



# High-Voltage, Low-Power Linear Regulators for Notebook Computers

## General Description

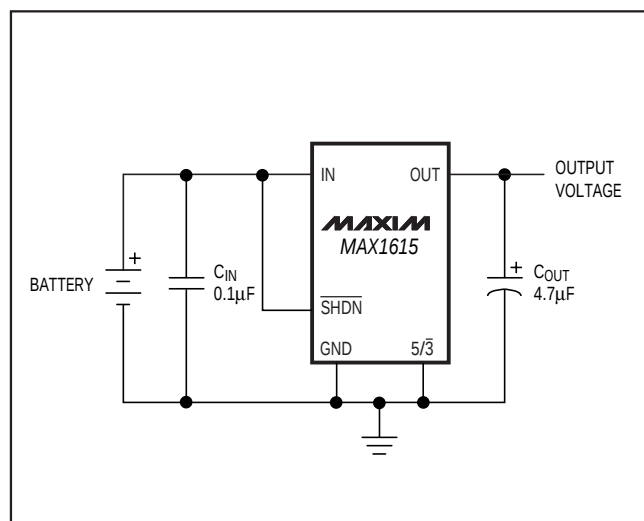
The MAX1615/MAX1616 are micropower, SOT23-5 linear regulators that supply always-on, keep-alive power to CMOS RAM and microcontrollers ( $\mu$ Cs) in systems with high-voltage batteries. Key features include wide input voltage range, low dropout voltage, and low quiescent supply current.

Despite a miserly  $8\mu\text{A}$  (max) no-load supply current, the MAX1615/MAX1616 have excellent line-transient response and AC power-supply rejection ratio. They provide a clean, fixed 5V or 3.3V output (MAX1615) or an adjustable 1.24V to 28V output (MAX1616), even when subjected to fast supply-voltage changes that occur during the switchover from battery to AC adapter input power. The space-saving SOT23-5 package has excellent thermal characteristics and tolerates up to 571mW of power dissipation. Fault protection is provided by internal foldback current limiting and thermal-shutdown circuitry. The MAX1615/MAX1616 are now available in lead-free packages.

## Applications

CMOS/RTC Backup Power  
Microcontroller Power  
Notebook Computers  
Smart-Battery Packs  
PDAs and Handy-Terminals  
Battery-Powered Systems

## Typical Operating Circuit



## Features

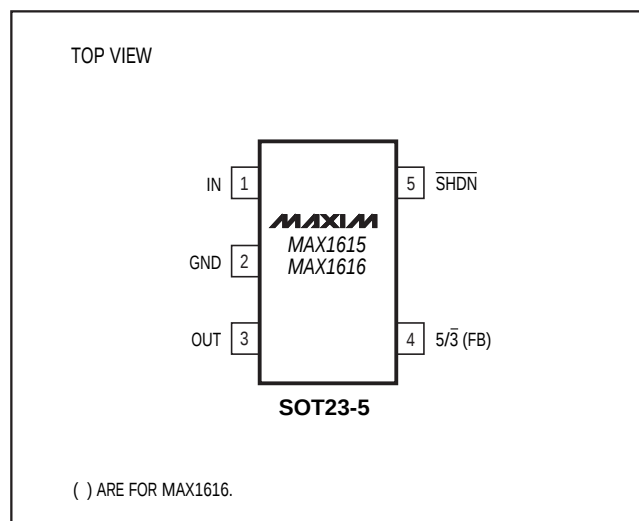
- ◆ 4V to 28V Input Range
- ◆ 8 $\mu\text{A}$  (max) Quiescent Supply Current
- ◆ <1 $\mu\text{A}$  Shutdown Supply Current
- ◆ 3.3V or 5V, Pin-Selectable Output (MAX1615)  
Adjustable 1.24V to 28V Output (MAX1616)
- ◆ 30mA Output Current
- ◆  $\pm 2\%$  Initial Output Accuracy
- ◆ Thermal-Overload Protection
- ◆ 5-Pin SOT23 Package
- ◆ Low Cost

## Ordering Information

| PART         | TEMP RANGE     | PIN-PACKAGE | SOT TOP MARK |
|--------------|----------------|-------------|--------------|
| MAX1615EUK-T | -40°C to +85°C | 5 SOT23-5   | ABZD         |
| MAX1615EUK+T | -40°C to +85°C | 5 SOT23-5   | ABZD         |
| MAX1616EUK-T | -40°C to +85°C | 5 SOT23-5   | ABZE         |
| MAX1616EUK+T | -40°C to +85°C | 5 SOT23-5   | ABZE         |

+Denotes lead-free package.

## Pin Configuration



# High-Voltage, Low-Power Linear Regulators for Notebook Computers

## ABSOLUTE MAXIMUM RATINGS

IN to GND .....-0.3V to 30V  
 Terminal Voltages to GND  
 $\overline{\text{SHDN}}$  to GND .....-0.3V to ( $V_{\text{IN}} + 0.3\text{V}$ )  
 $5/\overline{3}$  to GND .....-0.3V to ( $V_{\text{OUT}} + 0.3\text{V}$ )  
 FB (MAX1616) to GND .....-0.3V to ( $V_{\text{OUT}} + 0.3\text{V}$ )  
 OUT to GND.....-0.3V to 30V  
 OUT Short-Circuit to GND .....30sec

Continuous OUT Current.....40mA  
 Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ ) (Note 1)  
     SOT23-5 (derate 7.1mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ ).....571mW  
 Operating Temperature Range  
     MAX161\_EUK-T .....-40 $^\circ\text{C}$  to  $+85^\circ\text{C}$   
 Storage Temperature Range .....-65 $^\circ\text{C}$  to  $+160^\circ\text{C}$   
 Lead Temperature (soldering, 10s) .....+300 $^\circ\text{C}$

**Note 1:** See Operating Region and Power Dissipation section.

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

( $V_{\text{IN}} = 15\text{V}$ ,  $\overline{\text{SHDN}} = V_{\text{IN}}$ ,  $I_{\text{LOAD}} = 5\mu\text{A}$ ,  $T_A = T_{\text{MIN}}$  to  $T_{\text{MAX}}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 2)

| PARAMETER                             | SYMBOL           | CONDITIONS                                                                                                                                |                                                                                            | MIN   | TYP   | MAX   | UNITS             |
|---------------------------------------|------------------|-------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-------|-------|-------|-------------------|
| Input Voltage Range                   | V <sub>IN</sub>  |                                                                                                                                           |                                                                                            | 4     |       | 28    | V                 |
| Supply Current                        | I <sub>IN</sub>  | SHDN = IN, T <sub>A</sub> = +25°C                                                                                                         |                                                                                            | 6.2   |       | 8     | μA                |
|                                       |                  | SHDN = IN, V <sub>IN</sub> = 6V to 28V, T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>                                             |                                                                                            | 15    |       |       |                   |
| Minimum Load Current                  |                  |                                                                                                                                           |                                                                                            |       |       | 5     | μA                |
| Shutdown Supply Current               | I <sub>IN</sub>  | SHDN = GND<br>(shutdown mode)                                                                                                             | T <sub>A</sub> = +25°C                                                                     |       |       | 1.5   | μA                |
|                                       |                  |                                                                                                                                           | T <sub>MIN</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>                                    |       |       | 3     |                   |
| Dropout Supply Current                |                  | Output set to 5V,<br>V <sub>IN</sub> = 4V                                                                                                 | T <sub>A</sub> = +25°C                                                                     | 70    |       |       | μA                |
| Output Voltage (MAX1615)<br>(Note 3)  |                  | I <sub>LOAD</sub> = 1mA,<br>T <sub>A</sub> = +25°C,<br>V <sub>IN</sub> = 6V to 28V                                                        | 5/3 = GND                                                                                  | 3.26  | 3.33  | 3.40  | V                 |
|                                       |                  |                                                                                                                                           | 5/3 = OUT                                                                                  | 4.95  | 5.05  | 5.15  |                   |
|                                       |                  | I <sub>LOAD</sub> = 5μA to 30mA,<br>T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> ,<br>V <sub>IN</sub> = 6V to 28V                | 5/3 = GND                                                                                  | 3.15  |       | 3.48  |                   |
|                                       |                  |                                                                                                                                           | 5/3 = OUT                                                                                  | 4.75  |       | 5.25  |                   |
| FB Threshold (MAX1616)<br>(Note 3)    | V <sub>FBT</sub> | FB = OUT,<br>V <sub>IN</sub> = 6V to 28V                                                                                                  | T <sub>A</sub> = +25°C,<br>I <sub>LOAD</sub> = 1mA                                         | 1.215 | 1.240 | 1.265 | V                 |
|                                       |                  |                                                                                                                                           | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> ,<br>I <sub>LOAD</sub> = 5μA to 30mA | 1.18  |       | 1.28  |                   |
| FB Input Current (MAX1616)            | I <sub>FB</sub>  | V <sub>FB</sub> = 1.3V                                                                                                                    |                                                                                            | -10   | 12    | 30    | nA                |
| Dropout Voltage                       | ΔV <sub>DO</sub> | I <sub>LOAD</sub> = 30mA (Note 4)                                                                                                         |                                                                                            |       |       | 350   | mV                |
| Output Current Limit                  |                  | V <sub>IN</sub> = 6V                                                                                                                      |                                                                                            | 100   |       |       | mA                |
| OUT Reverse Leakage Current           |                  | IN = unconnected, V <sub>OUT</sub> forced to 5V                                                                                           |                                                                                            | 70    |       |       | μA                |
| Capacitive Load Requirements (Note 5) |                  | MAX1615                                                                                                                                   |                                                                                            | 0.16  |       |       | μF/mA             |
|                                       |                  | MAX1616                                                                                                                                   |                                                                                            | 0.23  |       |       |                   |
| Start-Up Time Response                |                  | Rising edge of IN or SHDN to OUT within specification limits, R <sub>L</sub> = 500Ω, C <sub>OUT</sub> = 6.8μF, V <sub>OUT</sub> set to 5V |                                                                                            |       |       | 1     | ms                |
| Start-Up Overshoot                    | V <sub>OSH</sub> | R <sub>L</sub> = 500Ω, C <sub>OUT</sub> = 10μF within 90% of nominal output voltage                                                       |                                                                                            | 0.5   |       |       | %V <sub>OUT</sub> |

# High-Voltage, Low-Power Linear Regulators for Notebook Computers

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{IN} = 15V$ ,  $\overline{SHDN} = V_{IN}$ ,  $I_{LOAD} = 5\mu A$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 2)

| PARAMETER                                 | SYMBOL     | CONDITIONS                                                       | MIN | TYP | MAX  | UNITS      |
|-------------------------------------------|------------|------------------------------------------------------------------|-----|-----|------|------------|
| $\overline{SHDN}$ Input Threshold Voltage | $V_{IL}$   |                                                                  |     |     | 0.25 | V          |
|                                           | $V_{IH}$   |                                                                  | 1.4 |     |      |            |
| $\overline{SHDN}$ Input Current           |            | $V_{\overline{SHDN}} = 0V$ or $15V$                              | -1  |     | 1    | $\mu A$    |
| Thermal-Shutdown Temperature              | $T_{SHDN}$ | $V_{\overline{SHDN}} = 0V$ or $15V$ , hysteresis = $+20^\circ C$ |     | 150 |      | $^\circ C$ |

**Note 2:** Limits are 100% production tested at  $T_A = +25^\circ C$ . Limits over the operating temperature range are guaranteed through correlation using standard quality-control (SQC) methods.

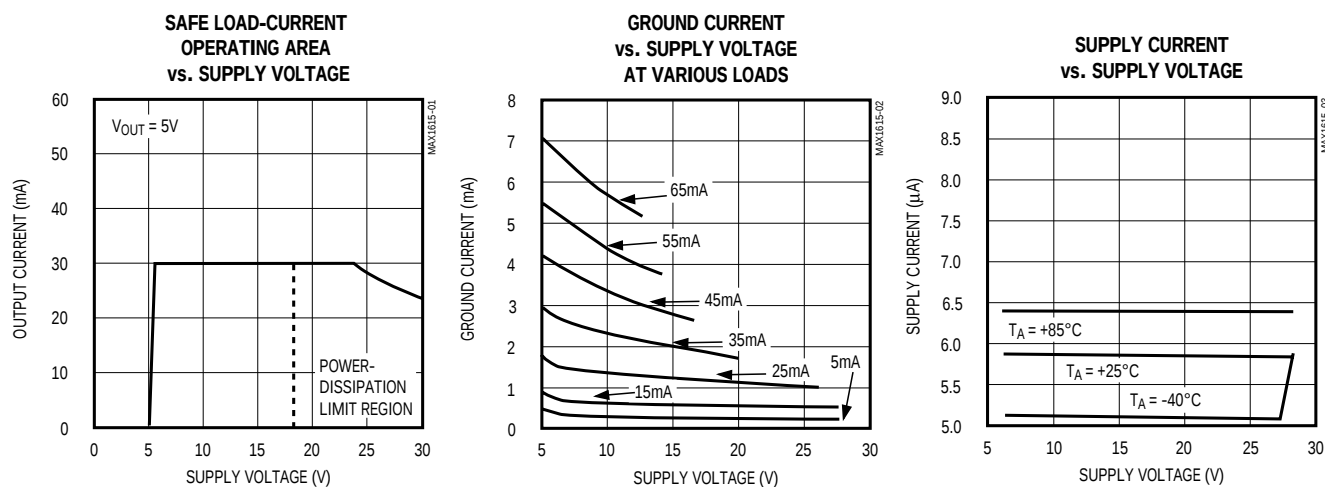
**Note 3:** Pulse tested at  $V_{IN} = 28V$ ,  $I_{LOAD} = 30mA$  to avoid exceeding package power-dissipation limits.

**Note 4:** Guaranteed by design. Tested with  $V_{OUT}$  set to 5V. Dropout voltage is tested by reducing the input voltage until  $V_{OUT}$  drops to 100mV below its nominal value, measured with  $V_{IN}$  starting 2V above  $V_{OUT}$ .

**Note 5:** Use at least 1 $\mu F$  minimum for light loads. Add 0.125 $\mu F/mA$  (0.2 $\mu F/mA$  for the MAX1616) for loads greater than 100 $\mu A$ , not production tested. See *Capacitor Selection* in the *Applications Information* section.

## Typical Operating Characteristics

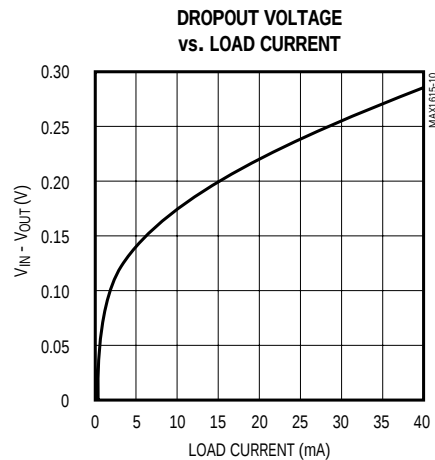
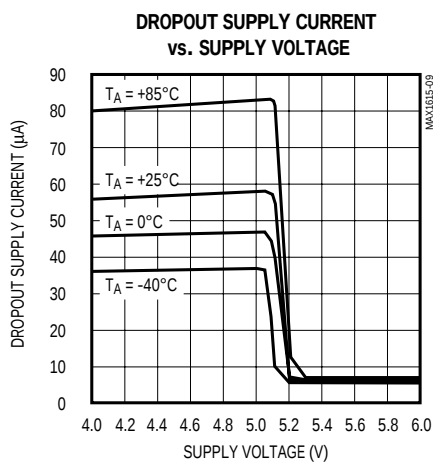
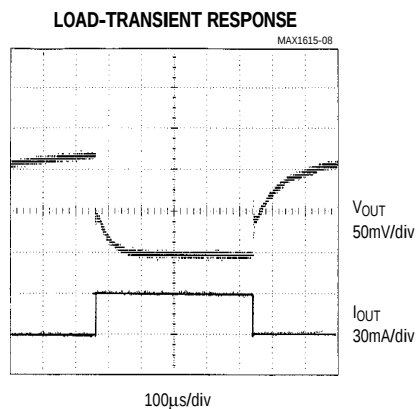
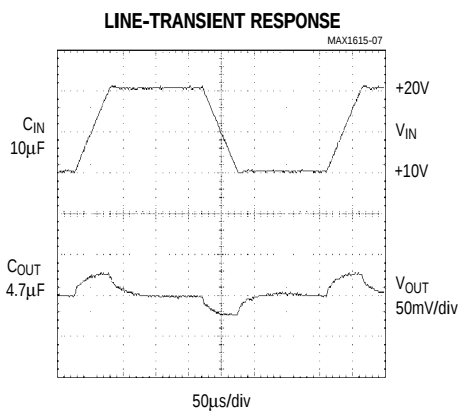
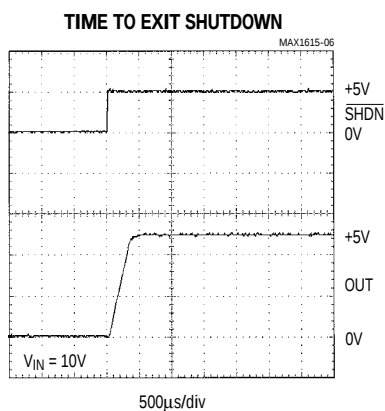
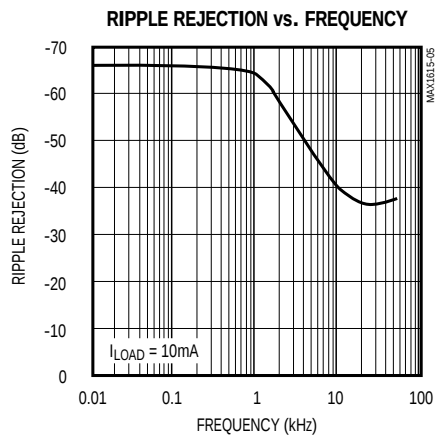
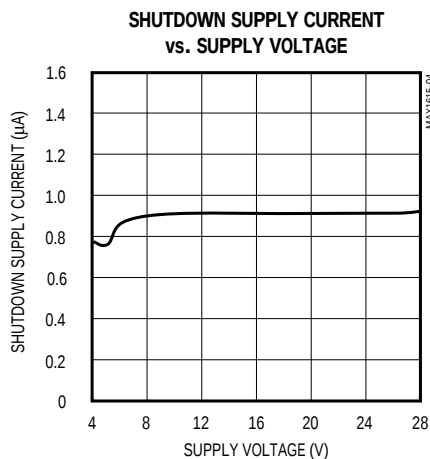
( $V_{OUT}$  set to 5V,  $T_A = +25^\circ C$ , unless otherwise noted.)



# High-Voltage, Low-Power Linear Regulators for Notebook Computers

## Typical Operating Characteristics (continued)

( $V_{OUT}$  set to 5V,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)



# High-Voltage, Low-Power Linear Regulators for Notebook Computers

## Pin Description

| PIN     |         | NAME                     | FUNCTION                                                                                |
|---------|---------|--------------------------|-----------------------------------------------------------------------------------------|
| MAX1615 | MAX1616 |                          |                                                                                         |
| 1       | 1       | IN                       | Positive Input Voltage. Connect to a +4V to +28V supply.                                |
| 2       | 2       | GND                      | Ground                                                                                  |
| 3       | 3       | OUT                      | Regulator Output                                                                        |
| 4       | —       | $5/\bar{3}$              | Preset Output Voltage Select. Connect to GND for 3.3V output or to OUT for 5.0V output. |
| —       | 4       | FB                       | Feedback Input. Regulates to 1.24V nominally.                                           |
| 5       | 5       | $\overline{\text{SHDN}}$ | Shutdown, active low input. Connect to IN for automatic start up.                       |

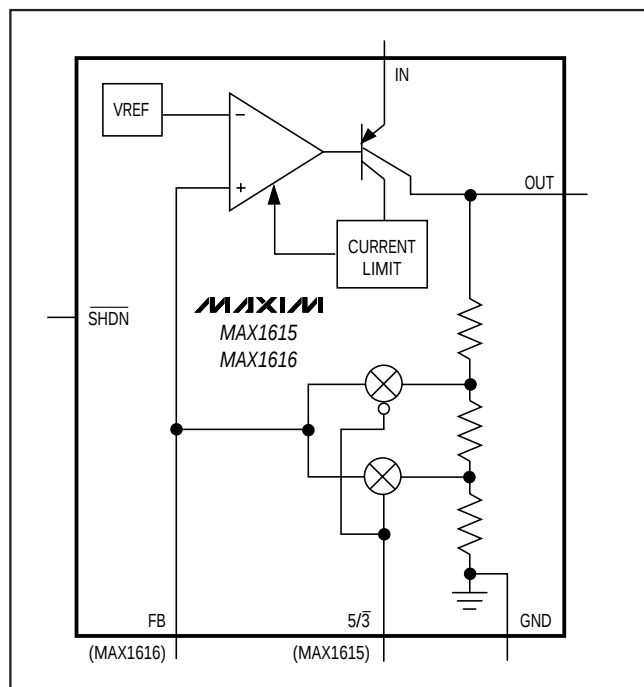


Figure 1. Functional Diagram

## Detailed Description

The MAX1615/MAX1616 low-quiescent-current linear regulators are designed primarily for high input voltage applications. The MAX1615 supplies a preselected 3.3V or 5.0V output for loads up to 30mA. The MAX1616 provides an adjustable voltage from 1.24V to 28V. The maximum output current is a function of the package's maximum power dissipation for a given temperature. A 5μA load is required to maintain output regulation.

The MAX1615's output voltage is fed back through an internal resistor voltage divider connected to OUT. Set the output voltage to either 3.3V or 5.0V with the  $5/\bar{3}$  pin. Select the 5V output by connecting  $5/\bar{3}$  to OUT, or the 3.3V output by connecting  $5/\bar{3}$  to GND.

The MAX1616 uses external feedback, allowing the output voltage to be set by external resistors (see *Setting the MAX1616 Output Voltage* section). The typical FB threshold is at 1.24V.

### Shutdown

The device enters shutdown mode when  $\overline{\text{SHDN}}$  is low. In shutdown mode, the pass transistor, control circuit, reference, and all biases turn off, reducing the supply current to below 1μA. Connect  $\overline{\text{SHDN}}$  to IN for automatic start-up.

### Current Limit

Output current is limited to 100mA (typical). The current limit exceeds the 30mA (max) safe operating limit. The output can be shorted to ground for 30 seconds without damaging the part.

### Thermal-Overload Protection

When the junction temperature exceeds  $T_J = +150^\circ\text{C}$ , the thermal sensor sends a signal to the shutdown logic, turning off the pass transistor and allowing the IC to cool. The thermal sensor turns the pass transistor on again after the IC's junction temperature cools by  $+20^\circ\text{C}$  (typical), resulting in a pulsating output during continuous thermal-overload conditions.

### Operating Region and Power Dissipation

Maximum power dissipation depends on the thermal resistance of the case and circuit board, the temperature difference between the die junction and ambient air, and the rate of air flow. The device's power dissipa-

# High-Voltage, Low-Power Linear Regulators for Notebook Computers

tion is  $P = I_{OUT}(V_{IN} - V_{OUT})$ . The power dissipation at +70°C ambient is 571mW (see *Absolute Maximum Ratings*). The thermal resistance junction-to-case of the SOT23-5 package is 81°C/W, and the maximum safe junction temperature is +150°C.

The GND pin performs the dual function of providing an electrical connection to ground and channeling heat away. Connect GND to ground using a large pad or ground plane.

## Applications Information

### Setting the MAX1616 Output Voltage

Set the MAX1616's output voltage with two resistors, R1 and R2 (Figure 2). Choose R2 = 250kΩ to maintain a 5μA minimum load and calculate R1 using the following equation:

$$R1 = R2 \left( \frac{V_{OUT}}{V_{FBT}} - 1 \right)$$

where  $V_{FBT} = 1.24V$  (typical).

### Capacitor Selection

Use a 0.1μF minimum capacitor on the input. Higher values will improve line-transient response.

Use 1μF minimum on the output, or 4.7μF for the full 30mA load current (6.8μF, MAX1616). Otherwise, use 1μF plus 0.125μF/mA (0.2μF/μA, MAX1616). For output voltages less than 3.3V, use 15μF instead of 6.8μF. The output capacitor's effective series resistance (ESR) must be less than 1Ω for stable operation.

### Output Voltage Noise

The MAX1615/MAX1616 typically exhibit 5mVp-p of noise during normal operation. This is negligible in most applications. In applications that include analog-to-digital converters (ADCs) of more than 12 bits, consider the ADC's power-supply-rejection specifications.

### Transient Response

The *Typical Operating Characteristics* show the MAX1615/MAX1616's load-transient response. Two of the output response's components can be observed on the load-transient graph: a DC shift from the output impedance due to the different load currents, and the transient response. Typical step changes in the load current from 10mA to 20mA produce 50mV transients. Increasing the output capacitor's value attenuates transient spikes.

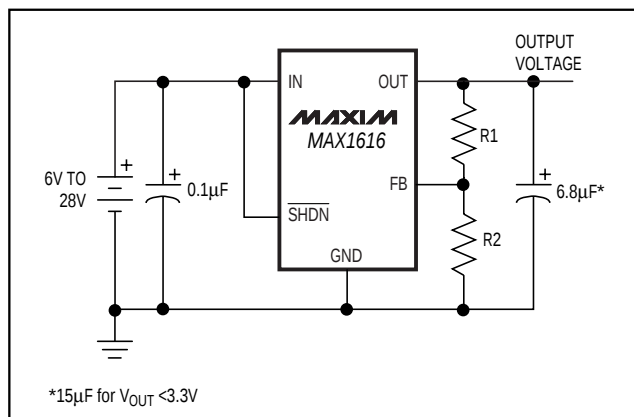


Figure 2. MAX1616 Typical Application Circuit

## Table 1. Surface-Mount Capacitor Manufacturers

| TYPE         | MANUFACTURER | CAPACITOR        |
|--------------|--------------|------------------|
| Electrolytic | AVX          | TPS series       |
|              | Matsuo       | 267 series       |
|              | Sprague      | 593D, 595 series |
| Ceramic      | AVX          | X7R              |
|              | Matsuo       | X7R              |

## Table 2. Component Suppliers

| SUPPLIER | PHONE          | FAX            |
|----------|----------------|----------------|
| AVX      | (803) 946-0690 | (803) 626-3123 |
| Matsuo   | (714) 969-2491 | (714) 960-6492 |
| Sprague  | (603) 224-1961 | (603) 224-1430 |

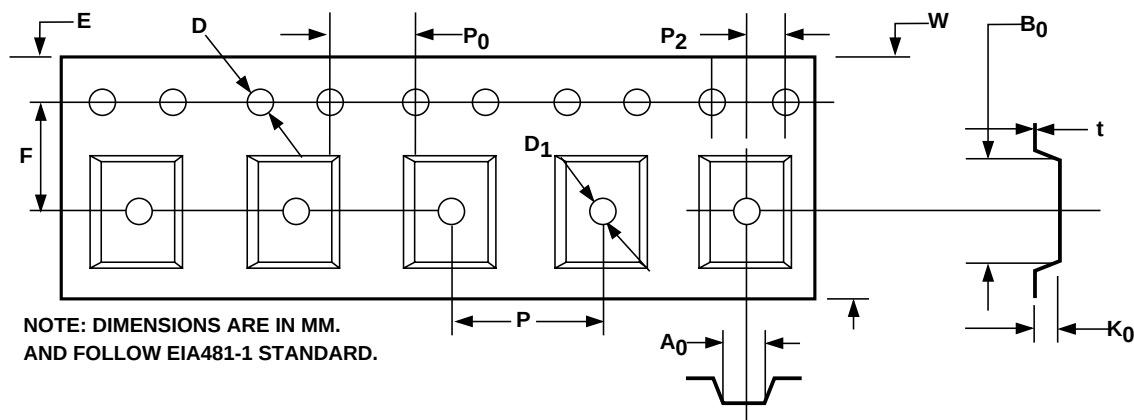
## Chip Information

TRANSISTOR COUNT: 386

# High-Voltage, Low-Power Linear Regulators for Notebook Computers

## Tape-and-Reel Information

MAX1615/MAX1616



NOTE: DIMENSIONS ARE IN MM.  
AND FOLLOW EIA481-1 STANDARD.

|                |       |                  |
|----------------|-------|------------------|
| A <sub>0</sub> | 3.200 | ±0.102           |
| B <sub>0</sub> | 3.099 | ±0.102           |
| D              | 1.499 | +0.102<br>+0.000 |
| D <sub>1</sub> | 0.991 | +0.254<br>+0.000 |

|                |       |        |
|----------------|-------|--------|
| E              | 1.753 | ±0.102 |
| F              | 3.505 | ±0.051 |
| K <sub>0</sub> | 1.397 | ±0.102 |
| P              | 3.988 | ±0.102 |

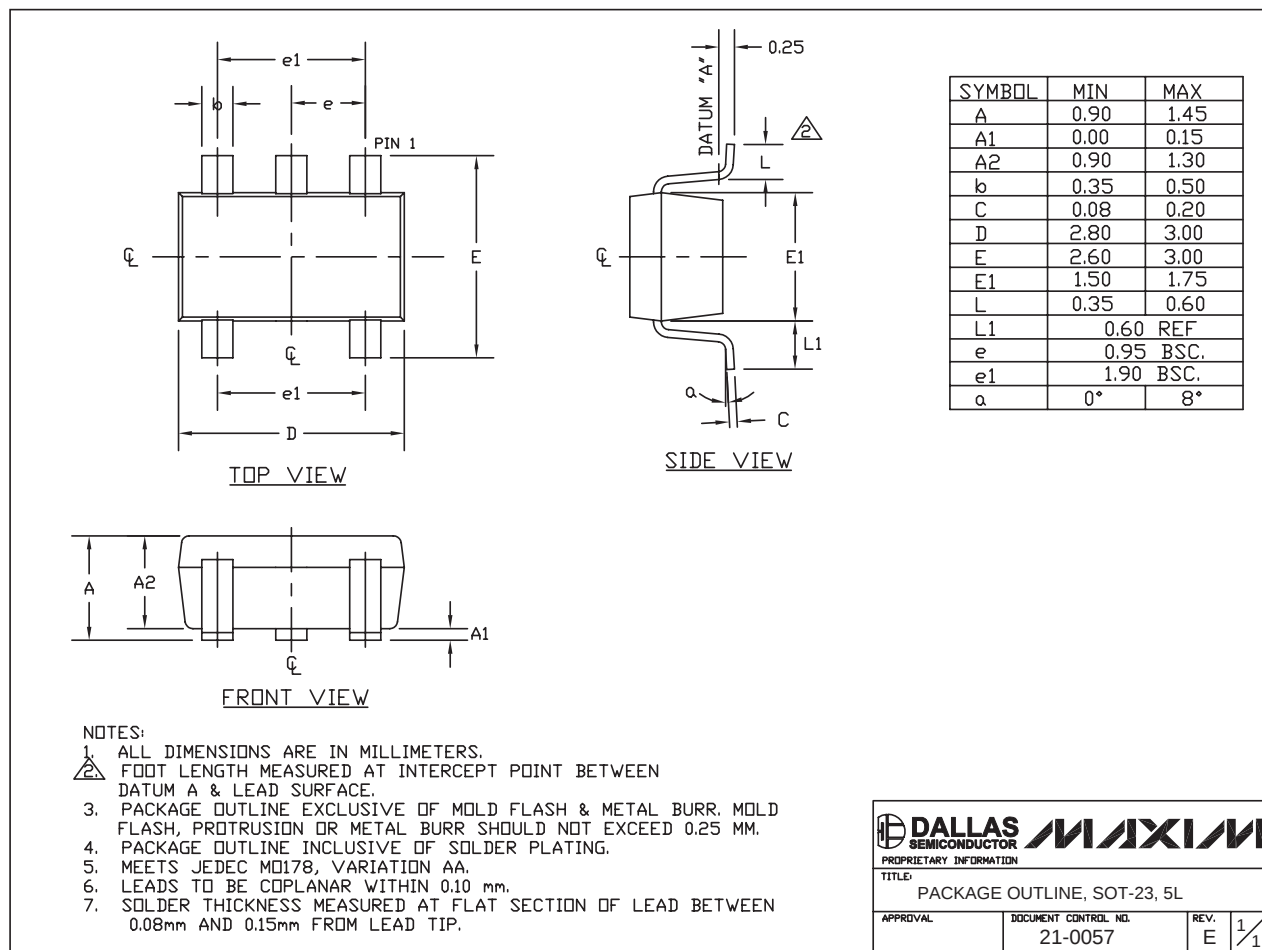
|                  |        |                  |
|------------------|--------|------------------|
| P <sub>0</sub>   | 3.988  | ±0.102           |
| P <sub>010</sub> | 40.005 | ±0.203           |
| P <sub>2</sub>   | 2.007  | ±0.051           |
| t                | 0.254  | ±0.127           |
| W                | 8.001  | +0.305<br>-0.102 |

5 SOT23-5

# High-Voltage, Low-Power Linear Regulators for Notebook Computers

## Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)



SOT-23 5L .EPS

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