

**EVALUATION KIT  
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# Battery-Powered Supply Systems

## General Description

The MAX714/715/716 battery-powered supply systems combine multiple regulated voltage outputs with micro-processor supervisory functions that are optimized for battery-powered supplies. High-level integration and low-power CMOS simplify high-efficiency power-supply design in portable and battery-operated instruments.

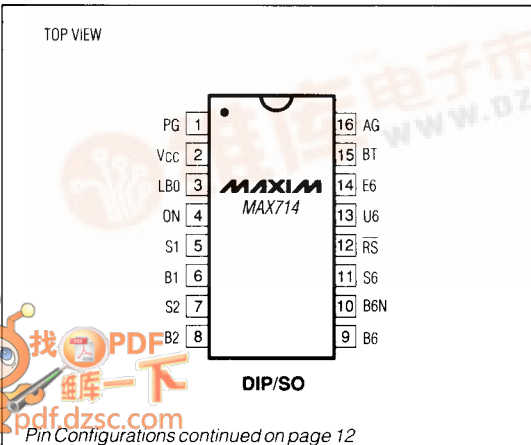
The MAX716 combines circuitry for four low-dropout linear regulators, three DC-DC switching regulators, and power-supervisory functions on a single IC. All but one regulator output is logic controlled so that loads may be shut down to extend battery life. Linear-regulator outputs are pre-trimmed to +5V and operate with only 0.1V input-output differential. In addition, three DC-DC switching regulators generate a fixed negative output (-5V, -12V, or -15V), a software-adjustable negative output (-5V to -26V) to power LCD displays, and a positive boosted output voltage (+12 or +15). Other functions include backup-battery switchover, low-voltage warning, and power-fail reset.

The MAX716 is supplied in 28-pin plastic DIP and wide SO packages. The MAX715, in 24-pin narrow plastic DIP and CERDIP packages, eliminates one linear-regulator output. The MAX714, in 16-pin packages, includes two linear regulators and the LCD display DC-DC converter.

## Applications

- Portable Computers
- Battery-Powered, Microprocessor-Based Systems
- Handheld Instruments, Terminals
- Bar-Code Readers
- Remote Data-Acquisition Systems

## Pin Configurations



## Features

- ◆ Four Logic-Controlled +5V Regulators
- ◆ Three Switching Regulators
- ◆ 35 $\mu$ A Quiescent Current in Standby Mode
- ◆ 100mV Dropout on Linear Regulators
- ◆ CMOS RAM Battery-Switchover Circuit
- ◆ Microprocessor Reset and Interrupt Outputs
- ◆ Hardware-On Signal
- ◆ Evaluation Kit Available – MAX716EVKIT

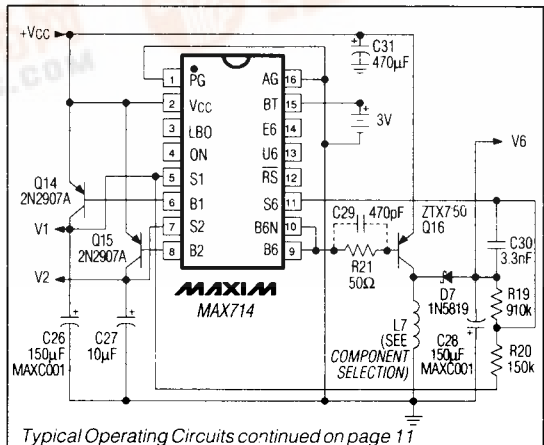
## Ordering Information

| PART      | TEMP. RANGE     | PIN-PACKAGE           |
|-----------|-----------------|-----------------------|
| MAX714CPE | 0°C to +70°C    | 16 Plastic DIP        |
| MAX714CWE | 0°C to +70°C    | 16 Wide SO            |
| MAX714C/D | 0°C to +70°C    | Dice*                 |
| MAX714EPE | -40°C to +85°C  | 16 Plastic DIP        |
| MAX714EWE | -40°C to +85°C  | 16 Wide SO            |
| MAX714MJE | -55°C to +125°C | 16 CERDIP             |
| MAX715CNG | 0°C to +70°C    | 24 Narrow Plastic DIP |
| MAX715CWG | 0°C to +70°C    | 24 Wide SO            |
| MAX715C/D | 0°C to +70°C    | Dice*                 |
| MAX715ENG | -40°C to +85°C  | 24 Narrow Plastic DIP |
| MAX715EWG | -40°C to +85°C  | 24 Wide SO            |
| MAX715MRG | -55°C to +125°C | 24 Narrow CERDIP      |

Ordering information continued on page 12.

\*Contact factory for dice specifications.

## Typical Operating Circuits



# Battery-Powered Supply Systems

## ABSOLUTE MAXIMUM RATINGS

### Input Supply Voltages

|                             |  |
|-----------------------------|--|
| V <sub>CC</sub> , BT        | -0.3V to +12V  |
| S1-S7, B1-B7, ON, E3-E7, U6 | -0.3V to the higher of V <sub>CC</sub> +0.3V or BT+0.3 |

LBO,  $\overline{RS}$  -0.3V to V1+0.3V

Maximum  $\Delta V/\Delta T$  on V<sub>CC</sub> 1V/ $\mu$ s

Maximum  $\Delta V/\Delta T$  on BT Infinite

### Continuous Power Dissipation

#### Plastic DIP

16-Pin (derate 7.41mW/°C above +70°C) 593mW

24-Pin Narrow (derate 8.7mW/°C above +70°C) 696mW

28-Pin (derate 9.09mW/°C above +70°C) 727mW

#### Wide SO

16-Pin (derate 9.52mW/°C above +70°C) 762mW

24-Pin (derate 11.76mW/°C above +70°C) 941mW

28-Pin (derate 12.50mW/°C above +70°C) 1000mW

### CERDIP

16-Pin (derate 10mW/°C above +70°C) 800mW

24-Pin Narrow (derate 12.5mW/°C above +70°C) 1000mW

28-Pin (derate 16.67mW/°C above +70°C) 1333mW

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

(AG = PG = 0V, V<sub>CC</sub> = +5.05V to +11V, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted.)

| PARAMETER  | SYMBOL          | CONDITIONS   | MIN    | TYP  | MAX   | UNITS   |
|--|-----------------|--|--------|------|-------|---------|
| Operating Voltage Range                                | V <sub>CC</sub> | Regulated output   | 5.05   |      | 11.00 | V       |
| Low Battery Indicator Threshold (Note 1)               | LBO             | MAX71_C_ _   | 5.05   | 5.16 | 5.27  | V       |
| Shutdown Voltage Range                                 |                 | MAX71_C_ _   | 4.81   | 4.92 | 5.05  | V       |
| Delta Between LBO and $\overline{RS}$ (Note 1)         |                 | MAX71_C_ _   | 0.19   | 0.24 | 0.29  | V       |
| Low Battery Indicator Threshold (Note 1)               | LBO             | MAX71_E/M_ _   | 4.94   | 5.16 | 5.27  | V       |
| Shutdown Voltage Range                                 |                 | MAX71_E/M_ _   | 4.70   | 4.92 | 5.05  | V       |
| Delta Between LBO and $\overline{RS}$ (Note 1)         |                 | MAX71_E/M_ _   | 0.17   | 0.24 | 0.31  | V       |
| Battery Input  | BT              |  | 2.3    |      | 4.0   | V       |
| Supply Current in Backup State                         |                 | V <sub>CC</sub> = 0V, BT = 3V, MAX71_C_ _  |        | 7    | 15    | $\mu$ A |
|  |                 | V <sub>CC</sub> = 0V, BT = 3V, MAX71_E/M_ _  |        | 7    | 20    | $\mu$ A |
| Supply Current in Standby State (ON = 0V)              |                 | V <sub>CC</sub> = 11V, BT = 3V   |        | 35   | 55    | $\mu$ A |
| Supply Current in Operating State (ON = V1)            |                 | V <sub>CC</sub> = 11V, BT = 3V,<br>V1 and V2 on only, I <sub>OUT</sub> = 0 $\mu$ A |        | 300  | 500   | $\mu$ A |
| $\overline{RS}$ Pulse Width                            |                 |  | 160    | 230  | 350   | ms      |
| V <sub>CC</sub> to BT Power-Supply Switchover (Note 2) |                 |  | -200   |      | -50   | mV      |
| BT to V <sub>CC</sub> Power-Supply Switchover (Note 2) |                 |  | 50     |      | 200   | mV      |
| BT Input Current (Note 3)                              |                 | BT = 3V, V <sub>CC</sub> = 5.05-11V  | -1.00  | 0.01 | 1.00  | $\mu$ A |
| Digital Input Levels; ON, E3-E7, U6                    | V <sub>IH</sub> |  | V1-0.7 |      |       | V       |
|  | V <sub>IL</sub> |  | V1-0.3 |      |       | V       |
|  | I <sub>IH</sub> | Digital input current  |        | 5    |       | $\mu$ A |
| Digital Outputs; $\overline{RS}$ , LBO                 | V <sub>OH</sub> | I <sub>OUT</sub> = -500 $\mu$ A  | V1-0.5 |      |       | V       |
|  | V <sub>OL</sub> | I <sub>OUT</sub> = 500 $\mu$ A   |        | 0.5  |       | V       |

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MAX714/715/716

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## ELECTRICAL CHARACTERISTICS (continued)

(AG = PG = 0V, VCC = +5.05V to +11V, TA = TMIN to TMAX, unless otherwise noted.)

| PARAMETER   | SYMBOL          | CONDITIONS                          | MIN          | TYP   | MAX   | UNITS         |    |
|---|-----------------|-------------------------------------|--------------|-------|-------|---------------|----|
| <b>LINEAR REGULATORS V1 - V4</b>  |                 |                                     |              |       |       |               |    |
| Output Voltage (Note 4)   | VOUT            | 5.05 < VCC < 11                     | 4.75         |       | 5.25  | V             |    |
|   |                 | VCC = 5.05, IOUT = 100mA            | 4.75         |       | 5.25  |               |    |
| Load Regulation (Note 4)  |                 | IOUT = 1mA to 100mA,<br>VCC = 9V    |              | 35    | 100   | mV            |    |
| Line Regulation (Note 4)  |                 | VCC = 5.05V to 11V,<br>IOUT = 1mA   |              | 20    | 100   | mV            |    |
| Additional Operating Supply Current when each V3, V4 Input is Enabled     |                 | VCC = 11V                           |              | 100   | 200   | μA            |    |
| Output Voltage Tracking Maximum Difference Between V1, V2, V3, V4         |                 | VCC = 5.05V to 11V,<br>IOUT ≤ 100mA | -300         |       | 300   | mV            |    |
| B1-B4 Maximum Sink Capability   |                 | VCC = 9V,<br>B1-B4 = 5V             | 10           | 50    | 85    | mA            |    |
| B1 Sink Capability  |                 | During standby mode                 |              | 100   |       | μA            |    |
| <b>DC-DC CONVERTERS V5 - V7</b>   |                 |                                     |              |       |       |               |    |
| Additional Operating Supply Current when each V5, V6, V7 Input is Enabled |                 | VCC = 11V                           |              | 125   | 200   | μA            |    |
| Extra Operating Supply Current when RC Oscillator Enabled (Note 5)        |                 | VCC = 11V                           |              | 225   | 300   | μA            |    |
| Oscillator Timing<br>High Period<br>Low Period                            | TON<br>(Note 6) | VCC = 5.5V, MAX71_C__               | 10.22        | 11.36 | 12.45 | μs            |    |
|   |                 | VCC = 11V, MAX71_C__                | 4.56         | 5.70  | 6.84  |               |    |
|   | TOFF            | VCC = 5.5V to 11V, MAX71_C__        | 11.25        | 12.50 | 13.75 |               |    |
| Oscillator Timing<br>High Period<br>Low Period                            | TON<br>(Note 6) | VCC = 5.5V, MAX71_E/M__             | 9.09         | 11.36 | 13.63 | μs            |    |
|   |                 | VCC = 11V, MAX71_E/M__              | 4.56         | 5.70  | 6.84  |               |    |
|   | TOFF            | VCC = 5.05V to 11V, MAX71_E/M__     | 10           | 12.50 | 15    |               |    |
| Input Leakage Current S5-S7   |                 | VCC = 11V, S5-S7 = 1V               | -1           |       | 1     | μA            |    |
| S5 Voltage  |                 | E5 = V1                             | -30          |       | 30    | mV            |    |
| S6 Voltage  |                 | E6 = V1,<br>controlled by DAC       | Code = 00000 | -70   |       | 70            | mV |
|   |                 |                                     | Code = 11111 | 1.18  |       | 1.32          | V  |
| S7 Voltage  |                 | E7 = V1                             | 1.18         | 1.25  | 1.32  | V             |    |
| B5, B6, B7 Drive Voltages   | VOL             | VCC = 5.5V, ISINK = 10mA            |              | 0.5   | 1.0   | V             |    |
|   | VOH             | VCC = 5.5V, ISOURCE = 10mA          | 4.0          | 4.5   |       |               |    |
| Efficiency  |                 |                                     |              | 85    |       | %<br>(Note 7) |    |

**Note 1:** Typical ramp rate 1V/ms.

**Note 2:** Tested with less than 1V/ms on VCC and BT separately.

**Note 3:** To minimize test time, a larger max spec was chosen. The typical value indicates the mean value.

**Note 4:** A Motorola 2N2907A PNP was used as the output transistor in Figure 1.

**Note 5:** RC oscillator is enabled whenever any one of the DC-DC converters is enabled.

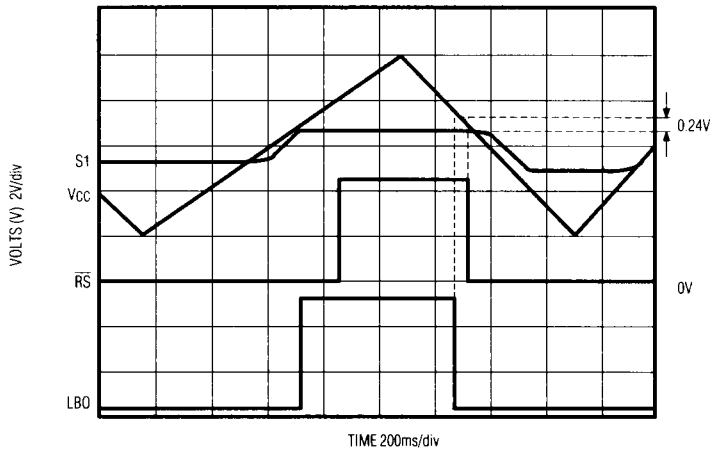
**Note 6:** TON varies proportionally to 1/VCC.

**Note 7:** The efficiency depends on external components and can be increased or decreased from this typical value.

# Battery-Powered Supply Systems

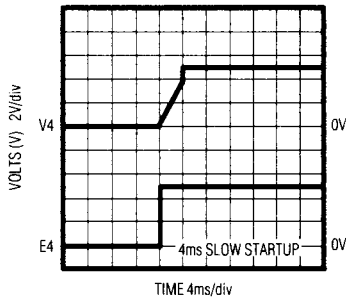
## Typical Operating Characteristics

BACKUP-BATTERY SWITCHING AND WARNING FLAGS



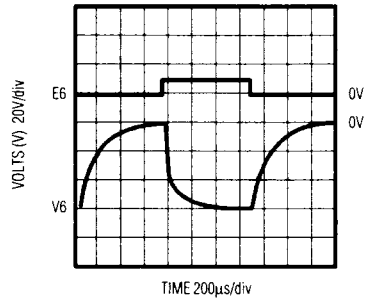
NOTE: THE BACKUP BATTERY IS AT 3V

REGULATOR 4 TURN-ON TIME



REGULATOR 4  $V_{OUT}$  0V TO +5V  
WITH LOAD OF 390 $\Omega$  AND 150 $\mu$ F

REGULATOR 7 TURN-ON TIME



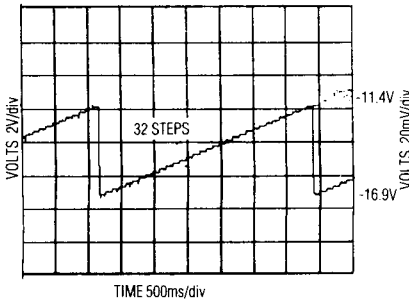
REGULATOR 7  $V_{OUT}$  0V TO -30V  
 $I_{OUT}$  0mA TO -30mA 10V/div

# Battery-Powered Supply Systems

## Typical Operating Characteristics (continued)

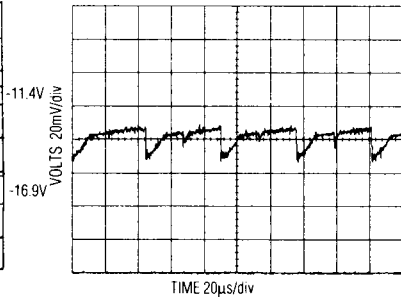
MAX714/715/716

**REGULATOR 7  $V_{out}$  STEPPING**



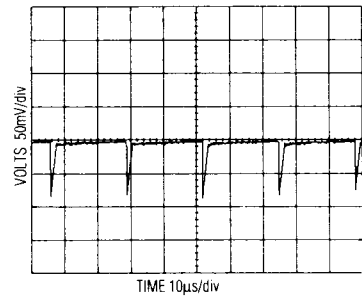
REGULATOR 7  $V_{out}$  -11.4 TO -16.9 V WITH 10k $\Omega$  LOAD

**REGULATOR 6 OUTPUT RIPPLE UNFILTERED**



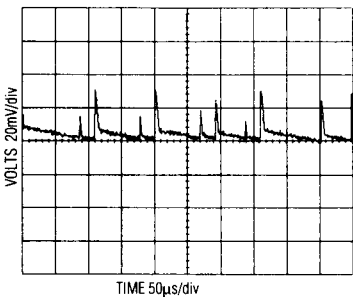
REGULATOR 6  $V_{out}$  = -5V WITH 250 $\Omega$  LOAD

**REGULATOR 7 OUTPUT RIPPLE UNFILTERED**



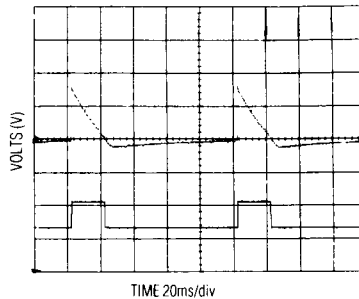
REGULATOR 7  $V_{out}$  = -30V WITH 150k $\Omega$  LOAD

**REGULATOR 8 OUTPUT RIPPLE UNFILTERED**



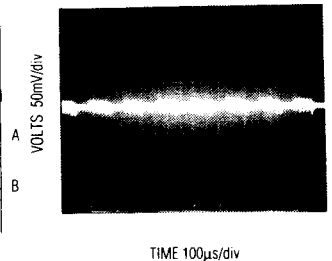
REGULATOR 8  $V_{out}$  = +15V WITH 1.5k $\Omega$  LOAD

**V2 LINE TRANSIENT RESPONSE**



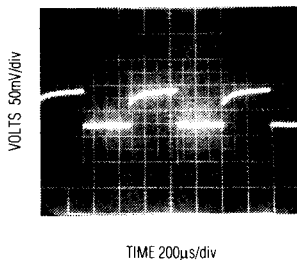
A = V2 VOLTAGE OUT 2V/div  
B = LINE TRANSIENT SWITCH 5V/div

**V5 LOAD-TRANSIENT RESPONSE**



0mA TO -40mA LOAD  
 $V_{CC}$  = +9V,  $V_{out}$  = -5V  
ZTX749 OUTPUT TRANSISTOR

**V4 LOAD-TRANSIENT/DROPOUT RESPONSE**



0mA TO 100mA LOAD  
 $V_{CC}$  = +9V,  $V_{out}$  = -5V  
2N2907 OUTPUT TRANSISTOR

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## Pin Description

| MAX714<br>PIN | MAX715<br>PIN | MAX716<br>PIN | NAME | FUNCTION   |
|---------------|---------------|---------------|------|--|
| 15            | 1             | 1             | BT   | Backup-Battery Input   |
| 16            | 2             | 2             | AG   | Analog Ground  |
| 1             | 3             | 3             | PG   | High-Power Ground  |
| 2             | 4             | 4             | VCC  | Main Supply Input: +5.05V to +11V                                      |
| 3             | 5             | 5             | LBO  | Low Battery Warning Output. High when VCC > 5.16V.                     |
| 4             | 6             | 6             | ON   | Hardware-On Input. Logic-high level activates V2-V7. V1 is always on.  |
| -             | -             | 7             | S4   | V4, Feedback-Sense Input   |
| -             | -             | 8             | B4   | V4, Base drive for linear regulator output transistor                  |
| 5             | 7             | 9             | S1   | V1, Feedback-Sense Input   |
| 6             | 8             | 10            | B1   | V1, Base drive for linear regulator output transistor                  |
| 7             | 9             | 11            | S2   | V2, Feedback-Sense Input   |
| 8             | 10            | 12            | B2   | V2, Base drive for linear regulator output transistor                  |
| -             | 11            | 13            | B3   | V3, Base drive for linear regulator output transistor                  |
| -             | 12            | 14            | S3   | V3, Feedback-Sense Input   |
| -             | 13            | 15            | B5   | V5, Base drive for the inverting output transistor                     |
| -             | 14            | 16            | S5   | V5, Feedback-Sense Input   |
| 9             | 15            | 17            | B6   | V6, Base drive for LCD inverting output transistor (MAX714 - B6P)      |
| 10            | -             | -             | B6N  | V6, MAX714 only  |
| 11            | 16            | 18            | S6   | V6, Feedback-Sense Input – for adjustable (LCD) switching regulator    |
| -             | 17            | 19            | B7   | V7, Base-/Gate-Drive Output – step-up switching transistor/MOSFET      |
| -             | 18            | 20            | S7   | V7, Feedback-Sense Input – step-up switching regulator                 |
| 12            | 19            | 21            | RS   | Reset Output – low during power-up, battery-backup, and standby states |
| -             | 20            | 22            | E3   | V3, Enable Input   |
| -             | -             | 23            | N.C. | No Connect   |
| -             | -             | 24            | E4   | V4, Enable Input   |
| 13            | 21            | 25            | U6   | Pulsing this input increments V6 negative output                       |
| -             | 22            | 26            | E5   | V5, Enable Input   |
| 14            | 23            | 27            | E6   | V6, Enable Input   |
| -             | 24            | 28            | E7   | V7, Enable Input   |

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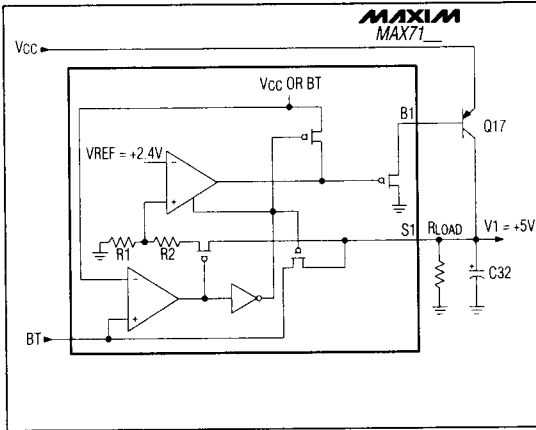


Figure 1. Functional Diagram and Circuit for Linear Regulator V1

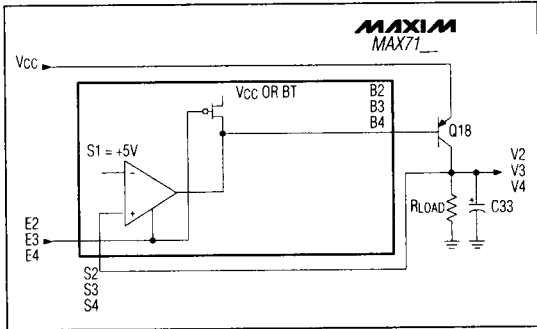


Figure 2. Functional Diagram and Circuit for Linear Regulators V2-V4

## Detailed Description

External PNP pass transistors provide low-dropout linear outputs while minimizing regulator interaction and maximizing line and load rejection. The switching regulators employ external switching transistors to maximize efficiency at low input voltages.

DC-DC converter output current is primarily determined by the selected inductors and transistors. Inductors and transistors for several voltage and current outputs are listed in Table 1.

A "speed-up" capacitor (C29) (see *Typical Operating Characteristics*, page 1) appears in dotted lines across the base resistor of the DC-DC converter's output transistor. This capacitor reduces switching time and increases efficiency by about 2%. It may be omitted if efficiency improvement is not needed. Linear-regulator (V1-V4) output current is determined by the current capability of

TABLE 1: COMPONENT SELECTION

| REGULATOR | TRANSISTOR | INDUCTOR*        | V <sub>OUT</sub> (V) | I <sub>OUT</sub> (mA) |
|-----------|------------|------------------|----------------------|-----------------------|
| V5        | 2N2907A    | 470μH CB 7070-33 | -5                   | -30                   |
| V5        | 2N2907A    | 390μH CB 7070-32 | -5                   | -36                   |
| V5        | ZTX750     | 100μH CB 7070-25 | -5                   | -100                  |
| V6        | 2N2907A    | 220μH CB 7070-29 | -18                  | -17                   |
| V6        | ZTX750     | 82μH CB 7070-24  | -26                  | -30                   |
| V6        | ZTX750     | 100μH CTX100-3   | -26                  | -28                   |
| V7        | 2N2222A    | 470μH CB 7070-33 | 15                   | 14                    |
| V7        | 2N2222A    | 220μH CB 7070-29 | 15                   | 30                    |

\* CB = Caddell-Burns, CTX = Coiltronics, ZTX = Zetex

the selected output PNP pass transistors. The 2N2907A transistors in Figure 1 can provide load currents up to approximately 600mA.

The Caddell-Burns (CB) inductors are ferrite-bobbin cylindrical coils and the Coiltronics (CTX) is a surface-mount toroidal inductor.

## Linear Regulators

Linear-regulator output current is a function of the selected PNP pass transistors. As the input voltage rises, power dissipation in the transistor limits the safe output current. Very little power is dissipated in the MAX714/715/716 devices, but each transistor must dissipate  $(V_{CC} - V_{OUT}) \times I_{OUT}$ . Consult the pass-transistor data sheets for power-dissipation and thermal-resistance limits.

To maintain stability, 10μF output capacitors are required at the V2-V4 linear regulator outputs. 150μF is recommended at V1, as it serves as the V2-V4 reference, and V1 output ripple may feed through to other regulator outputs.

For V2-V4, use these minimum capacitor values:

$$I_{LOAD} 500mA - 100\mu F$$

$$I_{LOAD} 50mA - 10\mu F$$

Outputs B1-B4 drive the bases of external PNP pass transistors and sink a minimum of 10mA. The output voltage at the collector of the external PNP transistor is sensed at S1-S4 to maintain regulation. When an output is turned off, the base-drive output rises to VCC (or BT whichever is higher), turning off the pass transistor.

Short-circuit current limiting and thermal shutdown are not implemented in the regulator outputs. Consequently,

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short-circuit current is limited only by the maximum B1-B4 sink current (85mA) and the transistor current gain (beta).

During standby, when the ON input is low or  $V_{CC} < 4.95V$ , B1 is limited to  $100\mu A$  to reduce power consumption during dropout (dropout occurs when  $V_{CC}$  falls below 5V). During start-up, V2-V4 base currents limit at approximately 0.5mA for about 4ms to prevent large load-current transients. The external PNP transistors should have betas above 100 and  $f_t$  above 200MHz. Typical transistors are 2N2907A and 2N3905.

All 5V outputs have a tolerance of  $\pm 5\%$  over the specified  $V_{CC}$  input voltage, output current, and temperature ranges. V1 serves as the reference for all other 5V outputs to maintain optimum tracking between outputs.

## Switching Regulators

### Inverters

Figures 3 and 4 show typical operating circuits for the V5 and V6 inverting regulators. V5's feedback input (S5) is kept at 0V in regulator 5. In regulator 6, S6 is digitally adjusted from 0V to +1.25V, providing a variable negative supply for LCD power.

When V5 (Figure 3) becomes less negative than the level set by the R23 and R24 resistor dividers, B5 toggles at the oscillator frequency ( $f_{OSC}$  varies with  $V_{CC}$ ; see *Electrical Characteristics*), turning on Q19 when B5 is low. When Q19 turns on, current increases in the L8 inductor, storing energy in its magnetic field. When Q19 is off, current flows through L8 in the same direction, flowing from C35 through D8, making V5 more negative. As inductor energy is transferred to C35, the inductor current decays linearly to zero and its magnetic field collapses. V6 (Figure 4) operates similarly to V5, except its output is varied by a digital input signal at V6.

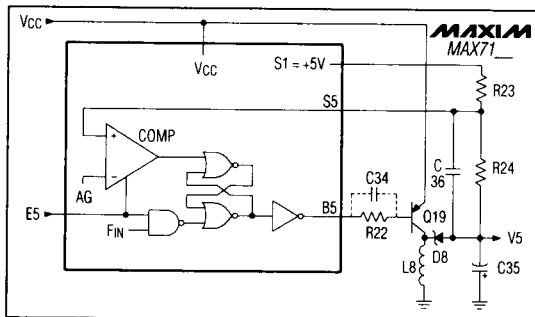


Figure 3. Functional Diagram and Circuit for DC-DC Converter V5

The B5 and B6 outputs are suitable for driving external PNP or logic-level P-channel MOSFET switching transistors (such as the Siliconix SMD10PO5L); however, PNP

transistors are less expensive for input voltages below 7V. Likewise, the B7 output can drive a logic-level N-channel MOSFET such as the Siliconix Si9956DY.

The output voltages of V5 and V6 are set by these equations:

$$R24 = -V5 \times (R23/5)$$

$$R27 = -R26 \times (V6 - V_{TH}) / (5 - V_{TH}), \quad V_{TH} = 0V \text{ to } +1.25V$$

The V6 output (Figure 4) is generated in the same fashion as V5, except that the S6 threshold can be varied from 0V to +1.25V with an internal 5-bit (32 step) DAC. The DAC is incremented by pulsing U6 and can only be incremented in one direction (more negative). To reduce the voltage (less negative), the DAC must loop completely around; to decrement by one step, U6 must be clocked 31 times. The DAC is set to 0V during standby and whenever V6 is turned off.

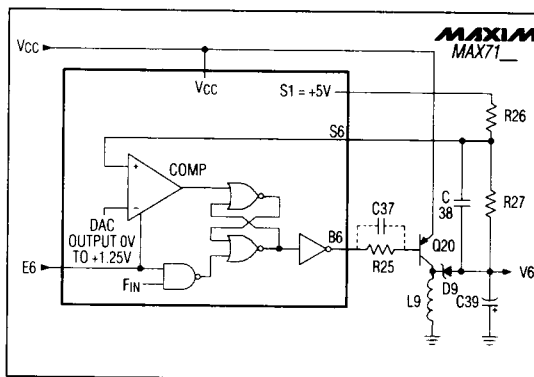


Figure 4. Functional Diagram and Circuit for DC-DC Converter V6

V6's output voltage range is set by an external resistor divider connected between V1 (used as a reference) and V6 (see Table 2). A good typical value for R26 is 150kΩ. The ratio of the resistors to each other sets the voltage ranges as follows. Choose the high value to be within the absolute maximum of the display.

TABLE 2: V6 (LCD POWER) VOLTAGE RANGE

| R27/R26 RATIO | V6 OUTPUT VOLTAGE RANGE (V) |
|---------------|-----------------------------|
| 6:1           | -30 to -21.3                |
| 5:1           | -25 to -17.5                |
| 4:1           | -20 to -13.8                |
| 3:1           | -15 to -10                  |
| 2:1           | -10 to -6.3                 |
| 1:1           | -5 to -2.5                  |



# Battery-Powered Supply Systems

## Step-Up Converter

Regulator V7 operates similarly to V5, except that it steps up rather than inverts. In Figure 5, the feedback input (S7) is kept at 1.25V. B7 swings from 0V to VCC, and can drive either the gate of an N-channel power MOSFET or the base of an NPN transistor. When V7 is at the desired voltage, B7 remains low, keeping Q21 off. When V7 falls below the preset level, B7 switches Q21 on and off at the clock frequency. When Q21 turns off, inductor current flows through D10 into C41, and VOUT rises. R30 is set by:

$$R30 = R29 \times 1.25 / (V7 - 1.25)$$

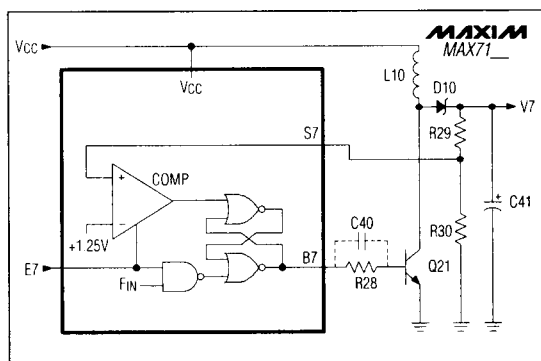


Figure 5. Functional Diagram and Circuit for DC-DC Converter V7

## Switching Frequency and Soft Start

The switching frequency is set by an internal oscillator. The oscillator high period (switch-on time) is inversely proportional to VCC and peak inductor current remains constant over variations in input voltage. The high period is typically 11.36µs with VCC = 5.5V, and 5.7µs with VCC = 11V. The low period (off time) is typically 12.5µs and is independent of VCC.

A soft-start circuit limits the oscillator duty cycle at start-up by enabling the switch during every 8th oscillator cycle only. The soft-start duration is approximately 4ms. This prevents large current drain at turn-on.

## Board Layout and Grounding

Since the V5-V7 DC-DC converters use feedback control circuitry, it is important to minimize the lengths of GND connections and feedback points. Minimize the size of the connections between S5, S6, S7, and the respective resistors, and place the transistors' output bases as close as possible to the respective B5, B6, and B7 base pins. The traces connecting the VCC pins to the input capacitor (C28 or C31 in *Typical Operating Circuits*) must be

separate from the high current traces of the linear switching circuits.

## Switching-Regulator Components

### Inductor Selection

The output power of each switching regulator depends on the selected inductor and switching transistor. Table 1 lists components for two ranges of output current (see *Typical Operating Characteristics*). Other inductor types may also be used, but be sure to observe their peak current ratings.

For the output power levels given in Table 1, Caddell-Burns 7070 inductors were used. However, smaller size inductors may be used in low output-current applications. In general, higher internal resistance and lower current ratings reduce efficiency and increase the chance of inductor saturation. Be sure to observe the manufacturer's ratings on substitute coils. Coiltronics produces surface-mount inductors that have relatively high-power capacity compared to their size. For alternate output voltage, current values, or coil selection, contact Maxim's applications department.

Coil saturation is the most likely cause of poor efficiency, overheating, and component damage in switching-regulator circuits. Test for saturation by applying the maximum load over the full input voltage range while monitoring the inductor current with a current probe. The normal inductor-current waveform is a sawtooth with a linear increase and decrease of current. Saturation creates a nonlinear current waveform where current slope increases as the current level rises.

### Capacitor Selection

The V5-V7 output ripple contains two elements. One is the result of change in the stored charge on the filter capacitor with each current pulse. The other element is the effect of the capacitor's charge/discharge current and its equivalent series resistance (ESR). With low-cost aluminum electrolytic capacitors, ESR-produced ripple may sometimes be greater than that caused by the change in charge. Consequently, high-quality aluminum or tantalum filter capacitors minimize output ripple, even when smaller capacitance values are used. Best results at reasonable cost are achieved with a high-quality aluminum electrolytic capacitor in parallel with a 0.1µF ceramic capacitor. For V5-V7, the MAXC001 or equivalent capacitor is recommended for an output filter.

The Typical Operating Circuit on page 11 shows capacitors C8-C10 as dashed lines connected in parallel with the base resistors of transistors Q5-Q7. These capacitors improve efficiency by about 2% by reducing switching time, but can be omitted if component count is critical.

# Battery-Powered Supply Systems

## Rectifier Selection

Since the current in the external rectifiers switches abruptly, they must have a fast turn-on time to minimize losses. For low-power circuits with peak inductor currents less than 100mA, signal diodes such as 1N4148s perform well. In higher-power applications, or for maximum efficiency at low power, Schottky rectifiers are recommended. Although 1N4001s and other general-purpose rectifiers are rated for high currents, they are unacceptable because their slow turn-on times result in excessive losses. Since Schottky rectifiers tend to have limited breakdown voltage, be careful to observe this limit, especially in the V6 and V7 inverting regulators. When the switch turns on, the voltage at the inductor-diode junction is pulled to  $V_{CC}$ . When the switch turns off, this junction "flies back" to the negative output. If the V7 output is -26V, the diode reverse voltage is +11V (-26V), or +37V, which is why the higher rated (40V) 1N5819 is used.

## System Operating Modes

There are three system operating modes:

- Battery Backup
- Standby
- Operating

### Battery-Backup Mode

In battery-backup mode, V1 provides a low current output to maintain CMOS RAM and/or a real-time clock. The input to V1 is supplied by the backup battery when  $V_{CC}$  is less than the backup-battery voltage. This will happen when the main battery is discharged, the line power switch is disconnected, or the main battery is being replaced. Battery-backup mode is entered whenever the voltage at BT is higher than  $V_{CC}$ . Supply current in this state is less than 15 $\mu$ A maximum with a 3V backup-battery voltage.

In battery-backup mode:

- 1) V1 connects to BT via an internal 500 $\Omega$  switch.
- 2) All other outputs (V2-V7) turn off.
- 3) S2-S4 connect to GND via internal 5k $\Omega$  resistors.
- 4) ON and  $\overline{RS}$  outputs are low.
- 5) All digital inputs are ignored. The allowed digital input range is 0V to V1.

### Changing Batteries

The V1 regulator picks the higher of either  $V_{CC}$  or BT. Either the main battery (at  $V_{CC}$ ) or the backup battery (but not both) may be removed without loss of backup power. The  $V_{CC}$  rate-of-rise must be limited to 1V/ $\mu$ s during power-up. The BT rate-of-rise need not be controlled.

The BT input must be connected to GND if a backup battery is not used. If BT is left unconnected, leakage

currents may raise the BT-terminal voltage to a level that causes erroneous switchover to the battery backup. The BT input range is 2.3V to 4.0V. BT voltage above 4V may damage external transistors.

### Standby Mode

Standby is entered from the operating mode when the ON input is low. The purpose of standby is to minimize power consumption between periods of normal operation. The MAX714/715/716 also enter standby if  $V_{CC}$  falls to approximately 4.95V (4.70V min). Operating circuitry must be shut down by the system processor before standby is entered; this prevents data loss that might result from power supplies turning off without warning. The low battery output provides early warning so that data can be saved.

In standby mode:

- 1) V1 = 5V (or  $V_{CC}$ , whichever is lower).
- 2) B1 output current is limited to 100 $\mu$ A typ.
- 3) V2-V7 are off.

Standby mode is also entered from the battery-backup mode whenever  $V_{CC}$  rises above BT.

The MAX714/715/716 power up in standby mode. The V1 output current is limited to 100 $\mu$ A times the beta of the pass transistor. If V1's load current is too high on power-up, there may be insufficient output current to regulate at 5V. For a transistor beta of 200, the load on V1 during power-up should be no more than 20mA.

### Operating Mode

Operating mode is entered from standby by driving the ON input high.  $V_{CC}$  MUST be above the low battery warning threshold to enter the operating mode. V2 turns on, but the other regulators (V3-V7) are controlled by E3-E7 regulator enable inputs.

### LBO Warning and $\overline{RS}$ Outputs

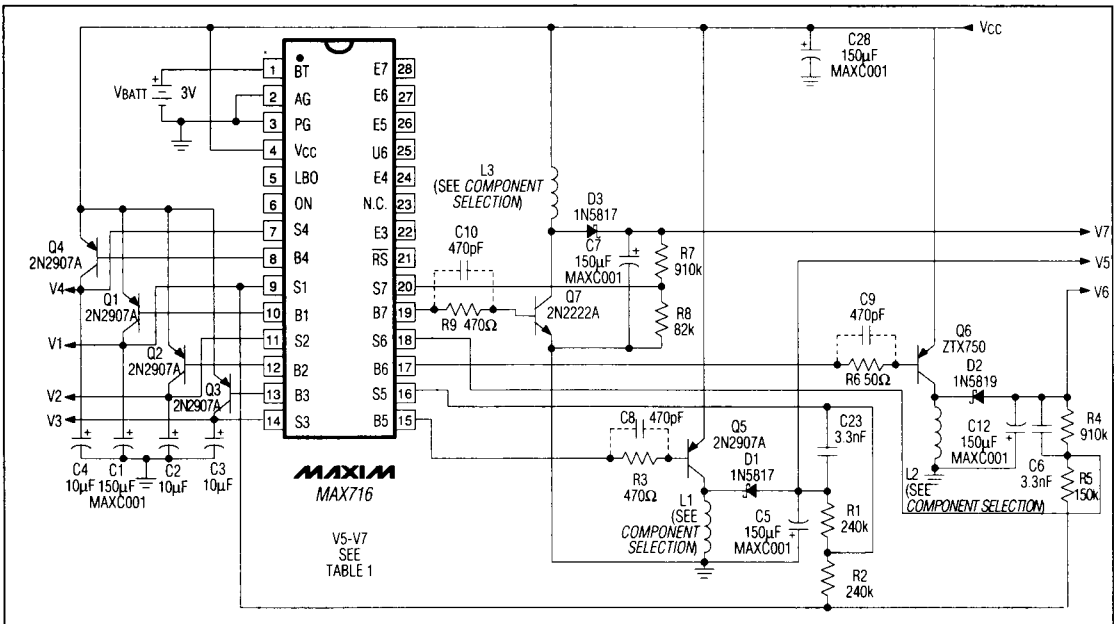
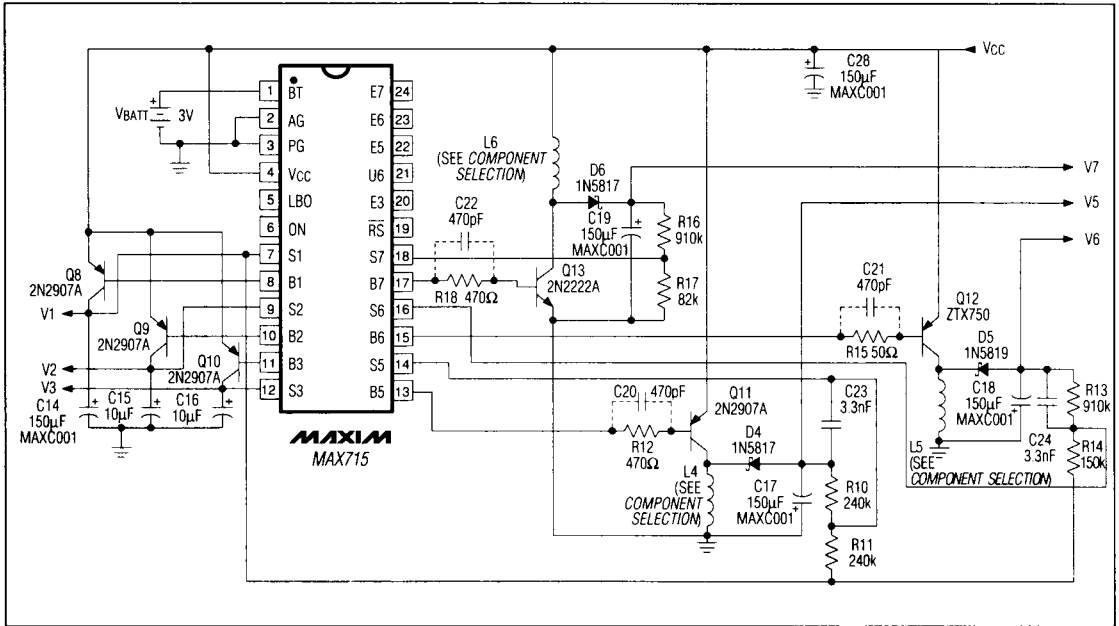
The low battery output (LBO) is normally a logic high (the V1 voltage). When  $V_{CC}$  falls to approximately 5.16V, LBO goes low. In a typical application, LBO drives the non-maskable interrupt (NMI) input of a microprocessor ( $\mu$ P). When LBO goes low, the  $\mu$ P should perform an orderly shutdown of the system, including turning off all MAX714/715/716 regulators. This shutdown should be completed before  $V_{CC}$  falls more than 240mV below the low-battery warning threshold. When  $V_{CC}$  falls to approximately 4.92V, standby mode begins whether or not standby has been commanded by the  $\mu$ P. All supplies except V1 are turned off.

$\overline{RS}$  goes low during battery-backup and standby modes. It remains low for approximately 230ms after the ON input rises, and  $V_{CC}$  is above the warning threshold.

# Battery-Powered Supply Systems

## Typical Operating Circuits (continued)

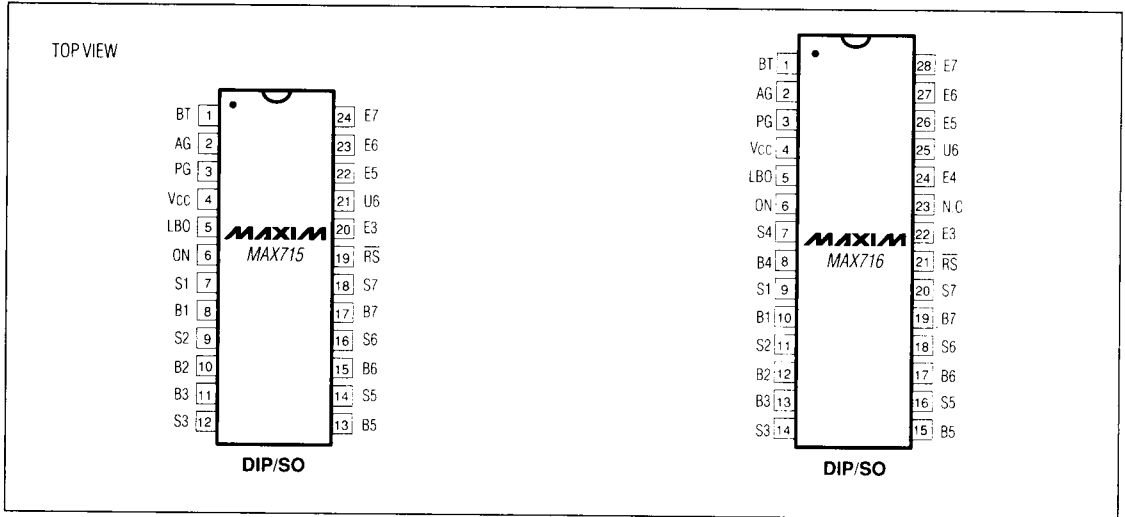
MAX714/715/716



4

# Battery-Powered Supply Systems

## Pin Configurations (continued)



## Ordering Information (continued)

## Chip Topography

| PART        | TEMP. RANGE     | PIN-PACKAGE    |
|-------------|-----------------|----------------|
| MAX716CPI   | 0°C to +70°C    | 28 Plastic DIP |
| MAX716CWI   | 0°C to +70°C    | 28 Wide SO     |
| MAX716C/D   | 0°C to +70°C    | Dice*          |
| MAX716EPI   | -40°C to +85°C  | 28 Plastic DIP |
| MAX716EWI   | -40°C to +85°C  | 28 Wide SO     |
| MAX716MJI   | -55°C to +125°C | 28 CERDIP      |
| MAX716EVKIT | Evaluation Kit  |                |

\*Contact factory for dice specifications.

