LM2787 Low Noise Regulated Switched Capacitor Voltage Inverter in DSBGA

Check for Samples: LM2787

FEATURES

- **Inverts and regulates the input supply voltage**
- **Small 8-Bump DSBGA and thin DSBGA packages**
- **91% typical charge pump power efficiency at 10mA**
- **Low output ripple**
- **Shutdown lowers Quiescent current to 0.05 µA (typical)**

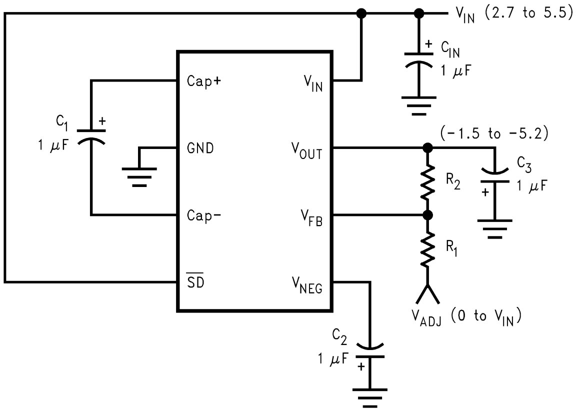
APPLICATIONS

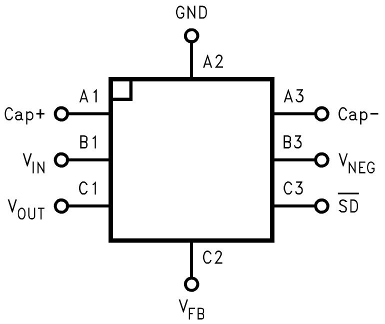
- **Wireless Communication Systems**
- **Cellular Phone Power Amplifier Biasing**
- **Interface Power Supplies**
- **Handheld Instrumentation**
- **Laptop Computers and PDA's**

DESCRIPTION

The LM2787 CMOS Negative Regulated Switched Capacitor Voltage Inverter delivers a very low noise adjustable output for an input voltage in the range of +2.7V to +5.5V. Four low cost capacitors are used in this circuit to provide up to 10mA of output current. The regulated output for the LM2787 is adjustable between −1.5V and −5.2V. The LM2787 operates at 260 kHz (typical) switching frequency to reduce output resistance and voltage ripple. With an operating current of only 400 µA (charge pump power efficiency greater than 90% with most loads) and 0.05 µA typical shutdown current, the LM2787 provides ideal performance for cellular phone power amplifier bias and other low current, low noise negative voltage needs. The device comes in small 8-Bump DSBGA and thin DSBGA packages.

Typical Application Circuit and Connection Diagram





8-Bump DSBGA (Top View)

PIN DESCRIPTIONS

Pin No.	Name	Function
A1	Cap+	Positive terminal for C_1.
B1	V_{IN}	Positive power supply input.
C1	V_{OUT}	Regulated negative output voltage.
C2	V_{FB}	Feedback input. Connect V_{FB} to an external resistor divider between V_{OUT} and a positive adjust voltage V_{ADJ} ($0 \le V_{ADJ} \le V_{IN}$). **DO NOT** leave unconnected.
C3	$\overline{SD}$	Active low, logic-level shutdown input.
B3	V_{NEG}	Negative unregulated output voltage.
A3	Cap−	Negative terminal for C_1.
A2	GND	Ground.

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings (1)(2)

Supply Voltage (V_{IN} to GND or GND to OUT)	+ 5.8V
$\overline{SD}$	(GND − 0.3V) to (V_{IN} + 0.3V)
V_{NEG} and V_{OUT} Continuous Output Current	10mA
V_{OUT} Short-Circuit Duration to GND (3)	1 sec.
Continuous Power Dissipation (T_A = 25°C) (4)	600mW
T_{JMAX} (4)	150°C
θ_{JA} (4)	220°C/W
Operating Input Voltage Range	2.7V to 5.5V
Operating Output Current Range	0mA to 10mA
Operating Ambient	−40°C to 85°C
Temp. Range	
Operating Junction Temp. Range	−40°C to 110°C
Storage Temperature	−65°C to 150°C
Lead Temp. (Soldering, 10 sec.)	300°C
ESD Rating (5)	2kV

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

(2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.

(3) OUT may be shorted to GND for one second without damage. However, shorting OUT to V_{IN} may damage the device and must be avoided. Also, for temperatures above T_A = 85°C, OUT must not be shorted to GND or V_{IN} or device may be damaged.

(4) The maximum power dissipation must be de-rated at elevated temperatures and is limited by T_{JMAX} (maximum junction temperature), T_A (ambient temperature) and θ_{JA} (junction-to-ambient thermal resistance). The maximum power dissipation at any temperature is:$PDiss_{MAX} = (T_{JMAX} — T_A)/\theta_{JA}$ up to the value listed in the Absolute Maximum Ratings.

(5) Rating is for the human body model, a 100pF capacitor discharged through a 1.5 kΩ resistor into each pin.

Electrical Characteristics

Limits with standard typeface apply for T_J = 25°C, and limits in **boldface type** apply over the full temperature range. Unless otherwise specified V_{IN} = 3.6V, $C_1 = C_2 = C_3$ = 1µF.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
I_Q	Supply Current	Open Circuit, No Load		400	**950**	µA
I_{SD}	Shutdown Supply Current			0.05	1	µA
F_{SW}	Switching Frequency (1)	V_{IN} = 3.6V	**140**	260	**450**	kHz
η_{POWER}	Power Efficiency at V_{NEG}	I_L = 3.6mA I_L = 10mA		94 91		%
T_{START}	Start Up time			120	600	µs

(1) The output switches operate at one half the oscillator frequency, $f_{OSC} = 2f_{SW}$.

Electrical Characteristics (continued)

Limits with standard typeface apply for T_J = 25°C, and limits in **boldface type** apply over the full temperature range. Unless otherwise specified V_{IN} = 3.6V, $C_1 = C_2 = C_3$ = 1µF.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
R_{NEG}	Output Resistance to V_{NEG}	(2)		30		Ω
V_R	Output Voltage Ripple (3)	I_L =2.5mA, V_{OUT} = −2.7V I_L = 10mA, V_{OUT} = −3.8V		1		mV
V_{FB}	Feedback Pin Reference Voltage	I_L = 2.5mA (4)	**−1.25**	−1.20	**−1.15**	V
V_{OUT}	Adjustable Output Voltage	5.5V ≥ V_{IN} ≥ 2.7V, 2.5mA ≥ I_L 5.5V ≥ V_{IN} ≥ 3.0V, 10mA ≥ I_L ≥ 0mA	**− (V_{IN} −0.3V)** **− (V_{IN} −1.2V)**			V
	Load Regulation	0 to 10mA, V_{OUT} = − 2.4V		5		mV/mA
	Line Regulation	5.5V ≥ V_{IN} ≥ 2.7V, I_L = 2.5mA		1		mV/V
V_{IH}	Shutdown Pin Input Voltage High	5.5V ≥ V_{IN} ≥ 2.7V	**2.4**			V
V_{IL}	Shutdown Pin Input Voltage Low	5.5V ≥ V_{IN} ≥ 2.7V			**0.8**	V

(2) Current drawn from V_{NEG} pin decreases power efficiency and will increase output voltage ripple.

(3) In the test circuit, capacitors C_1, C_2, and C_3 are 1µF, 0.30Ω maximum ESR capacitors. Capacitors with higher ESR will increase output resistance, increase output voltage ripple, and reduce efficiency.

(4) The feedback resistors R1 and R2 are 200kΩ resistors.

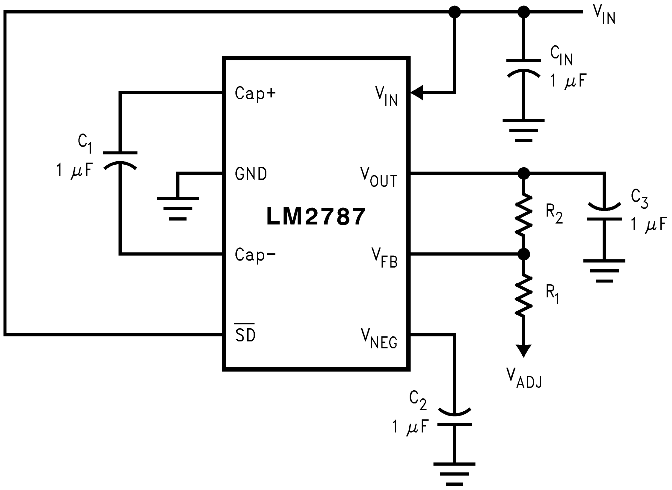


Figure 1. Standard Application Circuit

Typical Performance Characteristics

Unless otherwise specified, T_A = 25°C, V_{OUT} = −2.5V.

Output Voltage vs. Output Current

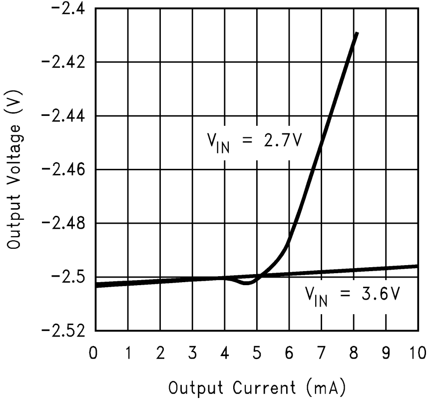


Figure 2.

Output Voltage vs. Input Voltage

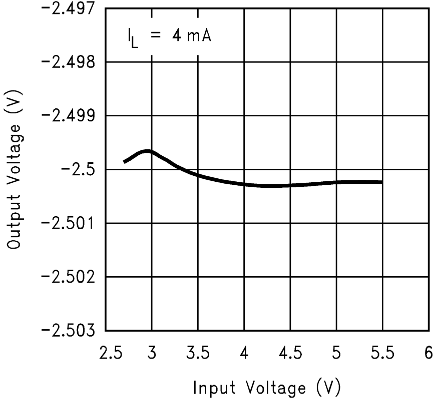


Figure 3.

Maximum V_{NEG} Current vs. Input Voltage

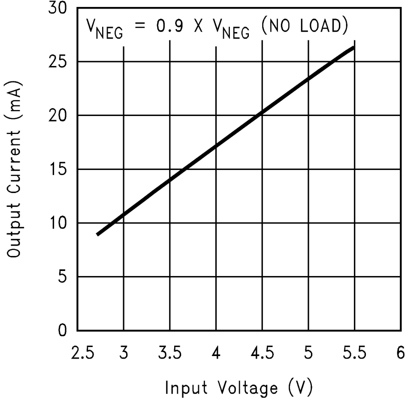


Figure 4.

No Load Supply Current vs. Input Voltage

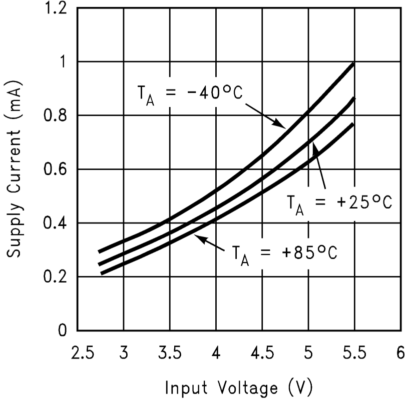


Figure 5.

Switching Frequency vs. Input Voltage

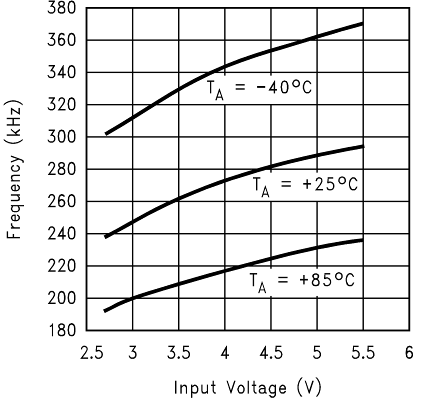


Figure 6.

V_{FB} vs. Temperature

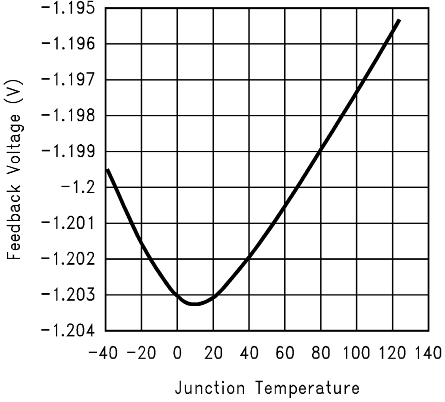
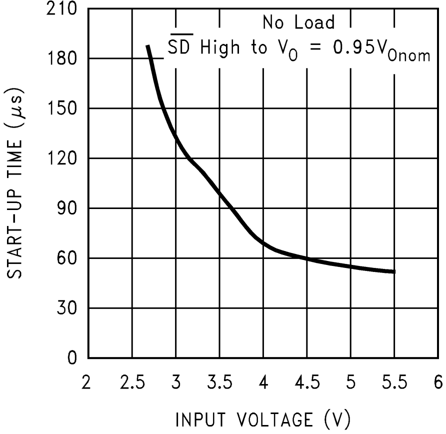


Figure 7.

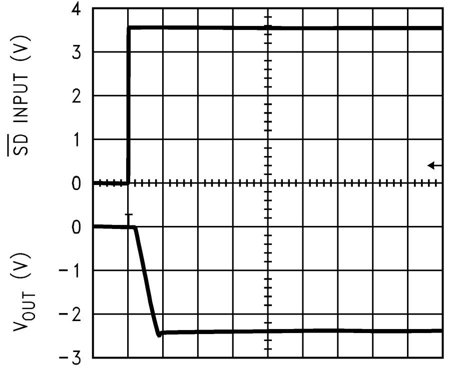
Typical Performance Characteristics (continued)

Unless otherwise specified, $T_A = 25°C$, $V_{OUT} = -2.5V$.



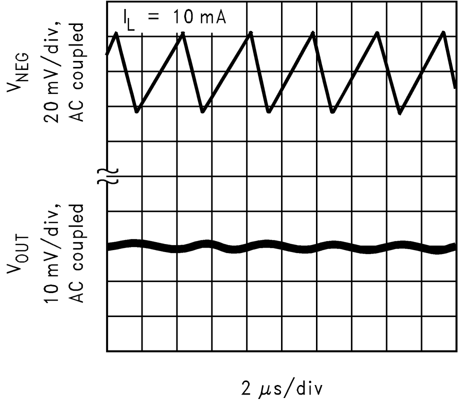
Start-up Time vs. Input Voltage

Figure 8.



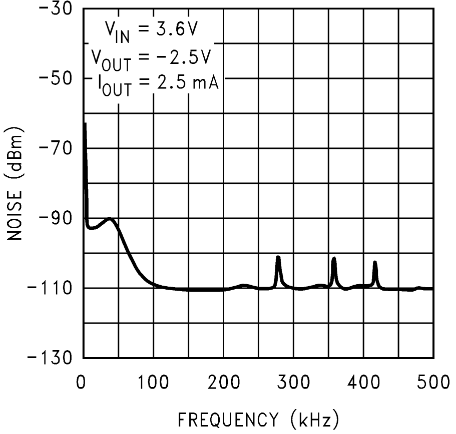
Start-up from Shutdown (no load)

Figure 9.



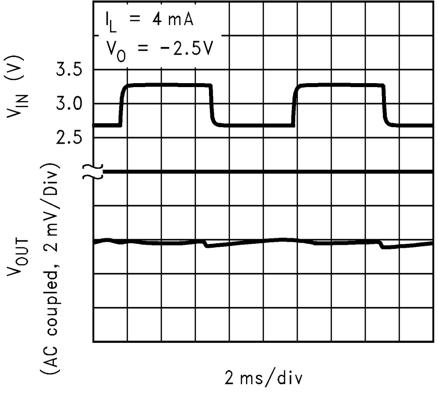
Output Ripple

Figure 10.



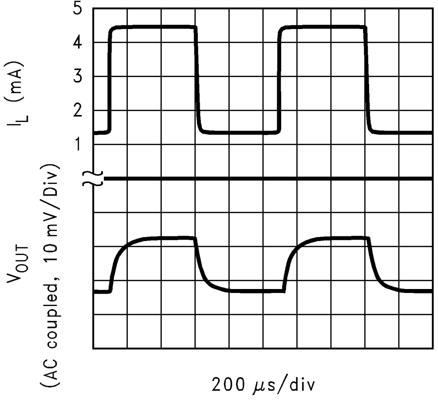
Output Noise Spectrum

Figure 11.



Line Transient Response

Figure 12.



Load Transient Response

Figure 13.

FUNCTIONAL BLOCK DIAGRAM

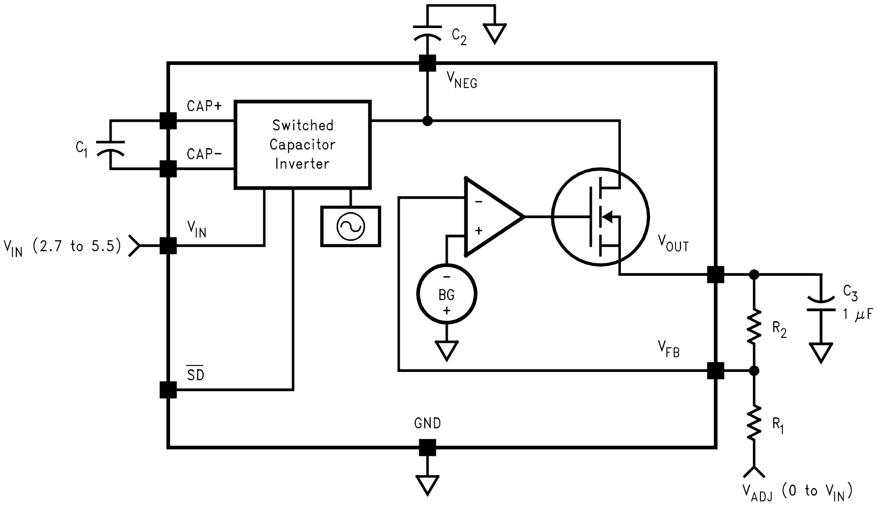


Figure 14. Functional Block Diagram

Device Description

The LM2787 is an inverting, regulated charge-pump power converter. It features low noise, small physical size, and is simple to use. It is an ideal solution for biasing GaAsFET devices such as power amplifier modules found in portable devices and cellular phones.

A switched capacitor charge-pump circuit is used to invert the input voltage V_{IN} to its corresponding negative value which is seen at V_{NEG}. This voltage is regulated by a low dropout linear regulator at V_{OUT} (Figure 14). The output voltage can be regulated anywhere from −1.5V to −5.2V and is determined by a pair of feedback resistors (see Setting the Output Voltage). The PSRR of the linear regulator reduces the output voltage ripple produced by the charge-pump inverter at the output V_{OUT}. The regulator also attenuates noise from the incoming supply due to its high PSRR.

Shutdown

The LM2787 features a logic-level shutdown feature. The function is active-low and will reduce the supply current to 0.05µA (typical) when engaged. When shutdown is active V_{OUT} and V_{NEG} are switched to ground.

APPLICATION INFORMATION

Setting the Output Voltage

The output voltage on the LM2787 is set by using a resistor divider between the output, the feedback pin, and an arbitrary voltage V_{ADJ} (Figure 14). V_{ADJ} can range from GND to any positive voltage up to V_{IN}. V_{ADJ} is usually chosen to be GND and should not be connected to a different voltage unless it is well regulated so the output will stay constant. The feedback pin is held at a constant voltage V_{FB} which equals −1.2V. The output voltage can be selected using the equation:

$$V_{OUT} = \frac{R_2}{R_1}(V_{FB} - V_{ADJ}) + V_{FB} \quad (1)$$

The current into the feedback pin I_{FB} is in the range of 10nA to 100nA. Therefore using a value of 500kΩ or smaller for R_1 should make this current of little concern when setting the output voltage. For best accuracy, use resistors with 1% or better tolerance.

Capacitor Selection

Selecting the right capacitors for your circuit is important. The capacitors affect the output resistance of the charge-pump, the output voltage ripple, and the overall dropout voltage (V_{IN}-|V_{OUT}|) of the circuit. The output resistance of the charge-pump inverter is:

$$R_{NEG} = R_{SW} + 4ESR_{C1} + ESR_{C2} + \frac{1}{f_{SW} \times C1} \tag{2}$$

The switching frequency is fixed at 260kHz and R_{SW} (the combined resistance of the internal switches) is typically 10Ω. It is clear from this equation that low ESR capacitors are desirable and that larger values of C_1 will further reduce the output resistance. The output resistance of the entire circuit (in dropout) is:

$$R_{OUT} = R_{NEG} + R_{regulator} \tag{3}$$

$R_{regulator}$ (the output impedance of the linear regulator) is approximately 10Ω. When the circuit is in regulation, the overall output resistance is equal to the linear regulator load regulation (5mV/mA). The dropout voltage is therefore affected by the capacitors used since it is simply defined as I_{OUT}*R_{OUT}.

A larger value of capacitor and lower ESR for C_2 will lower the output voltage ripple of the charge-pump. This ripple will then be subject to the PSRR of the linear regulator and reduced at V_{OUT}.

In summation, larger value capacitors with lower ESR will give the lowest output noise and ripple. C_1, C_2, and C_3 should be 1.0µF minimum with less than 0.3Ω ESR. Larger values may be used for any or all capacitors. All capacitors should be either ceramic, surface-mount chip tantalum, or polymer electrolytic.

Output Noise and Ripple

Low output noise and output voltage ripple are two of the attractive features of the LM2787. Because they are small, the noise and ripple can be hard to measure accurately. Ground loop error between the circuit and the oscilloscope caused by the switching of the charge-pump produces ground currents in the probe wires. This causes sharp voltage spikes on the oscilloscope waveform. To reduce this error, measure the output directly at the output capacitor (C_3) and use the shortest wires possible. Also, do not use the ground lead on the probe. Take the tip cover off of the probe and touch the grounding ring of the probe directly to the output ground. This should give the most accurate reading of the actual output waveform.

DSBGA Mounting

The DSBGA package requires specific mounting techniques which are detailed in Application Note AN1112. Referring to the section **Surface Mount Technology (SMT) Assembly Considerations**, it should be noted that the pad style which must be used with the 8-pin package is the NSMD (non-solder mask defined) type.

For best results during assembly, alignment ordinals on the PC board may be used to facilitate placement of the DSBGA device.

DSBGA Light Sensitivity

Exposing the DSBGA device to direct sunlight may cause misoperation of the device. Light sources such as Halogen lamps can also affect electrical performance if brought near the device.

The wavelengths which have the most detrimental effect are reds and infra-reds. The fluorescent lighting used inside of most buildings has very little effect on performance.

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