



## Low-Noise, Regulated, -2V GaAsFET Bias

### General Description

The MAX840/MAX843/MAX844 low-noise, inverting charge-pump power supplies are ideal for biasing GaAsFETs in cellular telephone transmitter amplifiers. They operate with inputs down to 2.5V.

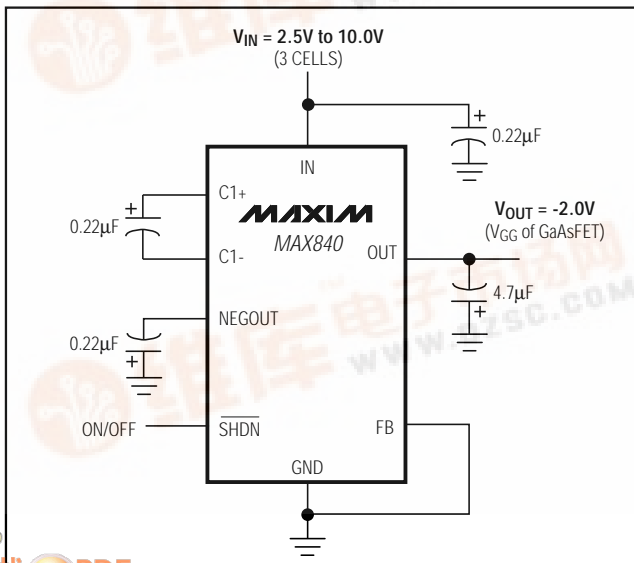
The MAX840 offers both a -2V preset output and a -0.5V to -9.4V adjustable output. The MAX843/MAX844 use an external positive control voltage to set the negative output voltage. Input voltage range for all the devices is 2.5V to 10V, and output current is 4mA with  $V_{IN} > 2.7V$ . These circuits can operate with small capacitors, as low as 0.22μF.

An internal linear regulator reduces the MAX840's output voltage ripple to 1mVp-p. With a well-filtered control voltage ( $V_{CTRL}$ ), the MAX843/MAX844 also achieve less than 1mVp-p typical output ripple. Supply current is 750μA, and reduces to less than 1μA in shutdown (MAX840/MAX843). The MAX844's unregulated output is active in shutdown, with the charge pump switching at 20kHz. It provides a low-power LCD supply.

### Applications

Cellular Phones  
GaAsFET Power Amplifier Modules  
Personal Communicators, PDAs  
Wireless Data Loggers  
Continuously Adjustable GaAsFET Bias  
LCD-Bias Contrast Control  
Regulated Negative Power Supplies

### Typical Operating Circuit



### Features

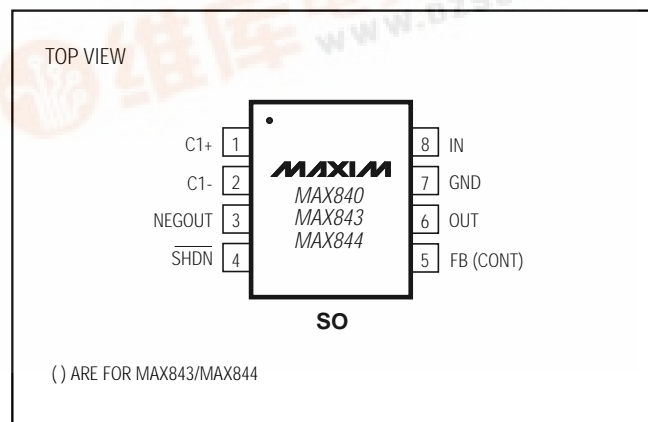
- ♦ Fixed -2V or Adjustable -0.5V to -9.4V Output at 4mA (MAX840)
- ♦ 2.5V to 10V Input Voltage Range
- ♦ Operate with Small Capacitors (as low as 0.22μF)
- ♦ 1mVp-p Output Voltage Ripple
- ♦ Charge-Pump Switching Frequency:  
100kHz in Normal Operation  
20kHz in Shutdown Mode (MAX844)
- ♦ 1μA Max Logic-Level Shutdown Over Temp. (MAX840/MAX843)
- ♦ Small 8-Pin SO Package

### Ordering Information

| PART             | TEMP. RANGE    | PIN-PACKAGE |
|------------------|----------------|-------------|
| <b>MAX840C/D</b> | 0°C to +70°C   | Dice*       |
| MAX840ISA        | -25°C to +85°C | 8 SO        |
| MAX840ESA        | -40°C to +85°C | 8 SO        |
| <b>MAX843C/D</b> | 0°C to +70°C   | Dice*       |
| MAX843ISA        | -25°C to +85°C | 8 SO        |
| MAX843ESA        | -40°C to +85°C | 8 SO        |
| <b>MAX844C/D</b> | 0°C to +70°C   | Dice*       |
| MAX844ISA        | -25°C to +85°C | 8 SO        |
| MAX844ESA        | -40°C to +85°C | 8 SO        |

\* Dice are specified at  $T_A = +25^\circ\text{C}$  only.

### Pin Configuration



( ) ARE FOR MAX843/MAX844

MAX840/MAX843/MAX844

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## ABSOLUTE MAXIMUM RATINGS

Supply Voltage,  $V_{IN}$  to GND .....-0.3V to 10.5V  
 $V_{NEGOUT}$  to GND .....-10.5V to 0.3V  
 $V_{IN}$  to  $V_{NEGOUT}$  .....-0.3V to 21V  
 $V_{OUT}$  to GND (Note 1) ..... $V_{NEGOUT}$  to 0.3V  
 $V_{SHDN}$  to GND .....-0.3V to ( $V_{IN} + 0.3V$ )  
 Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )  
     SO (derate 5.88mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ) .....471mW

### Operating Temperature Ranges

MAX84\_I\_A .....-25 $^\circ\text{C}$  to +85 $^\circ\text{C}$   
 MAX84\_E\_A .....-40 $^\circ\text{C}$  to +85 $^\circ\text{C}$   
 Storage Temperature Range .....-65 $^\circ\text{C}$  to +150 $^\circ\text{C}$   
 Lead Temperature (soldering, 10sec) .....+300 $^\circ\text{C}$

**Note 1:** The output may be shorted to NEGOUT or GND if the package power dissipation is not exceeded. Typical short-circuit current from 4V to GND is 40mA.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

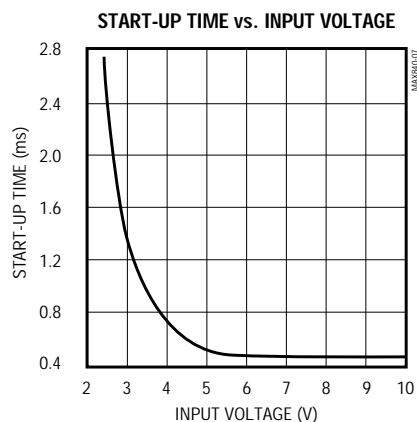
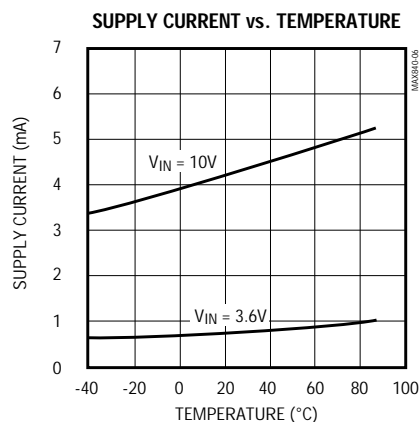
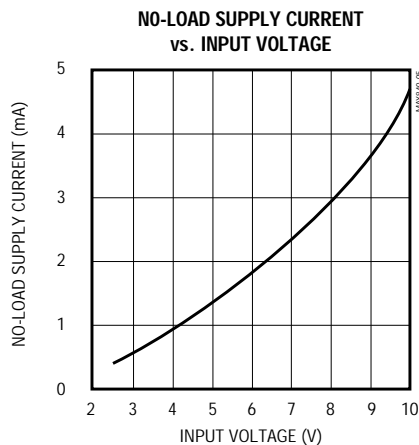
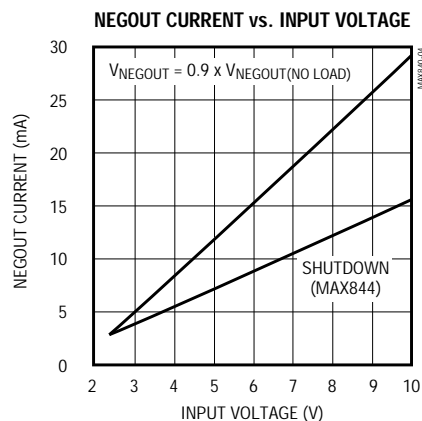
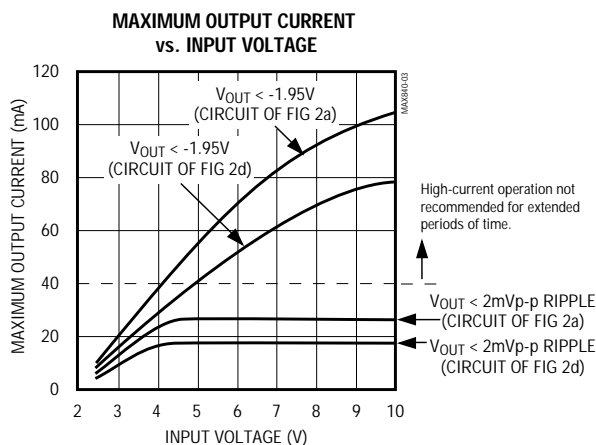
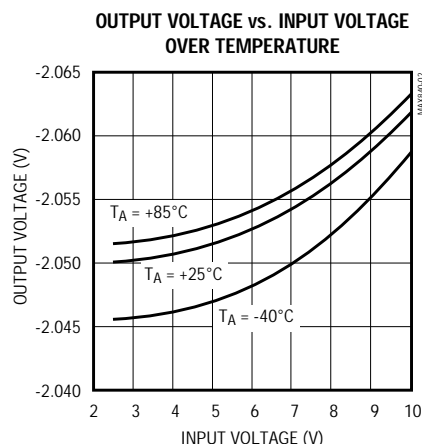
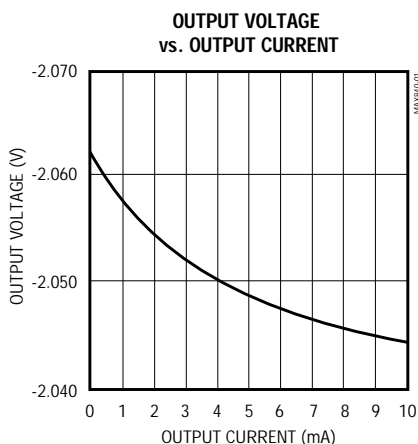
(Figures 2a and 2c,  $2.5V \leq V_{IN} \leq 10V$ ,  $V_{OUT} = -2V$ , GND = 0V,  $R_L = \infty$ ,  $\overline{SHDN} = V_{IN}$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are measured at  $V_{IN} = 3.6V$  and  $T_A = +25^\circ\text{C}$ .)

| PARAMETER                   | SYMBOL     | CONDITIONS   |  | MIN                           | TYP     | MAX       | UNITS         |
|-----------------------------|------------|--|--|-------------------------------|---------|-----------|---------------|
| Supply Voltage Range        | $V_{IN}$   |  |  | 2.5                           |         | 10        | V             |
| Output Voltage              | $V_{OUT}$  | MAX840, $V_{FB} = 0V$                                  | $V_{IN} \geq 2.5V$ ,<br>$I_{OUT} = 0mA$ to 3mA | -2.1                          | -2.0    | -1.9      | V             |
|                             |            |  | $V_{IN} \geq 2.7V$ ,<br>$I_{OUT} = 0mA$ to 4mA | -2.1                          | -2.0    | -1.9      |               |
|                             |            | MAX843/MAX844,<br>$V_{CTRL} = 2V$                      | $V_{IN} \geq 2.5V$ ,<br>$I_{OUT} = 0mA$ to 3mA | -2.05                         | -2.0    | -1.95     |               |
|                             |            |  | $V_{IN} \geq 2.7V$ ,<br>$I_{OUT} = 0mA$ to 4mA | -2.05                         | -2.0    | -1.95     |               |
| Output Voltage Adjust Range | $V_{OUT}$  |  |  | -0.5 to<br>( $V_{IN} - 0.6$ ) |         |           | V             |
| FB Voltage                  | $V_{FB}$   | MAX840, no load  |  | -0.516                        | -0.5    | -0.484    | V             |
| FB Leakage Current          | $I_{FB}$   | MAX840, $V_{FB} = -0.5V$                               |  |                               | $\pm 1$ | $\pm 100$ | nA            |
| CONT Leakage Current        | $I_{CONT}$ | MAX843/MAX844, $V_{CONT} = 0V$                         |  |                               | $\pm 1$ | $\pm 100$ | nA            |
| Supply Current              | $I_Q$      | No load, $V_{IN} \leq 3.6V$                            |  |                               | 750     | 1300      | $\mu\text{A}$ |
| Shutdown Supply Current     | $I_{SHUT}$ | MAX840/MAX843, $V_{IN} = 10V$ , $\overline{SHDN} = 0V$ |  |                               |         | 1         | $\mu\text{A}$ |
|                             |            | MAX844, $V_{IN} = 10V$ , $\overline{SHDN} = 0V$        |  |                               | 940     |           |               |
|                             |            | MAX844, $V_{IN} \leq 3.6V$ , $\overline{SHDN} = 0V$    |  |                               | 175     | 300       |               |
| $V_{OUT}$ Load Regulation   |            | $V_{IN} = 3.6V$ ,<br>$R_L = \infty$ or $500\Omega$     | MAX840, $V_{FB} = 0V$                          |                               | 3       | 8         | mV/mA         |
|                             |            |  | MAX843/MAX844,<br>$V_{CTRL} = 2V$              |                               | 2       | 8         |               |
| $V_{OUT}$ Ripple            |            | $C_4 = 10\mu\text{F}$                                  |  |                               | 1       |           | mVp-p         |
| Oscillator Frequency        | $F_{OSC}$  | $V_{IN} = 3.6V$ ,<br>$T_A = +25^\circ\text{C}$         | MAX840/MAX843/<br>MAX844                       | 80                            | 100     | 120       | kHz           |
|                             |            |  | MAX844, $\overline{SHDN} = 0V$                 | 14                            | 20      | 26        |               |
| Input High Voltage          | $V_{IH}$   | $\overline{SHDN}$                                      |  | 2.2                           |         |           | V             |
| Input Low Voltage           | $V_{IL}$   | $\overline{SHDN}$                                      |  |                               |         | 0.35      | V             |
| Input Current               | $I_{IN}$   | $\overline{SHDN}$                                      |  | -1                            |         | 1         | $\mu\text{A}$ |
| Input Capacitance           | $C_{IN}$   | $\overline{SHDN}$                                      |  |                               | 10      |           | pF            |

# Low-Noise, Regulated, -2V GaAsFET Bias

## Typical Operating Characteristics

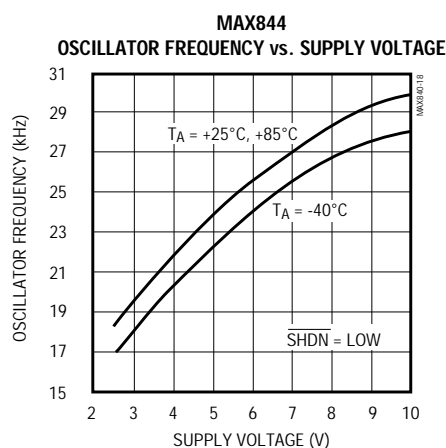
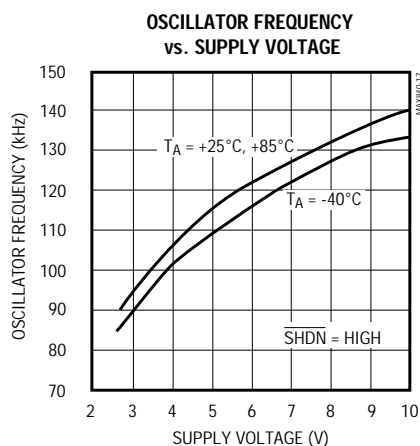
(Circuit of Figure 2a,  $V_{IN} = 3.6V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



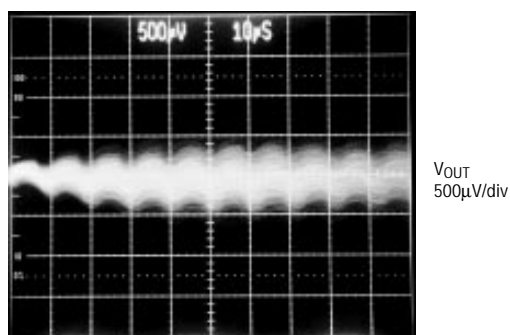
# Low-Noise, Regulated, -2V GaAsFET Bias

## Typical Operating Characteristics (continued)

(Circuit of Figure 2a,  $V_{IN} = 3.6V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

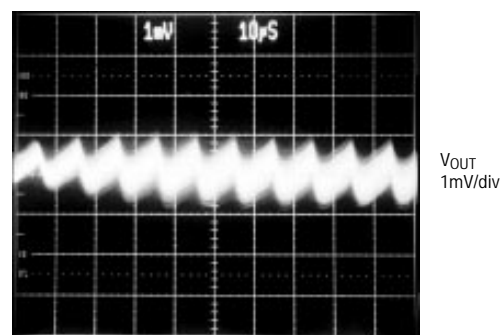


**MAX840 OUTPUT NOISE AND RIPPLE**  
( $C_1 = C_2 = C_3 = 1\mu F$ ,  $C_4 = 10\mu F$ )



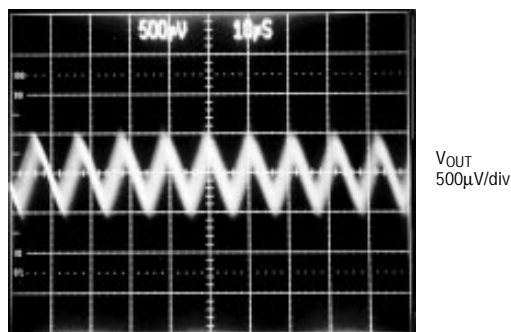
10µs/div  
 $V_{IN} = 3.6V$ ,  $V_{OUT} = -2V$ ,  $I_{OUT} = 4mA$ , AC COUPLED

**MAX840 OUTPUT NOISE AND RIPPLE**  
( $C_1 = C_2 = C_3 = 0.22\mu F$ ,  $C_4 = 4.7\mu F$ )



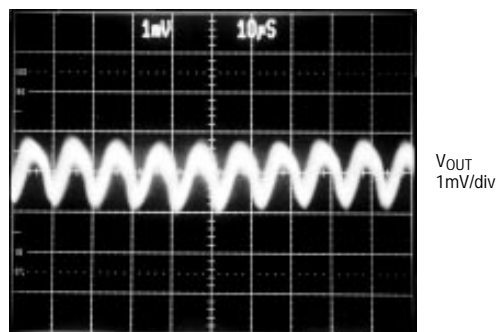
10µs/div  
 $V_{IN} = 3.6V$ ,  $V_{OUT} = -2V$ ,  $I_{OUT} = 4mA$ , AC COUPLED

**MAX843/MAX844 OUTPUT NOISE AND RIPPLE**  
( $C_1 = C_2 = C_3 = 1\mu F$ ,  $C_4 = 10\mu F$ )



10µs/div  
 $V_{IN} = 3.6V$ ,  $V_{OUT} = -2V$ ,  $I_{OUT} = 4mA$ , AC COUPLED

**MAX843/MAX844 OUTPUT NOISE AND RIPPLE**  
( $C_1 = C_2 = C_3 = 0.22\mu F$ ,  $C_4 = 4.7\mu F$ )

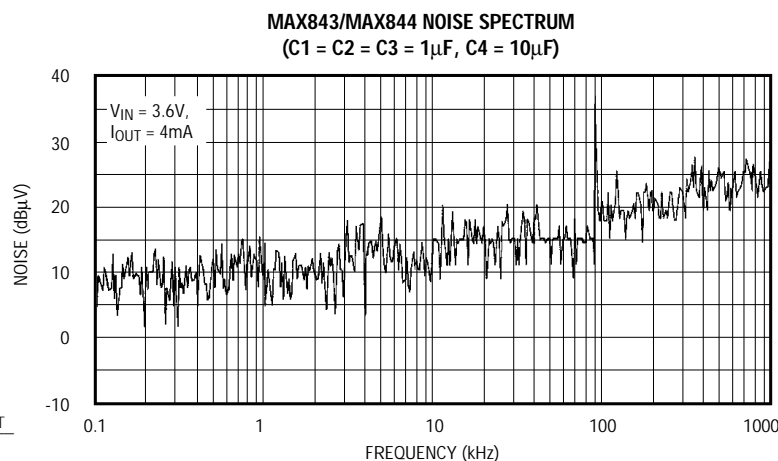
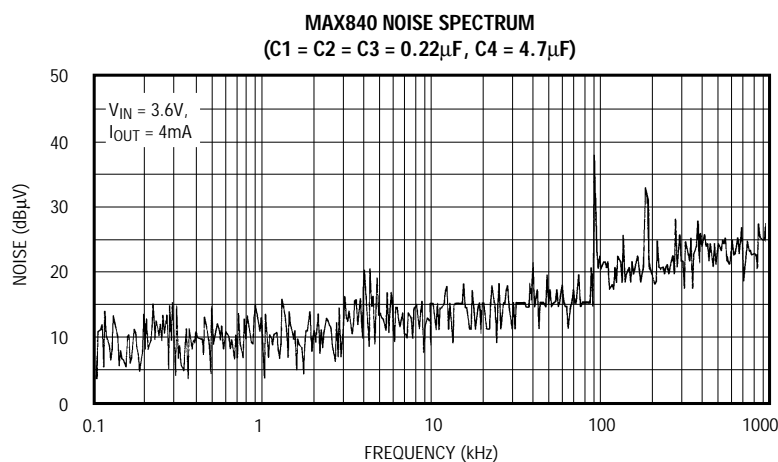
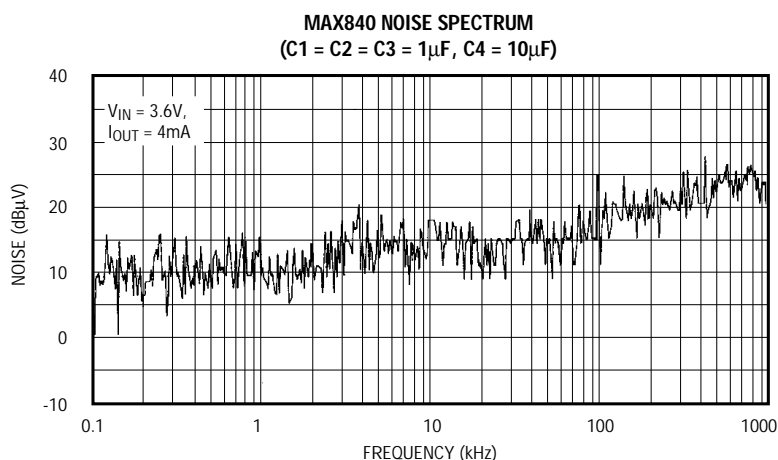


10µs/div  
 $V_{IN} = 3.6V$ ,  $V_{OUT} = -2V$ ,  $I_{OUT} = 4mA$ , AC COUPLED

# Low-Noise, Regulated, -2V GaAsFET Bias

## Typical Operating Characteristics (continued)

(Circuit of Figure 2a,  $V_{IN} = 3.6V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

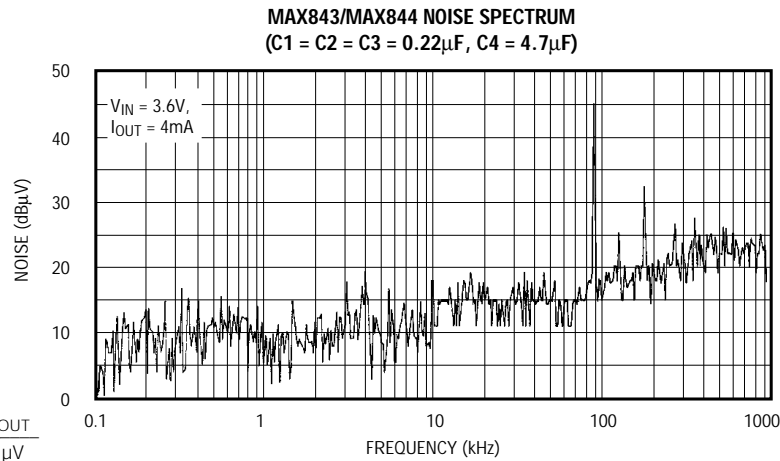


NOTE:  $dB\mu V = 20 \text{ LOG } \frac{V_{OUT}}{1\mu V}$

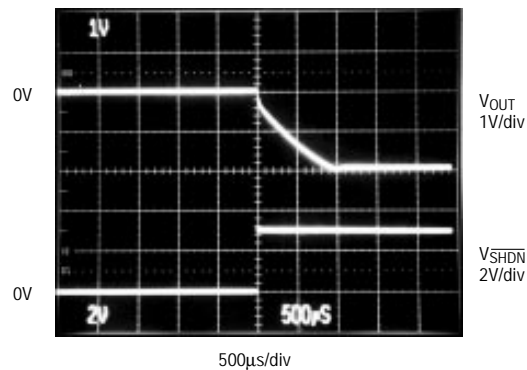
# Low-Noise, Regulated, -2V GaAsFET Bias

## Typical Operating Characteristics (continued)

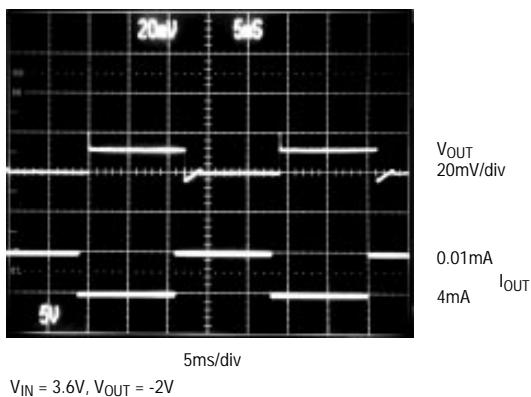
(Circuit of Figure 2a,  $V_{IN} = 3.6V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



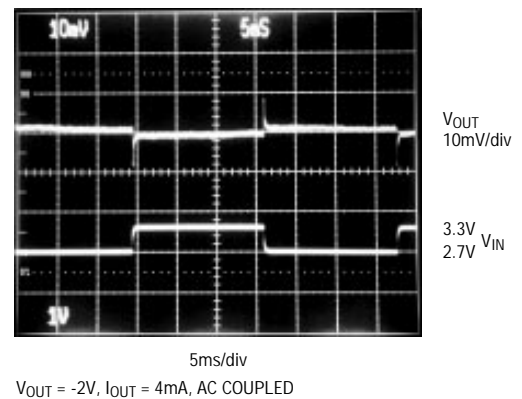
### START-UP FROM SHUTDOWN



### LOAD-TRANSIENT RESPONSE



### LINE-TRANSIENT RESPONSE



# Low-Noise, Regulated, -2V GaAsFET Bias

## Pin Description

| PIN    |                  | NAME                     | FUNCTION  |
|--------|------------------|--------------------------|---|
| MAX840 | MAX843<br>MAX844 |                          |   |
| 1      | 1                | C1+                      | Positive Terminal for C1  |
| 2      | 2                | C1-                      | Negative Terminal for C1  |
| 3      | 3                | NEGOUT                   | Negative Output Voltage (unregulated)   |
| 4      | 4                | $\overline{\text{SHDN}}$ | Active-Low, TTL Logic-Level Shutdown Input  |
| 5      | —                | FB                       | Dual Mode™ Feedback Input. When FB is grounded, the output is preset to -2V. To select other output voltages, connect FB to an external resistor divider (Figure 2b). |
| —      | 5                | CONT                     | Control Voltage Input. To set $V_{\text{OUT}}$ , connect a resistor divider between OUT and a positive control voltage between 0V and 10V (Figure 2c).                |
| 6      | 6                | OUT                      | Regulated Negative Output Voltage   |
| 7      | 7                | GND                      | Ground  |
| 8      | 8                | IN                       | Positive Power-Supply Input   |

Dual Mode is a trademark of Maxim Integrated Products.

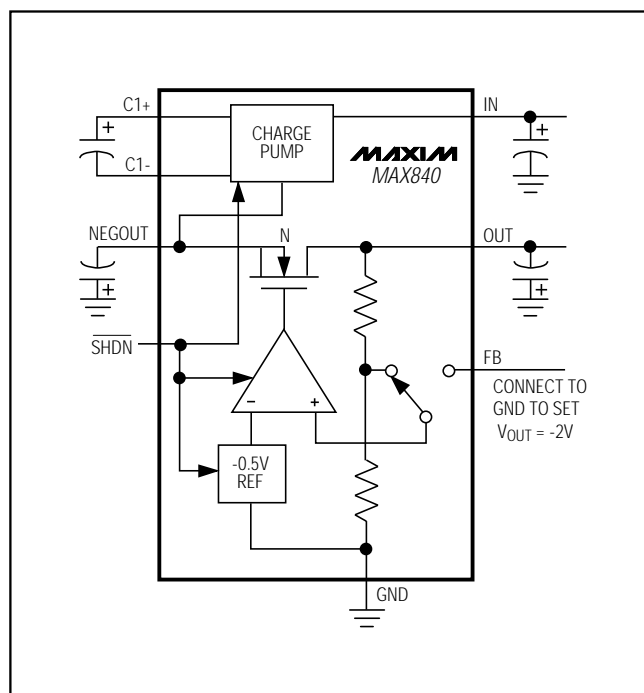


Figure 1a. MAX840 Block Diagram

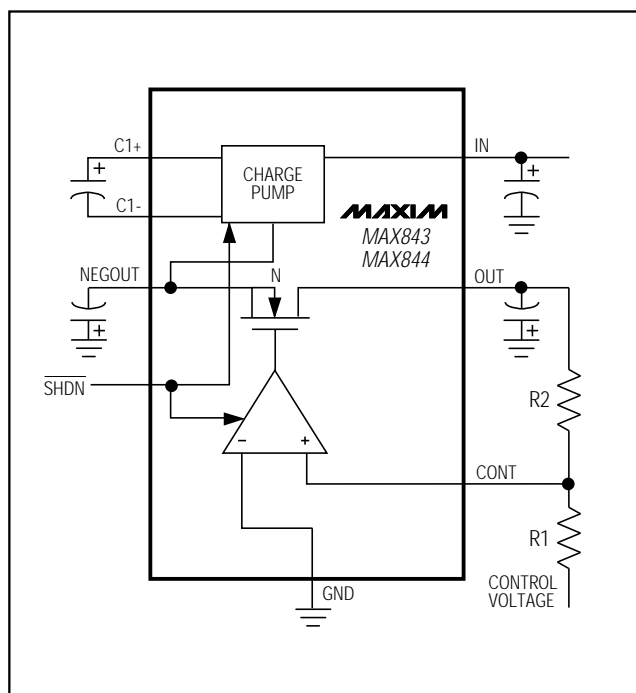


Figure 1b. MAX843/MAX844 Block Diagram

# Low-Noise, Regulated, -2V GaAsFET Bias

## Detailed Description

The MAX840/MAX843/MAX844 are low-noise, inverting, regulated charge-pump power supplies designed for biasing GaAsFET devices, such as power-amplifier modules in cellular handsets.

The applied input voltage ( $V_{IN}$ ) is first inverted to a negative voltage at NEGOUT by a capacitive charge pump. This voltage is then regulated by an internal low-noise linear regulator, and appears at OUT (Figure 1). The minimum (most negative) output voltage achievable is the inverted positive voltage, plus the 0.6V required by the post-regulator. For the MAX840, the linear regulator reduces ripple noise induced by the charge-pump inverter to 1mVp-p at  $V_{OUT}$ . In addition, the linear regulator's excellent AC rejection attenuates noise from the incoming supply.

## Applications Information

### Setting the Output Voltage

For the MAX840, select either a fixed or adjustable output voltage. Connect FB directly to GND for a fixed -2V output (Figure 2a). Select an alternate output voltage by connecting FB to the midpoint of a resistor voltage divider from OUT to GND (Figure 2b).  $V_{IN}$  must be 0.6V above the absolute value of  $V_{OUT}$  to allow proper regulation. The output voltage is calculated from the formula below. Choose  $R_2$  to be between 100k $\Omega$  and 400k $\Omega$ .

$$V_{OUT} = (-0.5V)(1 + R_2 / R_1)$$

For the MAX843/MAX844, set the output voltage by connecting a resistor voltage divider between OUT and a positive control voltage ( $V_{CTRL}$ ) (Figure 2c).

$$V_{OUT} = -V_{CTRL} (R_2 / R_1)$$

### Shutdown Mode

The MAX840/MAX843/MAX844 feature a shutdown mode that reduces the supply current to 1 $\mu$ A max over temperature (300 $\mu$ A max for the MAX844). When the MAX840/MAX843 are in shutdown, the outputs (OUT, NEGOUT) and the charge-pump oscillator are disabled. When the MAX844 is in shutdown, only the linear regulator is disabled and the NEGOUT output remains enabled. However, the charge-pump oscillation frequency is reduced to 20kHz, reducing the available power at NEGOUT. The output voltage at NEGOUT can be used to bias an LCD while in shutdown.

## Capacitors

Use capacitors with low effective series resistance (ESR) to maintain a low dropout voltage ( $V_{IN} - |V_{OUT}|$ ). The overall dropout voltage is a function of the charge pump's output resistance and the voltage drop across the linear regulator (N-channel pass transistor). At the 100kHz switching frequency, the charge-pump output resistance is a function of  $C_1$  and  $C_2$ 's ESR. Therefore, minimizing the ESR of the charge-pump capacitors minimizes the dropout voltage.

The output resistance of the entire circuit is approximately:

$$R_{OUT} = R_O + 4 \times ESR_{C1} + ESR_{C4} + \frac{1}{f_S \times C_1} + R(\text{linear regulator})$$

where  $[R_O + R(\text{linear regulator})]$ , the effective resistance of the internal switches and the resistance across the linear regulator, is approximately 71 $\Omega$  at  $V_{IN} = 2.5V$ , 48 $\Omega$  at  $V_{IN} = 5V$ , and 40 $\Omega$  at  $V_{IN} = 10V$ .

$C_1$ ,  $C_2$ , and  $C_3$  should be 1 $\mu$ F capacitors with less than 0.8 $\Omega$  ESR.  $C_4$  should be a 10 $\mu$ F capacitor with less than 0.2 $\Omega$  ESR. Smaller capacitor values can be used ( $C_1 = C_2 = C_3 = 0.22\mu$ F,  $C_4 = 4.7\mu$ F) with a small increase in output noise and ripple (Figure 2d). All capacitors should be either surface-mount chip tantalum or ceramic types. External capacitor values can be adjusted to optimize size and cost.

## Layout and Grounding

Good layout is important, primarily for good noise performance. Take the following steps to ensure good layout:

- 1) Mount all components as close together as possible.
- 2) Keep traces short to minimize parasitic inductance and capacitance. This includes connections to FB.
- 3) Use a ground plane.

## Noise and Ripple Measurement

Accurately measuring the output noise and ripple is a challenge. Slight momentary differences in ground potential between the MAX840/MAX843/MAX844 circuit and the oscilloscope (which results from the charge pump's switching action) cause ground currents in the probe's wires, inducing sharp voltage spikes. For best results, measure directly across the output capacitor ( $C_4$ ). Do not use the ground lead of the oscilloscope probe; instead, remove the probe's tip cover and touch the ground ring on the probe directly to  $C_4$ 's ground terminal. You can also use a Tektronix chassis-mount test jack (part no. 131-0258) to connect your scope probe directly. This direct connection gives the most accurate noise and ripple measurement.



# Low-Noise, Regulated, -2V GaAsFET Bias

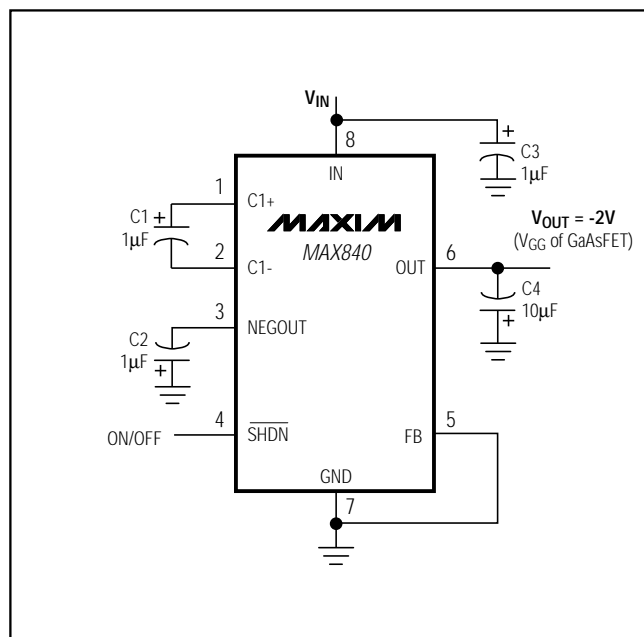


Figure 2a. MAX840 Standard Application Circuit

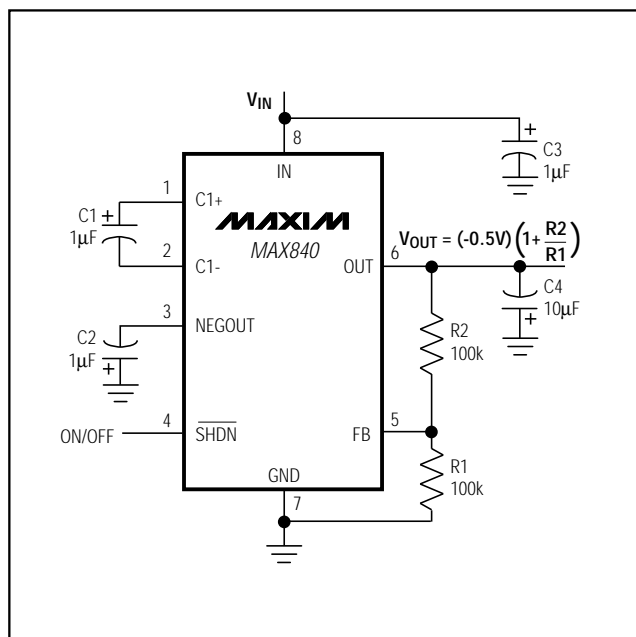


Figure 2b. MAX840 Adjustable Configuration

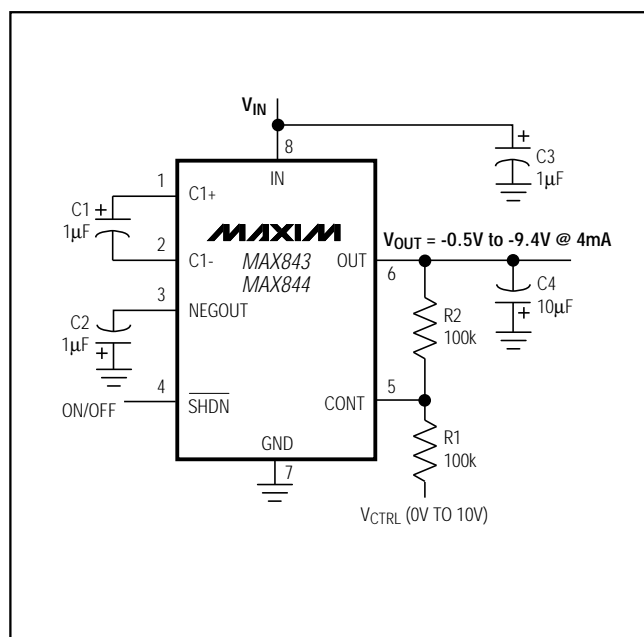


Figure 2c. MAX843/MAX844 Standard Application Circuit

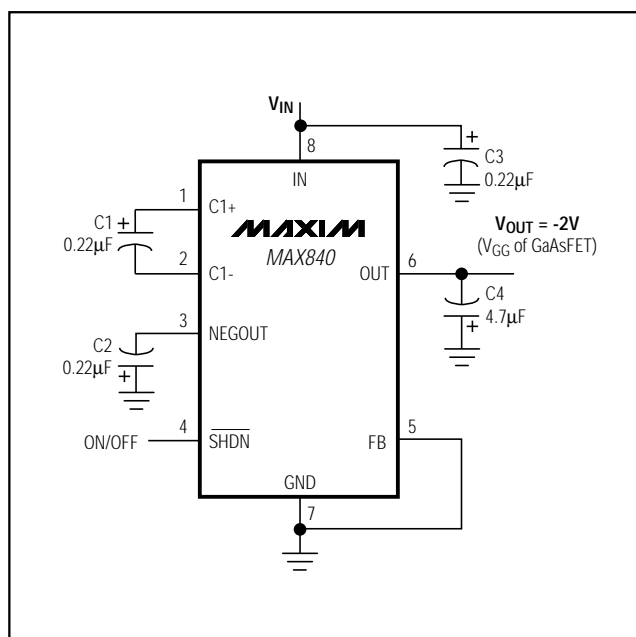
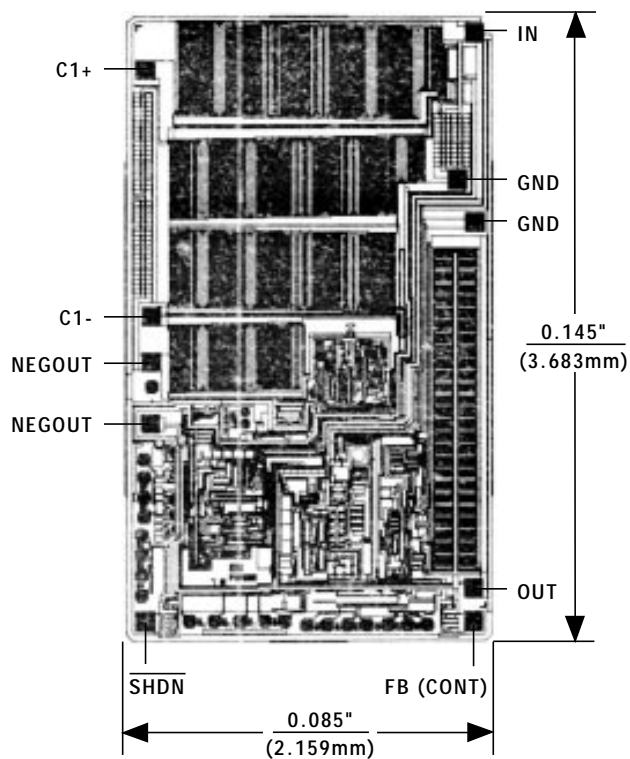


Figure 2d. MAX840 Application Circuit Using Smaller Capacitors

# Low-Noise, Regulated, -2V GaAsFET Bias

## Chip Topography



( ) ARE FOR MAX843/MAX844

TRANSISTOR COUNT: 148

SUBSTRATE CONNECTED TO IN