ECB and LCD Display Bias Supply with Accurate Output Voltage and Temperature Compensation

General Description
The MAX1729 micropower step-up/step-down DC-DC converter is ideally suited for electrically controlled birefringence (ECB) and liquid-crystal-display (LCD) bias-supply generation. It provides step-up/step-down voltage conversion and reduces output ripple by using a step-up DC-DC converter followed by a linear regulator. This architecture permits a physically smaller inductor than those used in competing SEPIC and flyback topologies. This device features low quiescent current (67µA typical). A logic-controlled shutdown mode further reduces quiescent current to 0.4µA typical.

The MAX1729 features an input that dynamically adjusts the output voltage to control display color or contrast. It offers two feedback modes: internal and external. Internal feedback mode allows output voltages between 2.5V and 16V, and is specifically designed to hold temperature drift to ±11ppm/°C. External feedback mode allows the MAX1729 output voltage range to be tailored for various displays.

An on-chip temperature sensor with a positive temperature coefficient provides compensation for LCD/ECB display temperature characteristics. In internal feedback mode, the buffered temperature sensor output is read and used to adjust the output voltage via a digital control signal. External feedback mode features an additional compensation method in which the temperature output is summed directly into the feedback network to provide first-order negative temperature compensation of the output voltage. The MAX1729 is available in the space-saving 10-pin µMAX package.

Features
- High-Accuracy Reference Voltage (±1%)
- ±11ppm/°C Output Voltage Drift
- On-Chip Temperature Sensor Output
- Accurate Voltage and Temperature Provide:
  Consistent ECB Colors
  Consistent LCD Gray-Scale Contrast
- +2.7V to +5.5V Input Voltage Range
- Output Voltage Range
  +2.5V to +16V in Internal Feedback Mode
  Programmable in External Feedback Mode
- Dynamic Control of the Output Voltage
- 67µA Supply Current
- 0.4µA Shutdown Current
- 10-Pin µMAX Package (1.09mm max height)
- Evaluation Kit Available (MAX1729EVKIT)

Applications
ECB Display Bias & Color Adjustment
LCD Display Bias & Contrast Adjustment
Cellular Phones
Personal Digital Assistants

Ordering Information

<table>
<thead>
<tr>
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<th>TEMP. RANGE</th>
<th>PIN-PACKAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX1729EUB</td>
<td>-40°C to +85°C</td>
<td>10 µMAX</td>
</tr>
</tbody>
</table>

Typical Operating Circuit

For free samples & the latest literature: http://www.maxim-ic.com, or phone 1-800-998-8800.
For small orders, phone 1-800-835-8769.
**ECB and LCD Display Bias Supply with Accurate Output Voltage and Temperature Compensation**

**ABSOLUTE MAXIMUM RATINGS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Voltage Range</td>
<td>$V_{IN}$</td>
<td>2.7</td>
<td>5.5</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undervoltage Lockout Threshold (Note 2)</td>
<td>$V_{LO}$</td>
<td>2.0</td>
<td>2.6</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IN Supply Current</td>
<td>$I_{IN}$</td>
<td>37</td>
<td>50</td>
<td>μA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PS Supply Current</td>
<td>$I_{PS}$</td>
<td>30</td>
<td>40</td>
<td>μA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shutdown Supply Current</td>
<td>$I_{SHDN}$</td>
<td>0.4</td>
<td>2</td>
<td>μA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference Output Voltage</td>
<td>$V_{REF}$</td>
<td>$I_{REF} = 0$</td>
<td>$T_A = +25^\circ C$</td>
<td>1.215</td>
<td>1.228</td>
<td>1.241</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T_A = -40^\circ C$ to $+85^\circ C$</td>
<td>1.200</td>
<td>1.256</td>
<td></td>
</tr>
<tr>
<td>Minimum Output Voltage</td>
<td>$V_{OUT}$ (MIN)</td>
<td>$F_B = GND$, $CTLIN = 0.1%$ duty cycle, $I_{OUT} = 0$ to 0.5mA</td>
<td>$T_A = 0^\circ C$ to $+85^\circ C$</td>
<td>2.35</td>
<td>2.45</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T_A = -40^\circ C$ to $+85^\circ C$</td>
<td>2.35</td>
<td>2.52</td>
<td></td>
</tr>
<tr>
<td>Maximum Output Voltage</td>
<td>$V_{OUT}$ (MAX)</td>
<td>$I_{OUT} = 0$ to 0.5mA</td>
<td>16</td>
<td>16.40</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>CTLIN to VOUT Gain</td>
<td>$V_{FB}$</td>
<td>$FB = GND$, $CTLIN = 0.1%$ to 100% duty cycle, $I_{OUT} = 0$</td>
<td>$T_A = 0^\circ C$ to $+85^\circ C$</td>
<td>13.90</td>
<td>13.95</td>
<td>14.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T_A = -40^\circ C$ to $+85^\circ C$</td>
<td>13.60</td>
<td>14.20</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Temperature Coefficient</td>
<td>$TC_{OUT}$</td>
<td>$V_{PS} = +18$V (Note 3)</td>
<td>$T_A = 0^\circ C$ to $+85^\circ C$</td>
<td>$\pm 11$</td>
<td>$\pm 30$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T_A = -40^\circ C$ to $+85^\circ C$</td>
<td>$\pm 18$</td>
<td>$\pm 65$</td>
<td></td>
</tr>
<tr>
<td>Maximum Output Current</td>
<td>$I_{OUT}$</td>
<td></td>
<td>0.5</td>
<td>2.5</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>TC Output Voltage</td>
<td>$V_{TC}$</td>
<td>$T_A = +25^\circ C$</td>
<td>1.178</td>
<td>1.228</td>
<td>1.278</td>
<td>V</td>
</tr>
<tr>
<td>TC Output Temperature Coefficient (Note 3)</td>
<td>$TC_{TC}$</td>
<td>$T_A = 0^\circ C$ to $+85^\circ C$</td>
<td>15.5</td>
<td>16.5</td>
<td>17.5</td>
<td>mV/^\circ C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T_A = -40^\circ C$ to $+85^\circ C$</td>
<td>14.5</td>
<td>16.5</td>
<td>18.5</td>
</tr>
<tr>
<td>TC Output Current</td>
<td>$I_{TC}$</td>
<td></td>
<td>$\pm 50$</td>
<td></td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>Feedback Set Voltage (FB)</td>
<td>$V_{FB}$</td>
<td>$T_A = +25^\circ C$</td>
<td>1.215</td>
<td>1.228</td>
<td>1.241</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T_A = -40^\circ C$ to $+85^\circ C$</td>
<td>1.200</td>
<td>1.256</td>
<td></td>
</tr>
<tr>
<td>FB Mode Threshold</td>
<td>$V_{MODE}$</td>
<td></td>
<td>90</td>
<td>122</td>
<td>150</td>
<td>mV</td>
</tr>
<tr>
<td>FB Bias Current</td>
<td>$I_{FB}$</td>
<td>$V_{FB} = +1.25$V</td>
<td>5</td>
<td>50</td>
<td>nA</td>
<td></td>
</tr>
<tr>
<td>CTLIN High Voltage</td>
<td>$V_{IH}$</td>
<td>$V_{IN} = +5.5$V</td>
<td>2</td>
<td></td>
<td>V</td>
<td></td>
</tr>
</tbody>
</table>

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**

$V_{IN} = +3$V, $CTLIN = IN$, $FB = GND$, $T_A = -40^\circ C$ to $+85^\circ C$, unless otherwise noted. Typical values are at $T_A = +25^\circ C$.) (Note 1)
**ECB and LCD Display Bias Supply with Accurate Output Voltage and Temperature Compensation**

**ELECTRICAL CHARACTERISTICS**

(VIN = +3V, CTLIN = IN, FB = GND, TA = -40°C to +85°C, unless otherwise noted. Typical values are at TA = +25°C.) (Note 1)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTLIN Low Voltage</td>
<td>VL</td>
<td>VIN = +2.7V to +5.5V</td>
<td>0.4</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>CTLIN Bias Current</td>
<td>I_{HL}</td>
<td>VIN = +5.5V, CTLIN = GND or IN</td>
<td>±1</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>COMP Impedance</td>
<td>R_{COMP}</td>
<td>VFB = 0, Internal Feedback Mode</td>
<td>33</td>
<td></td>
<td></td>
<td>kΩ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VFB = +1.25V, External Feedback Mode</td>
<td>60</td>
<td>150</td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td>CTLIN Minimum Pulse Width for Shutdown</td>
<td>t_{OFF}</td>
<td>(Note 4)</td>
<td>700</td>
<td>1250</td>
<td>2400</td>
<td>μs</td>
</tr>
<tr>
<td>CTLIN Minimum Pulse Width for VOUT Control</td>
<td>t_{CTLIN}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMP Rise/Fall Time</td>
<td>t_{R/F}</td>
<td>VFB = +1.25V</td>
<td>20</td>
<td></td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>Switch On-Resistance</td>
<td>R_{ON}</td>
<td>ILX = 30mA</td>
<td>2.5</td>
<td>5.0</td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VIN = +2.7V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VIN = +5.5V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switch Off-Leakage Current</td>
<td>I_{LX(OFF)}</td>
<td>VLI = 18V</td>
<td>0.1</td>
<td>1</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>LX to PS Diode Forward Voltage</td>
<td>V_{LX-PS}</td>
<td>IDIODE = 30mA</td>
<td>700</td>
<td>970</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>PFM On-Time Constant</td>
<td>K</td>
<td>TA = +25°C</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>V·μs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TA = -40°C to +85°C</td>
<td>5</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PS to OUT Voltage (Note 5)</td>
<td></td>
<td></td>
<td>0.4</td>
<td>0.6</td>
<td>1.0</td>
<td>V</td>
</tr>
</tbody>
</table>

**Note 1:** Specifications to -40°C are guaranteed by design, not production tested.

**Note 2:** When VIN is below this level, the boost and LDO outputs are disabled.

**Note 3:** Guaranteed by design.

**Note 4:** Minimum time to hold CTLIN low to invoke shutdown. If CTLIN is held low for less than t_{OFF}, device does not enter shutdown.

**Note 5:** Switching regulator regulates this voltage to keep LDO from dropping out.
ECB and LCD Display Bias Supply with Accurate Output Voltage and Temperature Compensation

Typical Operating Characteristics

(Circuit of Figure 2, $T_A = +25^\circ C$, unless otherwise noted.)

- **Efficiency vs. Output Current**
  - $V_{OUT} = 9.4$ (CTLIN at 50% DUTY CYCLE)
  - $V_{IN} = 5.5V$, $V_{IN} = 2.7V$

- **Efficiency vs. Output Current**
  - $V_{OUT} = 16.4$ (CTLIN = IN)
  - $V_{IN} = 5.5V$, $V_{IN} = 2.7V$

- **Maximum Output Current vs. Supply Voltage**
  - $V_{OUT} = 16.4V$, $V_{OUT} = 9.4V$, $V_{OUT} = 2.5V$

- **Power-Supply Rejection Ratio (PSRR)**
  - Frequency (Hz): 2.5, 4.0, 4.5, 3.0, 3.5, 5.0, 5.5, 6.0
  - PSRR (dB): -80, -60, -40, -20, 0

- **Shutdown Supply Current**
  - Input Voltage (V): 2.5, 3.5, 4.0, 3.0, 4.5, 5.0, 5.5, 6.0
  - Shutdown Current ($\mu$A): 0, 1.0, 0.5, 2.0, 1.5, 2.5, 3.0

- **Output Voltage vs. Duty Cycle**
  - Output Voltage (V): 0, 2, 4, 6, 8, 10, 12, 14, 16, 18
  - Duty Cycle (%): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

- **Start-Up Delay from Shutdown**
  - $V_{CTRL}$, $V_{IN}$, $V_{OUT}$, $V_{REF}$
  - Time (ms/div): 20, 500

- **Delay to Shutdown**
  - $V_{CTRL}$, $V_{IN}$, $V_{OUT}$, $V_{REF}$
  - Time (ms/div): 20, 500

MAX1729
ECB and LCD Display Bias Supply with Accurate Output Voltage and Temperature Compensation

Typical Operating Characteristics (continued)
(Circuit of Figure 2, $T_A = +25^\circ C$, unless otherwise noted.)

- **DELAY TO SHUTDOWN**
  - $V_{CLIN}$: 5V/div
  - $V_{REF}$: 1V/div
  - $V_{TC}$: 1V/div
  - $V_{OUT}$: 10V/div
  - $V_{IN} = 5V$
  - $I_O = 0.5mA$
  - 5ms/div

- **SWITCHING WAVEFORMS**
  - **HEAVY LOAD**
    - $I_L$: 20mA/div
    - OUTPUT RIPPLE: 10mV/div
    - $V_{OUT}$: 5V/div
    - 2μs/div
  - **MEDIUM LOAD**
    - $I_L$: 20mA/div
    - OUTPUT RIPPLE: 10mV/div
    - $V_{OUT}$: 5V/div
    - 2μs/div

- **LOAD-TRANSIENT RESPONSE**
  - $V_{OUT}$: 20mV/div
  - $I_{OUT}$: 250μA/div
  - 1ms/div

- **LINE-TRANSIENT RESPONSE**
  - $V_{OUT}$: 20mV/div
  - $V_{IN}$: 1V/div
  - 2ms/div

$\text{MAX1729}$
**ECB and LCD Display Bias Supply with Accurate Output Voltage and Temperature Compensation**

**Detailed Description**

The MAX1729 is designed to provide bias voltage for ECB or LCD displays. It is composed of a step-up DC-DC converter followed by a linear regulator (Figure 1), a combination that provides step-up/step-down voltage conversion while minimizing output ripple. The device allows you to adjust a display’s color or contrast by dynamically adjusting the MAX1729’s output voltage using a PWM control signal. In internal feedback mode, the output voltage is adjustable between +2.5V and +16V. In external feedback mode, the output voltage is adjustable, and its range is set by a resistor network that is programmed to match the output voltage range of LCD/ECB displays needing a maximum output up to +18V.

**Boost Converter**

The MAX1729’s DC-DC boost converter is implemented with an on-chip N-channel MOSFET, a diode, and an error comparator. The IC’s unique PFM control system varies the on-time and off-time of the switch based on the boost converter’s input and output voltage values, as follows:

\[ t_{ON} = \frac{K}{V_{IN}} \]

\[ t_{OFF} \geq \frac{K}{V_{PS} - V_{IN}} \]

where K is typically 8V-µs. This timing maintains discontinuous conduction and sets the peak inductor current (IPEAK) to:

\[ I_{PEAK} = \frac{K}{L} \]

where L is the inductance of L1 (Figures 2, 3, and 4).

When the error comparator detects that the drop across the linear regulator (V<sub>PS</sub> - V<sub>OUT</sub>) is less than approximately 0.6V, the internal switch is turned on (ION initiates) and current through the inductor ramps to IPEAK. At the end of ION, the switch is turned off for at least IOFF, allowing the

---

**Pin Description**

<table>
<thead>
<tr>
<th>PIN</th>
<th>NAME</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IN</td>
<td>Supply Input. Bypass with 0.1µF capacitor to ground. Connect to supply side of inductor (L1).</td>
</tr>
<tr>
<td>2</td>
<td>TC</td>
<td>Temperature-Sensor Output. Bypass to GND with a 1000pF capacitor.</td>
</tr>
<tr>
<td>3</td>
<td>REF</td>
<td>Reference Voltage Output. Bypass to GND with a 0.1µF capacitor.</td>
</tr>
<tr>
<td>4</td>
<td>COMP</td>
<td>Compensation Pin. In internal feedback mode (Figure 2), bypass with a 1µF capacitor. In external feedback mode, COMP is a buffered inverse version of CTLIN (Figure 3).</td>
</tr>
<tr>
<td>5</td>
<td>FB</td>
<td>Feedback and Mode Control Input. Connect to GND for internal feedback mode operation.</td>
</tr>
<tr>
<td>6</td>
<td>CTLIN</td>
<td>Control Input. Drive low for more than 1.2ms to put the device into shutdown.</td>
</tr>
<tr>
<td>7</td>
<td>OUT</td>
<td>Bypass to GND with a 1.0µF capacitor.</td>
</tr>
<tr>
<td>8</td>
<td>PS</td>
<td>Output of boost converter and input to LDO. Bypass to GND with a 0.068µF capacitor.</td>
</tr>
<tr>
<td>9</td>
<td>LX</td>
<td>Drain of the internal MOSFET Switch</td>
</tr>
<tr>
<td>10</td>
<td>GND</td>
<td>Ground</td>
</tr>
</tbody>
</table>
ECB and LCD Display Bias Supply with Accurate Output Voltage and Temperature Compensation

The PNP low-dropout linear regulator of the MAX1729 regulates the boost-converter output to the desired output voltage. The boost converter's regulation circuitry holds the linear regulator's input voltage (VPS) approximately 0.6V above the output voltage to keep the regulator out of dropout, thereby enhancing ripple rejection. The linear regulator incorporates short-circuit protection, which limits the output current to approximately 6mA.

**Temperature Sensor Output**
The MAX1729 generates a temperature sensor voltage (VTC) that varies at 16.5mV/°C (typ) and is nominally equal to the reference voltage at room temperature. TC is capable of sinking or sourcing 50µA. This output is used to compensate for ECB color or LCD contrast variations caused by changes in temperature. It may be read with an ADC and used to modify an external PWM control signal or, in external feedback mode, summed directly into the feedback-resistor network.

**Control Signal**
An externally generated PWM control signal on CTLIN controls VOUT in internal feedback mode and influences VOUT in external feedback mode. In either mode, if CTLIN is held low for longer than 1.24ms, the MAX1729 enters shutdown mode, decreasing the supply current below 2µA. Shutdown mode limits the minimum duty cycle and frequency that may be used to keep the device active. CTLIN frequencies between 2kHz and 12kHz are recommended.

**Internal Feedback Mode**
In internal feedback mode, the signal at CTLIN is inversely buffered, level-shifted, and output at COMP through a resistor. Internal resistance (33kΩ typical) and C6 then filter the signal before it is used by the internal feedback network to set VOUT. If temperature compensation is used, the temperature sensor output voltage is read by an ADC and used to adjust the duty cycle of the PWM control signal. See the Designing for Internal Feedback Mode section for more information.

**External Feedback Mode**
In external feedback mode, the output voltage of the MAX1729 is controlled by the duty cycle of the PWM control signal and an external resistor network, as shown in Figure 3. In this mode, the signal at CTLIN is inverted, level-shifted, and presented directly to COMP. R3, R4, and C6 filter the signal, before it is summed into the feedback node.

**Design Procedure**

**Designing for Internal Feedback Mode**
For a 3kHz PWM control signal use a 1µF low-leakage ceramic capacitor for C6. For applications requiring a higher-frequency PWM control signal, reduce the value of C6 to between 1µF and 0.22µF for frequencies between 3kHz and 12kHz. Higher C6 values reduce output ripple. In Figure 2, VOUT is governed by the following equation:

\[ V_{OUT} = V_{OUT(MIN)} + \text{Duty Cycle} \cdot \text{Gain} \]

where \( V_{OUT(MIN)} \) is 2.45V and Gain is nominally 13.95V/100%, as listed in the Electrical Characteristics.
To use a DC control signal to adjust the output voltage, use the circuit shown in Figure 4. In this configuration, V\text{OUT} is governed by the following equation:

\[ V_{\text{OUT}} = 24.67V_{\text{FB}} - 22.71V_{\text{COMP}} \]

The impedance looking into COMP is nominally 33kΩ. A source output impedance of less than 500Ω is recommended. Also, ensure V\text{OUT} \leq 18V by keeping V\text{COMP} above 0.6V.

**Designing for External Feedback Mode**

To solve for V\text{OUT} in external feedback mode, assume the current into the FB pin is zero and the voltage at FB is 1.228V. Then take the sum of the currents into FB and solve for V\text{OUT}:

\[ V_{\text{OUT}} = R_1 \left( \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3 + R_4} + \frac{1}{R_5} \right) V_{\text{FB}} - \left( \frac{R_1}{R_3 + R_4} \right) V_{\text{COMP}} - \left( \frac{R_1}{R_5} \right) V_{\text{TC}} \]

Using the following formulas, calculate the external component values required for MAX1729 operation in external feedback mode, as shown in Figure 3. An example follows the formulas.

**External Component Value Formulas**

1) Given the maximum output voltage needed (V\text{MAX}), choose the maximum feedback current and solve for R1 (10µA to 30µA is recommended for maximum feedback current) as follows:

\[ R_1 = \frac{V_{\text{MAX}} - V_{\text{FB}}}{I_{\text{FB}}} \]

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**Figure 2. Internal Feedback Mode**

**Figure 3. External Feedback Mode**

**Figure 4. Using a DC Control Signal**
2) Given the maximum output voltage ($V_{MAX}$) and minimum output voltage ($V_{MIN}$), calculate values for R3 and R4 as follows:

$$R3 = \frac{1}{2} \left( \frac{R1}{V_{MAX} - V_{MIN}} \right) V_{FB}$$

$$R4 = R3$$

3) For first-order temperature compensation, calculate R5 as shown below. (If temperature compensation is not used, leave R5 open.)

$$R5 = \left( \frac{R1}{\text{Tempco}} \right) 16.5\text{mV/°C}$$

where Tempco is the negative temperature coefficient needed to compensate the ECB or LCD display for changes in temperature.

4) Solve for $V_{COMP}$. The duty cycle used here corresponds to the duty cycle that yields the maximum output voltage, not including first-order temperature compensation.

$$V_{COMP} = V_{FB} \left[ 1 - \left( \text{Duty Cycle} \cdot \frac{R4}{R3 + R4} \right) \right]$$

where a 90% duty cycle corresponds to Duty Cycle = 0.9.

5) Use the results from the above calculations to solve for R2. (For applications not utilizing temperature compensation, use $1 / R5 = 0$.)

$$\frac{1}{R2} = \frac{1}{V_{FB}} \left( \frac{V_{OUT}}{R1} + \frac{V_{COMP}}{R3} + \frac{V_{FB}}{R5} \right) - \left( \frac{1}{R1} + \frac{1}{R3} + \frac{1}{R5} \right)$$

### External Component Value Example

The example application requires the output voltage to adjust between 5V and 10V, using the circuit shown in Figure 3. The device in our example needs a temperature coefficient of 33mV/°C, which yields the following results.

1) $V_{MAX} = 10V$ and $I_{FB} = 29.24\mu A$ is within the limits and yields a reasonable resistor value, therefore:

$$R1 = \frac{10V - 1.228V}{29.24\mu A} = 300k\Omega$$

2) $V_{MAX} = 10V$ and $V_{MIN} = 5V$, therefore:

$$R3 = \frac{1}{2} \left( \frac{300k\Omega}{5V} \right) 1.228 = 36,840\Omega$$

with $R3 = 36.7k\Omega$, then $V_{MIN} = 5.019V$. Let $R4 = R3 = 36.7k\Omega$.

3) Tempco = 33mV/°C, therefore:

$$R5 = \left( \frac{300k\Omega}{33\text{mV/°C}} \right) 16.5\text{mV/°C} = 150\Omega$$

4) If external circuitry limits the duty cycle to 90%, the following equation is true:

$$V_{COMP} = 1.228 \left( 1 - \frac{1}{2} \right) = 0.6754V$$

5) Solving for R2:

$$\frac{1}{R2} = \left( \frac{V_{OUT}}{R1} + \frac{V_{COMP}}{R3} + \frac{V_{FB}}{R5} \right) - \left( \frac{1}{R1} + \frac{1}{R3} + \frac{1}{R5} \right)$$

With $R2 = 56k\Omega$, a duty cycle of 87.4% generates a $V_{OUT}$ of 10V.

### Component Selection

#### Inductors

Use a 220µH inductor to maximize output current (2.5mA typical). Use an inductor with DC resistance less than 10Ω and a saturation current exceeding 35mA. For lower peak inductor current, use a 470µH inductor with DC resistance less than 20Ω and a saturation current over 18mA. This limits output current to typically less than 1mA. See Table 1 for a list of recommended inductors. The inductor should be connected from the battery to the LX pin, as close to the IC as possible.

#### Capacitors

The equivalent series resistance (ESR) of output capacitor C2 directly affects output ripple. To minimize output ripple, use a low-ESR capacitor. A physically smaller capacitor, such as a common ceramic capacitor, minimizes board space and cost while creating an output ripple that’s acceptable in most applications. Refer to Table 2 for recommended capacitor values.
**ECB and LCD Display Bias Supply with Accurate Output Voltage and Temperature Compensation**

### Table 1. Recommended Inductors

<table>
<thead>
<tr>
<th>SUPPLIER</th>
<th>PART</th>
<th>INDUCTANCE (µH)</th>
<th>DC RESISTANCE (Ω)</th>
<th>SATURATION CURRENT (mA)</th>
<th>MAX HEIGHT (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murata</td>
<td>LQH3C221K04M00</td>
<td>220</td>
<td>8.4</td>
<td>70</td>
<td>2.2</td>
</tr>
<tr>
<td>Panasonic</td>
<td>ELT3KN115B</td>
<td>470</td>
<td>19</td>
<td>40</td>
<td>1.6</td>
</tr>
</tbody>
</table>

### Table 2. Recommended Capacitor Values

<table>
<thead>
<tr>
<th>CAPACITOR</th>
<th>CAPACITANCE (µF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>0.1</td>
</tr>
<tr>
<td>C2</td>
<td>0.068</td>
</tr>
<tr>
<td>C3</td>
<td>0.1</td>
</tr>
<tr>
<td>C4</td>
<td>1</td>
</tr>
<tr>
<td>C5</td>
<td>1000pF</td>
</tr>
<tr>
<td>C6*</td>
<td>1</td>
</tr>
</tbody>
</table>

*Use a low-leakage capacitor.

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**Applications Information**

**PC Board Layout Considerations**

Proper PC board layout minimizes output ripple and increases efficiency. For best results, use a ground plane, minimize the space between C1, C2, and GND of the MAX1729, and place the inductor as close to LX and IN as possible. For an example of proper PC board layout, refer to the MAX1729 Evaluation Kit.

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**Chip Information**

TRANSISTOR COUNT: 1154
ECB and LCD Display Bias Supply with Accurate Output Voltage and Temperature Compensation

Package Information

MAX1729

Package Outline: 10L Micro MAX

Notes:
1. DAE DO NOT INCLUDE MOLD FLASH.
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm (.006").
3. CONTROLLING DIMENSIONS: INCHES
ECB and LCD Display Bias Supply with Accurate Output Voltage and Temperature Compensation

NOTES