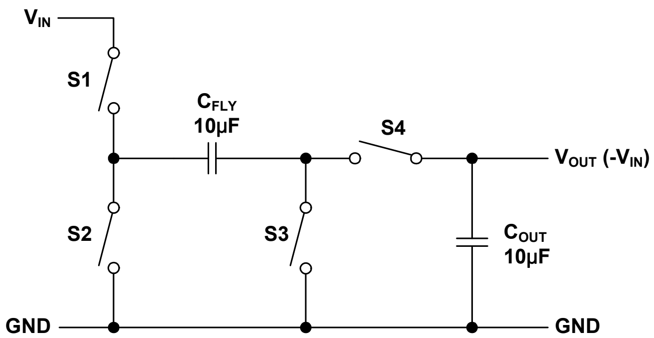


Figure 2. Operating Principle

Charge Pump Output Resistance

The SGM3209 device is not voltage regulator. The charge pump output source resistance is approximately 15Ω at room temperature (with V_{IN} = 15V), and V_{OUT} approaches -15V when lightly loaded. V_{OUT} will droop toward GND as load current increases.

$$V_{OUT} = -(V_{IN} - R_{OUT} \times I_{OUT})$$

$$R_{OUT} \approx \frac{1}{f_{OSC} \times C_{FLY}} + 4\left(2R_{SWITCH} + ESR_{CFLY}\right) + ESR_{COUT}$$

Where:
R_{OUT} = output resistance of the converter
R_{SWITCH} = resistance of a single MOSFET-switch inside the converter
f_{OSC} = oscillator frequency.

Efficiency Considerations

The power efficiency of a switched-capacitor voltage converter is affected by three factors: the internal losses in the converter IC, the resistive losses of the capacitors, and the conversion losses during charge transfer between the capacitors. The internal losses are associated with the IC's internal functions, such as driving the switches, oscillator, etc. These losses are affected by operating conditions such as input voltage, temperature, and frequency. The next two losses are associated with the voltage converter circuit's output resistance. Switch losses occur because of the on-resistance of the MOSFET switches in the IC. Charge pump capacitor losses occur because of their ESR. The relationship between these losses and the output resistance is as follows:

$$P_{CAPACITOR\ LOSSES} + P_{CONVERSION\ LOSSES} = I_{OUT}^2 \times R_{OUT}$$

The first term is the effective resistance from an ideal switched-capacitor circuit. Conversion losses occur during the charge transfer between C_{FLY} and C_{OUT} when there is a voltage difference between them. The power loss is:

$$P_{CONVERSION\ LOSS} = \left[\frac{1}{2} \times C_{FLY}\left(V_{IN}^2 - V_{OUT}^2\right) + \frac{1}{2}C_{OUT}\left(V_{PP}^2 - 2V_{OUT}V_{PP}\right)\right] \times f_{OSC}$$

The efficiency of the SGM3209 is dominated by their quiescent supply current at low output current and by their output impedance at higher current.

$$\eta \cong \frac{I_{OUT}}{I_{OUT} + I_Q}\left(1 - \frac{I_{OUT} \times R_{OUT}}{V_{IN}}\right)$$

Where:
I_Q = quiescent current.

DETAILED DESCRIPTION

Capacitor Selection

To maintain the lowest output resistance, use capacitors with low ESR (see Table 1). The charge pump output resistance is a function of C_{FLY}'s and C_{OUT}'s ESR. Therefore, minimizing the charge pump capacitor's ESR minimizes the total output resistance. The capacitor values are closely linked to the required output current and the output noise and ripple requirements. It is possible to only use 10μF capacitors of the same type.

Table 1. Recommended Capacitor Values

V_{IN} (V)	I_{OUT} (mA)	C_{IN} (μF)	C_{FLY} (μF)	C_{OUT} (μF)
3 to 18	100	10	10	10

Input Capacitor (C_{IN})

Bypass the incoming supply to reduce its AC impedance and the impact of the SGM3209 switching noise. The recommended bypassing depends on the circuit configuration and where the load is connected. When the inverter is loaded from OUT to GND, current from the supply switches between 2 × I_{OUT} and zero. Therefore, use a large bypass capacitor (e.g., equal to the value of C_{FLY}) if the supply has high AC impedance. When the inverter is loaded from IN to OUT, the circuit draws 2 × I_{OUT} constantly, except for short switching spikes. A 0.1μF bypass capacitor is sufficient.

Flying Capacitor (C_{FLY})

Increasing the flying capacitor's size reduces the output resistance. Small values increase the output resistance. Above a certain point, increasing C_{FLY}'s capacitance has a negligible effect, because the output resistance becomes dominated by the internal switch resistance and capacitor ESR.

Output Capacitor (C_{OUT})

Increasing the output capacitor's size reduces the output ripple voltage. Decreasing its ESR reduces both output resistance and ripple. Smaller 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.

$$V_{PP} = \frac{I_{OUT}}{f_{OSC} \times C_{OUT}} + 2 \times I_{OUT} \times ESR_{COUT}$$

Operating Frequency

The operating frequency of the SGM3209 is determined by an external resistor that is connected between the RP pin and ground. The value of the resistor sets the ramp current that is used to charge and discharge an internal timing capacitor within the oscillator. The R_{SET} resistor value can be determined by examining the Internal Switching Frequency vs. R_{SET} curve. To filtering switching noise, a 100nF capacitor should be connected between RP pin and GND.

APPLICATION INFORMATION

Simple Negative Voltage Converter

The majority of applications will undoubtedly utilize the SGM3209 for generation of negative supply voltages. Figure 3 shows typical connections to provide a negative supply where a positive supply of +3V to +18V is available.

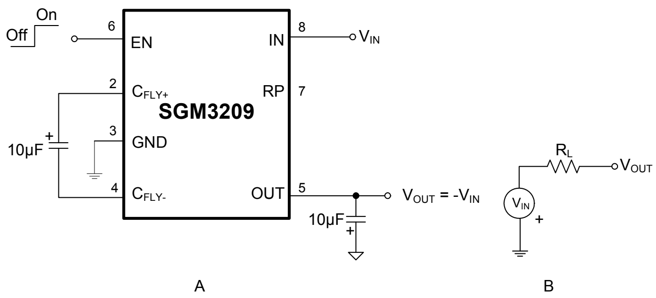


Figure 3. Simple Negative Converter and Its Output Equivalent

Paralleling Devices

Any number of the SGM3209 voltage converters may be paralleled to reduce output resistance (Figure 4). The reservoir capacitor, C_{OUT}, serves all devices, while each device requires its own pump capacitor, C_{FLY}. The resultant output resistance would be approximately:

$$R_{OUT} = \frac{R_{OUT}(\text{of the SGM3209})}{n \text{ (number of devices)}}$$

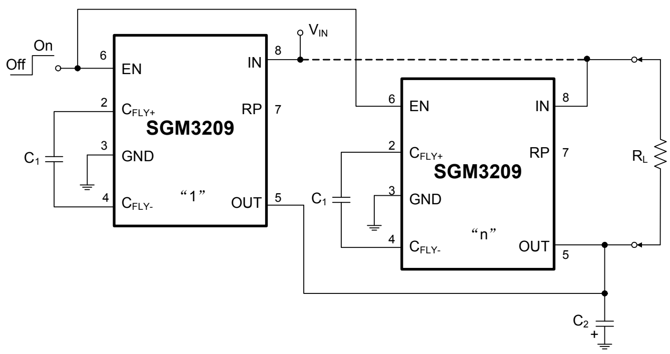


Figure 4. Paralleling Devices Lowers Output Impedance

Cascading Devices

The SGM3209 may be cascaded as shown (Figure 5) to produce larger negative multiplication of the initial supply voltage. However, due to the finite efficiency of each device, the practical limit is 10 devices for light loads. The output voltage is defined by:

$$V_{OUT} = -n \times V_{IN}$$

where n is an integer representing the number of devices cascaded. The resulting output resistance would be approximately the weighted sum of the individual SGM3209 R_{OUT} values.

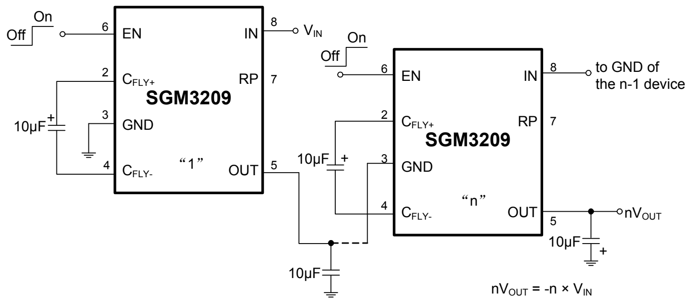


Figure 5. Increased Output Voltage by Cascading Devices

APPLICATION INFORMATION

Positive Voltage Doubling

The SGM3209 may be employed to achieve positive voltage doubling using the circuit shown in Figure 6. In this application, the pump inverter switches of the SGM3209 are used to charge C_{OUT} to a voltage level of V_{IN} - V_F (where V_{IN} is the supply voltage and V_F is the forward voltage on C_{FLY} plus the supply voltage V_{IN} applied through diode D_2 to capacitor C_{OUT}). The voltage thus created on C_{OUT} becomes $(2V_{IN})$ - $(2V_F)$, or twice the supply voltage minus the combined forward voltage drops of diodes D_1 and D_2.

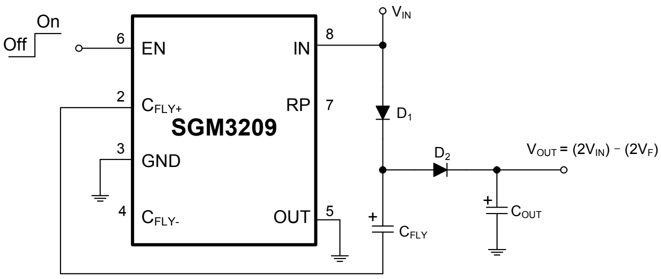


Figure 6. Positive Voltage Multiplier

Combined Negative Voltage Conversion and Positive Supply Multiplication

Figure 7 combines the functions shown in Figure 3 and Figure 6 to provide negative voltage conversion and positive voltage doubling simultaneously. This approach would be, for example, suitable for generating +9V and -5V from an existing +5V supply. In this instance, capacitors C_1 and C_3 perform the pump and reservoir functions, respectively, for the generation of the negative voltage, while capacitors C_2 and C_4 are pump and reservoir, respectively, for the doubled positive voltage. There is a penalty in this configuration which combines both functions, however, in that the source impedances of the generated supplies will be somewhat higher due to the finite impedance of the common charge pump driver at pin 2 of the device.

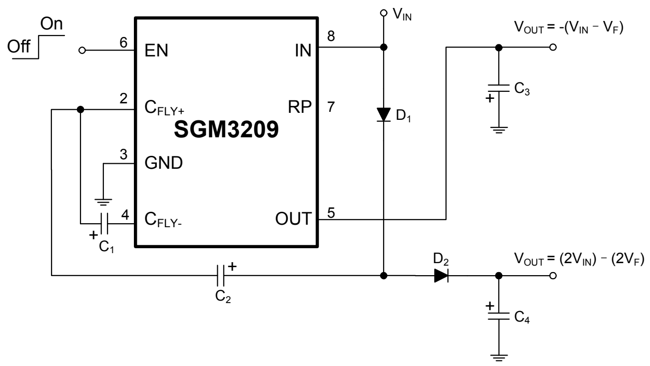
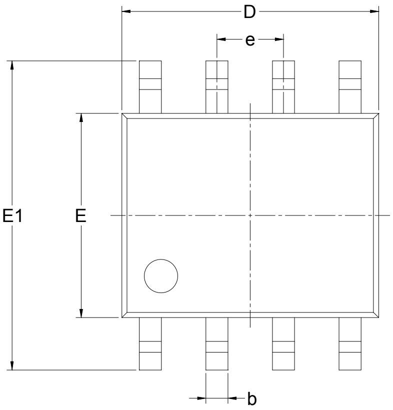
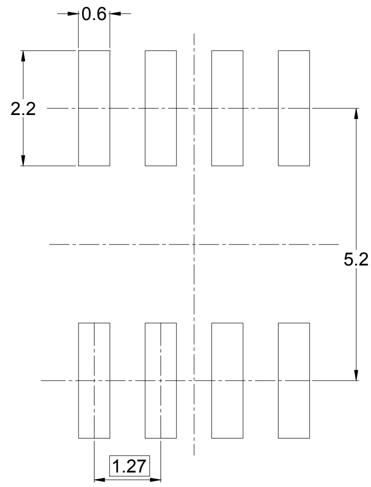


Figure 7. Combined Negative Converter and Positive Doubler

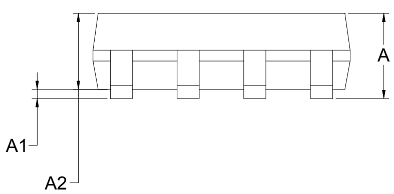
PACKAGE OUTLINE DIMENSIONS

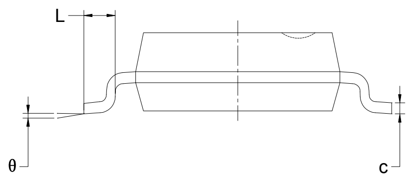
SOIC-8





RECOMMENDED LAND PATTERN (Unit: mm)

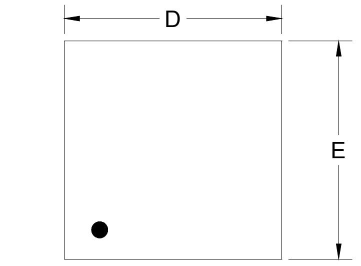




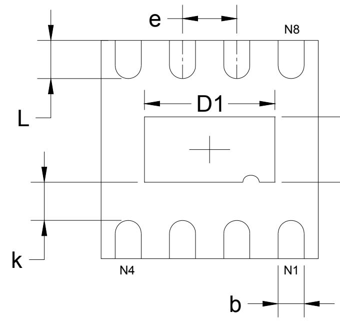
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.27 BSC		0.050 BSC	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

PACKAGE OUTLINE DIMENSIONS

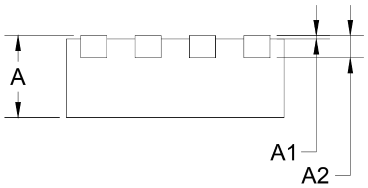
TDFN-2×2-8L



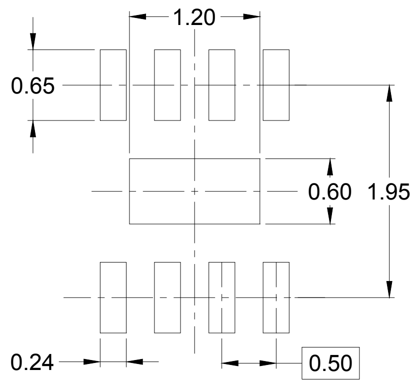
TOP VIEW



BOTTOM VIEW



SIDE VIEW

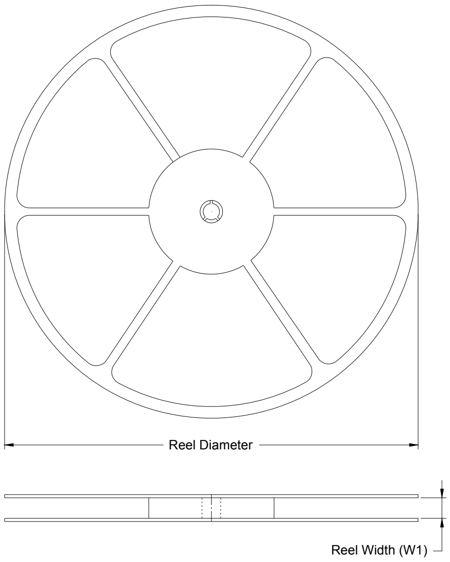


RECOMMENDED LAND PATTERN (Unit: mm)

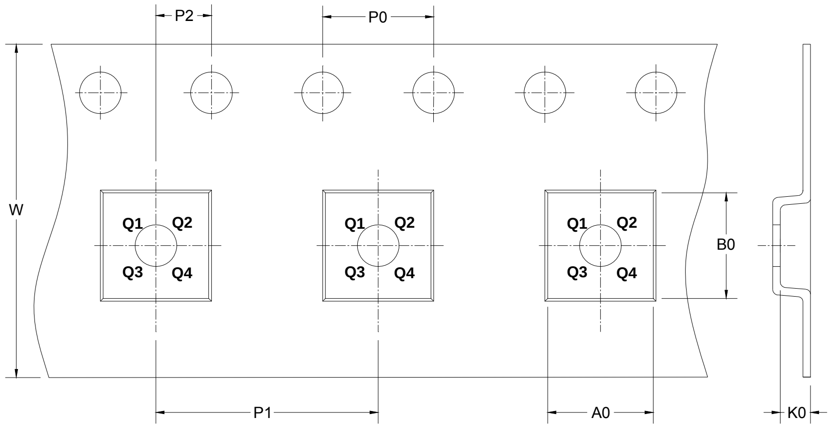
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF		0.008 REF	
D	1.900	2.100	0.075	0.083
D1	1.100	1.300	0.043	0.051
E	1.900	2.100	0.075	0.083
E1	0.500	0.700	0.020	0.028
k	0.200 MIN		0.008 MIN	
b	0.180	0.300	0.007	0.012
e	0.500 TYP		0.020 TYP	
L	0.250	0.450	0.010	0.018

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



DIRECTION OF FEED

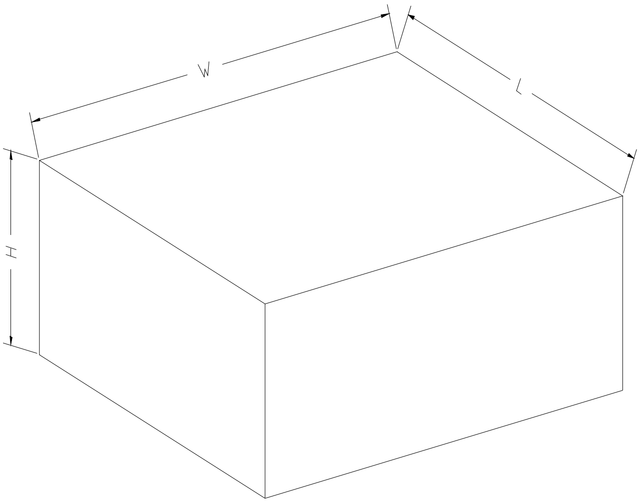
NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SOIC-8	13″	12.4	6.4	5.4	2.1	4.0	8.0	2.0	12.0	Q1
TDFN-2×2-8L	7″	9.5	2.30	2.30	1.10	4.00	4.00	2.00	8.00	Q1

DD0001

CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
7″ (Option)	368	227	224	8
7″	442	410	224	18
13″	386	280	370	5

DD0002