LTM4630
Dual 18A or Single 36A DC/DC µModule Regulator

DESCRIPTION
The LTM®4630 is a dual 18A or single 36A output switching mode step-down DC/DC µModule® (micromodule) regulator. Included in the package are the switching controllers, power FETs, inductors, and all supporting components. Operating from an input voltage range of 4.5V to 15V, the LTM4630 supports two outputs each with an output voltage range of 0.6V to 1.8V, each set by a single external resistor. Its high efficiency design delivers up to 18A continuous current for each output. Only a few input and output capacitors are needed. The LTM4630 is pin compatible with the LTM4620 and LTM4620A (dual 13A, single 26A) and the LTM4628 (dual 8A, single 16A).

The device supports frequency synchronization, multiphase operation, Burst Mode operation and output voltage tracking for supply rail sequencing and has an onboard temperature diode for device temperature monitoring. High switching frequency and a current mode architecture enable a very fast transient response to line and load changes without sacrificing stability.

Fault protection features include overvoltage and overcurrent protection. The LTM4630 is offered in 16mm × 16mm × 4.41mm LGA and 16mm × 16mm × 5.01mm BGA packages. The LTM4630 is ROHS compliant.

FEATURES
- Dual 18A or Single 36A Output
- Wide Input Voltage Range: 4.5V to 15V
- Output Voltage Range: 0.6V to 1.8V
- ±1.5% Maximum Total DC Output Error Over Line, Load and Temperature
- Differential Remote Sense Amplifier
- Current Mode Control/Fast Transient Response
- Adjustable Switching Frequency
- Overcurrent Foldback Protection
- Multiphase Parallel Current Sharing with Multiple LTM4630s Up to 144A
- Frequency Synchronization
- Internal Temperature Monitor
- Pin Compatible with the LTM4620 and LTM4620A (Dual 13A, Single 26A) and LTM4628 (Dual 8A, Single 16A)
- Selectable Burst Mode® Operation
- Soft-Start/Voltage Tracking
- Output Overvoltage Protection
- 16mm × 16mm × 4.41mm LGA and 16mm × 16mm × 5.01mm BGA Packages

APPLICATIONS
- Telecom and Networking Equipment
- Storage and ATCA Cards
- Industrial Equipment

TYPICAL APPLICATION
36A, 1.2V Output DC/DC µModule Regulator

For more information www.linear.com/LTM4630

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**LTM4630**

## Absolute Maximum Ratings (Note 1)

- **$V_{IN}$** (Note 8) ........................................... $-0.3V$ to 16V
- **$V_{SW1}$, $V_{SW2}$**, **$PGOOD1$, $PGOOD2$, $RUN1$, $RUN2$, $INTVCC$, $EXTVCC$** ........................................... $-0.3V$ to 6V
- **MODE_PLLIN**, **$f_{SET}$**, **TRACK1**, **TRACK2**, **DIFFOUT**, **PHASMD** ........................................... $-0.3V$ to $INTVCC$
- **$VOUT1$, $VOUT2$, $VOUTS1$, $VOUTS2$** (Note 6) ........ $-0.3V$ to 6V
- **DIFFP, DIFFN** ........................................... $-0.3V$ to $INTVCC$
- **COMP1, COMP2, $VFB1$, $VFB2$** (Note 6) ........ $-0.3V$ to 2.7V
- **Internal Operating Temperature Range** (Note 2) ........................................... $-40°C$ to $125°C$
- **Storage Temperature Range** .................. $-55°C$ to $125°C$
- **Peak Package Body Temperature** ............... $245°C$

## Pin Configuration

![Pin Configuration Diagram]

**LGA Package**

144-Lead (16mm × 16mm × 4.41mm)

$T_{JMAX} = 125°C$, $\Theta_{JJA} = 7°C/W$, $\Theta_{JCbottom} = 1.5°C/W$, $\Theta_{JBA} = 7°C/W$

$\Theta$ Values Defined Per JESD 51-12

Weight = 3.2g

**BGA Package**

144-Lead (16mm × 16mm × 4.41mm)

$T_{JMAX} = 125°C$, $\Theta_{JJA} = 7°C/W$, $\Theta_{JCbottom} = 1.5°C/W$, $\Theta_{JBA} = 7°C/W$

$\Theta$ Values Defined Per JESD 51-12

Weight = 3.2g

## Order Information

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PAD OR BALL FINISH</th>
<th>PART MARKING*</th>
<th>PACKAGE TYPE</th>
<th>MSL RATING</th>
<th>TEMPERATURE RANGE (Note 2)</th>
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<tbody>
<tr>
<td>LTM4630EV#PBF</td>
<td>Au (RoHS)</td>
<td>LTM4630V</td>
<td>LGA</td>
<td>3</td>
<td>$-40°C$ to $125°C$</td>
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<td>LTM4630IV#PBF</td>
<td>Au (RoHS)</td>
<td>LTM4630V</td>
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<tr>
<td>LTM4630EY#PBF</td>
<td>SAC305 (RoHS)</td>
<td>LTM4630Y</td>
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<tr>
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<td>SAC305 (RoHS)</td>
<td>LTM4630Y</td>
<td>BGA</td>
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<td>$-40°C$ to $125°C$</td>
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<tr>
<td>LTM4630IY</td>
<td>SnPb (63/37)</td>
<td>LTM4630Y</td>
<td>BGA</td>
<td>3</td>
<td>$-40°C$ to $125°C$</td>
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</tbody>
</table>

Consult Marketing for parts specified with wider operating temperature ranges. *Device temperature grade is indicated by a label on the shipping container. Pad or ball finish code is per IPC/JEDEC J-STD-609.

- **Terminal Finish Part Marking:** [www.linear.com/leadfree](http://www.linear.com/leadfree)
- **Recommended LGA and BGA PCB Assembly and Manufacturing Procedures:** [www.linear.com/umodule/pcbassembly](http://www.linear.com/umodule/pcbassembly)
- **LGA and BGA Package and Tray Drawings:** [www.linear.com/packaging](http://www.linear.com/packaging)
## ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the specified internal operating temperature range. Specified as each individual output channel. $T_A = 25°C$ (Note 2), $V_{IN} = 12V$ and $V_{RUN1}, V_{RUN2}$ at 5V unless otherwise noted. Per the typical application in Figure 23.

### SYMBOL | PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS
--- | --- | --- | --- | --- | --- | ---
$V_{IN}$ | Input DC Voltage | ● | 4.5 | 15 | V |
$V_{OUT}$ | Output Voltage | ● | 0.6 | 1.8 | V |
$V_{OUT(1DC), V_{OUT(2DC)}}$ | Output Voltage, Total Variation with Line and Load | ● | 1.477 | 1.5 | 1.523 | V |

### Input Specifications

| SYMBOL | PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
--- | --- | --- | --- | --- | --- | --- |
$V_{RUN1}, V_{RUN2}$ | RUN Pin On/Off Threshold | RUN Rising | 1.1 | 1.25 | 1.40 | V |
$V_{RUN1HV5}, V_{RUN2HV5}$ | RUN Pin On Hysteresis | 150 | mV |
$I_{INRUSH(VIN)}$ | Input Inrush Current at Start-Up | $I_{OUT} = 0A, C_H = 22µF \times 3, C_{SS} = 0.01µF, C_{OUT} = 100µF \times 3, V_{OUT1} = 1.5V, V_{OUT2} = 1.5V, V_{IN} = 12V$ | 1 | A |
$I_{Q(VIN)}$ | Input Supply Bias Current | $V_{IN} = 12V, V_{OUT} = 1.5V$, Burst Mode Operation | 3 | mA |
| | | $V_{IN} = 12V, V_{OUT} = 1.5V$, Pulse-Skipping Mode | 15 | mA |
| | | $V_{IN} = 12V, V_{OUT} = 1.5V$, Switching Continuous Shutdown, RUN = 0, VIN = 12V | 65 | mA |
| | | | 50 | µA |
$I_{S(VIN)}$ | Input Supply Current | $V_{IN} = 5V, V_{OUT} = 1.5V$, Burst Mode Operation | 6 | A |
| | | $V_{IN} = 12V, V_{OUT} = 1.5V$, Dynamic Mode Operation | 2.6 | A |

### Output Specifications

| SYMBOL | PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
--- | --- | --- | --- | --- | --- | --- |
$I_{OUT(1DC)}, I_{OUT(2DC)}$ | Output Continuous Current Range | $V_{IN} = 12V, V_{OUT} = 1.5V$ (Note 7) | 0 | 18 | A |
$\Delta V_{OUT(1LINE)/V_{OUT1}}, \Delta V_{OUT(2LINE)/V_{OUT2}}$ | Line Regulation Accuracy | $V_{OUT} = 1.5V, V_{IN}$ from 4.5V to 15V | $I_{OUT} = 0A$ for Each Output, | ● | 0.01 | 0.025 | %/V |
$\Delta V_{OUT(1V_{OUT1}), \Delta V_{OUT(2V_{OUT2)}}}$ | Load Regulation Accuracy | For Each Output, $V_{OUT} = 1.5V$, 0A to 18A | $V_{IN} = 12V$ (Note 7) | ● | 0.5 | 0.75 | % |
$V_{OUT(1AC), V_{OUT(2AC)}}$ | Output Ripple Voltage | For Each Output, $I_{OUT} = 0A, C_{OUT} = 100µF \times 3/X7R/Ceramic, 470µF POSCAP, V_{IN} = 12V, V_{OUT} = 1.5V$, Frequency = 450kHz | 15 | mVp-p |
$f_S$ (Each Channel) | Output Ripple Voltage Frequency | $V_{IN} = 12V, V_{OUT} = 1.5V$, $f_{SET} = 1.25V$ (Note 4) | 500 | kHz |
$f_{SYNC}$ (Each Channel) | SYNC Capture Range | | 400 | 780 | kHz |
$\Delta V_{OUT(START)}$ (Each Channel) | Turn-On Overshoot | $C_{OUT} = 100µF/X5R/Ceramic, 470µF POSCAP, V_{OUT} = 1.5V, I_{OUT} = 0A$ for Each Output, | $V_{IN} = 12V$ | 10 | mV |
$I_{START}$ (Each Channel) | Turn-On Time | $C_{OUT} = 100µF/X5R/Ceramic, 470µF POSCAP, No Load, TRACK/SS with 0.01µF to GND, $V_{IN} = 12V$ | 5 | ms |
$\Delta V_{OUT(L)}$ (Each Channel) | Peak Deviation for Dynamic Load | Load: 0% to 50% to 0% of Full Load | $C_{OUT} = 22µF \times 3/X5R/Ceramic, 470µF POSCAP, V_{IN} = 12V, V_{OUT} = 1.5V$ | 30 | mV |
$I_{SETTLE}$ (Each Channel) | Settling Time for Dynamic Load Step | Load: 0% to 50% to 0% of Full Load, $V_{IN} = 12V, C_{OUT} = 100µF, 470µF POSCAP$ | 20 | µs |
$I_{OUT(PK)}$ (Each Channel) | Output Current Limit | $V_{IN} = 12V, V_{OUT} = 1.5V$ | 30 | A |

### Control Section

| SYMBOL | PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
--- | --- | --- | --- | --- | --- | --- |
$V_{FB1}, V_{FB2}$ | Voltage at $V_{FB}$ Pins | $I_{OUT} = 0A, V_{OUT} = 1.5V$ | 0.592 | 0.600 | 0.606 | V |
$I_{FB}$ (Note 6) | | | $I_{FB} = -5$ | $-20$ | nA |
$V_{OVL}$ | Feedback Overvoltage Lockout | ● | 0.64 | 0.66 | 0.68 | V |
TRACK1 (I), TRACK2 (I) | Track Pin Soft-Start Pull-Up Current | TRACK1 (I), TRACK2 (I) Start at 0V | 1 | 1.25 | 1.5 | µA |

For more information www.linear.com/LTM4630
## ELECTRICAL CHARACTERISTICS

The ◆ denotes the specifications which apply over the specified internal operating temperature range. Specified as each individual output channel. \( T_A = 25°C \) (Note 2), \( V_{IN} = 12V \) and VRUN1, VRUN2 at 5V unless otherwise noted. Per the typical application in Figure 23.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
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<td>UVLO</td>
<td>Undervoltage Lockout (Falling)</td>
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<td>UVLO Hysteresis</td>
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<td>I(_{DH,(MIN)})</td>
<td>Minimum On-Time</td>
<td>(Note 6)</td>
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<td>R(<em>{FB1,H}, , R</em>{FB2,H})</td>
<td>Resistor Between V(<em>{OUTS1}, , V</em>{OUTS2}) and V(<em>{FB1}, , V</em>{FB2}) Pins for Each Output</td>
<td>60.05</td>
<td>60.4</td>
<td>60.75</td>
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<td>V(<em>{PGOOD,1}, , V</em>{PGOOD,2}) Low</td>
<td>PGOOD Voltage Low</td>
<td>( I_{PGOOD} = 2mA )</td>
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<td>0.3</td>
<td>V</td>
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<td>I(_{PGOOD})</td>
<td>PGOOD Leakage Current</td>
<td>( V_{PGOOD} = 5V )</td>
<td>±5</td>
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<td>µA</td>
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<td>V(_{PGOOD})</td>
<td>PGOOD Trip Level</td>
<td>V(_{FB}) with Respect to Set Output Voltage</td>
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<td></td>
<td>%</td>
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<td>V(_{FB}) Ramping Negative</td>
<td>10</td>
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<td>V(_{FB}) Ramping Positive</td>
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<td></td>
<td>INTV(_{CC})</td>
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<td>V(_{INTVCC})</td>
<td>Internal V(_{CC}) Voltage</td>
<td>6V &lt; V(_{IN} &lt; 15V)</td>
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<td>5.2</td>
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<td>V(_{INTVCC}) Load Regulation</td>
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<td>( I_{CC} = 0m\text{A} \text{ to } 50m\text{A} )</td>
<td>0.5</td>
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<td>V(_{EXTVCC})</td>
<td>EXTV(_{CC}) Switchover Voltage</td>
<td>EXTV(_{CC}) Ramping Positive</td>
<td>4.5</td>
<td>4.7</td>
<td>V</td>
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<td>V(_{EXTVCC,(DROP)})</td>
<td>EXTV(_{CC}) Dropout</td>
<td>( I_{CC} = 20m\text{A} \text{, } V_{EXTVCC} = 5V )</td>
<td>50</td>
<td>100</td>
<td>mV</td>
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<td>V(_{EXTVCC,(HYST)})</td>
<td>EXTV(_{CC}) Hysteresis</td>
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<td>220</td>
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<td>mV</td>
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<td>Frequency Nominal</td>
<td>Nominal Frequency</td>
<td>( f_{SET} = 1.2V )</td>
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<td>500</td>
<td>550</td>
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<td>Frequency Low</td>
<td>Lowest Frequency</td>
<td>( f_{SET} = 0V ) (Note 5)</td>
<td>210</td>
<td>250</td>
<td>290</td>
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<td>Frequency High</td>
<td>Highest Frequency</td>
<td>( f_{SET} &gt; 2.4V ), Up to INTV(_{CC})</td>
<td>700</td>
<td>780</td>
<td>860</td>
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<td>( f_{SET})</td>
<td>Frequency Set Current</td>
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<td>10</td>
<td>11</td>
<td>µA</td>
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<td>R(_{MODE,,PLL,IN})</td>
<td>MODE(_{,PLL,IN}) Input Resistance</td>
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<td>kΩ</td>
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<td>CLKOUT</td>
<td>Phase (Relative to V(_{OUT1}))</td>
<td>PHASMD = GND</td>
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<td>PHASMD = Float</td>
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<td>PHASMD = INTV(_{CC})</td>
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<td>V/V</td>
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<td>R(_{IN})</td>
<td>Input Resistance</td>
<td>Measured at DIFFP Input</td>
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<td>kΩ</td>
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<td>V(_{OS})</td>
<td>Input Offset Voltage</td>
<td>( V_{DIFFP} = V_{DIFFOUT} = 1.5V \text{, } I_{DIFFOUT} = 100µA )</td>
<td>3</td>
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<td>mV</td>
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<td>PSRR Differential Amplifier</td>
<td>Power Supply Rejection Ratio</td>
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<td>dB</td>
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<td>mA</td>
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<td>V(_{OUT,(MAX)})</td>
<td>Maximum Output Voltage</td>
<td>( I_{DIFFOUT} = 300µA \text{, INTV}_{CC} = 1.4 )</td>
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<td>V(_{TEMP})</td>
<td>Diode Connected PNP</td>
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<td>TC</td>
<td>Temperature Coefficient</td>
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<td>−2.2</td>
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</table>

For more information [www.linear.com/LTM4630](http://www.linear.com/LTM4630)
### ELECTRICAL CHARACTERISTICS

**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** The LTM4630 is tested under pulsed load conditions such that $T_J = T_A$. The LTM4630E is guaranteed to meet specifications from 0°C to 125°C internal temperature. Specifications over the –40°C to 125°C internal operating temperature range are assured by design, characterization and correlation with statistical process controls. The LTM4630I is guaranteed over the full –40°C to 125°C internal operating temperature range. Note that the maximum ambient temperature consistent with these specifications is determined by specific operating conditions in conjunction with board layout, the rated package thermal impedance and other environmental factors.

### TYPICAL PERFORMANCE CHARACTERISTICS

**Burst Mode and Pulse-Skip Mode Efficiency $V_{IN}=12V$, $V_{OUT}=1.2V$, $f_S=450kHz**

**1V Single Phase Output Load Transient Response**

**1.2V Single Phase Output Load Transient Response**

**Dual Phase Single Output Efficiency vs Output Current, $V_{IN}=12V$, $f_S=450kHz**

For more information [www.linear.com/LTM4630](http://www.linear.com/LTM4630)
## TYPICAL PERFORMANCE CHARACTERISTICS

### 1.5V Single Phase Output Load Transient Response

- **Load Step**: 2A/DIV
- **VOUT(AC)**: 50mV/Div
- **IIN**: 1A/Div

- **Details**: 12VIN, 1.5VOUT, 450kHz, 4.5A LOAD STEP, 4.5A/µs STEP-UP AND STEP-DOWN

### 1.8V Single Phase Output Load Transient Response

- **Load Step**: 2A/DIV
- **VOUT(AC)**: 50mV/Div
- **IIN**: 1A/Div

- **Details**: 12VIN, 1.8VOUT, 450kHz, 4.5A LOAD STEP, 4.5A/µs STEP-UP AND STEP-DOWN

### Single Phase Start-Up with No load

- **VSW**: 10V/Div
- **VOUT**: 0.5V/Div
- **IIN**: 0.2A/Div

- **Details**: 12VIN, 1.2VOUT, 450kHz

### Single Phase Short Circuit Protection with No load

- **VSW**: 10V/Div
- **VOUT**: 0.5V/Div
- **IIN**: 1A/Div

- **Details**: 12VIN, 1.2VOUT, 450kHz

### Single Phase Short Circuit Protection with 18A

- **VSW**: 10V/Div
- **VOUT**: 0.5V/Div
- **IIN**: 1A/Div

- **Details**: 12VIN, 1.2VOUT, 450kHz

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For more information [www.linear.com/LTM4630](http://www.linear.com/LTM4630)
PIN FUNCTIONS

**V\textsubscript{OUT1} (A1-A5, B1-B5, C1-C4):** Power Output Pins. Apply output load between these pins and GND pins. Recommend placing output decoupling capacitance directly between these pins and GND pins. Review Table 4. See Note 8 in the Electrical Characteristics section for output current guideline.

**GND (A6-A7, B6-B7, D1-D4, D9-D12, E1-E4, E10-E12, F1-F3, F10-F12, G1, G3, G10, G12, H1-H7, H9-H12, J1, J5, J8, J12, K1, K5-K8, K12, L1, L12, M1, M12):** Power Ground Pins for Both Input and Output Returns.

**V\textsubscript{OUT2} (A8-A12, B8-B12, C9-C12):** Power Output Pins. Apply output load between these pins and GND pins. Recommend placing output decoupling capacitance directly between these pins and GND pins. Review Table 4. See Note 8 in the Electrical Characteristics section for output current guideline.

**V\textsubscript{OUTS1, V\textsubscript{OUTS2} (C5, C8):** This pin is connected to the top of the internal top feedback resistor for each output. The pin can be directly connected to its specific output, or connected to DIFFOUT when the remote sense amplifier is used. In paralleling modules, one of the V\textsubscript{OUTS} pins is connected to the DIFFOUT pin in remote sensing or directly to V\textsubscript{OUT} with no remote sensing. It is very important to connect these pins to either the DIFFOUT or V\textsubscript{OUT} since this is the feedback path, and cannot be left open. See the Applications Information section.

**I\textsubscript{SET} (C6):** Frequency Set Pin. A 10\(\mu\)A current is sourced from this pin. A resistor from this pin to ground sets a voltage that in turn programs the operating frequency. Alternatively, this pin can be driven with a DC voltage that can set the operating frequency. See the Applications Information section.

**SGND (C7, D6, G6-G7, F6-F7):** Signal Ground Pin. Return ground path for all analog and low power circuitry. Tie a single connection to the output capacitor GND in the application. See layout guidelines in Figure 22.

**V\textsubscript{FB1, V\textsubscript{FB2} (D5, D7):** The Negative Input of the Error Amplifier for Each Channel. Internally, this pin is connected to V\textsubscript{OUTS1 or V\textsubscript{OUTS2} with a 60.4k\(\Omega\) precision resistor. Different output voltages can be programmed with an additional resistor between V\textsubscript{FB} and GND pins. In PolyPhase\textsuperscript{®} operation, tying the V\textsubscript{FB} pins together allows for parallel operation. See the Applications Information section for details.

**TRACK1, TRACK2 (E5, D8):** Output Voltage Tracking Pin and Soft-Start Inputs. Each channel has a 1.3\(\mu\)A pull-up current source. When one channel is configured to be master of the two channels, then a capacitor from this pin to ground will set a soft-start ramp rate. The remaining channel can be set up as the slave, and have the master's output applied through a voltage divider to the slave output's track pin. This voltage divider is equal to the slave output's feedback divider for coincidental tracking. See the Applications Information section.

**COMP1, COMP2 (E6, E7):** Current control threshold and error amplifier compensation point for each channel. The current comparator threshold increases with this control voltage. Tie the COMP pins together for parallel operation. The device is internal compensated.

**DIFFP (E8):** Positive input of the remote sense amplifier. This pin is connected to the remote sense point of the output GND. See the Applications Information section.

**DIFFN (E9):** Negative input of the remote sense amplifier. This pin is connected to the remote sense point of the output voltage. See the Applications Information section.

**MODE_PLLIN (F4):** Force Continuous Mode, Burst Mode Operation, or Pulse-Skipping Mode Selection Pin and External Synchronization Input to Phase Detector Pin. Connect this pin to SGND to force both channels into force continuous mode of operation. Connect to INTV\textsubscript{CC} to enable pulse-skipping mode of operation. Leaving the pin floating will enable Burst Mode operation. A clock on the pin will force both channels into continuous mode of operation and synchronized to the external clock applied to this pin.

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For more information: www.linear.com/LTM4630
**PIN FUNCTIONS**  
(Recommended to Use Test Points to Monitor Signal Pin Connections.)

**RUN1, RUN2 (F5, F9):** Run Control Pin. A voltage above 1.25V will turn on each channel in the module. A voltage below 1.25V on the RUN pin will turn off the related channel. Each RUN pin has a 1µA pull-up current, once the RUN pin reaches 1.2V an additional 4.5µA pull-up current is added to this pin.

**DIFFOUT (F8):** Internal Remote Sense Amplifier Output. Connect this pin to VOUTS1 or VOUTS2 depending on which output is using remote sense. In parallel operation connect one of the VOUTS pin to DIFFOUT for remote sensing.

**SW1, SW2 (G2, G11):** Switching node of each channel that is used for testing purposes. Also an R-C snubber network can be applied to reduce or eliminate switch node ringing, or otherwise leave floating. See the Applications Information section.

**PHASMD (G4):** Connect this pin to SGND, INTVCC, or floating this pin to select the phase of CLKOUT to 60 degrees, 120 degrees, and 90 degrees respectively.

**CLKOUT (G5):** Clock output with phase control using the PHASMD pin to enable multiphase operation between devices. See the Applications Information section.

**PGOOD1, PGOOD2 (G9, G8):** Output Voltage Power Good Indicator. Open drain logic output that is pulled to ground when the output voltage is not within ±10% of the regulation point.

**INTVCC (H8):** Internal 5V Regulator Output. The control circuits and internal gate drivers are powered from this voltage. Decouple this pin to PGND with a 4.7µF low ESR tantalum or ceramic. INTVCC is activated when either RUN1 or RUN2 is activated.

**TEMP (J6):** Onboard General Purpose Temperature Diode for Monitoring the VBE Junction Voltage Change with Temperature. See the Applications Information section.

**EXTVCC (J7):** External power input that is enabled through a switch to INTVCC whenever EXTVCC is greater than 4.7V. Do not exceed 6V on this input, and connect this pin to VIN when operating VIN on 5V. An efficiency increase will occur that is a function of the (VIN – INTVCC) multiplied by power MOSFET driver current. Typical current requirement is 30mA. VIN must be applied before EXTVCC, and EXTVCC must be removed before VIN.

**VIN (M2-M11, L2-L11, J2-J4, J9-J11, K2-K4, K9-K11):** Power Input Pins. Apply input voltage between these pins and GND pins. Recommend placing input decoupling capacitance directly between VIN pins and GND pins.
**Simplified Block Diagram**

**Decoupling Requirements**  $T_A = 25^\circ\text{C}$. Use Figure 1 configuration.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_{\text{INT1}, \text{INT2}}</td>
<td>External Input Capacitor Requirement</td>
<td>$V_{\text{IN1}} = 4.5\text{V to 15V}, V_{\text{OUT1}} = 1.5\text{V}$</td>
<td>44</td>
<td>44</td>
<td></td>
<td>µF</td>
</tr>
<tr>
<td>C_{\text{INT3}, \text{INT4}}</td>
<td>$V_{\text{IN2}} = 4.5\text{V to 15V}, V_{\text{OUT2}} = 1.2\text{V}$</td>
<td>$I_{\text{OUT1}} = 18\text{A}$ $I_{\text{OUT2}} = 18\text{A}$</td>
<td>400</td>
<td>400</td>
<td></td>
<td>µF</td>
</tr>
<tr>
<td>C_{\text{OUT1}}</td>
<td>External Output Capacitor Requirement</td>
<td>$V_{\text{IN1}} = 4.5\text{V to 15V}, V_{\text{OUT1}} = 1.5\text{V}$</td>
<td>$I_{\text{OUT1}} = 18\text{A}$ $I_{\text{OUT2}} = 18\text{A}$</td>
<td>22</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>C_{\text{OUT2}}</td>
<td>$V_{\text{IN2}} = 4.5\text{V to 15V}, V_{\text{OUT2}} = 1.2\text{V}$</td>
<td></td>
<td>22</td>
<td>22</td>
<td></td>
<td>µF</td>
</tr>
</tbody>
</table>

For more information www.linear.com/LTM4630
OPERATION

Power Module Description

The LTM4630 is a dual-output standalone nonisolated switching mode DC/DC power supply. It can provide two 18A outputs with few external input and output capacitors and setup components. This module provides precisely regulated output voltages programmable via external resistors from 0.6VDC to 1.8VDC over 4.5V to 15V input voltages. The typical application schematic is shown in Figure 23.

The LTM4630 has dual integrated constant-frequency current mode regulators and built-in power MOSFET devices with fast switching speed. The typical switching frequency is 500kHz. For switching-noise sensitive applications, it can be externally synchronized from 400kHz to 780kHz. A resistor can be used to program a free run frequency on the FSET pin. See the Applications Information section.

With current mode control and internal feedback loop compensation, the LTM4630 module has sufficient stability margins and good transient performance with a wide range of output capacitors, even with all ceramic output capacitors.

Current mode control provides cycle-by-cycle fast current limit and foldback current limit in an overcurrent condition. Internal overvoltage and undervoltage comparators pull the open-drain PGOOD outputs low if the output feedback voltage exits a ±10% window around the regulation point. As the output voltage exceeds 10% above regulation, the bottom MOSFET will turn on to clamp the output voltage. The top MOSFET will be turned off. This overvoltage protect is feedback voltage referred.

Pulling the RUN pins below 1.1V forces the regulators into a shutdown state, by turning off both MOSFETs. The TRACK pins are used for programming the output voltage ramp and voltage tracking during start-up or used for soft-starting the regulator. See the Applications Information section.

The LTM4630 is internally compensated to be stable over all operating conditions. Table 4 provides a guide line for input and output capacitances for several operating conditions. The Linear Technology µModule Power Design Tool will be provided for transient and stability analysis. The VFB pin is used to program the output voltage with a single external resistor to ground. A differential remote sense amplifier is available for sensing the output voltage accurately on one of the outputs at the load point, or in parallel operation sensing the output voltage at the load point.

Multiphase operation can be easily employed with the MODE_PLLIN, PHASMD, and CLKOUT pins. Up to 12 phases can be cascaded to run simultaneously with respect to each other by programming the PHASMD pin to different levels. See the Applications Information section.

High efficiency at light loads can be accomplished with selectable Burst Mode operation or pulse-skipping operation using the MODE_PLLIN pin. These light load features will accommodate battery operation. Efficiency graphs are provided for light load operation in the Typical Performance Characteristics section. See the Applications Information section for details.

A general purpose temperature diode is included inside the module to monitor the temperature of the module. See the Applications Information section for details.

The switch pins are available for functional operation monitoring and a resistor-capacitor snubber circuit can be careful placed on the switch pin to ground to dampen any high frequency ringing on the transition edges. See the Applications Information section for details.
APPLICATIONS INFORMATION

The typical LTM4630 application circuit is shown in Figure 23. External component selection is primarily determined by the maximum load current and output voltage. Refer to Table 4 for specific external capacitor requirements for particular applications.

**V\text{IN} to V\text{OUT} Step-Down Ratios**

There are restrictions in the maximum V\text{IN} and V\text{OUT} step-down ratio that can be achieved for a given input voltage. Each output of the LTM4630 is capable of 98% duty cycle, but the V\text{IN} to V\text{OUT} minimum dropout is still shown as a function of its load current and will limit output current capability related to high duty cycle on the top side switch. Minimum on-time t\text{ON(MIN)} is another consideration in operating at a specified duty cycle while operating at a certain frequency due to the fact that t\text{ON(MIN)} < D/f\text{SW}, where D is duty cycle and f\text{SW} is the switching frequency. t\text{ON(MIN)} is specified in the electrical parameters as 90ns.

**Output Voltage Programming**

The PWM controller has an internal 0.6V reference voltage. As shown in the Block Diagram, a 60.4kΩ internal feedback resistor connects between the V\text{OUTS1} to V\text{FB1} and V\text{OUTS2} to V\text{FB2}. It is very important that these pins be connected to their respective outputs for proper feedback regulation. Overvoltage can occur if these V\text{OUTS1} and V\text{OUTS2} pins are left floating when used as individual regulators, or at least one of them is used in paralleled regulators. The output voltage will default to 0.6V with no feedback resistor on either V\text{FB1} or V\text{FB2}. Adding a resistor R\text{FB} from V\text{FB} pin to GND programs the output voltage:

\[
V\text{OUT} = 0.6V \times \frac{60.4k + R\text{FB}}{R\text{FB}}
\]

**Table 1. V\text{FB} Resistor Table vs Various Output Voltages**

<table>
<thead>
<tr>
<th>V\text{OUT}</th>
<th>0.6V</th>
<th>1.0V</th>
<th>1.2V</th>
<th>1.5V</th>
<th>1.8V</th>
</tr>
</thead>
<tbody>
<tr>
<td>R\text{FB}</td>
<td>Open</td>
<td>90.9k</td>
<td>60.4k</td>
<td>40.2k</td>
<td>30.2k</td>
</tr>
</tbody>
</table>

For parallel operation of multiple channels the same feedback setting resistor can be used for the parallel design. This is done by connecting the V\text{OUTS1} to the output as shown in Figure 2, thus tying one of the internal 60.4k resistors to the output. All of the V\text{FB} pins tie together with one programming resistor as shown in Figure 2.

In parallel operation, the V\text{FB} pins have an I\text{FB} current of 20nA maximum each channel. To reduce output voltage error due to this current, an additional V\text{OUTS} pin can be tied to V\text{OUT}, and an additional R\text{FB} resistor can be used to lower the total Thevenin equivalent resistance seen by this current. For example in Figure 2, the total Thevenin equivalent resistance of the V\text{FB} pin is \( (60.4k/R\text{FB}) \), which is 30.2k where R\text{FB} is equal to 60.4k for a 1.2V output. Four phases connected in parallel equates to a worse case feedback current of \( 4 \times I\text{FB} = 80nA \) maximum. The voltage error is 80nA \times 30.2k = 2.4mV. If V\text{OUTS2} is connected, as shown in Figure 2, to V\text{OUT}, and another 60.4k resistor is connected from V\text{FB2} to ground, then the voltage error is reduced to 1.2mV. If the voltage error is acceptable then no additional connections are necessary. The onboard 60.4k resistor is 0.5% accurate and the V\text{FB} resistor can be chosen by the user to be as accurate as needed. All COMP pins are tied together for current sharing between the phases. The TRACK/SS pins can be tied together and a single soft-start capacitor can be used to soft-start the regulator. The soft-start equation will need to have the soft-start current parameter increased by the number of paralleled channels. See Output Voltage Tracking section.
APPLICATIONS INFORMATION

Input Capacitors

The LTM4630 module should be connected to a low ac-impedance DC source. For the regulator input four 22µF input ceramic capacitors are used for RMS ripple current. A 47µF to 100µF surface mount aluminum electrolytic bulk capacitor can be used for more input bulk capacitance. This bulk input capacitor is only needed if the input source impedance is compromised by long inductive leads, traces or not enough source capacitance. If low impedance power planes are used, then this bulk capacitor is not needed.

For a buck converter, the switching duty-cycle can be estimated as:

\[ D = \frac{V_{OUT}}{V_{IN}} \]

Without considering the inductor current ripple, for each output, the RMS current of the input capacitor can be estimated as:

\[ I_{CIN(RMS)} = \frac{I_{OUT(MAX)}}{\eta\%} \cdot \sqrt{D \cdot (1-D)} \]

In the above equation, \( \eta\% \) is the estimated efficiency of the power module. The bulk capacitor can be a switcher-rated electrolytic aluminum capacitor, Polymer capacitor.

Output Capacitors

The LTM4630 is designed for low output voltage ripple noise and good transient response. The bulk output capacitors defined as \( C_{OUT} \) are chosen with low enough effective series resistance (ESR) to meet the output voltage ripple and transient requirements. \( C_{OUT} \) can be a low ESR tantalum capacitor, the low ESR polymer capacitor or ceramic capacitor. The typical output capacitance range for each output is from 200µF to 470µF. Additional output filtering may be required by the system designer, if further reduction of output ripples or dynamic transient spikes is required. Table 4 shows a matrix of different output voltages and output capacitors to minimize the voltage droop and overshoot during a 4.5A/µs transient. The table optimizes total equivalent ESR and total bulk capacitance to optimize the transient performance. Stability criteria are considered in the Table 4 matrix, and the Linear Technology µModule Power Design Tool will be provided for stability analysis. Multiphase operation will reduce effective output ripple as a function of the number of phases. Application Note 77 discusses this noise reduction versus output ripple current cancellation, but the output capacitance should be considered carefully as a function of stability and transient response. The Linear Technology µModule Power Design Tool can calculate the output ripple reduction as the number of implemented phases increases by \( N \) times. A small value 10Ω to 50Ω resistor can be place in series from \( V_{OUT} \) to the \( V_{OUTS} \) pin to allow for a bode plot analyzer to inject a signal into the control loop and validate the regulator stability. The same resistor could be place in series from \( V_{OUT} \) to \( DIFFP \) and a bode plot analyzer could inject a signal into the control loop and validate the regulator stability.

Burst Mode Operation

The LTM4630 is capable of Burst Mode operation on each regulator in which the power MOSFETs operate intermittently based on load demand, thus saving quiescent current. For applications where maximizing the efficiency at very light loads is a high priority, Burst Mode operation should be applied. Burst Mode operation is enabled with the MODE_PLLIN pin floating. During this operation, the peak current of the inductor is set to approximately one third of the maximum peak current value in normal operation even though the voltage at the COMP pin indicates a lower value. The voltage at the COMP pin drops when the inductor’s average current is greater than the load requirement. As the COMP voltage drops below 0.5V, the BURST comparator trips, causing the internal sleep line to go high and turn off both power MOSFETs.

In sleep mode, the internal circuitry is partially turned off, reducing the quiescent current to about 450µA for each output. The load current is now being supplied from the output capacitors. When the output voltage drops, causing COMP to rise above 0.5V, the internal sleep line goes low, and the LTM4630 resumes normal operation. The next oscillator cycle will turn on the top power MOSFET and the switching cycle repeats. Either regulator can be configured for Burst Mode operation.
APPLICATIONS INFORMATION

Pulse-Skipping Mode Operation

In applications where low output ripple and high efficiency at intermediate currents are desired, pulse-skipping mode should be used. Pulse-skipping operation allows the LTM4630 to skip cycles at low output loads, thus increasing efficiency by reducing switching loss. Tying the MODE_PLLIN pin to INTVCC enables pulse-skipping operation. At light loads the internal current comparator may remain tripped for several cycles and force the top MOSFET to stay off for several cycles, thus skipping cycles. The inductor current does not reverse in this mode. This mode will maintain higher effective frequencies thus lower output ripple and lower noise than Burst Mode operation. Either regulator can be configured for pulse-skipping mode.

Forced Continuous Operation

In applications where fixed frequency operation is more critical than low current efficiency, and where the lowest output ripple is desired, forced continuous operation should be used. Forced continuous operation can be enabled by tying the MODE_PLLIN pin to GND. In this mode, inductor current is allowed to reverse during low output loads, the COMP voltage is in control of the current comparator threshold throughout, and the top MOSFET always turns on with each oscillator pulse. During start-up, forced continuous mode is disabled and inductor current is prevented from reversing until the LTM4630’s output voltage is in regulation. Either regulator can be configured for forced continuous mode.

Multiphase Operation

For output loads that demand more than 18A of current, two outputs in LTM4630 or even multiple LTM4630s can be paralleled to run out of phase to provide more output current without increasing input and output voltage ripples. The MODE_PLLIN pin allows the LTM4630 to synchronize to an external clock (between 400kHz and 780kHz) and the internal phase-locked-loop allows the LTM4630 to lock onto incoming clock phase as well. The CLKOUT signal can be connected to the MODE_PLLIN pin of the following stage to line up both the frequency and the phase of the entire system. Tying the PHASMD pin to INTVCC, SGND, or (floating) generates a phase difference (between MODE_PLLIN and CLKOUT) of 120 degrees, 60 degrees, or 90 degrees respectively. A total of 12 phases can be cascaded to run simultaneously with respect to each other by programming the PHASMD pin of each LTM4630 channel to different levels. Figure 3 shows a 2-phase design, 4-phase design and a 6-phase design example for clock phasing with the PHASMD table.

A multiphase power supply significantly reduces the amount of ripple current in both the input and output capacitors. The RMS input ripple current is reduced by, and the effective ripple frequency is multiplied by, the number of phases used (assuming that the input voltage is greater than the number of phases used times the output voltage). The output ripple amplitude is also reduced by the number of phases used when all of the outputs are tied together to achieve a single high output current design.

The LTM4630 device is an inherently current mode controlled device, so parallel modules will have very good current sharing. This will balance the thermals on the design. Figure 26 shows an example of parallel operation and pin connection.

Input RMS Ripple Current Cancellation

Application Note 77 provides a detailed explanation of multiphase operation. The input RMS ripple current cancellation mathematical derivations are presented, and a graph is displayed representing the RMS ripple current reduction as a function of the number of interleaved phases. Figure 4 shows this graph.

Frequency Selection and Phase-Lock Loop (MODE_PLLIN and fSET Pins)

The LTM4630 device is operated over a range of frequencies to improve power conversion efficiency. It is recommended to operate the module at 500kHz over the output range for the best efficiency and inductor current ripple.

The LTM4630 switching frequency can be set with an external resistor from the fSET pin to SGND. An accurate 10µA current source into the resistor will set a voltage that programs the frequency or a DC voltage can be
Figure 3. Examples of 2-Phase, 4-Phase, and 6-Phase Operation with PHASMD Table

<table>
<thead>
<tr>
<th>PHASMD</th>
<th>SGNd</th>
<th>FLOAT</th>
<th>INTVcc</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROLLER1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CONTROLLER2</td>
<td>180</td>
<td>180</td>
<td>240</td>
</tr>
<tr>
<td>CLKOUT</td>
<td>60</td>
<td>90</td>
<td>120</td>
</tr>
</tbody>
</table>

Figure 4. Input RMS Current Ratios to DC Load Current as a Function of Duty Cycle
APPLICATIONS INFORMATION

Low duty cycle applications may approach this minimum on-time limit and care should be taken to ensure that:

\[ \frac{V_{OUT}}{V_{IN} \cdot \text{FREQ}} > t_{ON(MIN)} \]

If the duty cycle falls below what can be accommodated by the minimum on-time, the controller will begin to skip cycles. The output voltage will continue to be regulated, but the output ripple and current will increase. The on-time can be increased by lowering the switching frequency. A good rule of thumb is to keep on-time longer than 110ns.

Output Voltage Tracking

Output voltage tracking can be programmed externally using the TRACK pins. The output can be tracked up and down with another regulator. The master regulator’s output is divided down with an external resistor divider that is the same as the slave regulator’s feedback divider to implement coincident tracking. The LTM4630 uses an accurate 60.4k resistor internally for the top feedback resistor for each channel. Figure 6 shows an example of coincident tracking. Equations:

\[ \text{SLAVE} = \left(1 + \frac{60.4k}{R_{TA}}\right) \cdot V_{\text{TRACK}} \]

\( V_{\text{TRACK}} \) is the track ramp applied to the slave’s track pin. \( V_{\text{TRACK}} \) has a control range of 0V to 0.6V, or the internal reference voltage. When the master’s output is divided down with the same resistor values used to set the slave’s output, then the slave will coincident track with the master until it reaches its final value. The master will continue to its final value from the slave’s regulation point. Voltage tracking is disabled when \( V_{\text{TRACK}} \) is more than 0.6V. \( R_{TA} \) in Figure 6 will be equal to the \( R_{FB} \) for coincident tracking. Figure 7 shows the coincident tracking waveforms.

The TRACK pin of the master can be controlled by a capacitor placed on the master regulator TRACK pin to ground. A 1.3\( \mu \)A current source will charge the TRACK pin up to the reference voltage and then proceed up.

Minimum On-Time

Minimum on-time \( t_{ON} \) is the smallest time duration that the LTM4630 is capable of turning on the top MOSFET on either channel. It is determined by internal timing delays, and the gate charge required turning on the top MOSFET.
Regardless of the mode selected by the MODE_PLLIN pin, the regulator channels will always start in pulse-skipping mode up to TRACK = 0.5V. Between TRACK = 0.5V and 0.54V, it will operate in forced continuous mode and revert to the selected mode once TRACK > 0.54V. In order to track with another channel once in steady state operation, the LTM4630 is forced into continuous mode operation as soon as VFB is below 0.54V regardless of the setting on the MODE_PLLIN pin.

Ratiometric tracking can be achieved by a few simple calculations and the slew rate value applied to the master’s TRACK pin. As mentioned above, the TRACK pin has a control range from 0 to 0.6V. The master’s TRACK pin slew rate is directly equal to the master’s output slew rate in Volts/Time. The equation:

\[
\frac{MR}{SR} \cdot 60.4k = R_{TB}
\]

where MR is the master’s output slew rate and SR is the slave’s output slew rate in Volts/Time. When coincident tracking to INTVCC. After the 0.6V ramp, the TRACK pin will no longer be in control, and the internal voltage reference will control output regulation from the feedback divider. Foldback current limit is disabled during this sequence of turn-on during tracking or soft-starting. The TRACK pins are pulled low when the RUN pin is below 1.2V. The total soft-start time can be calculated as:

\[
t_{SOFT-START} = \left( \frac{CSS}{1.3\mu A} \right) \cdot 0.6
\]
APPLICATIONS INFORMATION

tracking is desired, then MR and SR are equal, thus $R_{TB}$ is equal the 60.4k. $R_{TA}$ is derived from equation:

$$R_{TA} = \frac{0.6V}{\frac{V_{FB}}{60.4k} + \frac{V_{FB}}{R_{FB}} - \frac{V_{TRACK}}{R_{TB}}}$$

where $V_{FB}$ is the feedback voltage reference of the regulator, and $V_{TRACK}$ is 0.6V. Since $R_{TB}$ is equal to the 60.4k top feedback resistor of the slave regulator in equal slew rate or coincident tracking, then $R_{TA}$ is equal to $R_{FB}$ with $V_{FB} = V_{TRACK}$. Therefore $R_{TB} = 60.4k$, and $R_{TA} = 60.4k$ in Figure 6.

In ratiometric tracking, a different slew rate maybe desired for the slave regulator. $R_{TB}$ can be solved for when SR is slower than MR. Make sure that the slave supply slew rate is chosen to be fast enough so that the slave output voltage will reach it final value before the master output.

For example, $MR = 1.5V/1ms$, and $SR = 1.2V/1ms$. Then $R_{TB} = 76.8k$. Solve for $R_{TA}$ to equal to 49.9k.

Each of the TRACK pins will have the 1.3µA current source on when a resistive divider is used to implement tracking on that specific channel. This will impose an offset on the TRACK pin input. Smaller values resistors with the same ratios as the resistor values calculated from the above equation can be used. For example, where the 60.4k is used then a 6.04k can be used to reduce the TRACK pin offset to a negligible value.

Power Good

The PGOOD pins are open drain pins that can be used to monitor valid output voltage regulation. This pin monitors a 10% window around the regulation point. A resistor can be pulled up to a particular supply voltage no greater than 6V maximum for monitoring.

Stability Compensation

The module has already been internally compensated for all output voltages. Table 4 is provided for most application requirements. The Linear Technology µModule Power Design Tool will be provided for other control loop optimization.

Run Enable

The RUN pins have an enable threshold of 1.4V maximum, typically 1.25V with 150mV of hysteresis. They control the turn on each of the channels and INTVCC. These pins can be pulled up to VIN for 5V operation, or a 5V Zener diode can be placed on the pins and a 10k to 100k resistor can be placed up to higher than 5V input for enabling the channels. The RUN pins can also be used for output voltage sequencing. In parallel operation the RUN pins can be tie together and controlled from a single control. See the Typical Application circuits in Figure 6.

INTVCC and EXTVCC

The LTM4630 module has an internal 5V low dropout regulator that is derived from the input voltage. This regulator is used to power the control circuitry and the power MOSFET drivers. This regulator can source up to 70mA, and typically uses ~30mA for powering the device at the maximum frequency. This internal 5V supply is enabled by either RUN1 or RUN2.

EXTVCC allows an external 5V supply to power the LTM4630 and reduce power dissipation from the internal low dropout 5V regulator. The power loss savings can be calculated by:

$$(V_{IN} - 5V) \cdot 30mA = PLOSS$$

EXTVCC has a threshold of 4.7V for activation, and a maximum rating of 6V. When using a 5V input, connect this 5V input to EXTVCC also to maintain a 5V gate drive level. EXTVCC must sequence on after $V_{IN}$, and EXTVCC must sequence off before $V_{IN}$.

Differential Remote Sense Amplifier

An accurate differential remote sense amplifier is provided to sense low output voltages accurately at the remote load points. This is especially true for high current loads. The amplifier can be used on one of the two channels, or on a single parallel output. It is very important that the DIFFP and DIFFN are connected properly at the output, and DIFFOUT is connected to either $V_{OUTS1}$ or $V_{OUTS2}$. In parallel operation, the DIFFP and DIFFN are connected properly at the output, and DIFFOUT is connected to one of the $V_{OUTS}$ pins. Review the parallel schematics in Figure 24 and review Figure 2.
APPLICATIONS INFORMATION

SW Pins

The SW pins are generally for testing purposes by monitoring these pins. These pins can also be used to dampen out switch node ringing caused by LC parasitic in the switched current paths. Usually a series R-C combination is used called a snubber circuit. The resistor will dampen the resonance and the capacitor is chosen to only affect the high frequency ringing across the resistor. If the stray inductance or capacitance can be measured or approximated then a somewhat analytical technique can be used to select the snubber values. The inductance is usually easier to predict. It combines the power path board inductance in combination with the MOSFET interconnect bond wire inductance.

First the SW pin can be monitored with a wide bandwidth scope with a high frequency scope probe. The ring frequency can be measured for its value. The impedance Z can be calculated:

\[ Z_L = 2\pi f L, \]

where \( f \) is the resonant frequency of the ring, and \( L \) is the total parasitic inductance in the switch path. If a resistor is selected that is equal to \( Z \), then the ringing should be dampened. The snubber capacitor value is chosen so that its impedance is equal to the resistor at the ring frequency. Calculated by: \( Z_C = 1/(2\pi f C) \). These values are a good place to start with. Modification to these components should be made to attenuate the ringing with the least amount of power loss.

Temperature Monitoring

A diode connected PNP transistor is used for the TEMP monitor function by monitoring its voltage over temperature. The temperature dependence of this diode voltage can be understood in the equation:

\[ V_D = nV_T \ln\left( \frac{I_D}{I_S} \right) \]

where \( V_T \) is the thermal voltage (kT/q), and \( n \), the ideality factor, is 1 for the diode connected PNP transistor being used in the LTM4630. \( I_S \) is expressed by the typical empirical equation:

\[ I_S = I_0 \exp\left( \frac{-V_G}{V_T} \right) \]

where \( I_0 \) is a process and geometry dependent current, \( I_0 \) is typically around 20k orders of magnitude larger than \( I_S \) at room temperature) and \( V_G \) is the band gap voltage of 1.2V extrapolated to absolute zero or \(-273°C\).

If we take the \( I_S \) equation and substitute into the \( V_D \) equation, then we get:

\[ V_D = V_G - \left( \frac{kT}{q} \right) \ln\left( \frac{I_0}{I_D} \right), \quad V_T = \frac{kT}{q} \]

The expression shows that the diode voltage decreases (linearly if \( I_0 \) were constant) with increasing temperature and constant diode current. Figure 6 shows a plot of \( V_D \) vs Temperature over the operating temperature range of the LTM4630.

If we take this equation and differentiate it with respect to temperature \( T \), then:

\[ \frac{dV_D}{dT} = -\frac{V_G - V_D}{T} \]

This \( dV_D/dT \) term is the temperature coefficient equal to about \(-2mV/K \) or \(-2mV/°C \). The equation is simplified for the first order derivation.

Solving for \( T \), \( T = -(V_G - V_D)/(dV_D/dT) \) provides the temperature.

1st Example: Figure 8 for 27°C, or 300K the diode voltage is 0.598V, thus, 300K = -(1200mV - 598mV)/\(-2.0\ mV/K\)

2nd Example: Figure 8 for 75°C, or 350K the diode voltage is 0.50V, thus, 350K = -(1200mV - 500mV)/\(-2.0\ mV/K\)
APPLICATIONS INFORMATION

Converting the Kelvin scale to Celsius is simply taking the Kelvin temp and subtracting 273 from it.

A typical forward voltage is given in the electrical characteristics section of the data sheet, and Figure 6 is the plot of this forward voltage. Measure this forward voltage at 27°C to establish a reference point. Then using the above expression while measuring the forward voltage over temperature will provide a general temperature monitor. Connect a resistor between TEMP and VIN to set the current to 100µA. See Figure 24 for an example.

Figure 8. Diode Voltage VD vs Temperature T(K) for Different Bias Currents

Thermal Considerations and Output Current Derating

The thermal resistances reported in the Pin Configuration section of the data sheet are consistent with those parameters defined by JESD51-9 and are intended for use with finite element analysis (FEA) software modeling tools that leverage the outcome of thermal modeling, simulation, and correlation to hardware evaluation performed on a µModule package mounted to a hardware test board—also defined by JESD51-9 (“Test Boards for Area Array Surface Mount Package Thermal Measurements”). The motivation for providing these thermal coefficients is found in JESD 51-12 (“Guidelines for Reporting and Using Electronic Package Thermal Information”).

Many designers may opt to use laboratory equipment and a test vehicle such as the demo board to anticipate the µModule regulator’s thermal performance in their application at various electrical and environmental operating conditions to compliment any FEA activities. Without FEA software, the thermal resistances reported in the Pin Configuration section are in-and-of themselves not relevant to providing guidance of thermal performance; instead, the derating curves provided in the data sheet can be used in a manner that yields insight and guidance pertaining to one’s application-usage, and can be adapted to correlate thermal performance to one’s own application.

The Pin Configuration section typically gives four thermal coefficients explicitly defined in JESD 51-12; these coefficients are quoted or paraphrased below:

1. $\theta_{JA}$, the thermal resistance from junction to ambient, is the natural convection junction-to-ambient air thermal resistance measured in a one cubic foot sealed enclosure. This environment is sometimes referred to as “still air” although natural convection causes the air to move. This value is determined with the part mounted to a JESD 51-9 defined test board, which does not reflect an actual application or viable operating condition.

2. $\theta_{JCbottom}$, the thermal resistance from junction to the bottom of the product case, is the junction-to-board thermal resistance with all of the component power dissipation flowing through the bottom of the package. In the typical µModule, the bulk of the heat flows out the bottom of the package, but there is always heat flow out into the ambient environment. As a result, this thermal resistance value may be useful for comparing packages but the test conditions don’t generally match the user’s application.

3. $\theta_{JCTOP}$, the thermal resistance from junction to top of the product case, is determined with nearly all of the component power dissipation flowing through the top of the package. As the electrical connections of the typical µModule are on the bottom of the package, it is rare for an application to operate such that most of the heat flows from the junction to the top of the part. As in the case of $\theta_{JCbottom}$, this value may be useful for comparing packages but the test conditions don’t generally match the user’s application.
APPLICATIONS INFORMATION

4. θ_{JB}, the thermal resistance from junction to the printed circuit board, is the junction-to-board thermal resistance where almost all of the heat flows through the bottom of the µModule and into the board, and is really the sum of the θ_{JCbottom} and the thermal resistance of the bottom of the part through the solder joints and through a portion of the board. The board temperature is measured a specified distance from the package, using a two sided, two layer board. This board is described in JESD 51-9.

A graphical representation of the aforementioned thermal resistances is given in Figure 9; blue resistances are contained within the µModule regulator, whereas green resistances are external to the µModule.

As a practical matter, it should be clear to the reader that no individual or sub-group of the four thermal resistance parameters defined by JESD 51-12 or provided in the Pin Configuration section replicates or conveys normal operating conditions of a µModule. For example, in normal board-mounted applications, never does 100% of the device’s total power loss (heat) thermally conduct exclusively through the top or exclusively through bottom of the µModule—as the standard defines for θ_{JCtop} and θ_{JCbottom}, respectively. In practice, power loss is thermally dissipated in both directions away from the package—granted, in the absence of a heat sink and airflow, a majority of the heat flow is into the board.

Within a SIP (system-in-package) module, be aware there are multiple power devices and components dissipating power, with a consequence that the thermal resistances relative to different junctions of components or die are not exactly linear with respect to total package power loss. To reconcile this complication without sacrificing modeling simplicity—but also, not ignoring practical realities—an approach has been taken using FEA software modeling along with laboratory testing in a controlled-environment chamber to reasonably define and correlate the thermal resistance values supplied in this data sheet: (1) Initially, FEA software is used to accurately build the mechanical geometry of the µModule and the specified PCB with all of the correct material coefficients along with accurate power loss source definitions; (2) this model simulates a software-defined JEDEC environment consistent with JESD51-9 to predict power loss heat flow and temperature readings at different interfaces that enable the calculation of the JEDEC-defined thermal resistance values; (3) the model and FEA software is used to evaluate the µModule with heat sink and airflow; (4) having solved for and analyzed these thermal resistance values and simulated various operating conditions in the software model, a thorough laboratory evaluation replicates the simulated conditions with thermocouples within a controlled-environment chamber while operating the device at the same power loss as that which was simulated. An outcome of this process and due-diligence yields a set of derating curves provided in other sections of this data sheet. After these laboratory test have been performed and correlated to the µModule model, then the θ_{JB} and θ_{BA} are summed together to correlate quite well with the µModule model with no airflow or heat sinking in a properly define chamber. This θ_{JB} + θ_{BA}
Applications Information

The LTM4630 module has been designed to effectively remove heat from both the top and bottom of the package. The bottom substrate material has very low thermal resistance to the printed circuit board. An external heat sink can be applied to the top of the device for excellent heat sinking with airflow.

Figures 10 and 11 show temperature plots of the LTM4630 with no heat sink and 200LFM airflow.

These plots equate to a paralleled 12V to 1.0V at 36A design operating at 84.5% efficiency, and 12V to 1.2V at 36A design operating at 86% efficiency.

Safety Considerations

The LTM4630 modules do not provide isolation from VIN to VOUT. There is no internal fuse. If required, a slow blow fuse with a rating twice the maximum input current needs to be provided to protect each unit from catastrophic failure. The device does support over current protection. A temperature diode is provided for monitoring internal temperature, and can be used to detect the need for thermal shutdown that can be done by controlling the RUN pin.

Power Derating

The 1.0V and 1.5V power loss curves in Figures 13 and 14 can be used in coordination with the load current derating curves in Figures 15 to 22 for calculating an approximate \( \Theta_{JA} \) thermal resistance for the LTM4630 with various heat sinking and airflow conditions. The power loss curves are taken at room temperature, and are increased with a 1.35 to 1.4 multiplicative factor at 125°C. These factors come from the fact that the power loss of the regulator increases about 45% from 25°C to 150°C, thus a 50% spread over 125°C delta equates to -0.35%/°C loss increase. A 125°C maximum junction minus 25°C room temperature equates to a 100°C increase. This 100°C increase multiplied by 0.35%/°C equals a 35% power loss increase at the 125°C junction, thus the 1.35 multiplier.

The derating curves are plotted with CH1 and CH2 in parallel single output operation starting at 36A of load with low ambient temperature. The output voltages are 1.0V and 1.5V. These are chosen to include the lower and higher output voltage ranges for correlating the thermal resistance. Thermal models are derived from several temperature measurements in a controlled temperature chamber along with thermal modeling analysis.

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The junction temperatures are monitored while ambient temperature is increased with and without airflow. The power loss increase with ambient temperature change is factored into the derating curves. The junctions are maintained at ~120°C maximum while lowering output current or power while increasing ambient temperature. The decreased output current will decrease the internal module loss as ambient temperature is increased.

The monitored junction temperature of 120°C minus the ambient operating temperature specifies how much module temperature rise can be allowed. As an example in Figure 15, the load current is derated to ~25A at ~86°C with no air or heat sink and the power loss for the 12V to 1.0V at 25A output is a ~5.5W loss. The 5.5W loss is calculated with the ~4.1W room temperature loss from the 12V to 1.0V power loss curve at 25A, and the 1.35 multiplying factor at 125°C ambient. If the 86°C ambient temperature is subtracted from the 120°C junction temperature, then the difference of 34°C divided 5.5W equals a 6.2°C/W \( \Theta_{JA} \) thermal resistance. Table 2 specifies a 7°C/W value which is pretty close. The airflow graphs are more accurate due to the fact that the ambient temperature environment is controlled better with airflow. As an example in Figure 19, the load current is derated to ~30A at ~72°C with 200LFM of airflow and the power loss for the 12V to 1.5V at 30A output is a ~7.9W loss. The 7.9W loss is calculated with the ~5.9W room temperature loss from the 12V to 1.5V power loss curve at 22A, and the 1.35 multiplying factor at 125°C ambient. If the 72°C ambient temperature is subtracted from the 120°C junction temperature, then the difference of 48°C divided 7.9W equals a 6.0°C/W \( \Theta_{JA} \) thermal resistance. Table 2 specifies a 6.0°C/W value which is pretty close. Tables 2 and 3 provide equivalent thermal resistances for 1.0V and 1.5V outputs with and without airflow and heat sinking.

The derived thermal resistances in Tables 2 and 3 for the various conditions can be multiplied by the calculated power loss as a function of ambient temperature to derive temperature rise above ambient, thus maximum junction temperature. Room temperature power loss can be derived from the efficiency curves and adjusted with the above ambient temperature multiplicative factors. The printed circuit board is a 1.6mm thick four layer board with two ounce copper for the two outer layers and one ounce copper for the two inner layers. The PCB dimensions are 101mm × 114mm. The BGA heat sinks are listed in Table 3.

### Layout Checklist/Example

The high integration of LTM4630 makes the PCB board layout very simple and easy. However, to optimize its electrical and thermal performance, some layout considerations are still necessary.

- Use large PCB copper areas for high current paths, including \( V_{IN} \), \( GND \), \( V_{OUT1} \) and \( V_{OUT2} \). It helps to minimize the PCB conduction loss and thermal stress.
- Place high frequency ceramic input and output capacitors next to the \( V_{IN} \), \( PGND \) and \( V_{OUT} \) pins to minimize high frequency noise.
- Place a dedicated power ground layer underneath the unit.
- To minimize the via conduction loss and reduce module thermal stress, use multiple vias for interconnection between top layer and other power layers.
- Do not put via directly on the pad, unless they are capped or plated over.
- Use a separated SGND ground copper area for components connected to signal pins. Connect the SGND to GND underneath the unit.
- For parallel modules, tie the \( V_{OUT} \), \( V_{FB} \), and \( COMP \) pins together. Use an internal layer to closely connect these pins together. The TRACK pin can be tied a common capacitor for regulator soft-start.
- Bring out test points on the signal pins for monitoring.

Figure 12 gives a good example of the recommended layout. LGA and BGA PCB layouts are identical with the exception of circle pads for BGA (see Package Description).
APPLICATIONS INFORMATION

Figure 12. Recommended PCB Layout (LGA Shown, for BGA Use Circle Pads)

Table 2. 1.0V Output

<table>
<thead>
<tr>
<th>DERATING CURVE</th>
<th>$V_{IN}$ (V)</th>
<th>POWER LOSS CURVE</th>
<th>AIRFLOW (LFM)</th>
<th>HEAT SINK</th>
<th>$\theta_{JA}$ (°C/W)</th>
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<tr>
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<td>5, 12</td>
<td>Figure 13</td>
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<td>Figures 15, 16</td>
<td>5, 12</td>
<td>Figure 13</td>
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<td>6</td>
</tr>
<tr>
<td>Figures 15, 16</td>
<td>5, 12</td>
<td>Figure 13</td>
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<td>None</td>
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<td>Figures 17, 18</td>
<td>5, 12</td>
<td>Figure 13</td>
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<td>BGA Heat Sink</td>
<td>6.5</td>
</tr>
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<td>Figures 17, 18</td>
<td>5, 12</td>
<td>Figure 13</td>
<td>200</td>
<td>BGA Heat Sink</td>
<td>5</td>
</tr>
<tr>
<td>Figures 17, 18</td>
<td>5, 12</td>
<td>Figure 13</td>
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<td>BGA Heat Sink</td>
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Table 3. 1.5V Output

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<th>DERATING CURVE</th>
<th>$V_{IN}$ (V)</th>
<th>POWER LOSS CURVE</th>
<th>AIRFLOW (LFM)</th>
<th>HEAT SINK</th>
<th>$\theta_{JA}$ (°C/W)</th>
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<td>Figure 14</td>
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<td>Figures 19, 20</td>
<td>5, 12</td>
<td>Figure 14</td>
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<td>6</td>
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<tr>
<td>Figures 19, 20</td>
<td>5, 12</td>
<td>Figure 14</td>
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<td>None</td>
<td>5.5</td>
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<tr>
<td>Figures 21, 22</td>
<td>5, 12</td>
<td>Figure 14</td>
<td>0</td>
<td>BGA Heat Sink</td>
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<tr>
<td>Figures 21, 22</td>
<td>5, 12</td>
<td>Figure 14</td>
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<tr>
<td>Figures 21, 22</td>
<td>5, 12</td>
<td>Figure 14</td>
<td>400</td>
<td>BGA Heat Sink</td>
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</tbody>
</table>

HEAT SINK MANUFACTURER | PART NUMBER | WEBSITE
-----------------------|-------------|--------------|
Aavid Thermalloy        | 375424B00034G | www.aavid.com |
APPLICATIONS INFORMATION

Table 4. Output Voltage Response vs Component Matrix (Refer to Figure 23) 0A to 7A Load Step Typical Measured Values

<table>
<thead>
<tr>
<th>VENDORS</th>
<th>VALUE</th>
<th>PART NUMBER</th>
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<tbody>
<tr>
<td>TDK, COUT1 Ceramic</td>
<td>100µF 6.3V</td>
<td>C4532X5R0J107MZ</td>
</tr>
<tr>
<td>Murata, COUT1 Ceramic</td>
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<td>18126D107MAT</td>
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<td>2R5TPD470M5</td>
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<tr>
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<td>470µF 6.3V</td>
<td>6TPD470M</td>
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<td>Sanyo, CIN Bulk</td>
<td>56µF 25V</td>
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<table>
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<th>VOUT (V)</th>
<th>CIN (CERAMIC)</th>
<th>CIN (BULK)</th>
<th>COUT (CERAMIC)</th>
<th>COUT (BULK)</th>
<th>CFF (pF)</th>
<th>VIN (V)</th>
<th>DROOP (mV)</th>
<th>P-P DEVIATION (mV)</th>
<th>RECOVERY TIME (µs)</th>
<th>LOAD STEP (A)</th>
<th>LOAD STEP (A/µs)</th>
<th>RFB (kΩ)</th>
<th>FREQ (kHz)</th>
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<td>100µF</td>
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<td>450</td>
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<td>100µF × 4</td>
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<td>None</td>
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<td>20</td>
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<td>4.5</td>
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</tr>
<tr>
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<td>None</td>
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<td>20</td>
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<td>450</td>
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<tr>
<td>1.8</td>
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<td>4.5</td>
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</table>

Figure 13. 1.0V Power Loss Curve

Figure 14. 1.5V Power Loss Curve

Figure 15. 12V to 1V Derating Curve, No Heat Sink

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APPLICATIONS INFORMATION

Figure 16. 5V to 1V Derating Curve, No Heat Sink

Figure 17. 12V to 1V Derating Curve, BGA Heat Sink

Figure 18. 5V to 1V Derating Curve, BGA Heat Sink

Figure 19. 12V to 1.5V Derating Curve, No Heat Sink

Figure 20. 5V to 1.5V Derating Curve, No Heat Sink

Figure 21. 12V to 1.5V Derating Curve, BGA Heat Sink

Figure 22. 5V to 1.5V Derating Curve, BGA Heat Sink
Figure 23. Typical 4.5V\textsubscript{IN} to 15V\textsubscript{IN}, 1.5V and 1.2V at 18A Outputs
Figure 24. LTM4630 2-Phase, 1.5V @ 36A Design
Figure 26. LTM4630 4-Phase, 1.2V at 70A
## LTM4630 Component LGA and BGA Pinout

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<thead>
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<th>FUNCTION</th>
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<th>FUNCTION</th>
<th>PIN ID</th>
<th>FUNCTION</th>
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<td>E1</td>
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<td>E2</td>
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<td>VOUT1</td>
<td>C3</td>
<td>VOUT1</td>
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<td>GND</td>
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PACKAGE DESCRIPTION

Please refer to http://www.linear.com/design/tools/packaging/ for the most recent package drawings.

LGA Package

144-Lead (16mm × 16mm × 4.41mm)
(Reference LTC DVS # 05-08-1901 Rev B)

NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994
2. ALL DIMENSIONS ARE IN MILLIMETERS
3. LAND DESIGNATION PER JESD MO-222, SPP-010
4. PRIMARY DATUM -Z- IS SEATING PLANE
5. THE TOTAL NUMBER OF PADS: 144
6. THE TOTAL NUMBER OF GAYAS PAD: 144
7. PACKAGE ROW AND COLUMN LABELING MAY VARY AMONG µModule PRODUCTS. REVIEW EACH PACKAGE LAYOUT CAREFULLY!

PACKAGE TOP VIEW

PACKAGE BOTTOM VIEW

SUGGESTED PCB LAYOUT

SYMBOLS

DIMENSIONS

NOTES

TOTAL NUMBER OF GAYAS PAD: 144
PACKAGE DESCRIPTION

Please refer to http://www.linear.com/designtools/packaging/ for the most recent package drawings.

PACKAGE TOP VIEW

PACKAGE BOTTOM VIEW

PACKAGE SIDE VIEW

BGA Package

144-Lead (16mm × 16mm × 5.01mm) (Reference LTC DWG # 05-08-1969 Rev Ø)

NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994
2. ALL DIMENSIONS ARE IN MILLIMETERS. DRAWING NOT TO SCALE
3. BALL DESIGNATION PER JESD MS-028 AND JEP95
4. PRIMARY DATUM Z IS SEATING PLANE
5. SOLDER BALL COMPOSITION IS 96.5% Sn/3.0% Ag/0.5% Cu
6. PACKAGE ROW AND COLUMN LABELING MAY VARY AMONG µModule PRODUCTS. REVIEW EACH PACKAGE LAYOUT CAREFULLY

MIN
NOM
MAX

NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994
2. ALL DIMENSIONS ARE IN MILLIMETERS. DRAWING NOT TO SCALE
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For more information www.linear.com/LTM4630
REVISION HISTORY

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LTM4630

PACKAGE PHOTO

LTM4630

DESIGN RESOURCES

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| µModule Design and Manufacturing Resources | Design:  
- Selector Guides  
- Demo Boards and Gerber Files  
- Free Simulation Tools  

Manufacturing:  
- Quick Start Guide  
- PCB Design, Assembly and Manufacturing Guidelines  
- Package and Board Level Reliability |

| µModule Regulator Products Search | 1. Sort table of products by parameters and download the result as a spreadsheet.  
2. Search using the Quick Power Search parametric table. |

TechClip Videos  
Quick videos detailing how to bench test electrical and thermal performance of µModule products.

Digital Power System Management  
Linear Technology's family of digital power supply management ICs are highly integrated solutions that offer essential functions, including power supply monitoring, supervision, marging and sequencing, and feature EEPROM for storing user configurations and fault logging.

RELATED PARTS

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<th>DESCRIPTION</th>
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<td>Dual 13A Single 26A µModule Regulator</td>
<td>Pin Compatible with LTM4630; 4.5V ≤ VIN ≤ 16V, 0.6V ≤ VOUT ≤ 2.5V, 15mm × 15mm × 4.32mm</td>
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<tr>
<td>LTM4628</td>
<td>Dual 8A, Single 16A µModule Regulator</td>
<td>Pin Compatible with LTM4630; 4.5V ≤ VIN ≤ 26.5V, 0.6V ≤ VOUT ≤ 5.5V, 15mm × 15mm × 4.32mm</td>
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<td>LTM4627</td>
<td>15A µModule Regulator</td>
<td>4.5V ≤ VIN ≤ 20V, 0.6V ≤ VOUT ≤ 5.5V, 15mm × 15mm × 4.32mm</td>
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<td>LTM4611</td>
<td>Ultralow VIN, 15A µModule Regulator</td>
<td>1.5V ≤ VIN ≤ 5.5V, 0.8V ≤ VOUT ≤ 5V, 15mm × 15mm × 4.32mm</td>
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<td>LTM4619</td>
<td>Dual 26VIN, 4A DC/DC µModule Regulator</td>
<td>4.5V ≤ VIN ≤ 26.5V; 0.8V ≤ VOUT ≤ 5V</td>
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<td>LTM4615</td>
<td>Triple Low VIN, 4A DC/DC µModule Regulator</td>
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<td>LTM4616</td>
<td>Dual 8A, Low VIN, DC/DC µModule Regulator</td>
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| LTM8062/    | 32VIN, 2A µModule Battery Charger with Maximum   | Adjustable VBAT Up to 14.4V (18.8V for the LTM8062A), C/10 or Timer  
              | Peak Power Tracking (MPPT)                        | Termination, 9mm × 15mm × 4.32mm LGA Package |
| LTM8062A    |                                                  |                      |
| LTM8027     | 60VIN, 4A DC/DC Step-Down µModule Regulator      | 4.5V ≤ VIN ≤ 60V, 2.5V ≤ VOUT ≤ 24V, 15mm × 15mm × 4.32mm LGA Package |
| LTM4613     | EN55022B Compliant 36VIN, 8A Step-Down µModule  | 5V ≤ VIN ≤ 36V, 3.3V ≤ VOUT ≤ 15V, Synchronizable, Parallelable,  
              | Regulator                                          | 15mm × 15mm × 4.32mm LGA Package |

Linear Technology Corporation  
1630 McCarthy Blvd., Milpitas, CA 95035-7417  
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com/LTM4630