PRELIMINARY

LTC1550/LTC1551

Low Noise, Switched Capacitor-Regulated Voltage Inverters

June 1995

FEATURES

- **Regulated Negative Voltage from Single Positive Supply**
- **Low Output Ripple: Less Than 1mV Typ**
- **High Charge Pump Frequency: 900kHz Typ**
- **REG Output Indicates Output Is in Regulation**
- Small Charge Pump Capacitors: 0.1µF
- Requires Only Four External Capacitors
- Fixed –4.1V or Adjustable Output
- Shutdown Mode Drops Supply Current to 1µA
- Output Current: Up to 20mA
- Output Regulation: 5%
- Available in 8-Pin SO and 16-Pin SSOP Packages

APPLICATIONS

- GaAs FET Bias Generators
- Negative Supply Generators
- Battery-Powered Systems
- Single Supply Applications

DESCRIPTION

The LTC®1550/LTC1551 are switched-capacitor voltage inverters with internal linear post regulators. Each is available in a fixed –4.1V version while the LTC1550 also offers an adjustable output voltage version. Typical output ripple is below 1mV. The LTC1550/LTC1551 are designed for use as bias voltage generators for GaAs transmitter FETs in portable RF and cellular telephone applications.

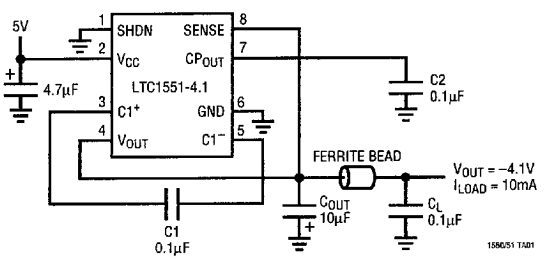
The LTC1550/LTC1551 operate from a single 4.5V to 6.5V supply, with a typical quiescent current of 5mA at V_{CC} = 5V. Both devices include a TTL compatible shutdown pin which drops supply current to 0.2µA typically. The LTC1550 shutdown pin is active low ($\overline{SHDN}$) while the LTC1551 shutdown pin is active high (SHDN). Only four external components are required for fixed output parts: an input bypass capacitor, two 0.1µF charge pump capacitors and a 10µF filter capacitor at the linear regulator output. Adjustable parts require two additional resistors to set the output voltage.

Each version of the LTC1550/LTC1551 will supply up to 20mA output current with guaranteed output regulation of ±5%. The 16-pin version of the LTC1550/LTC1551 includes an open-drain REG output which pulls low to indicate that the output is within 5% of the set value.

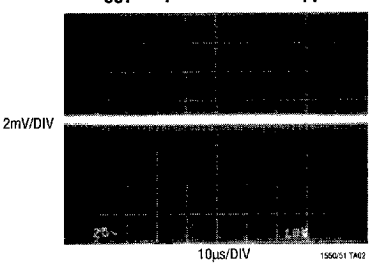
For applications with V_{CC} supplies as low as 3V, see the LTC1261. For applications requiring an external synchronization clock and V_{CC} as low as 3V, see the LTC1429.

TYPICAL APPLICATION

–4V Generator with 1mV$_{P-P}$ Noise



V_{OUT} Output Noise and Ripple

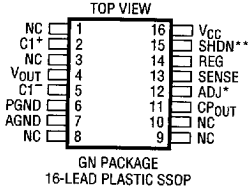


ABSOLUTE MAXIMUM RATINGS

(Note 1)

Supply Voltage (Note 2) 7V
Output Voltage ..... 0.3V to (V_{CC} – 14V)
Total Voltage, V_{CC} to CP_{OUT} (Note 2) 14V
Input Voltage (SHDN Pin) ..... –0.3V to (V_{CC} + 0.3V)
Input Voltage (REG Pin) ..... –0.3V to 12V
Output Short-Circuit Duration ..... Indefinite
Operating Temperature Range ..... 0°C to 70°C
Storage Temperature Range ..... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) ..... 300°C

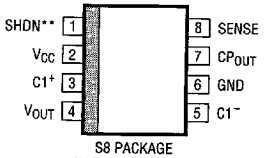
PACKAGE/ORDER INFORMATION



GN PACKAGE
16-LEAD PLASTIC SSOP

T_{JMAX} = 150°C, θ_{JA} = 150°C/W

ORDER PART NUMBER
LTC1550CGN LTC1550CGN-4.1 LTC1551CGN-4.1
GN PART MARKING
1550 15504I 15514I



S8 PACKAGE
8-LEAD PLASTIC SO

T_{JMAX} = 150°C, θ_{JA} = 150°C/W

ORDER PART NUMBER
LTC1550CS8-4.1 LTC1551CS8-4.1
S8 PART MARKING
15504 15514

Consult factory for Industrial and Military grade parts.

* NC for fixed output versions.
** $\overline{SHDN}$ for LTC1550, SHDN for LTC1551

ELECTRICAL CHARACTERISTICS (Note 3)

V_{CC} = 4.5V to 6.5V, C1 = C2 = 0.1µF, C_{OUT} = 10µF, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{CC}	Supply Voltage	(Note 2)		4.5		6.5	V
V_{REF}	Reference Voltage				1.24		V
I_S	Supply Current	V_{SHDN} = GND (LTC1551)or V_{CC} (LTC1550)	●		5.0	7.0	mA
		V_{SHDN} = V_{CC} = 5V (LTC1551) or GND (LTC1550)	●		0.2	10.0	µA
f_{OSC}	Internal Oscillator Frequency				900		kHz
V_{OL}	REG Output Low Voltage	I_{REG} = 1mA, V_{CC} = 5V	●		0.1	0.8	V
I_{REG}	REG Sink Current	V_{REG} = 0.8V, V_{CC} = 5V	●	8	15		mA
V_{IH}	SHDN Input High Voltage		●	2.0			V
V_{IL}	SHDN Input Low Voltage		●			0.8	V
I_{IN}	SHDN Input Current	V_{SHDN} = V_{CC}	●		0.1	1	µA
t_{ON}	Turn On Time	I_{OUT} = 10mA			1		ms

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ELECTRICAL CHARACTERISTICS (Note 3)

V_S = 4.5V to 6.5V, C1 = C2 = 0.1µF, C_{OUT} = 10µF, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
ΔV_{OUT}	Output Regulation (LTC1550 Only)	V_{CC} = 5V, 0 ≤ I_{OUT} ≤ 10mA	●		1	5	%
		V_{CC} = 6V, 0 ≤ I_{OUT} ≤ 20mA	●		1	5	%
V_{OUT}	Output Voltage (LTC1550-4.1, LTC1551-4.1)	V_{CC} = 4.5V, 0 ≤ I_{OUT} ≤ 5mA	●	–3.9	–4.1	–4.3	V
		V_{CC} = 5V, 0 ≤ I_{OUT} ≤ 10mA	●	–3.9	–4.1	–4.3	V
		V_{CC} = 6V, 0 ≤ I_{OUT} ≤ 20mA	●	–3.9	–4.1	–4.3	V
I_{SC}	Output Short-Circuit Current	V_{OUT} = 0V, V_{CC} = 5V	●		50	125	mA
		V_{OUT} = 0V, V_{CC} = 6V	●		60	125	mA
V_{RIPPLE}	Output Ripple Voltage				1		mV

The ● denotes specifications which apply over the full operating temperature range.

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: The output should never be set to exceed V_{CC} – 14V.

Note 3: All currents into device pins are positive; all currents out of device pins are negative. All voltages are referenced to ground unless otherwise specified. All typicals are given at T_A = 25°C.

PIN FUNCTIONS

SHDN: Shutdown (TTL Compatible). This pin is active low ($\overline{SHDN}$) for the LTC1550 and active high (SHDN) for the LTC1551. When this pin is at V_{CC} (GND for LTC1551), the LTC1550 operates normally. When SHDN is pulled LOW (HIGH for LTC1551), the LTC1550 enters shutdown mode. In shutdown, the charge pump stops, the output collapses to 0V, and the quiescent current drops typically to 0.2µA.

V_{CC}: Power Supply. V_{CC} requires an input voltage between 4.5V and 6.5V. The difference between the input voltage and output should never be set to exceed 14V or damage to the chip may occur. V_{CC} must be bypassed to PGND (GND for the 8-pin package) with at least a 1µF capacitor placed in close proximity to the chip. A 4.7µF or larger bypass capacitor is recommended to minimize noise and ripple at the output.

C1⁺: C1 Positive Input. Connect a 0.1µF capacitor between C1⁺ and C1⁻.

V_{OUT}: Negative Voltage Output. This pin must be bypassed to ground with a 4.7µF or larger capacitor to ensure regulator loop stability. At least 10µF is recommended to provide specified output ripple. An additional low ESR 0.1µF capacitor is recommended to minimize high frequency spikes at the output.

C1⁻: C1 Negative Input. Connect a 0.1µF capacitor from C1⁺ to C1⁻.

GND: Ground. Connect to a low impedance ground. A ground plane will help minimize regulation errors.

CP_{OUT}: Negative Charge Pump Output. This pin requires a 0.1µF storage capacitor to ground.

SENSE: Connect to V_{OUT}. The LTC1550/LTC1551 internal regulator uses this pin to sense the output voltage. For optimum regulation, SENSE should be connected close to the output load.

16-Pin SSOP Only

PGND: Power Ground. Connect to a low impedance ground. PGND should be connected to the same potential as AGND.

AGND: Analog Ground. Connect to a low impedance ground. AGND should be connected to a ground plane to minimize regulation errors.

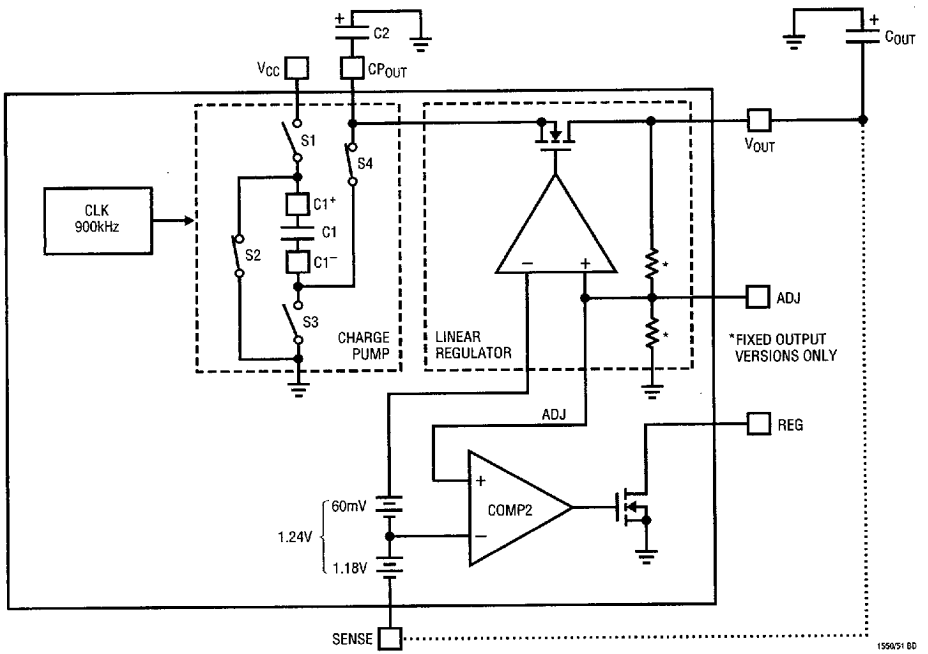
REG: This is an open-drain output that pulls low when the output voltage is within 5% of the set value. It will sink 8mA to ground with a 5V supply. The external circuitry must provide a pull-up or REG will not swing high. The voltage at REG may exceed V_{CC} and can be pulled up to 12V above ground without damage.

PIN FUNCTIONS

ADJ: For adjustable versions only, this is the feedback point for the external resistor divider string. Connect a divider string from AGND to V_{OUT} with the divided tap connected to ADJ. Note that the resistor string needs to be connected "upside-down" from a traditional negative regulator. See the Applications Information section for hook-up details.

NC: No Internal Connection.

BLOCK DIAGRAM



APPLICATIONS INFORMATION

THEORY OF OPERATION

The LTC1550/LTC1551 are switched-capacitor, inverting charge pumps with integral linear post regulators to provide a regulated, low ripple negative output voltage. The charge pump runs at a high 900kHz frequency to keep noise out of the 400kHz to 600kHz IF bands commonly used by portable radio frequency systems, and to minimize the size of the external capacitors required. The LTC1550/LTC1551 require only two external 0.1µF charge pump capacitors: an input bypass capacitor and a single output capacitor. At least 4.7µF is required at the output to maintain loop stability; for optimum output stability over temperature and minimum ripple, 10µF or greater is recommended.

The LTC1550 features an active-low shutdown pin which drops quiescent current to below 1µA. The LTC1551 is identical to the LTC1550 but the shutdown pin is active high. Both the LTC1550/LTC1551 are available with fixed –4.1V output voltage, and the LTC1550 is also available in an adjustable output version. Both devices can be configured with other output voltages. Contact the Linear Technology marketing for more information.

Minimizing Output Noise and Ripple

Output ripple is largely eliminated by the internal linear regulator. It is typically below $1mV_{P-P}$ with output loads between zero and 10mA. Residual ripple is at the 900kHz switching frequency of the charge pump and is usually not a problem in most systems. This high frequency ripple can be minimized by using a low ESR capacitor at the output. An 0.1µF ceramic capacitor in parallel with a 10µF tantalum makes a good combination.

Figure 1a shows the test circuit used for spectrum analysis with test conditions V_{CC} = 6V, I_{OUT} = 5mA. Figures 1b and 1c are the V_{OUT} spectrum plots for the test circuit in Figure 1a, covering from 100Hz to 1MHz and to 10MHz respectively. The fundamental switching frequency appears at 900kHz.

Output ripple can be further reduced by increasing the size of the output capacitor, or by including a small external RC or LC filter at the output. A ferrite bead in series with the output capacitor will reduce the output ripple to negligible levels.

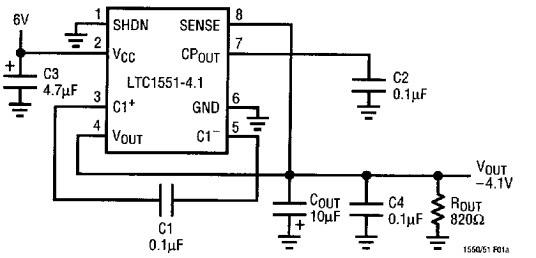


Figure 1a. Test Circuit Used for Spectrum Analysis

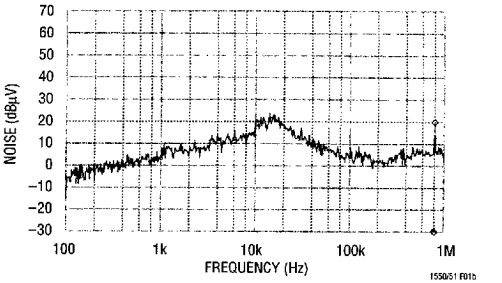


Figure 1b. Spectrum Plot of V_{OUT} from 100Hz to 1MHz

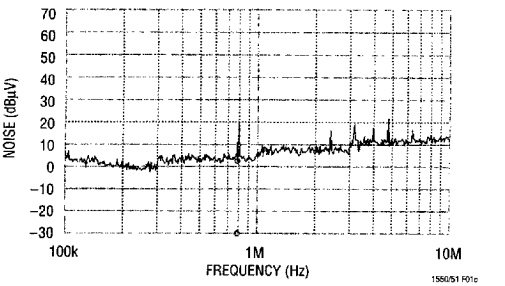


Figure 1c. Spectrum Plot of V_{OUT} from 100kHz to 10MHz

Output load and line transient response can be optimized by increasing the size of the output bypass capacitor. Adjustable parts can further improve transient response by bypassing the upper resistor R1 (Figure 2) in the feedback divider with a capacitor. A 100pF bypass capacitor is usually adequate.

APPLICATIONS INFORMATION

Adjustable Hookup

The LTC1550 is available in an adjustable output version in the 16-pin SSOP package. The output voltage is set with a resistor divider from GND to SENSE/V_{OUT} (Figure 2). Note that the internal reference and the internal feedback amplifier are set up as a positive-output regulator referenced to the SENSE pin, not a negative regulator referenced to ground. The output resistor divider must be set to provide a 1.24V at the ADJ pin with respect to V_{OUT}. For example, a –3.0V output would require a 13k resistor from GND to ADJ, and a 9.1k resistor to SENSE/V_{OUT}. If, after connecting the divider resistors, the output voltage is not what you expected, try swapping them.

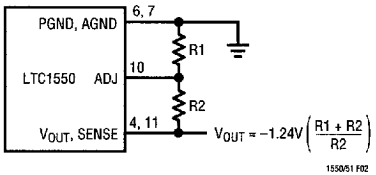
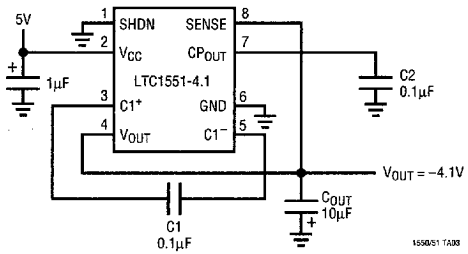


Figure 2. External Resistor Connections

TYPICAL APPLICATION

Minimum Part Count, Negative –4.1V Generator



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1054	Switched Capacitor Voltage Converter with Regulator	100mA Switched Capacitor Converter
LTC1261	Switched Capacitor Regulated Voltage Inverter	Selectable Fixed Output Voltages
LTC1429	Clock-Synchronized Switched Capacitor Voltage Inverter	Synchronizable

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