

SIM Power Supply and Level Translator

June 1997

FEATURES

- Step-Up/Step-Down Charge Pump Generates 5V
- Input Voltage Range: 2.7V to 10V
- Output Current: 10mA ($V_{IN} \geq 2.7V$)
20mA ($V_{IN} \geq 3V$)
- 3V to 5V Signal Level Translators
- > 10kV ESD on All SIM Contact Pins
- Short-Circuit and Overtemperature Protected
- Very Low Operating Current: 60 μ A
- Very Low Shutdown Current: < 1 μ A
- Soft Start Limits Inrush Current at Turn-On
- Programmable 3V or 5V Output Voltage
- 650kHz Switching Frequency
- Auxiliary 4.3V LDO/Power Switch (LTC1556 Only)
- Available in a 16- and 20-Pin Narrow SSOP

APPLICATIONS

- SIM Interface in GSM Cellular Telephones
- Smart Card Readers

DESCRIPTION

The LTC[®]1555/LTC1556 provide power conversion and level shifting needed for 3V GSM cellular telephones to interface with either 3V or 5V Subscriber Identity Modules (SIMs). These parts contain a charge pump DC/DC converter that delivers a regulated 5V to the SIM card. Input voltage may range from 2.7V to 10V, allowing direct connection to the battery. Output voltage may be programmed to 3V, 5V or direct connection to the V_{IN} pin.

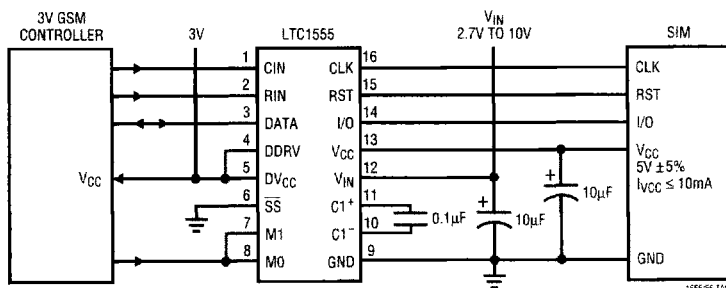
A soft start feature limits inrush current at turn-on, mitigating start-up problems that may result when the input is supplied by another low power DC/DC converter. The LTC1556 also includes an auxiliary LDO regulator/power switch that may be used to power the frequency synthesizer VCO or other low power circuitry.

Battery life is maximized by 60 μ A operating current and 1 μ A shutdown current. Board area is minimized by miniature 16- and 20-pin narrow SSOP packages and the need for only three small external capacitors.

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TYPICAL APPLICATION

GSM Cellular Telephone SIM Interface



1555-96-114-1

ABSOLUTE MAXIMUM RATINGS

(Note 1)

V_{IN} , DV_{CC} to GND -0.3V to 12V
 V_{CC} to GND -0.3V to 12V
 Digital Inputs to GND -0.3V to 12V
 LDO, CLK, RST, I/O to GND -0.3V to ($V_{CC} + 0.3V$)
 V_{CC} , LDO Short-Circuit Duration Indefinite
 Storage Temperature Range -65°C to 150°C

Commercial Temperature Range 0°C to 70°C
 Industrial Temperature Range
 (Note 3) -40°C to 85°C
 Extended Commercial Operating Temperature Range
 (Note 2) -40°C to 85°C
 Lead Temperature (Soldering, 10 sec) 300°C

PACKAGE/ORDER INFORMATION

| | | | |
|--|---|---|---|
| <p>GN PACKAGE 16-LEAD PLASTIC SSOP $T_{JMAX} = 150^{\circ}C$, $\theta_{JA} = 135^{\circ}C/W$</p> | <p>ORDER PART NUMBER</p> <p>LTC1555CGN LTC1555IGN</p> | <p>GN PACKAGE 20-LEAD PLASTIC SSOP $T_{JMAX} = 150^{\circ}C$, $\theta_{JA} = 95^{\circ}C/W$</p> | <p>ORDER PART NUMBER</p> <p>LTC1556CGN LTC1556IGN</p> |
| | | | |

Consult factory for Military grade parts.

ELECTRICAL CHARACTERISTICS

$V_{IN} = 2.7V$ to $10V$, $DV_{CC} = 1.8V$ to $5.5V$, controller digital pins tied to DV_{CC} , SIM digital pins floating, EN, FB pins tied to GND (LTC1556), $C_1 = 0.1\mu F$, $C_{OUT} = 10\mu F$ unless otherwise specified. (Note 2)

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS | |
|--------------------------------|--|-----|----------------|--------------|--------------|---|
| V_{IN} Operating Voltage | | ● | 2.7 | 10 | V | |
| DV_{CC} Operating Voltage | | ● | 1.8 | 5.5 | V | |
| V_{IN} Operating Current | $2.7V \leq V_{IN} \leq 5V$, $V_{CC} = 5V$, $I_{VCC} = 0$ $5V < V_{IN} \leq 10V$, $V_{CC} = 5V$, $I_{VCC} = 0$ | ● | 60 75 | 100 135 | μA | |
| V_{IN} Shutdown Current | $M0, M1 = 0V$, $2.7V \leq V_{IN} \leq 5V$ $M0, M1 = 0V$, $2.7V \leq V_{IN} \leq 5V$ $M0, M1 = 0V$, $5V < V_{IN} \leq 10V$ | ● | | 1 2 25 | μA | |
| DV_{CC} Operating Current | $M0, M1 = DV_{CC}$, $C_{IN} = 1MHz$ | ● | 3 | 10 | μA | |
| DV_{CC} Shutdown Current | $M0, M1 = 0V$ | ● | | 1 | μA | |
| V_{CC} Output Voltage | $0 \leq I_{VCC} \leq 10mA$, $2.7V \leq V_{IN} \leq 10V$ $0 \leq I_{VCC} \leq 20mA$, $3V \leq V_{IN} \leq 10V$ $M0, M1 = DV_{CC}$ $M0 = DV_{CC}$, $M1 = 0$ $M0 = 0$, $M1 = DV_{CC}$ | ● | 4.75 2.80 | 5.00 3.00 | 5.25 3.20 | V |
| V_{CC} Short-Circuit Current | V_{CC} Shorted to GND | ● | $V_{IN} - 0.3$ | V_{IN} | V | |
| | | | 12.5 | 40 | mA | |

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| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---------------------------------------|--|--------|-----|------|-----------|
| Auxiliary LDO V_{OUT} (V_{LDO}) | EN = High, $V_{CC} = 5V$, FB = LDO, $I_{LDO} = 5mA$ | ● 4.00 | 4.3 | 4.55 | V |
| Auxiliary Switch Resistance | EN = High, $V_{CC} = 5V$, FB = GND | ● | 18 | 30 | Ω |
| FB Input Resistance | | ● 100 | 200 | 300 | $k\Omega$ |
| Charge Pump f_{OSC} | | ● 500 | 650 | 800 | kHz |

Controller Inputs/Outputs, $DV_{CC} = 3V$

| | | | | | |
|---|---|---------------------------------|----------------------|---|--------------------|
| Input Current (I_{IH} , I_{IL}) | M0, M1, \overline{SS} , RIN, CIN DDR, EN | ● -1 ● -5 | | 1 5 | μA μA |
| High Level Input Current (I_{IH}) | DATA | ● -20 | | 20 | μA |
| Low Level Input Current (I_{IL}) | DATA | ● | | 1 | mA |
| High Input Voltage Threshold (V_{IH}) | M0, M1, RIN, CIN, DDR, EN DATA | ● | | $0.7 \times DV_{CC}$ $DV_{CC} - 0.6$ | V V |
| Low Input Voltage Threshold (V_{IL}) | M0, M1, RIN, CIN, DDR, EN DATA | ● $0.2 \times DV_{CC}$ ● 0.4 | | | V V |
| High Level Output Voltage (V_{OH}) | DATA Source Current = $20\mu A$, I/O = V_{CC} | ● | $0.7 \times DV_{CC}$ | | V |
| Low Level Output Voltage (V_{OL}) | DATA Sink Current = $-200\mu A$, I/O = 0V (Note 4) | ● | | 0.4 | V |
| DATA Pull-up Resistance | Between DATA and DV_{CC} | ● 13 | 20 | 28 | $k\Omega$ |
| DATA Output Rise/Fall Time | DATA Loaded with 30pF | ● | 1.3 | 2 | μs |

SIM Inputs/Outputs, $DV_{CC} = 3V$, $V_{CC} = 3V$ or $5V$

| | | | | | |
|---|---|---|--|---------------------|-----------|
| I/O High Input Voltage Threshold (V_{IH}) | $I_{IH(MAX)} = \pm 20\mu A$ | ● | $0.5 \times V_{CC}$ | $0.7 \times V_{CC}$ | V |
| I/O Low Input Voltage Threshold (V_{IL}) | $I_{IL(MAX)} = 1mA$ | ● | 0.4 | | V |
| High Level Output Voltage (V_{OH}) | I/O, Sink Current = $20\mu A$, DATA or DDR = DV_{CC} RST, CLK, Source Current = $20\mu A$ | ● | $0.8 \times V_{CC}$ $0.9 \times V_{CC}$ | | V V |
| Low Level Output Voltage (V_{OL}) | I/O, Sink Current = $-1mA$, DATA or DDR = 0V (Note 4) RST, CLK, Sink Current = $-200\mu A$ | ● | | 0.4 0.4 | V V |
| I/O Pull-Up Resistance | Between I/O and V_{CC} | ● | 6.5 | 10 | $k\Omega$ |

SIM Timing Parameters, $DV_{CC} = 3V$, $V_{CC} = 5V$

| | | | | | |
|-------------------------------|---|---|--|--------|----------|
| CLK Rise/Fall Time | CLK Loaded with 30pF | ● | | 18 | ns |
| RST, I/O Rise/Fall Time | RST, I/O Loaded with 30pF | ● | | 1 | μs |
| CLK Frequency | CLK Loaded with 30pF | ● | | 5 | MHz |
| V_{CC} Turn-On Time | $\overline{SS} = DV_{CC}$, $C_{OUT} = 10\mu F$, $I_{VCC} = 0$ $\overline{SS} = 0V$, $C_{OUT} = 10\mu F$, $I_{VCC} = 0$ | | | 1 5 | ms ms |
| V_{CC} Discharge Time to 1V | $I_{VCC} = 0$, $V_{CC} = 5V$, $C_{OUT} = 10\mu F$ | | | 3 | ms |

The ● denotes specifications which apply over the specified temperature range.

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

Note 2: C grade device specifications are guaranteed over the $0^\circ C$ to $70^\circ C$ temperature range. In addition, C grade device specifications are assured

over the $-40^\circ C$ to $85^\circ C$ temperature range by design or correlation, but are not production tested.

Note 3: I grade device specifications are guaranteed over the $-40^\circ C$ to $85^\circ C$ temperature range.

Note 4: The DATA and I/O pull-down drivers must also sink current sourced by the internal pull-up resistors.

PIN FUNCTIONS

LTC1555/LTC1556

CIN (Pin 1): Clock Input Pin from Controller.

RIN (Pin 2): Reset Input Pin from Controller.

DATA (Pin 3): Controller Side Data Input/Output Pin. Can be used for single pin bidirectional data transfer between the controller and the SIM card as long as the controller data pin is open drain. The controller output must be able to sink 1mA max when driving the DATA pin low due to the internal pull-up resistors on the DATA and I/O pins. If the controller data output is not open drain, then the DDRV pin should be used for sending data to the SIM card and the DATA pin used for receiving data from the SIM card (see Figure 1).

DDRV (Pin 4): Optional Data Input Pin for Sending Data to the SIM card. When not needed, the DDRV pin should be left floating or tied to DV_{CC} (an internal 1 μ A current source will pull the DDRV pin up to DV_{CC} if left floating).

DV_{CC} (Pins 5/7): Supply Voltage for Controller Side Digital I/O Pins. May be between 1.8V and 5.5V (typically 3V).

SS (Pins 6/8): Soft Start Enable Pin. A logic low will enable the charge pump inrush current limiting feature. A logic high will disable the soft start feature and allow V_{CC} to be ramped as quickly as possible upon start-up and coming out of shutdown.

M1 (Pins 7/9): Mode Control Bit 1 (see Truth Table).

M0 (Pins 8/10): Mode Control Bit 0 (see Truth Table).

This table defines the various operating modes that may be obtained via the M0 and M1 mode control pins.

Truth Table

| M0 | M1 | MODE |
|------------------|------------------|-----------------------------------|
| 0V | 0V | Shutdown (V _{CC} = 0V) |
| 0V | DV _{CC} | V _{CC} = V _{IN} |
| DV _{CC} | 0V | V _{CC} = 3V |
| DV _{CC} | DV _{CC} | V _{CC} = 5V |

GND (Pins 9/11, 12): Ground for Both the SIM and the Controller. Should be connected to the SIM GND contact as well as to the V_{IN}/Controller GND. Proper grounding and supply bypassing is required to meet 10kV ESD specifications.

C1⁻ (Pins 10/12): Charge Pump Flying Capacitor Negative Input.

C1⁺ (Pins 11/13): Charge Pump Flying Capacitor Positive Input.

V_{IN} (Pins 12/14): Charge Pump Input Voltage Pin. Input voltage range is 2.7V to 10V. Connect 10 μ F input bypass capacitor close to the V_{IN} pin.

V_{CC} (Pins 13/15): SIM Card V_{CC} Output. This pin should be connected to the SIM V_{CC} contact. The V_{CC} output voltage is determined by the M0 and M1 pins (see Truth Table). V_{CC} is discharged to GND during shutdown (M0, M1 = 0V). A 10 μ F output capacitor should connect close to the V_{CC} pin.

I/O (Pins 14/18): SIM Side I/O Pin. The pin is an open drain output with a nominal pull-up resistance of 10k and should be connected to the SIM I/O contact. The SIM card must sink up to 1mA max when driving the I/O pin low due to the internal pull-up resistors on the I/O and DATA pins.

RST (Pins 15/19): Level Shifted Reset Output Pin. Should be connected to the SIM RST contact.

CLK (Pins 16/20): Level Shifted Clock Output Pin. Should be connected to the SIM CLK contact. Careful trace routing is recommended due to fast rise and fall edge speeds.

LTC1556 Only

EN (Pin 5): Auxiliary LDO/Power Switch Enable Pin. A logic high on this pin from the controller will enable the auxiliary LDO output. When the LDO is disabled, the LDO output will float or be pulled to ground by the load. If left floating, the EN pin will be pulled down to GND by an internal 1 μ A current source.

FB (Pin 6): Auxiliary LDO Feedback Pin. When FB is connected to the LDO pin (Pin 17), the LDO output is regulated to 4.3V (typ). If the FB pin is left open or tied to ground, the regulator acts as a $\leq 30\Omega$ switch between V_{CC} and LDO.

LDO (Pin 17): LDO Output Pin. This pin should be tied to the FB pin for 4.3V LDO operation. The LDO output may be used as a $\leq 30\Omega$ power switch if the FB pin is grounded or left floating. When used as a regulator, LDO must be bypassed to GND with a $\geq 3.3\mu$ F capacitor.

APPLICATIONS INFORMATION

The V_{CC} output can be programmed to either 5V or 3V via the M0 and M1 mode pins. This feature is useful in applications where either a 5V or 3V SIM may be used. The charge pump V_{CC} output may also be connected directly to V_{IN} if desired. When the charge pump is put into shutdown (M0, M1 = 0), V_{CC} is pulled to GND via an internal switch to aid in proper system supply sequencing.

The soft start feature limits inrush currents upon start-up or coming out of shutdown mode. When the SS pin is tied to GND, the soft start feature is enabled. This limits the effective inrush current out of V_{IN} to approximately 25mA ($C_{OUT} = 10\mu\text{F}$). Inrush current limiting is especially useful when powering the LTC1555/LTC1556 from a 3V DC/DC output since the unlimited inrush current may approach 200mA and cause voltage transients on the 3V supply. However, in cases where fast turn-on time is desired, the soft start feature may be overridden by tying the SS pin to DV_{CC} .

Level Translators

All SIMs and smart cards contain a clock input, reset input and a bidirectional data input/output. The LTC1555/LTC1556 provide level translators to allow controllers to communicate with the SIM (see Figures 1a and 1b). The CLK and RST inputs to the SIM are level shifted from the controller supply rails (DV_{CC} and GND) to the SIM supply rails (V_{CC} and GND). The data input to the SIM may be provided two different ways. The first method is to use the DATA pin as a bidirectional level translator. This configuration is only allowed if the controller data output pin is open drain (all SIM I/O pins are open drain). Internal pull-up resistors are provided for both the DATA pin and the I/O pin on the SIM side. The second method is to use the

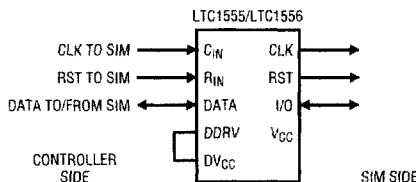


Figure 1a. Level Translator Connections for Bidirectional Controller DATA Pin

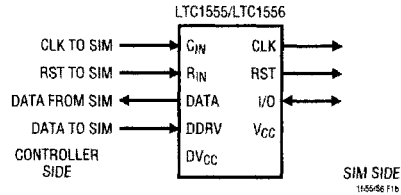


Figure 1b. Level Translator Connections for One-Directional Controller Side DATA Flow

DDRV pin to send data to the SIM and use the DATA pin to receive data from the SIM. When the DDRV pin is not used, it should either be left floating or tied to DV_{CC} .

Level Translation with $DV_{CC} > V_{CC}$

It is assumed that most applications for these parts will use controller supply voltages (DV_{CC}) less than or equal to V_{CC} . In cases where DV_{CC} is greater than V_{CC} by more than 0.6V or so, the parts' operation will be affected in the following ways: 1) A small DC current (up to 100 μA) will flow from DV_{CC} to V_{CC} through the DATA pull-up resistor, N-channel pass device and the I/O pull-up resistor (except when the part is in shutdown at which time DV_{CC} is disconnected from V_{CC} by turning off the pass device). If the V_{CC} load current is less than the DV_{CC} current, the V_{CC} output may be pulled out of regulation until sufficient load current pulls V_{CC} back into regulation. 2) When the SIM is sending data back to the controller, a logic high on the I/O pin will result in the DATA pin being pulled up to $[V_{CC} + 1/3(DV_{CC} - V_{CC})]$, not all the way up to DV_{CC} . For example, if DV_{CC} is 5V and V_{CC} is 3V, the DATA pin will only swing from $\approx 0.1\text{V}$ to 3.67V when receiving data from the SIM side.

Optional LDO Output

The LTC1556 also contains an internal LDO regulator for providing a low noise boosted supply voltage for low power external circuitry (e.g., frequency synthesizers, etc.) Tying the FB pin to the LDO pin provides a regulated 4.3V at the LDO output (see Figure 2). A 3.3 μF (minimum) capacitor is required to ensure output stability. A 10 μF low ESR capacitor is recommended, however, to minimize LDO output noise. The LDO output may also be used as an auxiliary switch to V_{CC} . If the FB pin is left floating or is tied

APPLICATIONS INFORMATION

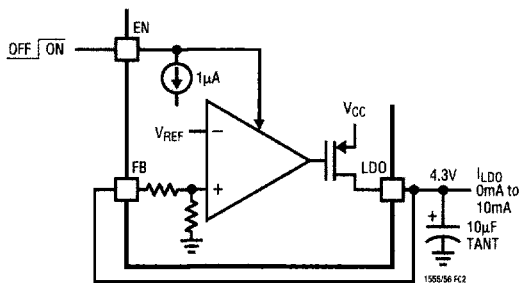


Figure 2. Auxiliary LDO Connections (LTC1556 Only)

to GND, the LDO pin will be internally connected to the V_{CC} output through the P-channel pass device. The LDO may be disabled at any time by switching the EN pin from DV_{CC} to GND.

10kV ESD Protection

All pins that connect to the SIM (CLK, RST, I/O, V_{CC} , GND) withstand over 10kV of human body model ESD. In order to ensure proper ESD protection, careful board layout is required. The GND pins should be tied directly to a GND plane. The V_{CC} capacitor should be located very close to the V_{CC} pin and tied immediately to the GND plane.

RELATED PARTS

| PART NUMBER | DESCRIPTION | COMMENTS |
|-----------------------|--|--|
| LTC1044A | 12V Charge Pump DC/DC Converter | $1.5V \leq V_{IN} \leq 12V$ |
| LTC1514-3.3/LTC1514-5 | Regulated Step-Up/Step-Down Charge Pumps with Low Bat Comparator | 3.3V and 5V Output Versions |
| LTC1515 Series | Regulated Step-Up/Step-Down Charge Pumps with Reset Output | Adjustable, 3V/5V, 3.3V/5V Versions |
| LTC1516 | Micropower, Regulated 5V Charge Pump DC/DC Converter | $I_{OUT} = 20mA$ ($V_{IN} \geq 2V$), $I_{OUT} = 50mA$ ($V_{IN} \geq 3V$) |
| LTC1550-4.1 | Low Noise, Charge Pump Voltage Inverter | 1mV _{p-p} Ripple at 900kHz |
| LTC660 | 100mA Charge Pump DC/DC Converter | 5V to -5V at 100mA |