**EVALUATION KIT AVAILABLE**

*MAXIM*

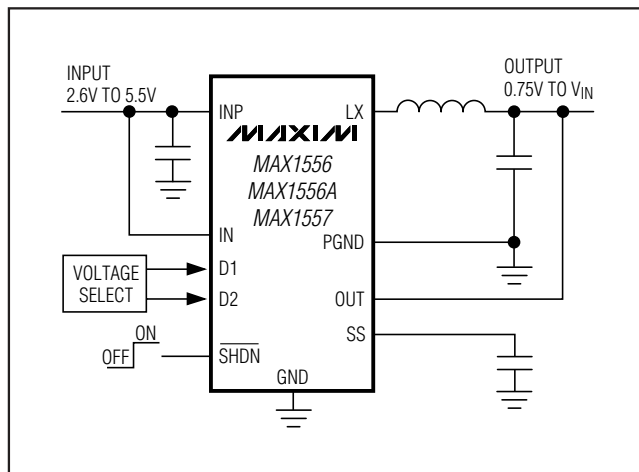# 16µA IQ, 1.2A PWM Step-Down DC-DC Converters

## General Description

The MAX1556/MAX1556A/MAX1557 are low-operating-current (16µA), fixed-frequency step-down regulators. High efficiency, low-quiescent operating current, low dropout, and minimal (27µA) quiescent current in dropout make these converters ideal for powering portable devices from 1-cell Li-ion or 3-cell alkaline/NiMH batteries. The MAX1556 delivers up to 1.2A; has pin-selectable 1.8V, 2.5V, and 3.3V outputs; and is also adjustable. The MAX1557 delivers up to 600mA; has pin-selectable 1V, 1.3V, and 1.5V outputs; and is also adjustable.

The MAX1556/MAX1556A/MAX1557 contain a low-on-resistance internal MOSFET switch and synchronous rectifier to maximize efficiency and dropout performance while minimizing external component count. A proprietary topology offers the benefits of a high fixed-frequency operation while still providing excellent efficiency at both light and full loads. A 1MHz PWM switching frequency keeps components small. Both devices also feature an adjustable soft-start to minimize battery transient loading.

The MAX1556/MAX1556A/MAX1557 are available in a tiny 10-pin TDFN (3mm x 3mm) package.

## Applications

PDAs and Palmtop Computers

Cell Phones and Smart Phones

Digital Cameras and Camcorders

Portable MP3 and DVD Players

Hand-Held Instruments

## Features

♦ **Up to 97% Efficiency**

♦ **95% Efficiency at 1mA Load Current**

♦ **Low 16µA Quiescent Current**

♦ **1MHz PWM Switching**

♦ **Tiny 3.3µH Inductor**

♦ **Selectable 3.3V, 2.5V, 1.8V, 1.5V, 1.3V, 1.2V, 1.0V, and Adjustable Output**

♦ **1.2A Guaranteed Output Current (MAX1556/MAX1556A)**

♦ **Voltage Positioning Optimizes Load-Transient Response**

♦ **Low 27µA Quiescent Current in Dropout**

♦ **Low 0.1µA Shutdown Current**

♦ **No External Schottky Diode Required**

♦ **Analog Soft-Start with Zero Overshoot Current**

♦ **Small, 10-Pin, 3mm x 3mm TDFN Package**

## Ordering Information

| PART | TEMP RANGE | PIN-PACKAGE | TOP MARK |
|------|-----------|-------------|----------|
| **MAX1556**ETB | -40°C to +85°C | 10 TDFN-EP* (T1033-1) | ACQ |
| **MAX1556A**ETB | -40°C to +85°C | 10 TDFN-EP* (T1033-1) | AUJ |
| **MAX1557**ETB | -40°C to +85°C | 10 TDFN-EP* (T1033-1) | ACR |

*EP = Exposed paddle.

## Typical Operating Circuit



## Pin Configuration
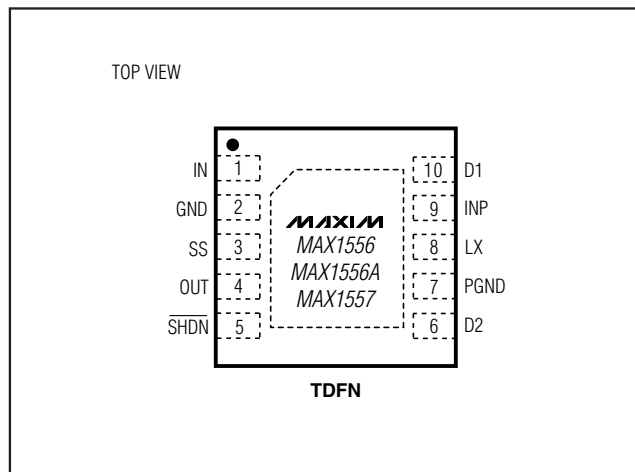


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*For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.*

# 16µA IQ, 1.2A PWM DC-DC Step-Down Converters

## ABSOLUTE MAXIMUM RATINGS

IN, INP, OUT, D2, $\overline{\text{SHDN}}$ to GND ..........................-0.3V to +6.0V
SS, D1 to GND............................................-0.3V to ($V_{IN}$ + 0.3V)
PGND to GND ......................................................-0.3V to +0.3V
LX Current (Note 1)..........................................................±2.25A
Output Short-Circuit Duration....................................Continuous
Continuous Power Dissipation ($T_A$ = +70°C)
   10-Pin TDFN (derate 24.4mW/°C above +70°C) .......1951mW

Operating Temperature Range ...........................-40°C to +85°C
Junction Temperature.....................................................+150°C
Storage Temperature Range ...........................-65°C to +150°C
Lead Temperature (soldering, 10s) .................................+300°C

**Note 1:** LX has internal clamp diodes to GND and IN. Applications that forward bias these diodes should take care not to exceed the IC's package power-dissipation limits.

*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

($V_{IN}$ = $V_{INP}$ = $V_{\overline{SHDN}}$ = 3.6V, $T_A$ = - 40°C to +85°C. Typical values are at $T_A$ = +25°C, unless otherwise noted.) (Note 1)

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Input Voltage | | | 2.6 | | 5.5 | V |
| Undervoltage-Lockout Threshold | $V_{IN}$ rising and falling, 35mV hysteresis (typ) | | 2.20 | 2.35 | 2.55 | V |
| Quiescent Supply Current | No switching, D1 = D2 = GND | | | 16 | 25 | µA |
| | Dropout | | | 27 | 42 | |
| Shutdown Supply Current | $\overline{\text{SHDN}}$ = GND | $T_A$ = +25°C | | 0.1 | 1 | µA |
| | | $T_A$ = +85°C | | 0.1 | | |
| Output Voltage Range | | | 0.75 | | $V_{IN}$ | V |
| Output Accuracy | $T_A$ = 0°C to +85°C (Note 2) | No load | -0.25 | +0.75 | +1.75 | % |
| | | 300mA load | -0.75 | 0 | +0.75 | |
| | | 600mA load | -1.5 | -0.75 | 0 | |
| | | 1200mA load, MAX1556 | -2.75 | -2.25 | -1.25 | |
| | | 1200mA load, MAX1556A | | -2.25 | | |
| | $T_A$ = -40°C to +85°C (Note 2) | No load | -0.75 | | +2.25 | |
| | | 300mA load | -1.5 | | +1.5 | |
| | | 600mA load | -2.25 | | +0.50 | |
| | | 1200mA load, MAX1556 | -4.0 | | -1.0 | |
| Maximum Output Current | MAX1556/MAX1556A | | 1200 | | | mA |
| | MAX1557 | | 600 | | | |
| OUT Bias Current | D1 = D2 = GND MAX1556/MAX1557 | $T_A$ = +25°C | | 0.01 | 0.1 | µA |
| | | $T_A$ = +85°C | | 0.01 | | |
| | For preset output voltages | | | 3 | 4.5 | |
| FB Threshold Accuracy | D1 = D2 = GND, $V_{OUT}$ = 0.75V at 300mA (typ), $T_A$ = 0°C to +85°C MAX1556/MAX1557 | No load | -0.50 | +0.75 | +1.75 | % |
| | | 300mA load | -1.2 | 0 | +1.2 | |
| | | 600mA load | -1.75 | -0.75 | +0.25 | |
| | | 1200mA load, MAX1556 only | -3.25 | -2.25 | -1.25 | |
| | D1 = D2 = GND, $V_{OUT}$ = 0.75V at 300mA (typ), $T_A$ = -40°C to +85°C MAX1556/MAX1557 | No load | -1.25 | | +2.25 | |
| | | 300mA load | -1.75 | | +1.50 | |
| | | 600mA load | -2.75 | | +0.25 | |
| | | 1200mA load, MAX1556 only | -4.25 | | -1.00 | |

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## *16µA IQ, 1.2A PWM DC-DC*
## *Step-Down Converters*

## ELECTRICAL CHARACTERISTICS (continued)

($V_{IN}$ = $V_{INP}$ = $V_{\overline{SHDN}}$ = 3.6V, $T_A$ = - 40°C to +85°C. Typical values are at $T_A$ = +25°C, unless otherwise noted.) (Note 1)

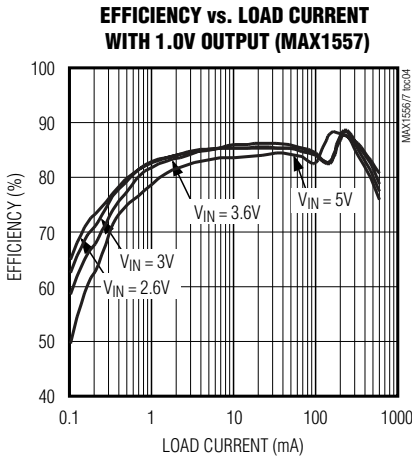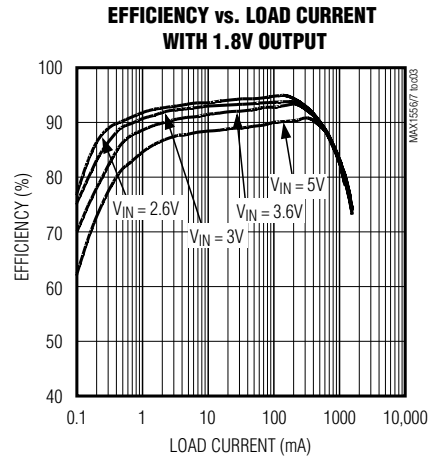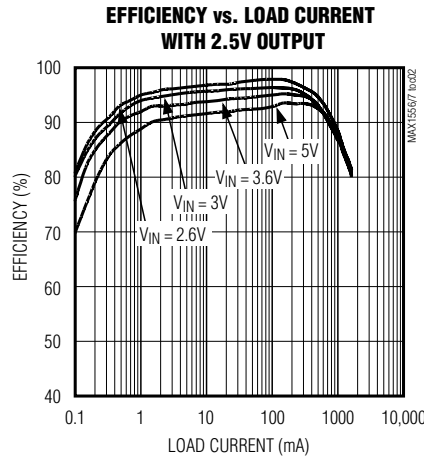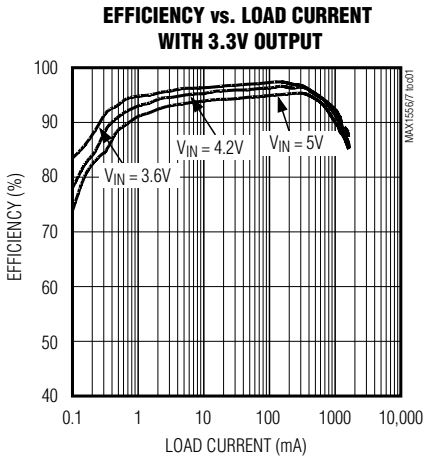| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| Line Regulation | MAX1556, D1 = IN, D2 = GND; MAX1556A D1 = D2 = IN | $V_{IN}$ = 2.6V to 3.6V | | -0.37 | | % |
| | | $V_{IN}$ = 3.6V to 5.5V | | 0.33 | | |
| | MAX1557, D1 = IN, D2 = GND | $V_{IN}$ = 2.6V to 3.6V | | -0.1 | | |
| | | $V_{IN}$ = 3.6V to 5.5V | | 0.09 | | |
| p-Channel On-Resistance | MAX1556/MAX1556A | $V_{IN}$ = 3.6V | | 0.19 | 0.35 | Ω |
| | | $V_{IN}$ = 2.6V | | 0.23 | | |
| | MAX1557 | $V_{IN}$ = 3.6V | | 0.35 | 0.7 | |
| | | $V_{IN}$ = 2.6V | | 0.42 | | |
| n-Channel On-Resistance | $V_{IN}$ = 3.6V | | | 0.27 | 0.48 | Ω |
| | $V_{IN}$ = 2.6V | | | 0.33 | | |
| p-Channel Current-Limit Threshold | MAX1556/MAX1556A | | 1.5 | 1.8 | 2.1 | A |
| | MAX1557 | | 0.8 | 1.0 | 1.2 | |
| n-Channel Zero Crossing Threshold | | | 20 | 35 | 45 | mA |
| RMS LX Output Current | MAX1556/MAX1556A | | | | 1.8 | $A_{RMS}$ |
| | MAX1557 | | | | 1.0 | |
| LX Leakage Current | $V_{IN}$ = 5.5V, LX = GND or IN | $T_A$ = +25°C | | 0.1 | 10 | µA |
| | | $T_A$ = +85°C | | 0.1 | | |
| Maximum Duty Cycle | | | 100 | | | % |
| Minimum Duty Cycle | | | | | 0 | % |
| Internal Oscillator Frequency | | | 0.9 | 1 | 1.1 | MHz |
| SS Output Impedance | $\Delta V_{SS}$ / $I_{SS}$ for $I_{SS}$ = 2µA | | 130 | 200 | 300 | kΩ |
| SS Discharge Resistance | $\overline{SHDN}$ = GND, 1mA sink current | | | 90 | 200 | Ω |
| Thermal-Shutdown Threshold | | | | +160 | | °C |
| Thermal-Shutdown Hysteresis | | | | 15 | | °C |
| **LOGIC INPUTS (D1, D2, $\overline{SHDN}$)** | | | | | | |
| Input-Voltage High | 2.6V ≤ $V_{IN}$ ≤ 5.5V | | 1.4 | | | V |
| Input-Voltage Low | | | | | 0.4 | V |
| Input Leakage | $T_A$ = +25°C | | | 0.1 | 1 | µA |
| | $T_A$ = +85°C | | | 0.1 | | |

**Note 1:** All units are 100% production tested at $T_A$ = +25°C. Limits over the operating range are guaranteed by design.
**Note 2:** For the MAX1556, 3.3V output accuracy is specified with a 4.2V input.

# 16µA IQ, 1.2A PWM DC-DC Step-Down Converters

(V$_{IN}$ = V$_{INP}$ = 3.6V, D1 = D2 = $\overline{SHDN}$ = IN, Circuits of Figures 2 and 3, T$_A$ = +25°C, unless otherwise noted.)

<div style="writing-mode: vertical">MAX1556/MAX1556A/MAX1557</div>



EFFICIENCY vs. LOAD CURRENT WITH 3.3V OUTPUT



EFFICIENCY vs. LOAD CURRENT WITH 2.5V OUTPUT



EFFICIENCY vs. LOAD CURRENT WITH 1.8V OUTPUT



EFFICIENCY vs. LOAD CURRENT WITH 1.0V OUTPUT (MAX1557)



OUTPUT VOLTAGE vs. LOAD CURRENT



OUTPUT VOLTAGE vs. INPUT VOLTAGE WITH 600mA LOAD



OUTPUT VOLTAGE vs. INPUT VOLTAGE WITH NO LOAD



SUPPLY CURRENT vs. INPUT VOLTAGE



HEAVY-LOAD SWITCHING WAVEFORMS

**MAXIM**
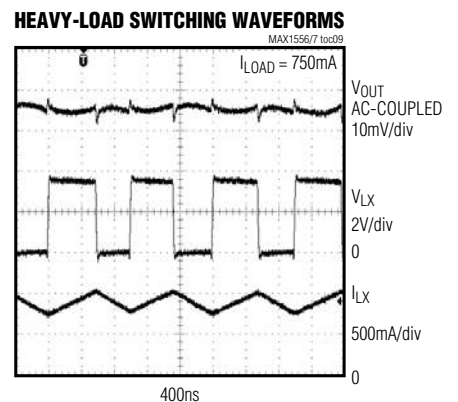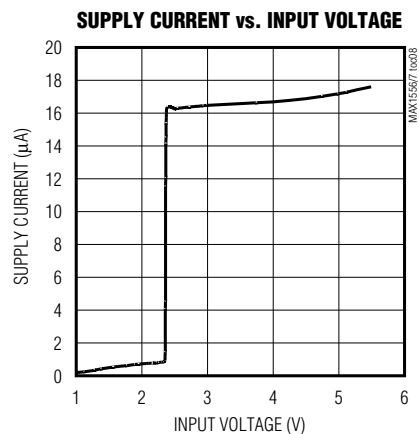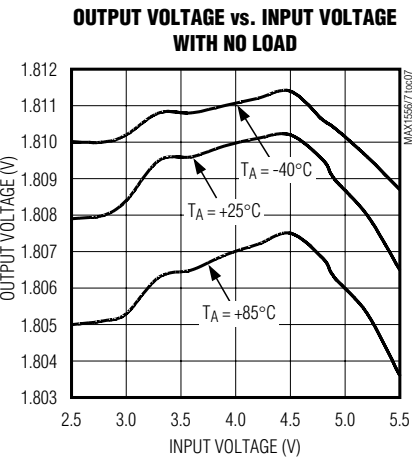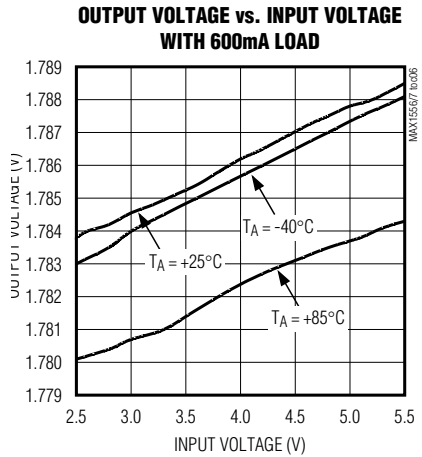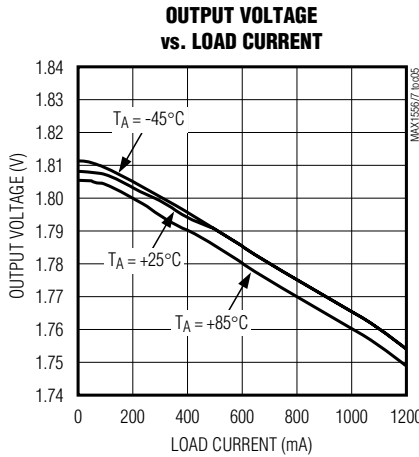
## Typical Operating Characteristics (continued)

($V_{IN} = V_{INP} = 3.6V$, D1 = D2 = $\overline{SHDN}$ = IN, Circuits of Figures 2 and 3, $T_A = +25°C$, unless otherwise noted.)

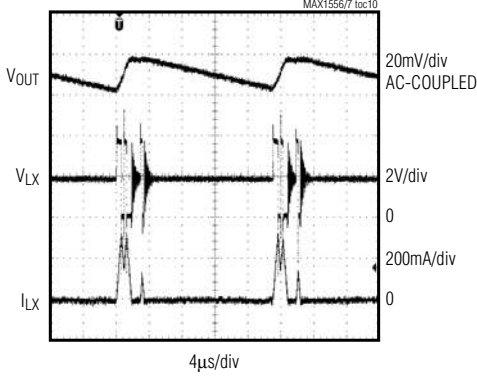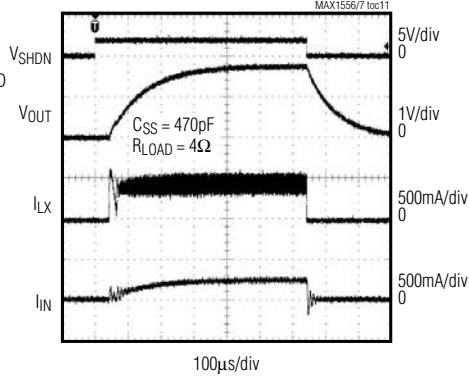**LIGHT-LOAD SWITCHING WAVEFORMS**
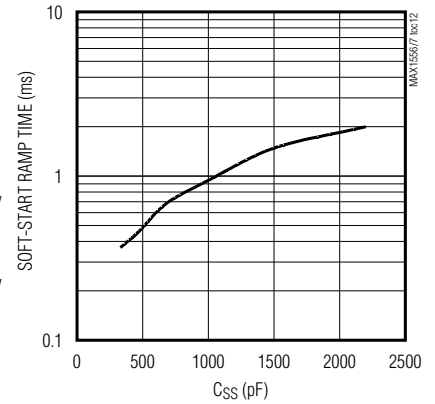
MAX1556/7 toc10

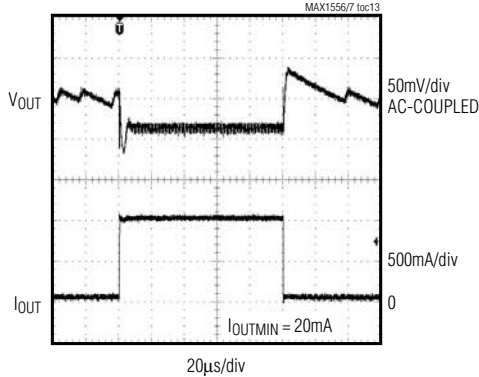$V_{OUT}$ — 20mV/div AC-COUPLED

$V_{LX}$ — 2V/div, 0

$I_{LX}$ — 200mA/div, 0

4µs/div

**SOFT-START/SHUTDOWN WAVEFORMS**

MAX1556/7 toc11

$V_{SHDN}$ — 5V/div, 0

$V_{OUT}$ — 1V/div, 0

$C_{SS}$ = 470pF
$R_{LOAD}$ = 4Ω

$I_{LX}$ — 500mA/div, 0

$I_{IN}$ — 500mA/div, 0

100µs/div

**SOFT-START RAMP TIME vs. $C_{SS}$**

MAX1556/7 toc12

SOFT-START RAMP TIME (ms)

$C_{SS}$ (pF)

**LOAD TRANSIENT**

MAX1556/7 toc13

$V_{OUT}$ — 50mV/div AC-COUPLED

$I_{OUT}$ — 500mA/div, 0

$I_{OUTMIN}$ = 20mA

20µs/div

**LOAD TRANSIENT**

MAX1556/7 toc14

$V_{OUT}$ — 50mV/div AC-COUPLED

$I_{OUT}$ — 500mA/div, 0

$I_{OUTMIN}$ = 180mA

20µs/div

**LINE TRANSIENT**

MAX1556/7 toc15

$V_{IN}$ — 4V, 3.5V

$V_{OUT}$ — 10mV/div AC-COUPLED

$I_{LX}$ — 200mA/div, 0

40µs/div

**BODE PLOT**

MAX1556/7 toc16

GAIN (dB)

PHASE (DEGREES)

0dB

PHASE MARGIN = 53°

$C_{OUT}$ = 22µF, $R_{LOAD}$ = 4Ω

FREQUENCY (kHz)

_**MAXIM**_ _____ 5

# 16µA IQ, 1.2A PWM DC-DC
# Step-Down Converters

| PIN | NAME | FUNCTION |
|---|---|---|
| 1 | IN | Supply Voltage Input. Connect to a 2.6V to 5.5V source. |
| 2 | GND | Ground. Connect to PGND. |
| 3 | SS | Soft-Start Control. Connect a 1000pF capacitor ($C_{SS}$) from SS to GND to eliminate input-current overshoot during startup. $C_{SS}$ is required for normal operation of the MAX1556/MAX1557. For greater than 22µF total output capacitance, increase $C_{SS}$ to $C_{OUT}$ / 22,000 for soft-start. SS is internally discharged through 200Ω to GND in shutdown. |
| 4 | OUT | Output Sense Input. Connect to the output of the regulator. D1 and D2 select the desired output voltage through an internal feedback resistor-divider. The internal feedback resistor-divider remains connected in shutdown. |
| 5 | $\overline{SHDN}$ | Shutdown Input. Drive $\overline{SHDN}$ low to enable low-power shutdown mode. Drive high or connect to IN for normal operation. |
| 6 | D2 | OUT Voltage-Select Input. See Table 1. |
| 7 | PGND | Power Ground. Connect to GND. |
| 8 | LX | Inductor Connection. Connected to the drains of the internal power MOSFETs. High impedance in shutdown mode. |
| 9 | INP | Supply Voltage, High-Current Input. Connect to a 2.6V to 5.5V source. Bypass with a 10µF ceramic capacitor to PGND. |
| 10 | D1 | OUT Voltage-Select Input. See Table 1. |
| EP | — | Exposed Paddle. Connect to ground plane. EP also functions as a heatsink. Solder to circuit-board ground plane to maximize thermal dissipation. |

## Table 1. Output-Voltage-Select Truth Table

| D1 | D2 | MAX1556 $V_{OUT}$ | MAX1556A $V_{OUT}$ | MAX1557 $V_{OUT}$ |
|---|---|---|---|---|
| 0 | 0 | Adjustable ($V_{FB}$ = 0.75) from 0.75V to $V_{IN}$ | 3.3V | Adjustable ($V_{FB}$ = 0.75) from 0.75V to $V_{IN}$ |
| 0 | 1 | 3.3V | 1.5V | 1.5V |
| 1 | 0 | 2.5V | 1.2V | 1.3V |
| 1 | 1 | 1.8V | 2.5V | 1.0V |

_A zero represents D_ being driven low or connected to GND._
_A 1 represents D_ being driven high or connected to IN._

## _Detailed Description_

The MAX1556/MAX1557 synchronous step-down converters deliver a guaranteed 1.2A/600mA at output voltages from 0.75V to $V_{IN}$. They use a 1MHz PWM current-mode control scheme with internal compensation, allowing for tiny external components and a fast transient response. At light loads the MAX1556/MAX1557 automatically switch to pulse-skipping mode to keep the quiescent supply current as low as 16µA. Figures 2 and 3 show the typical application circuits.

## _Control Scheme_

During PWM operation the converters use a fixed-frequency, current-mode control scheme. The heart of the current-mode PWM controller is an open-loop, multiple-input comparator that compares the error-amp voltage feedback signal against the sum of the amplified current-sense signal and the slope-compensation ramp. At the beginning of each clock cycle, the internal high-side p-channel MOSFET turns on until the PWM comparator trips. During this time the current in the inductor ramps up, sourcing current to the output and storing energy in the inductor's magnetic field. When the p-channel turns off, the internal low-side n-channel MOSFET turns on. Now the inductor releases the stored energy while the current ramps down, still providing current to the output. The output capacitor stores charge when the inductor current exceeds the load and discharges when the inductor current is lower than the load. Under overload conditions, when the inductor current exceeds the current limit, the high-side MOSFET is turned off and the low-side MOSFET remains on until the next clock cycle.
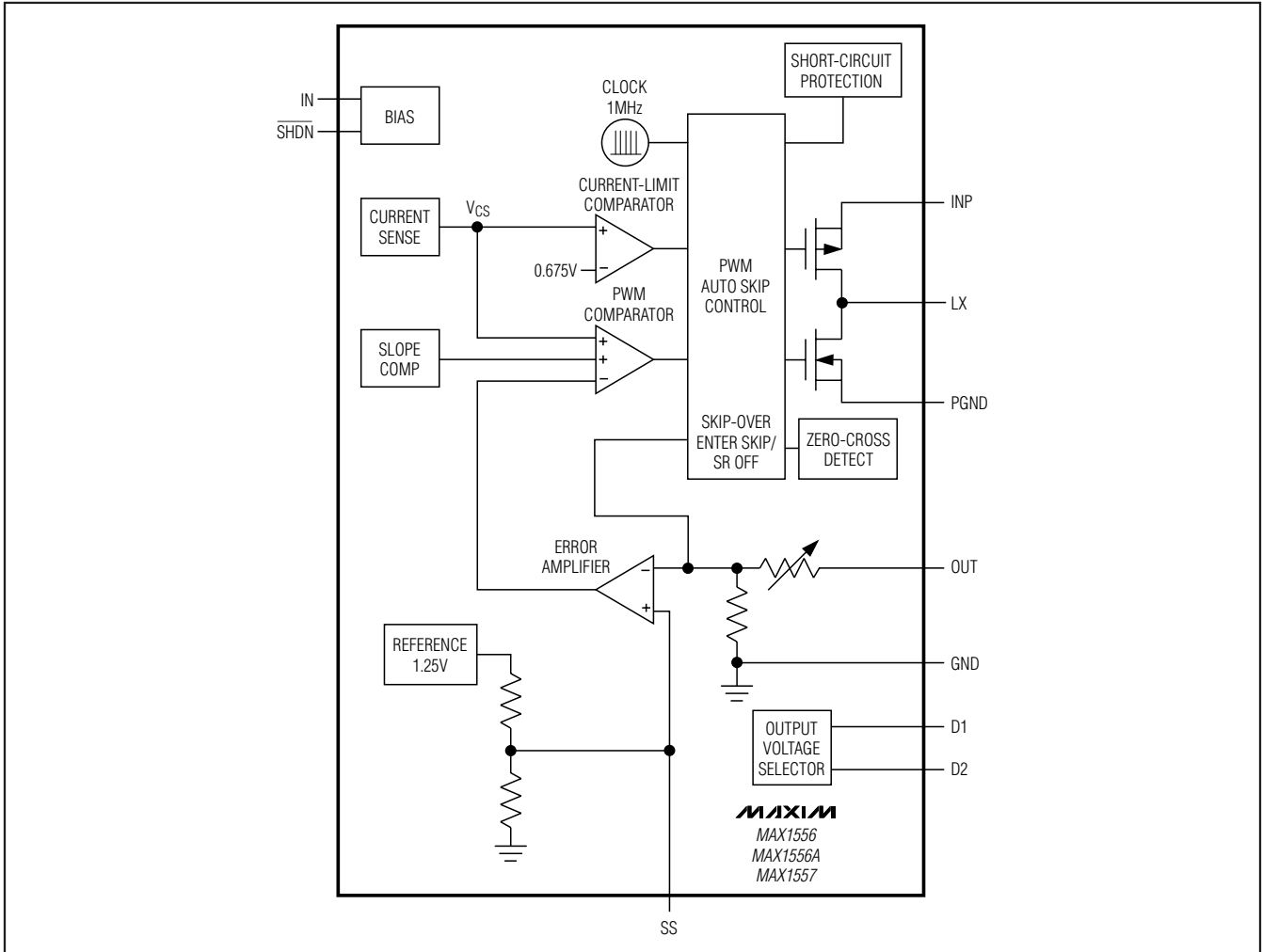
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MAX1556/MAX1556A/MAX1557
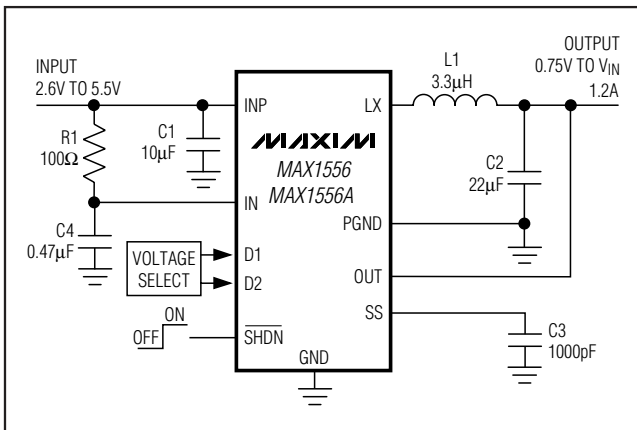


Figure 1. Functional Diagram
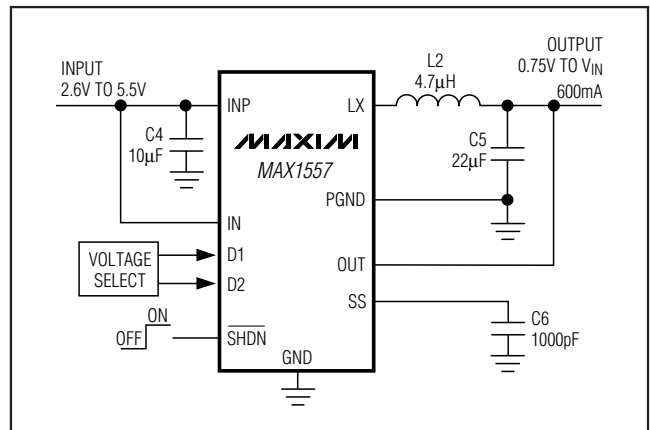


Figure 2. MAX1556 Typical Application Circuit



Figure 3. MAX1557 Typical Application Circuit

# 16µA IQ, 1.2A PWM DC-DC Step-Down Converters

As the load current decreases, the converters enter a pulse-skip mode in which the PWM comparator is disabled. At light loads, efficency is enhanced by a pulse-skip mode in which switching occurs only as needed to service the load. Quiescent current in skip mode is typically 16µA. See the Light-Load Switching Waveforms and Load Transient graphs in the *Typical Operating Characteristics*.

### *Load-Transient Response/ Voltage Positioning*

The MAX1556/MAX1556A/MAX1557 match the load regulation to the voltage droop seen during transients. This is sometimes called voltage positioning. The load line used to achieve this behavior is shown in Figures 4 and 5. There is minimal overshoot when the load is removed and minimal voltage drop during a transition from light load to full load. Additionally, the MAX1556, MAX1556A, and MAX1557 use a wide-bandwidth feedback loop to respond more quickly to a load transient than regulators using conventional integrating feedback loops (see Load Transient in the *Typical Operating Characteristics*).

The MAX1556/MAX1556A/MAX1557 use of a wide-band control loop and voltage positioning allows superior load-transient response by minimizing the amplitude and duration of overshoot and undershoot in response to load transients. Other DC-DC converters, with high gain- control loops, use external compensation to maintain tight DC load regulation but still allow large voltage droops of 5% or greater for several hundreds of microseconds during transients. For example, if the load is a CPU running at 600MHz, then a dip lasting 100µs corresponds to 60,000 CPU clock cycles.

Voltage positioning on the MAX1556/MAX1556A/ MAX1557 allows up to 2.25% (typ) of load-regulation voltage shift but has no further transient droop. Thus, during load transients, the voltage delivered to the CPU remains within spec more effectively than with other regulators that might have tighter initial DC accuracy. In summary, a 2.25% load regulation with no transient droop is much better than a converter with 0.5% load regulation and 5% or more of voltage droop during load transients. Load-transient variation can be seen only with an oscilloscope (see the *Typical Operating Characteristics*), while DC load regulation read by a voltmeter does not show how the power supply reacts to load transients.

### *Dropout/100% Duty-Cycle Operation*

The MAX1556/MAX1556A/MAX1557 function with a low input-to-output voltage difference by operating at 100% duty cycle. In this state, the high-side p-channel
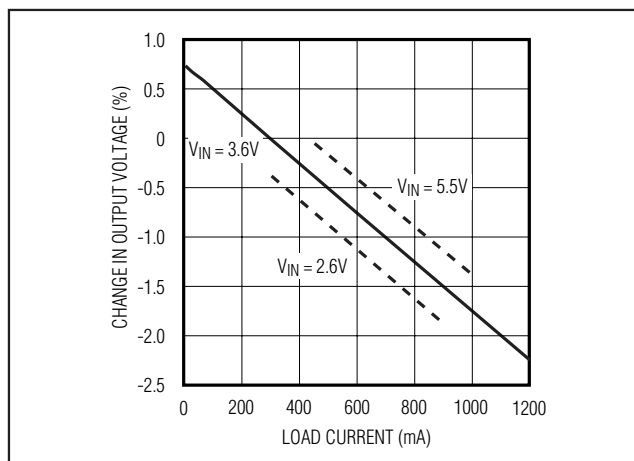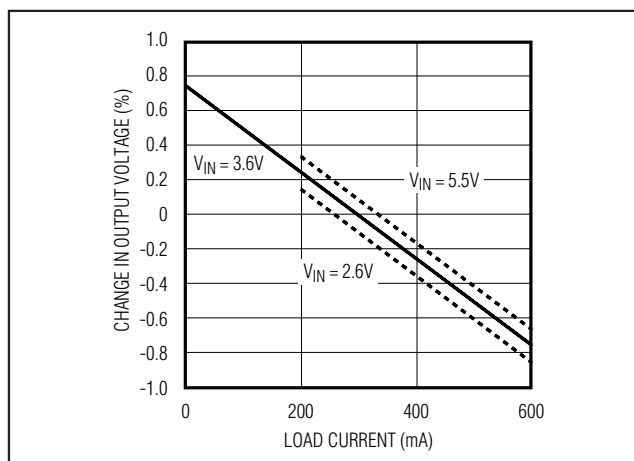


Figure 4. MAX1556 Voltage-Positioning Load Line



Figure 5. MAX1557 Voltage-Positioning Load Line

MOSFET is always on. This is particularly useful in battery-powered applications with a 3.3V output. The system and load might operate normally down to 3V or less. The MAX1556/MAX1556A/MAX1557 allow the output to follow the input battery voltage as it drops below the regulation voltage. The quiescent current in this state rises minimally to only 27µA (typ), which aids in extending battery life. This dropout/100% duty-cycle operation achieves long battery life by taking full advantage of the entire battery range.

The input voltage required to maintain regulation is a function of the output voltage and the load. The difference between this minimum input voltage and the output voltage is called the dropout voltage. The dropout voltage is therefore a function of the on-resistance of the internal p-channel MOSFET ($R_{DS(ON)P}$) and the inductor resistance (DCR).

*/VI/IXI/VI*

## Table 2. Inductor Selection

| MANUFACTURER | PART | VALUE (µH) | DCR (mΩ) | I$_{SAT}$ (mA) | SIZE (mm) | SHIELDED |
|---|---|---|---|---|---|---|
| Taiyo Yuden | LMNP04SB3R3N | 3.3 | 36 | 1300 | 5 x 5 x 2.0 | Yes |
| Taiyo Yuden | LMNP04SB4R7N | 4.7 | 50 | 1200 | 5 x 5 x 2.0 | Yes |
| TOKO | D52LC | 3.5 | 73 | 1340 | 5 x 5 x 2.0 | Yes |
| TOKO | D52LC | 4.7 | 87 | 1140 | 5 x 5 x 2.0 | Yes |
| Sumida | CDRH3D16 | 4.7 | 50 | 1200 | 3.8 x 3.8 x 1.8 | Yes |
| TOKO | D412F | 4.7 | 100* | 1200* | 4.8 x 4.8 x 1.2 | Yes |
| Murata | LQH32CN | 4.7 | 97 | 790 | 2.5 x 3.2 x 2.0 | No |
| Sumitomo | CXL180 | 4.7 | 70* | 1000* | 3.0 x 3.2 x 1.7 | No |
| Sumitomo | CXLD140 | 4.7 | 100* | 800* | 2.8 x 3.2 x 1.5 | No |

*Estimated based upon similar-valued prototype inductors.

$$V_{DROPOUT} = I_{OUT} \times (R_{DS(ON)P} + DCR)$$

$R_{DS(ON)P}$ is given in the *Electrical Characteristics*. DCR for a few recommended inductors is listed in Table 2.

### Soft-Start

The MAX1556/MAX1556A/MAX1557 use soft-start to eliminate inrush current during startup, reducing transients at the input source. Soft-start is particularly useful for higher-impedance input sources such as Li+ and alkaline cells. Connect the required soft-start capacitor from SS to GND. For most applications using a 22µF output capacitor, connect a 1000pF capacitor from SS to GND. If a larger output capacitor is used, then use the following formula to find the value of the soft-start capacitor:

$$C_{SS} = \frac{C_{OUT}}{22000}$$

Soft-start is implemented by exponentially ramping up the output voltage from 0 to $V_{OUT(NOM)}$ with a time constant equal to $C_{SS}$ times 200kΩ (see the *Typical Operating Characteristics*). Assuming three time constants to full output voltage, use the following formula to calculate the soft-start time:

$$t_{SS} = 600 \times 10^3 \times C_{SS}$$

### Shutdown Mode

Connecting $\overline{SHDN}$ to GND or logic low places the MAX1556/MAX1556A/MAX1557 in shutdown mode and reduces supply current to 0.1µA. In shutdown, the control circuitry and the internal p-channel and n-channel MOSFETs turn off and LX becomes high impedance. Connect $\overline{SHDN}$ to IN or logic high for normal operation.

### Thermal Shutdown

As soon as the junction temperature of the MAX1556/MAX1556A/MAX1557 exceeds +160°C, the ICs go into thermal shutdown. In this mode the internal p-channel switch and the internal n-channel synchronous rectifier are turned off. The device resumes normal operation when the junction temperature falls below +145°C.

## Applications Information

The MAX1556/MAX1556A/MAX1557 are optimized for use with small external components. The correct selection of inductors and input and output capacitors ensures high efficiency, low output ripple, and fast transient response.

### Adjusting the Output Voltage

The adjustable output is selected when D1 = D2 = 0 and an external resistor-divider is used to set the output voltage (see Figure 6). The MAX1556/MAX1557 have a defined line- and load-regulation slope. The load regulation is for both preset and adjustable outputs and is described in the *Electrical Characteristics* table and Figures 4 and 5. The impact of the line-regulation slope can be reduced by applying a correction factor to the feedback resistor equation.

First, calculate the correction factor, k, by plugging the desired output voltage into the following formula:

$$k = 1.06 \times 10^{-2}V \times \left( \frac{V_{OUTPUT} - 0.75V}{3.6V} \right)$$

k represents the shift in the operating point at the feedback node (OUT).

Select the lower feedback resistor, R3, to be ≤35.7kΩ to ensure stability and solve for R2:

$$\left(\frac{0.75V - k}{V_{OUTPUT}}\right) = \frac{R3}{(R3 + R2)}$$

### Inductor Selection

A 4.7µH inductor with a saturation current of at least 800mA is recommended for the MAX1557 full-load (600mA) application. For the MAX1556/MAX1556A application with 1.2A full load, use a 3.3µH inductor with at least 1.34A saturation current. For lower full-load currents the inductor current rating can be reduced. For maximum efficiency, the inductor's resistance (DCR) should be as low as possible. Please note that the core material differs among different manufacturers and inductor types and has an impact on the efficiency. See Table 2 for recommended inductors and manufacturers.

### Capacitor Selection

Ceramic input and output capacitors are recommended for most applications. For best stability over a wide temperature range, use capacitors with an X5R or better dielectric due to their small size, low ESR, and low temperature coefficients.

### Output Capacitor

The output capacitor $C_{OUT}$ is required to keep the output voltage ripple small and to ensure regulation loop stability. $C_{OUT}$ must have low impedance at the switching frequency. A 22µF ceramic output capacitor is recommended for most applications. If a larger output capacitor is used, then paralleling smaller capacitors is suggested to keep the effective impedance of the capacitor low at the switching frequency.

### Input Capacitor

Due to the pulsating nature of the input current in a buck converter, a low-ESR input capacitor at INP is required for input voltage filtering and to minimize interference with other circuits. The impedance of the input capacitor $C_{INP}$ should be kept very low at the switching frequency. A minimum value of 10µF is recommended at INP for most applications. The input capacitor can be increased for better input filtering.

### IN Input Filter

In all MAX1557 applications, connect INP directly to IN and bypass INP as described in the *Input Capacitor* section. No additional bypass capacitor is required at IN. For applications using the MAX1556 and MAX1556A, an RC filter between INP and IN keeps power-supply noise from entering the IC. Connect a
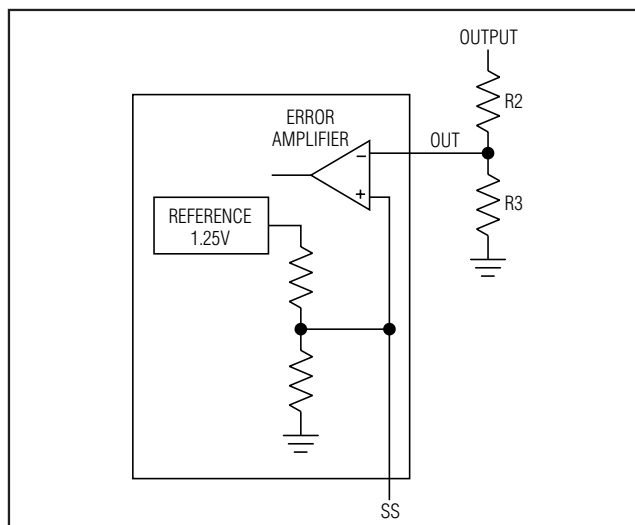


Figure 6. Adjustable Output Voltage

100Ω resistor between INP and IN, and connect a 0.47µF capacitor from IN to GND.

### Soft-Start Capacitor

The soft-start capacitor, $C_{SS}$, is required for proper operation of the MAX1556/MAX1556A/MAX1557. The recommended value of $C_{SS}$ is discussed in the *Soft-Start* section. Soft-start times for various soft-start capacitors are shown in the *Typical Operating Characteristics*.

### PC Board Layout and Routing

Due to fast-switching waveforms and high-current paths, careful PC board layout is required. An evaluation kit (MAX1556EVKIT) is available to speed design.

When laying out a board, minimize trace lengths between the IC, the inductor, the input capacitor, and the output capacitor. Keep these traces short, direct, and wide. Keep noisy traces, such as the LX node trace, away from OUT. The input bypass capacitors should be placed as close to the IC as possible. Connect GND to the exposed paddle and star PGND and GND together at the output capacitor. The ground connections of the input and output capacitors should be as close together as possible.

### _____Chip Information

TRANSISTOR COUNT: 7567

PROCESS: BiCMOS

## Package Information

For the latest package outline information, go to **www.maxim-ic.com/packages**.

| PACKAGE TYPE | PACKAGE CODE | DOCUMENT NO. |
|---|---|---|
| 10 TDFN | T1033-1 | **21-0137** |

# 16µA IQ, 1.2A PWM DC-DC Step-Down Converters

_____ *Revision History*

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|---|---|---|---|
| 0 | 7/04 | Initial release | — |
| 1 | 3/08 | Adding MAX1556A as a new version | 1–12 |