



# THE DATASHEET OF LTM8055EY-1#PBF

# LTM8055/LTM8055-1

## 36V<sub>IN</sub>, 8.5A Buck-Boost μModule Regulator

### FEATURES

- Complete Buck-Boost Switch Mode Power Supply
- V<sub>OUT</sub> Equal, Greater, Less Than V<sub>IN</sub>
- Wide Input Voltage Range: 5V to 36V
- 12V/3A Output from 6V<sub>IN</sub>
- 12V/6A Output from 12V<sub>IN</sub>
- 12V/8.5A Output from 24V<sub>IN</sub>
- Up to 97.5% Efficient
- Adjustable Input and Output Average Current Limits
- Input and Output Current Monitors
- Parallelable for Increased Output Current
- Wide Output Voltage Range: 1.2V to 36V
- Selectable Switching Frequency: 100kHz to 800kHz
- Synchronization from 200kHz to 700kHz
- External Compensation (LTM8055-1)
- 15mm × 15mm × 4.92mm BGA Package

### APPLICATIONS

- High Power Battery-Operated Devices
- Industrial Control
- Solar Powered Voltage Regulator
- Solar Powered Battery Charging

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### DESCRIPTION

The **LTM®8055/LTM8055-1** is a 36V<sub>IN</sub>, buck-boost μModule® (micromodule) regulator. Included in the package are the switching controller, power switches, inductor and support components. A resistor to set the switching frequency, a resistor divider to set the output voltage, and input and output capacitors are all that are needed to complete the design. Other features such as input and output average current regulation may be implemented with just a few components. The LTM8055/LTM8055-1 operates over an input voltage range of 5V to 36V, and can regulate output voltages between 1.2V and 36V. The SYNC input and CLKOUT output allow easy synchronization.

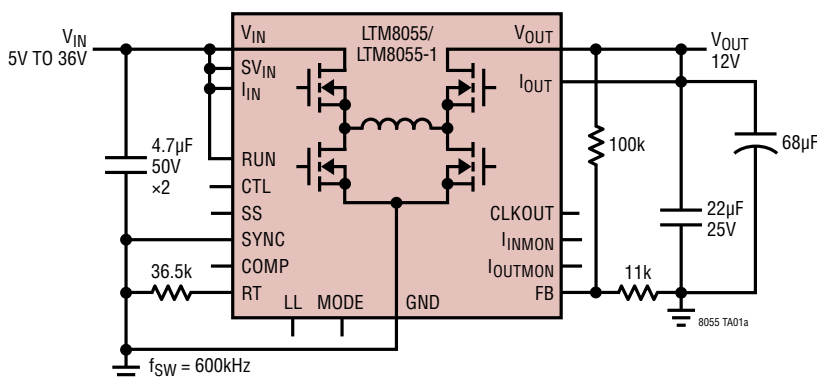
The LTM8055/LTM8055-1 is housed in a compact overmolded ball grid array (BGA) package suitable for automated assembly by standard surface mount equipment. The LTM8055/LTM8055-1 is RoHS compliant.

**Buck-Boost Selection Table**

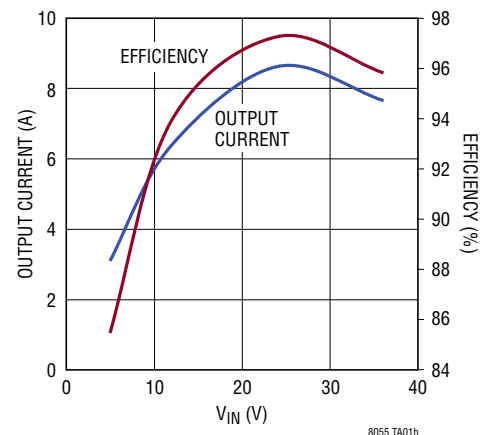
|                                                                   | LTM8054                      | LTM8055/LTM8055-1                                     | LTM8056 |
|-------------------------------------------------------------------|------------------------------|-------------------------------------------------------|---------|
| V <sub>IN</sub> (Operation)                                       | 36                           | 36                                                    | 58      |
| V <sub>IN</sub> Abs Max                                           | 40                           | 40                                                    | 60      |
| V <sub>OUT</sub> Abs Max                                          | 40                           | 40                                                    | 60      |
| I <sub>OUT</sub> (Peak)<br>24V <sub>IN</sub> , 12V <sub>OUT</sub> | 5.4                          | 8.5                                                   | 5.5     |
| Package                                                           | 15 × 11.25mm ×<br>3.42mm BGA | 15 × 15mm × 4.92mm BGA<br>Pin and Function Compatible |         |

### TYPICAL APPLICATION

**12V<sub>OUT</sub> from 5V<sub>IN</sub> to 36V<sub>IN</sub> Buck-Boost Regulator**



**Maximum Output Current and Efficiency vs V<sub>IN</sub>**



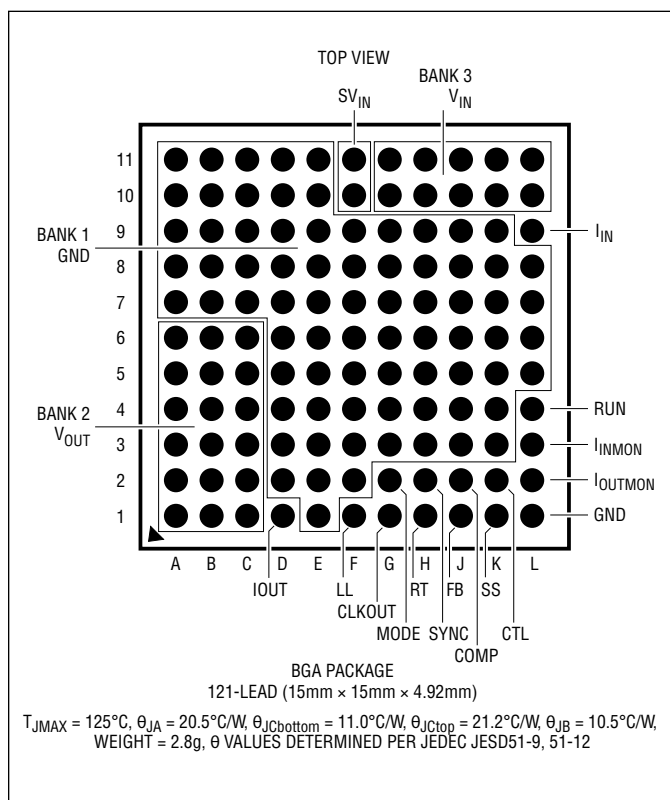
# LTM8055/LTM8055-1

## ABSOLUTE MAXIMUM RATINGS

(Note 1)

|                                                                            |                |
|----------------------------------------------------------------------------|----------------|
| $V_{IN}$ , $SV_{IN}$ , $V_{OUT}$ , RUN, $I_{IN}$ , $I_{OUT}$ Voltage ..... | 40V            |
| FB, SYNC, CTL, MODE Voltage .....                                          | 6V             |
| $I_{INMON}$ , $I_{OUTMON}$ Voltage .....                                   | 6V             |
| LL Voltage .....                                                           | 15V            |
| Maximum Junction Temperature (Notes 2, 3) .....                            | 125°C          |
| Storage Temperature .....                                                  | -55°C to 125°C |
| Peak Solder Reflow Body Temperature .....                                  | 245°C          |

## PIN CONFIGURATION



## ORDER INFORMATION

| PART NUMBER     | TERMINAL FINISH | PART MARKING* |             | PACKAGE TYPE | MSL RATING | TEMPERATURE RANGE (SEE NOTE 2) |
|-----------------|-----------------|---------------|-------------|--------------|------------|--------------------------------|
|                 |                 | DEVICE        | FINISH CODE |              |            |                                |
| LTM8055EY#PBF   | SAC305 (RoHS)   | LTM8055Y      | e1          | BGA          | 3          | -40°C to 125°C                 |
| LTM8055IY#PBF   | SAC305 (RoHS)   | LTM8055Y      | e1          | BGA          | 3          | -40°C to 125°C                 |
| LTM8055IY       | SnPb(63/37)     | LTM8055Y      | e0          | BGA          | 3          | -40°C to 125°C                 |
| LTM8055MPY#PBF  | SAC305 (RoHS)   | LTM8055Y      | e1          | BGA          | 3          | -55°C to 125°C                 |
| LTM8055MPY      | SnPb(63/37)     | LTM8055Y      | e0          | BGA          | 3          | -55°C to 125°C                 |
| LTM8055EY-1#PBF | SAC305 (RoHS)   | LTM8055Y-1    | e1          | BGA          | 3          | -40°C to 125°C                 |
| LTM8055IY-1#PBF | SAC305 (RoHS)   | LTM8055Y-1    | e1          | BGA          | 3          | -40°C to 125°C                 |

- Device temperature grade is indicated by a label on the shipping container.
- Pad or ball finish code is per IPC/JEDEC J-STD-609.
- [BGA Package and Tray Drawings](#)

This product is not recommended for second side reflow.  
This product is moisture sensitive. For more information, go to [Recommended BGA PCB Assembly and Manufacturing Procedures](#).

## ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ . RUN = 1.5V unless otherwise noted. (Note 2)

| PARAMETER                                            | CONDITIONS                                                                        |   | MIN            | TYP            | MAX            | UNITS                     |
|------------------------------------------------------|-----------------------------------------------------------------------------------|---|----------------|----------------|----------------|---------------------------|
| Minimum Input Voltage                                | $V_{IN} = SV_{IN}$                                                                | ● |                |                | 5.0            | V                         |
| Output DC Voltage                                    | $FB = V_{OUT}$ Through 100k<br>$R_{FB} = 100k/3.40k$                              |   |                | 1.2<br>36      |                | V<br>V                    |
| Output DC Current                                    | $V_{IN} = 6V, V_{OUT} = 12V$<br>$V_{IN} = 24V, V_{OUT} = 12V$                     |   |                | 3<br>8.5       |                | A<br>A                    |
| Quiescent Current Into $V_{IN}$ (Tied to $SV_{IN}$ ) | RUN = 0.3V (Disabled)<br>No Load, MODE = 0.3V (DCM)<br>No Load, MODE = 1.5V (FCM) |   |                | 0.1<br>8<br>45 | 1<br>30<br>100 | $\mu\text{A}$<br>mA<br>mA |
| Output Voltage Line Regulation                       | $5V < V_{IN} < 36V, I_{OUT} = 1A$                                                 |   |                | 0.5            |                | %                         |
| Output Voltage Load Regulation                       | $V_{IN} = 12V, 0.1A < I_{OUT} < 6A$                                               |   |                | 0.5            |                | %                         |
| Output RMS Voltage Ripple                            | $V_{IN} = 12V, I_{OUT} = 3A$                                                      |   |                | 25             |                | mV                        |
| Switching Frequency                                  | $R_T = 453k$<br>$R_T = 24.9k$                                                     |   |                | 100<br>800     |                | kHz<br>kHz                |
| Voltage at FB Pin                                    |                                                                                   | ● | 1.188<br>1.176 | 1.2            | 1.212<br>1.220 | V<br>V                    |
| RUN Falling Threshold                                | LTM8055/LTM8055-1 Stops Switching                                                 | ● | 1.15           |                | 1.25           | V                         |
| RUN Hysteresis                                       | LTM8055/LTM8055-1 Starts Switching                                                |   |                | 25             |                | mV                        |
| RUN Low Threshold                                    | LTM8055/LTM8055-1 Disabled                                                        |   |                |                | 0.3            | V                         |
| RUN Pin Current                                      | RUN = 1V<br>RUN = 1.6V                                                            |   | 2              | 3              | 5<br>100       | $\mu\text{A}$<br>nA       |
| $I_{IN}$ Bias Current                                |                                                                                   |   |                | 90             |                | $\mu\text{A}$             |
| Input Current Sense Threshold ( $I_{IN}-V_{IN}$ )    |                                                                                   | ● | 44             |                | 56             | mV                        |
| $I_{OUT}$ Bias Current                               |                                                                                   |   |                | 20             |                | $\mu\text{A}$             |
| Output Current Sense Threshold ( $V_{OUT}-I_{OUT}$ ) | $V_{CTL} = \text{Open}$                                                           | ● | 54.5<br>53     |                | 61.5<br>63     | mV<br>mV                  |
| $I_{INMON}$ Voltage                                  | LTM8055/LTM8055-1 in Input Current Limit                                          |   | 0.96           |                | 1.04           | V                         |
| $I_{OUTMON}$ Voltage                                 | LTM8055/LTM8055-1 in Output Current Limit                                         |   | 1.14           |                | 1.26           | V                         |
| CTL Input Bias Current                               | $V_{CTL} = 0V$                                                                    |   |                | 22             |                | $\mu\text{A}$             |
| SS Pin Current                                       | $V_{SS} = 0V$                                                                     |   |                | 35             |                | $\mu\text{A}$             |
| CLKOUT Output High                                   | 10k to GND                                                                        |   | 4              |                |                | V                         |
| CLKOUT Output Low                                    | 10k to 5V                                                                         |   |                |                | 0.7            | V                         |
| SYNC Input Low Threshold                             |                                                                                   |   |                |                | 0.3            | V                         |
| SYNC Input High Threshold                            |                                                                                   |   | 1.5            |                |                | V                         |
| SYNC Bias Current                                    | SYNC = 1V                                                                         |   |                | 11             |                | $\mu\text{A}$             |
| MODE Input Low Threshold                             |                                                                                   |   |                |                | 0.3            | V                         |
| MODE Input High Threshold                            |                                                                                   |   | 1.5            |                |                | V                         |

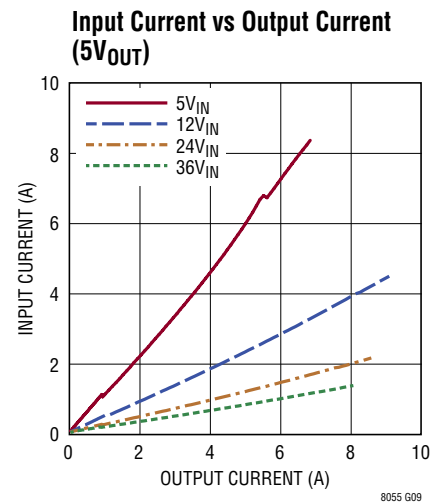
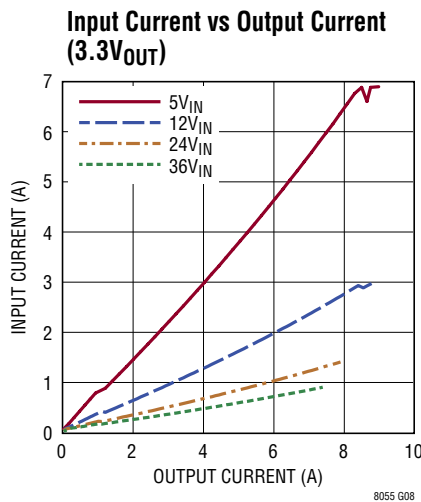
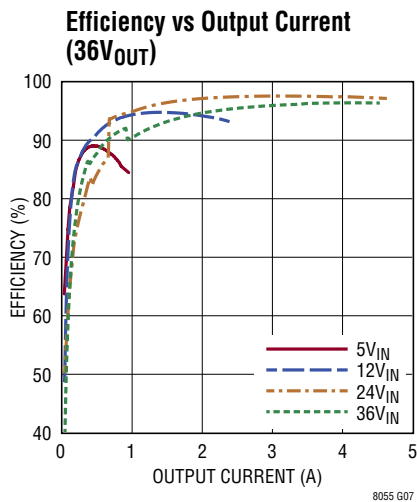
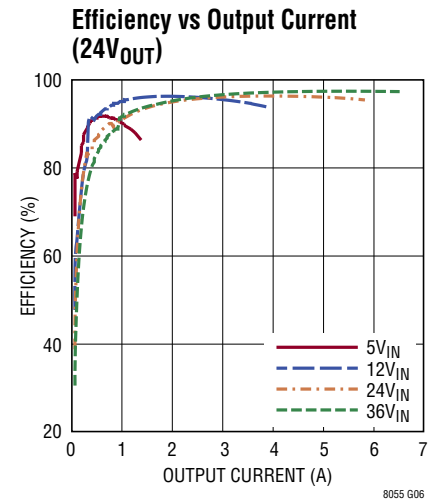
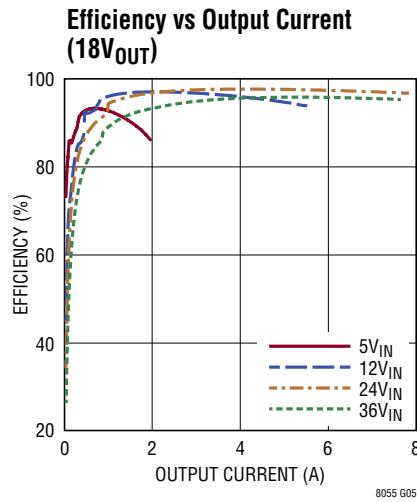
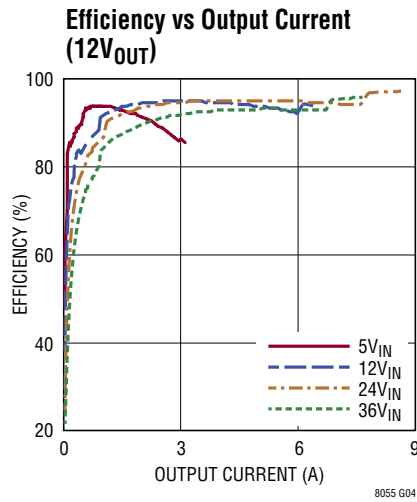
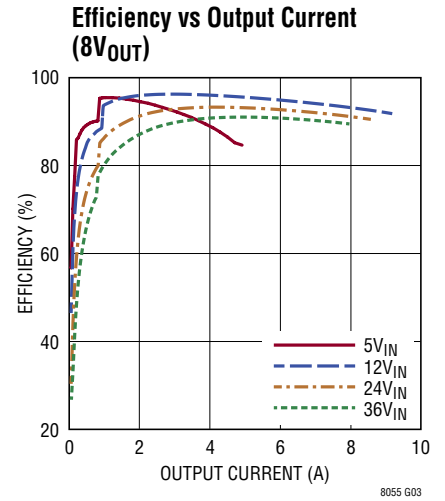
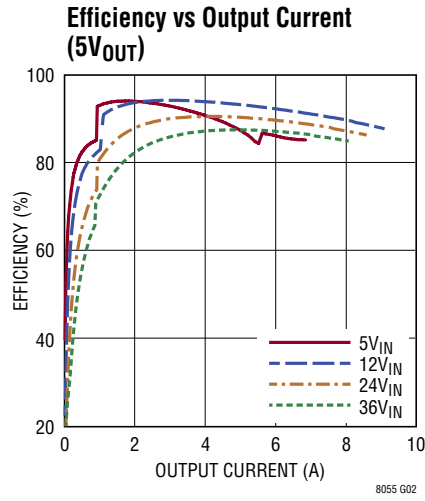
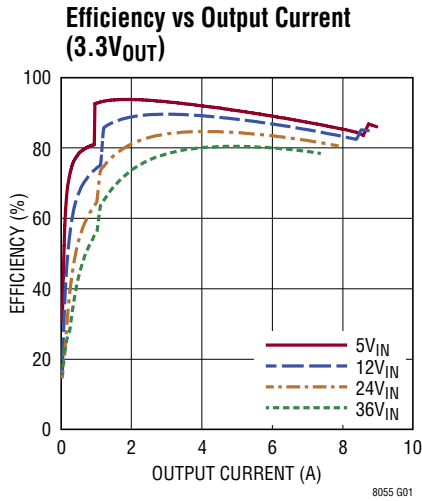
**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** The LTM8055E/LTM8055E-1 is guaranteed to meet performance specifications from  $0^\circ\text{C}$  to  $125^\circ\text{C}$  internal. Specifications over the full  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  internal operating temperature range are assured by design, characterization and correlation with statistical process controls. The LTM8055I/LTM8055I-1 is guaranteed to meet specifications over the full  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  internal operating temperature range. The LTM8055MP/LTM8055MP-1 is guaranteed to meet specifications over

the full  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  internal operating temperature range. Note that the maximum internal temperature is determined by specific operating conditions in conjunction with board layout, the rated package thermal resistance and other environmental factors.

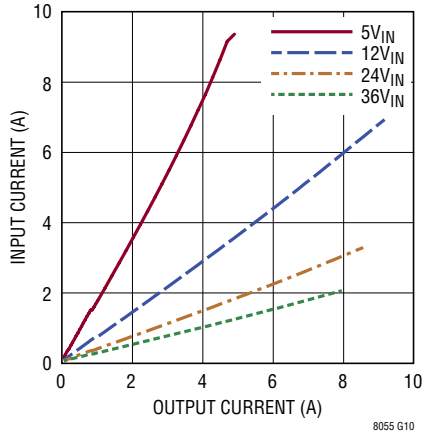
**Note 3:** The LTM8055/LTM8055-1 contains overtemperature protection that is intended to protect the device during momentary overload conditions. The internal temperature exceeds the maximum operating junction temperature when the overtemperature protection is active. Continuous operation above the specified maximum operating junction temperature may impair device reliability.

# TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25^\circ\text{C}$ , unless otherwise noted.

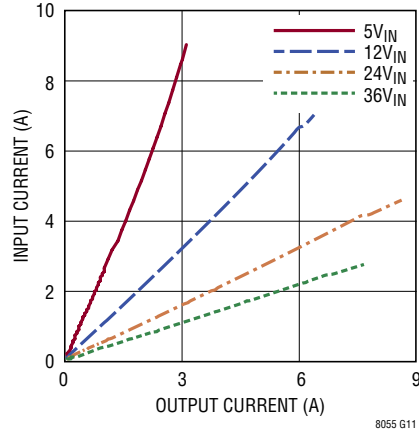


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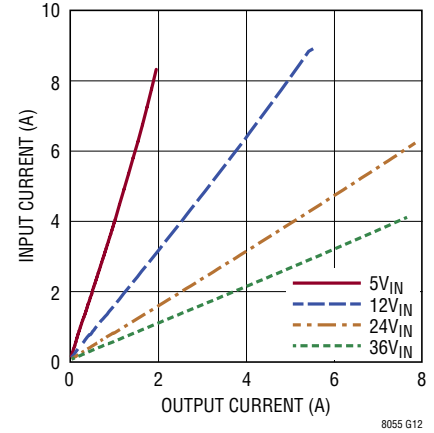
Input Current vs Output Current  
( $8V_{OUT}$ )



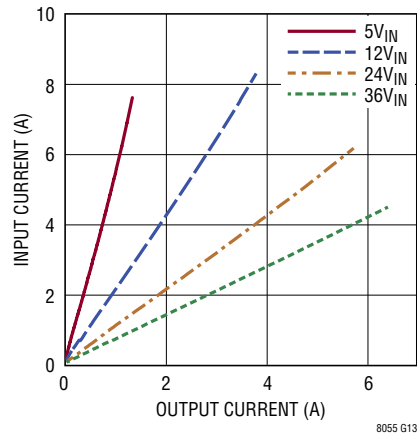
Input Current vs Output Current  
( $12V_{OUT}$ )



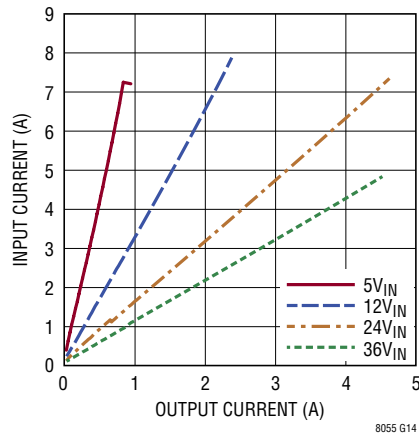
Input Current vs Output Current  
( $18V_{OUT}$ )



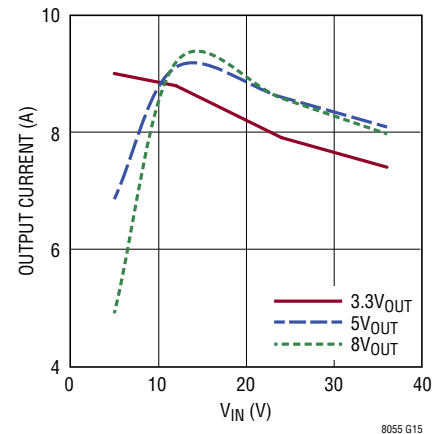
Input Current vs Output Current  
( $24V_{OUT}$ )



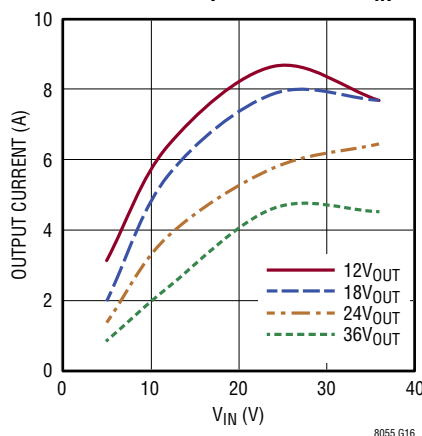
Input Current vs Output Current  
( $36V_{OUT}$ )



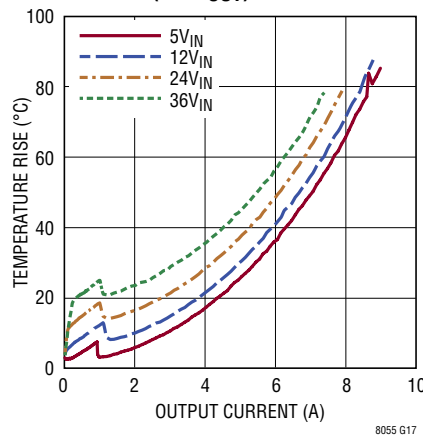
Maximum Output Current vs  $V_{IN}$



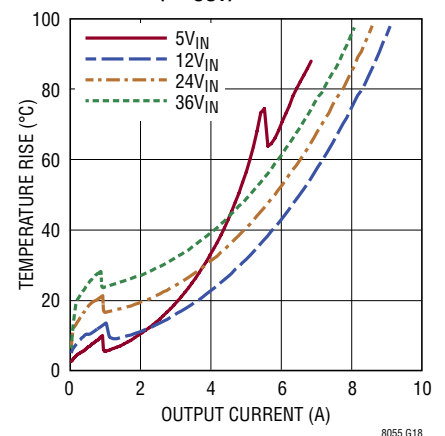
Maximum Output Current vs  $V_{IN}$



Temperature Rise vs Output  
Current ( $3.3V_{OUT}$ )

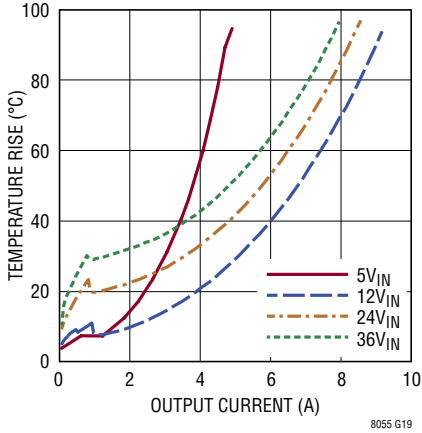


Temperature Rise vs Output  
Current ( $5V_{OUT}$ )

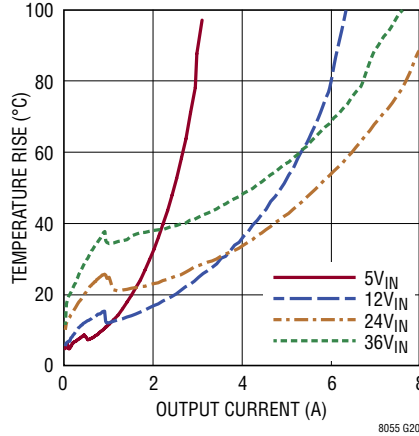


## TYPICAL PERFORMANCE CHARACTERISTICS $T_A = 25^\circ\text{C}$ , unless otherwise noted.

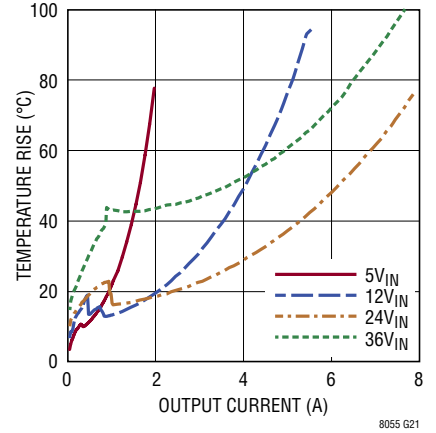
Temperature Rise vs Output Current ( $8V_{OUT}$ )



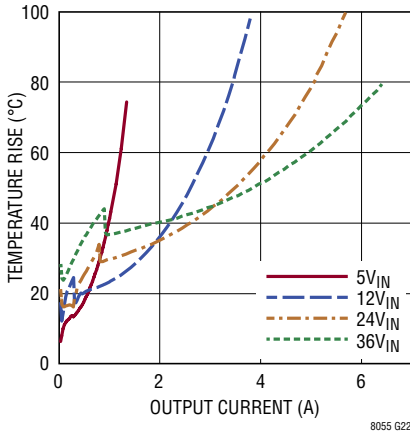
Temperature Rise vs Output Current ( $12V_{OUT}$ )



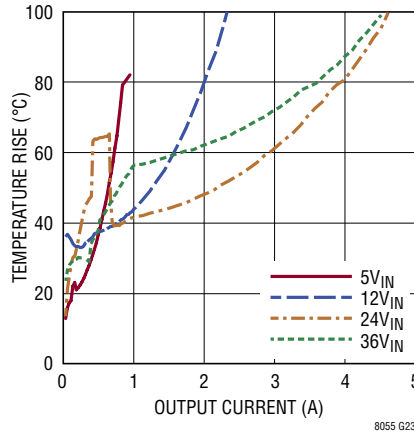
Temperature Rise vs Output Current ( $18V_{OUT}$ )



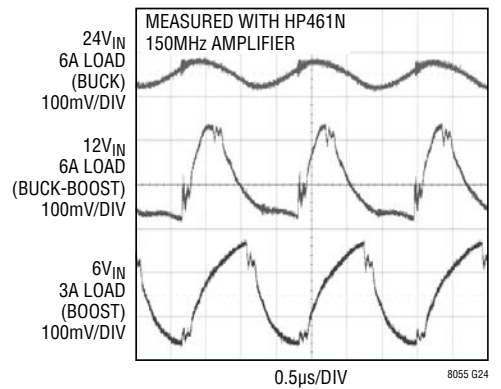
Temperature Rise vs Output Current ( $24V_{OUT}$ )



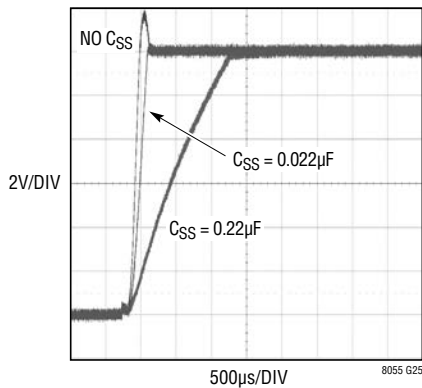
Temperature Rise vs Output Current ( $36V_{OUT}$ )



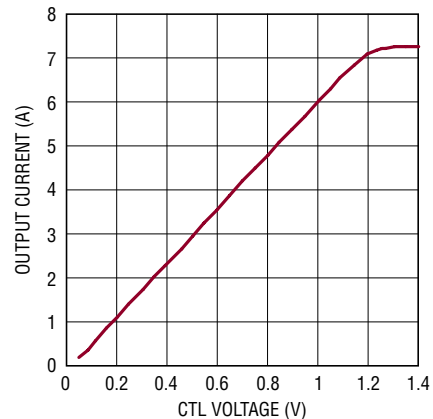
Output Voltage Ripple, Unmodified DC2017A Demo Board  $12V_{OUT}$



Start-Up Behavior, DC2017A,  $24V_{IN}$ , 3A Resistive Load



Maximum Output Current vs CTL Voltage, Unmodified DC2017A,  $12V_{IN}$



## PIN FUNCTIONS

**GND (Bank 1, Pin L1):** Tie these GND pins to a local ground plane below the LTM8055/LTM8055-1 and the circuit components. In most applications, the bulk of the heat flow out of the LTM8055/LTM8055-1 is through these pads, so the printed circuit design has a large impact on the thermal performance of the part. See the PCB Layout and Thermal Considerations sections for more details. Return the  $R_{FB1}/R_{FB2}$  feedback divider to this net.

**V<sub>OUT</sub> (Bank 2):** Power Output Pins. Apply output filter capacitors between these pins and GND pins.

**V<sub>IN</sub> (Bank 3):** Input Power. The V<sub>IN</sub> pin supplies current to the LTM8055/LTM8055-1's internal power switches and to one terminal of the optional input current sense resistor. This pin must be locally bypassed with an external, low ESR capacitor; see Table 1 for recommended values.

**I<sub>OUT</sub> (Pin D1):** Output Current Sense. Tie this pin to the output current sense resistor. The output average current sense threshold is 58mV, so the LTM8055/LTM8055-1 will regulate the output current to  $58\text{mV}/R_{\text{SENSE}}$ , where  $R_{\text{SENSE}}$  is the value of the output current sense resistor in ohms. The load is powered through the sense resistor connected at this pin. Tie this pin to V<sub>OUT</sub> if no output current sense resistor is used. Keep this pin within  $\pm 0.5\text{V}$  of V<sub>OUT</sub> under all conditions.

**LL (Pin F1):** Light Load Indicator. This open drain pin indicates that the output current, as sensed through the resistor connected between V<sub>OUT</sub> and I<sub>OUT</sub>, is approximately equivalent to 6mV or less. Its state is meaningful only if a current sense resistor is applied between V<sub>OUT</sub> and I<sub>OUT</sub>. This is useful to change the switching behavior of the LTM8055/LTM8055-1 in light load conditions.

**SV<sub>IN</sub> (Pins F10, F11):** Controller Power Input. Apply a separate voltage above 5V if the LTM8055/LTM8055-1 is required to operate when the main power input (V<sub>IN</sub>) is below 5V. Bypass these pins with a high quality, low ESR capacitor. If a separate supply is not used, connect these pins to V<sub>IN</sub>.

**CLKOUT (Pin G1):** Clock Output. Use this pin as a clock source when synchronizing other devices to the switching frequency of the LTM8055/LTM8055-1. When this function is not used, leave this pin open.

**MODE (Pin G2):** Switching Mode Input. The LTM8055/LTM8055-1 operates in forced continuous mode when MODE is open, and can operate in discontinuous switching mode when MODE is low. In discontinuous switching mode, the LTM8055/LTM8055-1 will block reverse inductor current. This pin is normally left open or tied to LL. This pin may be tied to GND for the purpose of blocking reverse current if no output current sense resistor is used.

**RT (Pin H1):** Timing Resistor. The RT pin is used to program the switching frequency of the LTM8055/LTM8055-1 by connecting a resistor from this pin to ground. The range of oscillation is 100kHz to 800kHz. The Applications Information section of the data sheet includes a table to determine the resistance value based on the desired switching frequency. Minimize capacitance at this pin.

**SYNC (Pin H2):** External Synchronization Input. The SYNC pin has an internal pull-down resistor. See the Synchronization section in Applications Information for details. Tie this pin to GND when not used.

**FB (Pin J1):** Output Voltage Feedback. The LTM8055/LTM8055-1 regulates the FB pin to 1.2V. Connect the FB pin to a resistive divider between the output and GND to set the output voltage. See Table 1 for recommended FB divider resistor values.

**COMP (Pin J2):** Compensation Pin. The LTM8055 is equipped with internal compensation that works well with most applications, so this pin is usually left open. Some applications, however, may benefit from a compensation network other than the one integrated into the LTM8055. In such cases, use the LTM8055-1, which has no internal compensation network and apply an appropriate external compensation network for optimal and proper operation.

**SS (Pin K1):** Soft-Start. Connect a capacitor from this pin to GND to increase the soft-start time. Soft-start reduces the input power source's surge current by gradually increasing the controller's current limit. Larger values of the soft-start capacitor result in longer soft-start times. If no soft-start is required, leave this pin open.

**CTL (Pin K2):** Current Sense Adjustment. Apply a voltage below 1.2V to reduce the current limit threshold of I<sub>OUT</sub>. Drive CTL to less than 50mV to stop switching. The CTL pin has an internal pull-up resistor to 2V. If not used, leave open.

## PIN FUNCTIONS

**I<sub>OUTMON</sub> (Pin L2):** Output Current Monitor. This pin produces a voltage that is proportional to the voltage between  $V_{OUT}$  and  $I_{OUT}$ .  $I_{OUTMON}$  will equal 1.2V when  $V_{OUT} - I_{OUT} = 58\text{mV}$ . This feature is generally useful only if a current sense resistor is applied between  $V_{OUT}$  and  $I_{OUT}$ . This is a high impedance output. Use a buffer to drive a load.

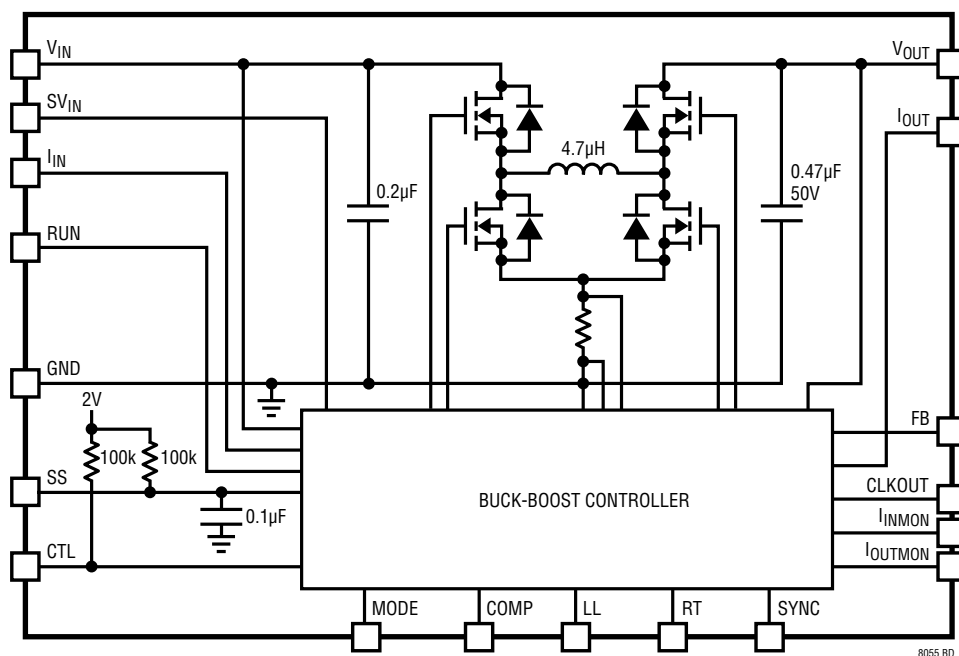
**I<sub>INMON</sub> (Pin L3):** Input Current Monitor. This pin produces a voltage that is proportional to the voltage between  $I_{IN}$  and  $V_{IN}$ .  $I_{INMON}$  will equal 1V when  $I_{IN} - V_{IN} = 50\text{mV}$ . This feature is generally useful only if a current sense resistor is applied between  $V_{IN}$  and  $I_{IN}$ .

**RUN (Pin L4):** LTM8055/LTM8055-1 Enable. Raise the RUN pin voltage above 1.2V for normal operation. Above 1.2V

(typical), but below 6V, the RUN pin input bias current is less than  $1\mu\text{A}$ . Below 1.2V and above 0.3V, the RUN pin sinks  $3\mu\text{A}$  so the user can define the hysteresis with the external resistor selection. This will also reset the soft-start function. If RUN is 0.3V or less, the LTM8055/LTM8055-1 is disabled and the  $SV_{IN}$  quiescent current is below  $1\mu\text{A}$ .

**I<sub>IN</sub> (Pin L9):** Input Current Sense. Tie this pin to the input current sense resistor. The input average current sense threshold is 50mV, so the LTM8055/LTM8055-1 will regulate the input current to  $50\text{mV}/R_{SENSE}$ , where  $R_{SENSE}$  is the value of the input current sense resistor in ohms. Tie to  $V_{IN}$  when not used. Keep this pin within  $\pm 0.5\text{V}$  of  $V_{IN}$  under all conditions.

## BLOCK DIAGRAM



## OPERATION

The LTM8055/LTM8055-1 is a standalone nonisolated buck-boost switching DC/DC power supply. The buck-boost topology allows the LTM8055/LTM8055-1 to regulate its output voltage for input voltages both above and below the magnitude of the output. The maximum output current depends upon the input voltage. Higher input voltages yield higher maximum output current.

This converter provides a precisely regulated output voltage programmable via an external resistor divider from 1.2V to 36V. The input voltage range is 5V to 36V, but the LTM8055/LTM8055-1 may be operated at lower input voltages if  $SV_{IN}$  is powered by a voltage source above 5V. A simplified block diagram is given on the previous page.

The LTM8055/LTM8055-1 contains a current mode controller, power switching elements, power inductor and a modest amount of input and output capacitance. The LTM8055/LTM8055-1 is a fixed frequency PWM regulator. The switching frequency is set by connecting the appropriate resistor value from the RT pin to GND.

The output voltage of the LTM8055/LTM8055-1 is set by connecting the FB pin to a resistor divider between  $V_{OUT}$  and GND.

In addition to regulating its output voltage, the LTM8055/LTM8055-1 is equipped with average current control loops for both the input and output. Add a current sense resistor between  $I_{IN}$  and  $V_{IN}$  to limit the input current below some maximum value. The  $I_{INMON}$  pin reflects the current flowing through the sense resistor between  $I_{IN}$  and  $V_{IN}$ .

A current sense resistor between  $V_{OUT}$  and  $I_{OUT}$  allows the LTM8055/LTM8055-1 to accurately regulate its output current to a maximum value set by the value of the sense resistor. When the resistor is present, the  $I_{OUTMON}$  pin reflects the output current flowing through  $V_{OUT}$ .

In general, the LTM8055/LTM8055-1 should be used with an output sense resistor to limit the maximum output current, as buck-boost regulators are capable of delivering large currents when the output voltage is lower than the input, if demanded.

Furthermore, while the LTM8055/LTM8055-1 does not require an output sense resistor to operate, it uses information from the sense resistor to optimize its performance. If an out-put sense resistor is not used, the efficiency or output ripple may degrade, especially if the current through the integrated inductor is discontinuous. In some cases, an output sense resistor is required to adequately protect the LTM8055/LTM8055-1 against output overload or short-circuit.

A voltage less than 1.2V applied to the CTL pin reduces the maximum output current. Drive CTL to about 50mV to stop switching. The current flowing through the sense resistor is reflected by the output voltage of the  $I_{OUTMON}$  pin.

Driving the SYNC pin will synchronize the LTM8055/LTM8055-1 to an external clock source. The CLKOUT pin sources a signal that is the same frequency but approximately 180° out of phase with the internal oscillator.

If more output current is required than a single LTM8055/LTM8055-1 can provide, multiple devices may be operated in parallel. Refer to the Parallel Operation section of Applications Information for more details.

An internal regulator provides power to the control circuitry and the gate driver to the power MOSFETs. This internal regulator draws power from the  $SV_{IN}$  pin. The RUN pin is used to place the LTM8055/LTM8055-1 in shutdown, disconnecting the output and reducing the input current to less than 1μA.

The LTM8055/LTM8055-1 is equipped with a thermal shutdown that inhibits power switching at high junction temperatures. The activation threshold of this function is above 125°C to avoid interfering with normal operation, so prolonged or repetitive operation under a condition in which the thermal shutdown activates may damage or impair the reliability of the device.

The LTM8055 features an integrated compensation network that works well under most conditions. Some applications, however, benefit from a different compensation network. In such cases, use the LTM8055-1, which has no internal compensation network. Apply an appropriate external compensation network for optimal and proper operation.

## APPLICATIONS INFORMATION

For most applications, the design process is straight forward, summarized as follows:

1. Look at Table 1 and find the row that has the desired input range and output voltage.
2. Apply the recommended  $C_{IN}$ ,  $C_{OUT}$ ,  $R_{FB1}/R_{FB2}$  and  $R_T$  values.
3. Apply the output sense resistor to set the output current limit. The output current is limited to  $58mV/R_{SENSE}$ , where  $R_{SENSE}$  is the value of the output current sense resistor in ohms.
4. When using the LTM8055-1, place the external compensation network as close as possible to the COMP pin.

While these component combinations have been tested for proper operation, it is incumbent upon the user to verify proper operation over the intended system's line, load and environmental conditions. Bear in mind that the maximum output current is limited by junction temperature, the relationship between the input and output voltage magnitude and other factors. Please refer to

the graphs in the Typical Performance Characteristics section for guidance.

The maximum frequency (and attendant  $R_T$  value) at which the LTM8055/LTM8055-1 should be allowed to switch is given in Table 1 in the  $f_{MAX}$  column, while the recommended frequency (and  $R_T$  value) for optimal efficiency over the given input condition is given in the  $f_{OPTIMAL}$  column. There are additional conditions that must be satisfied if the synchronization function is used. Please refer to the Synchronization section for details.

Note that Table 1 calls out both ceramic and electrolytic output capacitors. Both of the capacitors called out in the table must be applied to the output. The electrolytic capacitors in Table 1 are described by voltage rating, value and ESR. The voltage rating of the capacitor may be increased if the application requires a higher voltage stress derating. The LTM8055/LTM8055-1 can tolerate variation in the ESR; other capacitors with different ESR may be used, but the user must verify proper operation over line, load and environmental conditions. Table 2

**Table 1. Recommended Component Values and Configuration ( $T_A = 25^\circ C$ )**

| $V_{IN}$ RANGE | $V_{OUT}$ | $C_{IN}$                             | $C_{OUT}$                                                                             | $R_{FB1}/R_{FB2}$ | $f_{OPTIMAL}$ (kHz) | $R_{T(OPTIMAL)}$ | $f_{MAX}$ (kHz) | $R_{T(MAX)}$ |
|----------------|-----------|--------------------------------------|---------------------------------------------------------------------------------------|-------------------|---------------------|------------------|-----------------|--------------|
| 5V to 24V      | 3.3V      | $2 \times 4.7\mu F$ , 50V, X5R, 0805 | 22 $\mu F$ , 6.3V, X5R, 0805<br>100 $\mu F$ , 6V, 75m $\Omega$ , Electrolytic         | 100k/56.2k        | 600                 | 36.5k            | 800             | 24.9k        |
| 5V to 28V      | 5V        | $2 \times 4.7\mu F$ , 50V, X5R, 0805 | 22 $\mu F$ , 6.3V, X5R, 0805<br>100 $\mu F$ , 6V, 75m $\Omega$ , Electrolytic         | 100k/31.6k        | 550                 | 39.2k            | 800             | 24.9k        |
| 5V to 31V      | 8V        | $2 \times 4.7\mu F$ , 50V, X5R, 0805 | 47 $\mu F$ , 10V, X5R, 1206<br>100 $\mu F$ , 16V, 100m $\Omega$ , Electrolytic        | 100k/17.4k        | 500                 | 45.3k            | 800             | 24.9k        |
| 5V to 36V      | 12V       | $2 \times 4.7\mu F$ , 50V, X5R, 1210 | 22 $\mu F$ , 25V, X5R, 0805<br>68 $\mu F$ , 16V, 200m $\Omega$ , Electrolytic         | 100k/11k          | 600                 | 36.5k            | 800             | 24.9k        |
| 5V to 36V      | 18V       | $2 \times 4.7\mu F$ , 50V, X7R, 1210 | $2 \times 22\mu F$ , 25V, X5R, 1210<br>47 $\mu F$ , 25V, 900m $\Omega$ , Electrolytic | 100k/6.98k        | 500                 | 45.3k            | 800             | 24.9k        |
| 5V to 36V      | 24V       | $2 \times 4.7\mu F$ , 50V, X7R, 1210 | 22 $\mu F$ , 25V, X5R, 1210<br>33 $\mu F$ , 35V 300m $\Omega$ , Electrolytic          | 100k/5.23k        | 650                 | 31.6k            | 800             | 24.9k        |
| 5.5V to 36V    | 36V       | $2 \times 4.7\mu F$ , 50V, X7R, 1210 | 10 $\mu F$ , 50V, X5R, 1206<br>10 $\mu F$ , 50V 120m $\Omega$ , Electrolytic          | 100k/3.40k        | 650                 | 31.6k            | 800             | 24.9k        |

**Notes:** An input bulk capacitor is required. The output capacitance uses a combination of a ceramic and electrolytic in parallel. Other combinations of resistor values for the RFB network are acceptable.

**Table 2. Electrolytic Caps Used in LTM8055/LTM8055-1 Testing**

| DESCRIPTION                                                      | MANUFACTURER | PART NUMBER      |
|------------------------------------------------------------------|--------------|------------------|
| 100 $\mu F$ , 6V, 75m $\Omega$ , Tantalum C Case                 | AVX          | TPSC107M006R0075 |
| 100 $\mu F$ , 16V, 100m $\Omega$ , Tantalum Y Case               | AVX          | TPSY107M016R0100 |
| 68 $\mu F$ , 16V, 200m $\Omega$ , Tantalum C Case                | AVX          | TPSC686M016R0200 |
| 47 $\mu F$ , 25V, 900m $\Omega$ , Tantalum D Case                | AVX          | TAJD476M025R     |
| 33 $\mu F$ , 35V, 300m $\Omega$ , Tantalum D Case                | AVX          | TPSD336M035R0300 |
| 10 $\mu F$ , 50V, 120m $\Omega$ , Aluminum 6.3 $\times$ 6mm case | Suncon       | 50HVP10M         |

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gives the description and part numbers of electrolytic capacitors used in the LTM8055/LTM8055-1 development testing and design validation.

### Capacitor Selection Considerations

The  $C_{IN}$  and  $C_{OUT}$  capacitor values in Table 1 are the minimum recommended values for the associated operating conditions. Applying capacitor values below those indicated in Table 1 is not recommended, and may result in undesirable operation. Using larger values is generally acceptable, and can yield improved dynamic response, if it is necessary. Again, it is incumbent upon the user to verify proper operation over the intended system's line, load and environmental conditions.

Ceramic capacitors are small, robust and have very low ESR. However, not all ceramic capacitors are suitable. X5R and X7R types are stable over temperature and applied voltage and give dependable service. Other types, including Y5V and Z5U have very large temperature and voltage coefficients of capacitance. In an application circuit they may have only a small fraction of their nominal capacitance resulting in much higher output voltage ripple than expected.

A final precaution regarding ceramic capacitors concerns the maximum input voltage rating of the LTM8055/LTM8055-1. A ceramic input capacitor combined with trace or cable inductance forms a high Q (underdamped) tank circuit. If the LTM8055/LTM8055-1 circuit is plugged into a live supply, the input voltage can ring to twice its nominal value, possibly exceeding the device's rating. This situation is easily avoided; see the Hot-Plugging Safely section.

### Frequency Selection

The LTM8055/LTM8055-1 uses a constant frequency PWM architecture that can be programmed to switch from 100kHz to 800kHz by tying a resistor from the  $R_T$  pin to ground. Table 3 provides a list of  $R_T$  resistor values and their resultant frequencies.

**Table 3. Switching Frequency vs  $R_T$  Value**

| FREQUENCY | $R_T$ VALUE (k $\Omega$ ) |
|-----------|---------------------------|
| 100       | 453                       |
| 200       | 147                       |
| 300       | 84.5                      |
| 400       | 59                        |
| 500       | 45.3                      |
| 600       | 36.5                      |
| 700       | 29.4                      |
| 800       | 24.9                      |

An external resistor from  $R_T$  to GND is required. Do not leave this pin open, even when synchronizing to an external clock. When synchronizing the switching of the LTM8055/LTM8055-1 to an external signal source, the frequency range is 200kHz to 700kHz.

### Operating Frequency Trade-Offs

It is recommended that the user apply the optimal  $R_T$  value given in Table 1 for the input and output operating condition. System level or other considerations, however, may necessitate another operating frequency. While the LTM8055/LTM8055-1 is flexible enough to accommodate a wide range of operating frequencies, a haphazardly chosen one may result in undesirable operation under certain operating or fault conditions. A frequency that is too high can reduce efficiency, generate excessive heat or even damage the LTM8055/LTM8055-1 if the output is overloaded or short circuited. A frequency that is too low can result in a final design that has too much output ripple, too large of an output capacitor or is unstable.

### Parallel Operation

Two or more LTM8055/LTM8055-1s may be combined to provide increased output current by configuring them as a master and a slave, as shown in Figure 1. Each LTM8055/LTM8055-1 is equipped with an  $I_{OUTMON}$  and a CTL pin. The  $I_{OUTMON}$  pin's 0 to 1.2V signal reflects the current passing through the output sense resistor, while a voltage less than 1.2V applied to the CTL pin will limit the current passing through the output sense resistor. By applying the voltage of the master's  $I_{OUTMON}$  pin to the slave's CTL

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pin, the two units will source the same current to the load, assuming each LTM8055/LTM8055-1 output current sense resistor is the same value.

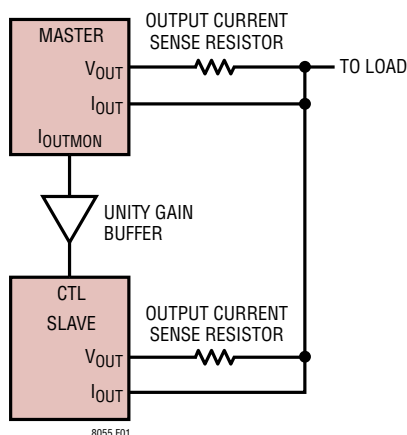


**Figure 1. Two or More LTM8055/LTM8055-1s May Be Connected in a Master/Slave Configuration for Increased Output Current**

The design of a master-slave configuration is straight forward:

1. Apply the FB resistor network to the master, choosing the proper values for the desired output voltage. Suggested values for popular output voltages are provided in Table 1.
2. Apply a FB resistor network to the individual slaves so that the resulting output is higher than the desired output voltage.
3. Apply the appropriate output current sense resistors between  $V_{OUT}$  and  $I_{OUT}$ . If the same value is used for the master and slave units, they will share current equally.
4. Connect the master  $I_{OUTMON}$  to the slaves' CTL pin through a unity gain buffer. The unity gain buffer is required to isolate the output impedance of the LTM8055/LTM8055-1 from the integrated pull-up on the CTL pins.
5. Tie the outputs together.

Note that this configuration does not require the inputs to be tied together, making it simple to power a single heavy load from multiple input sources. Ensure that each input power source has sufficient voltage and current sourcing capability to provide the necessary power. Please refer to the Maximum Output Current vs  $V_{IN}$  and Input Current vs Output Current curves in the Typical Performance Characteristics section for guidance.

Paralleled LTM8055/LTM8055-1s should normally be allowed to switch in discontinuous mode to prevent current from flowing from the output of one unit into another; that is, the MODE pin should be tied to LL. In some cases, operating the master in forced continuous (MODE open) and the slaves in discontinuous mode (MODE = LL) is desirable. If so, current from the output can flow into the master's input. Please refer to Input Precaution in this section for a discussion of this behavior.

### Minimum Input Voltage and RUN

The LTM8055/LTM8055-1 needs a minimum of 5V for proper operation, but system parameters may dictate that the device operate only above some higher input voltage. For example, a LTM8055/LTM8055-1 may be used to produce 12V $_{OUT}$ , but the input power source may not be budgeted to provide enough current if the input supply voltage is below 8V.

The RUN pin has a typical falling voltage threshold of 1.2V and a typical hysteresis of 25mV. In addition, the pin sinks 3 $\mu$ A below the RUN threshold. Based upon the above information and the circuit shown in Figure 2, the  $V_{IN}$  rising (turn-on) threshold is:

$$V_{IN} = (3\mu A \cdot R1) + 1.225V \frac{R1+R2}{R2}$$

and the  $V_{IN}$  falling turn-off threshold is:

$$V_{IN} = 1.2 \frac{R1+R2}{R2}$$

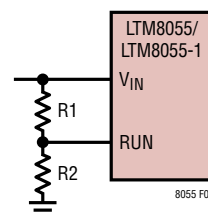


**Figure 2. This Simple Resistor Network Sets the Minimum Operating Input Voltage Threshold with Hysteresis**

### Minimum Input Voltage and $SV_{IN}$

The minimum input voltage of the LTM8055/LTM8055-1 is 5V, but this is only if  $V_{IN}$  and  $SV_{IN}$  are tied to the same voltage source. If  $SV_{IN}$  is powered from a power source at or above 5VDC,  $V_{IN}$  can be allowed to fall below 5V and

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the LTM8055/LTM8055-1 can still operate properly. Some examples of this are provided in the Typical Applications section.

### Soft-Start

Soft-start reduces the input power sources' surge currents by gradually increasing the controller's current. As indicated in the Block Diagram, the LTM8055/LTM8055-1 has an internal soft-start RC network. Depending upon the load and operating conditions, the internal network may be sufficient for the application. To increase the soft-start time, simply add a capacitor from SS to GND.

### Output Current Limit ( $I_{OUT}$ )

The LTM8055/LTM8055-1 features an accurate average output current limit set by an external sense resistor placed between  $V_{OUT}$  and  $I_{OUT}$  as shown in Figure 3.  $V_{OUT}$  and  $I_{OUT}$  internally connect to a differential amplifier that limits the current when the voltage  $V_{OUT}-I_{OUT}$  reaches 58mV. The current limit is:

$$I_{OUT(LIM)} = \frac{58mV}{R_{SENSE}}$$

where  $R_{SENSE}$  is the value of the sense resistor in ohms.

Most applications should use an output sense resistor as shown in Figure 3, if practical. The internal buck-boost power stage is current limited, but is nonetheless capable of delivering large amounts of current in an overload condition, especially when the output voltage is much lower than the input and the power stage is operating as a buck converter.

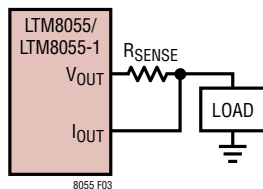


**Figure 3. Set The LTM8055/LTM8055-1 Output Current Limit with an External Sense Resistor**

When the voltage across the output sense resistor falls to about 1/10th of full scale, the LL pin pulls low. If there is no output sense resistor, and  $I_{OUT}$  is tied to  $V_{OUT}$ , LL will be active low. Applying an output sense resistor and

tying the LL and MODE pins together can improve performance—see Switching Mode in this section.

In high step-down voltage regulator applications, the internal current limit can be quite high to allow proper operation. This can potentially damage the LTM8055/LTM8055-1 in overload or short-circuit conditions. Apply an output current sense resistor to set an appropriate current limit to protect the LTM8055/LTM8055-1 against these fault conditions.

### Output Current Limit Control (CTL)

Use the CTL input to reduce the output current limit from the value set by the external sense resistor applied between  $V_{OUT}$  and  $I_{OUT}$ . The typical control range is between 0V and 1.2V. The CTL pin does not directly affect the input current limit. If this function is not used, leave CTL open. Drive CTL to less than about 50mV to stop switching. The CTL pin has an internal pull-up resistor to 2V.

### Input Current Limit ( $I_{IN}$ )

Some applications require that LTM8055/LTM8055-1 draw no more than some predetermined current from the power source. Current limited power sources and power sharing are two examples. The LTM8055/LTM8055-1 features an accurate input current limit set by an external sense resistor placed between  $I_{IN}$  and  $V_{IN}$  as shown in Figure 4.  $V_{IN}$  and  $I_{IN}$  internally connect to a differential amplifier that limits the current when the voltage  $I_{IN}-V_{IN}$  reaches 50mV. The current limit is:

$$I_{IN(LIM)} = \frac{50mV}{R_{SENSE}}$$

where  $R_{SENSE}$  is the value of the sense resistor in ohms.

If input current limiting is not required, simply tie  $I_{IN}$  to  $V_{IN}$ .

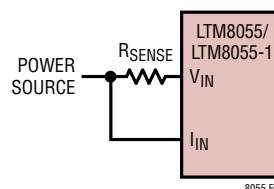


**Figure 4. Set the LTM8055/LTM8055-1 Input Current Limit with an External Sense Resistor**

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### Input Current Monitor ( $I_{INMON}$ )

The  $I_{INMON}$  pin produces a voltage equal to approximately 20 times the voltage of  $I_{IN} - V_{IN}$ . Since the LTM8055/LTM8055-1 input current limit engages when  $I_{IN} - V_{IN} = 50\text{mV}$ ,  $I_{INMON}$  will be 1V at maximum input current.

### Output Current Monitor ( $I_{OUTMON}$ )

The  $I_{OUTMON}$  pin produces a voltage proportional to the voltage of  $V_{OUT} - I_{OUT}$ . Since the LTM8055/LTM8055-1 output current limit engages when  $V_{OUT} - I_{OUT} = 58\text{mV}$ ,  $I_{OUTMON}$  will be 1.2V at maximum output current.

### Synchronization

The LTM8055/LTM8055-1 switching frequency can be synchronized to an external clock using the SYNC pin. Driving SYNC with a 50% duty cycle waveform is a good choice, otherwise maintain the duty cycle between about 10% and 90%. When synchronizing, a valid resistor value (that is, a value that results in a free-running frequency of 100kHz to 800kHz) must be connected from RT to GND.

While an RT resistor is required for proper operation, the value of this resistor is independent of the frequency of the externally applied SYNC signal. Be aware, however, that the LTM8055/LTM8055-1 will switch at the frequency prescribed by the RT value if the SYNC signal terminates, so choose an appropriate resistor value.

### CLKOUT

The CLKOUT signal reflects the internal switching clock of the LTM8055/LTM8055-1. It is phase shifted by approximately  $180^\circ$  with respect to the leading edge of the internal clock. If CLKOUT is connected to the SYNC input of another LTM8055/LTM8055-1, the two devices will switch about  $180^\circ$  out of phase.

### Input Precaution

In applications where the output voltage is deliberately pulled up above the set regulation voltage or the FB pin is abruptly driven to a new voltage, the LTM8055/LTM8055-1 may attempt to regulate the voltage by removing energy from the load for a short period of time after the output is pulled up. Since the LTM8055/LTM8055-1 is a syn-

chronous switching converter, it delivers this energy to the input. If there is nothing on the LTM8055/LTM8055-1 input to consume this energy, the input voltage may rise. If the input voltage rises without intervention, it may rise above the absolute maximum rating, damaging the part. Carefully examine the input voltage behavior to see if the application causes it to rise.

In many cases, the system load on the LTM8055/LTM8055-1 input bus will be sufficient to absorb the energy delivered by the  $\mu$ Module regulator. The power required by other devices will consume more than enough to make up for what the LTM8055/LTM8055-1 delivers. In cases where the LTM8055/LTM8055-1 is the largest or only power converter, this may not be true and some means may need to be devised to prevent the LTM8055/LTM8055-1's input from rising too high. Figure 5a shows a passive crowbar circuit that will dissipate energy during momentary overvoltage conditions. The break-down voltage of the Zener diode is chosen in conjunction with the resistor R to set the circuit's trip point. The trip point is typically set well above the maximum  $V_{IN}$  voltage under normal operating conditions. This circuit does not have a precision threshold, and is subject to both part-to-part and temperature variations, so it is most suitable for applications where the maximum input voltage is much less than the  $40V_{IN}$  absolute maximum. As stated earlier, this type of circuit is best suited for momentary overvoltages.

Figure 5a is a crowbar circuit, which attempts to prevent the input voltage from rising above some level by dumping energy to GND through a power device. In some cases, it is possible to simply turn off the LTM8055/LTM8055-1 when the input voltage exceeds some threshold. An example of this circuit is shown in Figure 5b. When the power source on the output drives  $V_{IN}$  above a predetermined threshold, the comparator pulls down on the RUN pin and stops switching in the LTM8055/LTM8055-1. When this happens, the input capacitance needs to absorb the energy stored within the LTM8055/LTM8055-1's internal inductor, resulting in an additional voltage rise. This voltage rise depends upon the input capacitor size and how much current is flowing from the LTM8055/LTM8055-1 output to input.

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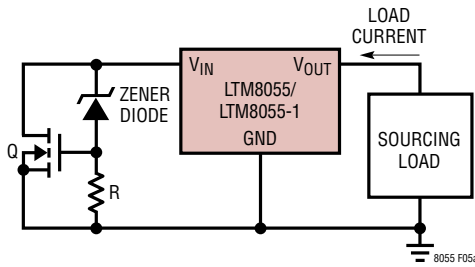


**Figure 5a. The MOSFET Q Dissipates Momentary Energy to GND. The Zener Diode and Resistor Are Chosen to Ensure That the MOSFET Turns On Above the Maximum  $V_{IN}$  Voltage Under Normal Operation**

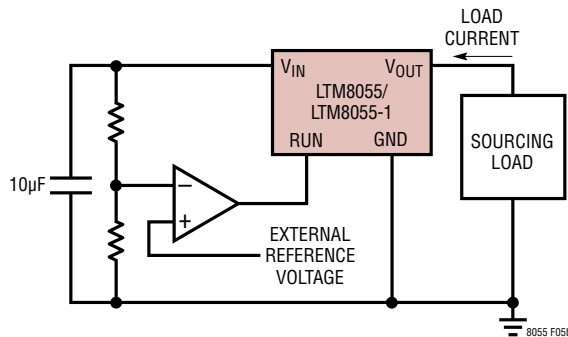


**Figure 5b. This Comparator Circuit Turns Off the LTM8055/LTM8055-1 if the Input Rises Above a Predetermined Threshold. When the LTM8055/LTM8055-1 Turns Off, the Energy Stored in the Internal Inductor Will Raise  $V_{IN}$  a Small Amount Above the Threshold**

### Switching Mode

The MODE pin allows the user to select either discontinuous mode or forced continuous mode switching operation. In forced continuous mode, the LTM8055/LTM8055-1 will not skip cycles, even when the internal inductor current falls to zero or even reverses direction. This has the advantage of operating at the same fixed frequency for all load conditions, which can be useful when designing to EMI or output noise specifications. Forced continuous mode, however, uses more current at light loads, and allows current to flow from the load back into the input if the output is raised above the regulation point. This reverse current can raise the input voltage and be hazardous if the input is allowed to rise uncontrollably. Please refer to Input Precautions in this section for a discussion of this behavior.

Forced continuous operation may provide improved output regulation when the LTM8055/LTM8055-1 transitions

from buck, buck-boost or boost operating modes, especially at lighter loads. In such a case, it can be desirable to operate in forced continuous mode except when the internal inductor current is about to reverse. If so, apply a current sense resistor between  $V_{OUT}$  and  $I_{OUT}$  and tie the LL and MODE pins together. The LL pin is low when the current through the output sense resistor is about one-tenth the full-scale maximum. When the output current falls to this level, the LL pin will pull the MODE pin down, putting the LTM8055/LTM8055-1 in discontinuous mode, preventing reverse current from flowing from the output to the input. In the case where MODE and LL are tied together, a small capacitor ( $\sim 0.1\mu\text{F}$ ) from these pins to GND may improve the light load transient response by delaying the transition from the discontinuous to forced continuous switching modes. MODE may be tied to GND for the purpose of blocking reverse current if no output current sense resistor is used.

### FB Resistor Divider and Load Regulation

The LTM8055/LTM8055-1 regulates its FB pin to 1.2V, using a resistor divider to sense the output voltage. The location at which the output voltage is sensed affects the load regulation. If there is a current sense resistor between  $V_{OUT}$  and  $I_{OUT}$ , and the output is sensed at  $V_{OUT}$ , the voltage at the load will drop by the value of the current sense resistor multiplied by the output current. If the output voltage can be sensed at  $I_{OUT}$ , the load regulation may be improved.

### PCB Layout

Most of the headaches associated with PCB layout have been alleviated or even eliminated by the high level of integration of the LTM8055/LTM8055-1. The LTM8055/LTM8055-1 is nevertheless a switching power supply, and care must be taken to minimize EMI and ensure proper operation. Even with the high level of integration, you may fail to achieve specified operation with a haphazard or poor layout. See Figure 6 for a suggested layout. Ensure that the grounding and heat sinking are acceptable.

A few rules to keep in mind are:

1. Place the  $R_{FB}$  and  $R_T$  resistors as close as possible to their respective pins.

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- Place the  $C_{IN}$  capacitor as close as possible to the  $V_{IN}$  and GND connection of the LTM8055/LTM8055-1.
- Place the  $C_{OUT}$  capacitor as close as possible to the  $V_{OUT}$  and GND connection of the LTM8055/LTM8055-1.
- Minimize the trace resistance between the optional output current sense resistor,  $R_{OUT}$ , and  $V_{OUT}$ . Minimize the loop area of the  $I_{OUT}$  trace and the trace from  $V_{OUT}$  to  $R_{OUT}$ .
- Minimize the trace resistance between the optional input current sense resistor,  $R_{IN}$  and  $V_{IN}$ . Minimize the loop area of the  $I_{IN}$  trace and the trace from  $V_{IN}$  to  $R_{IN}$ .
- Place the  $C_{IN}$  and  $C_{OUT}$  capacitors such that their ground current flow directly adjacent or underneath the LTM8055/LTM8055-1.
- Connect all of the GND connections to as large a copper pour or plane area as possible on the top layer. Avoid breaking the ground connection between the external components and the LTM8055/LTM8055-1.
- Use vias to connect the GND copper area to the board's internal ground planes. Liberally distribute these GND vias to provide both a good ground connection and thermal path to the internal planes of the printed circuit

board. Pay attention to the location and density of the thermal vias in Figure 6. The LTM8055/LTM8055-1 can benefit from the heat sinking afforded by vias that connect to internal GND planes at these locations, due to their proximity to internal power handling components. The optimum number of thermal vias depends upon the printed circuit board design. For example, a board might use very small via holes. It should employ more thermal vias than a board that uses larger holes.

### Hot-Plugging Safely

The small size, robustness and low impedance of ceramic capacitors make them an attractive option for the input bypass capacitor of LTM8055/LTM8055-1. However, these capacitors can cause problems if the LTM8055/LTM8055-1 is plugged into a live supply (see Linear Technology Application Note 88 for a complete discussion). The low loss ceramic capacitor combined with stray inductance in series with the power source forms an underdamped tank circuit, and the voltage at the  $V_{IN}$  pin of the LTM8055/LTM8055-1 can ring to more than twice the nominal input voltage, possibly exceeding the LTM8055/LTM8055-1's rating and damaging the part. If the input supply is poorly controlled or the LTM8055/LTM8055-1 is hot-plugged into

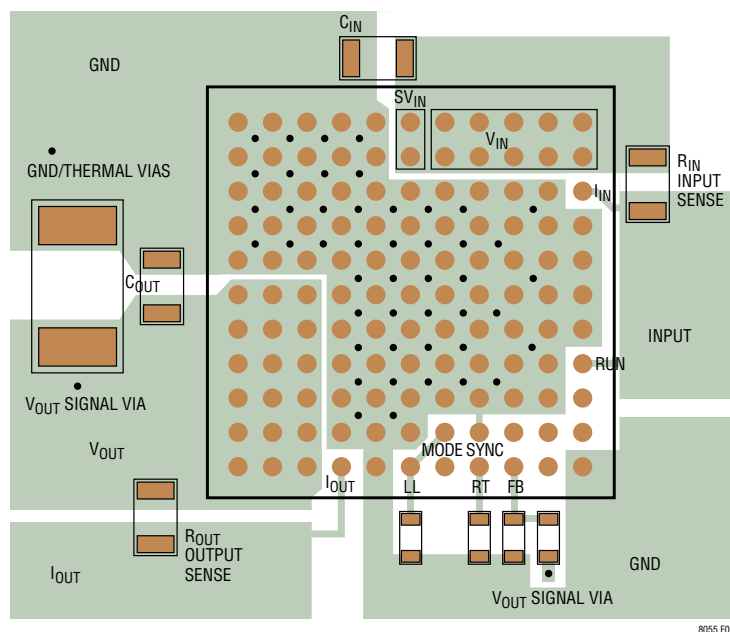


**Figure 6. Layout Showing Suggested External Components, GND Plane and Thermal Vias**

## APPLICATIONS INFORMATION

an energized supply, the input network should be designed to prevent this overshoot. This can be accomplished by installing a small resistor in series with  $V_{IN}$ , but the most popular method of controlling input voltage overshoot is to add an electrolytic bulk capacitor to the  $V_{IN}$  net. This capacitor's relatively high equivalent series resistance damps the circuit and eliminates the voltage overshoot. The extra capacitor improves low frequency ripple filtering and can slightly improve the efficiency of the circuit, though it is likely to be the largest component in the circuit.

### Thermal Considerations

The LTM8055/LTM8055-1 output current may need to be derated if it is required to operate in a high ambient temperature or deliver a large amount of continuous power. The amount of current derating is dependent upon the input voltage, output power and ambient temperature. The temperature rise curves given in the Typical Performance Characteristics section can be used as a guide. These curves were generated by a LTM8055/LTM8055-1 mounted to a 58cm<sup>2</sup> 4-layer FR4 printed circuit board. Boards of other sizes and layer count can exhibit different thermal behavior, so it is incumbent upon the user to verify proper operation over the intended system's line, load and environmental operating conditions.

The thermal resistance numbers listed in the Pin Configuration of the data sheet are based on modeling the  $\mu$ Module package mounted on a test board specified per JESD 51-9 (Test Boards for Area Array Surface Mount Package Thermal Measurements). The thermal coefficients provided on this page are based on JESD 51-12 (Guidelines for Reporting and Using Electronic Package Thermal Information).

For increased accuracy and fidelity to the actual application, many designers use FEA to predict thermal performance. To that end, the Pin Configuration of the data sheet typically gives four thermal coefficients:

$\theta_{JA}$  – Thermal resistance from junction to ambient.

$\theta_{JCbottom}$  – Thermal resistance from junction to the bottom of the product case.

$\theta_{JCTop}$  – Thermal resistance from junction to top of the product case.

$\theta_{JB}$  – Thermal resistance from junction to the printed circuit board.

While the meaning of each of these coefficients may seem to be intuitive, JEDEC has defined each to avoid confusion and inconsistency. These definitions are given in JESD 51-12, and are quoted or paraphrased below:

$\theta_{JA}$  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.

$\theta_{JCbottom}$  is the thermal resistance between the junction and bottom of the package with all of the component power dissipation flowing through the bottom of the package. In the typical  $\mu$ Module converter, 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.

$\theta_{JCTop}$  is determined with nearly all of the component power dissipation flowing through the top of the package. As the electrical connections of the typical  $\mu$ Module converter 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.

$\theta_{JB}$  is the junction-to-board thermal resistance where almost all of the heat flows through the bottom of the  $\mu$ Module converter and into the board, and is really the sum of the  $\theta_{JCbottom}$  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 2-sided, 2-layer board. This board is described in JESD 51-9.

## APPLICATIONS INFORMATION

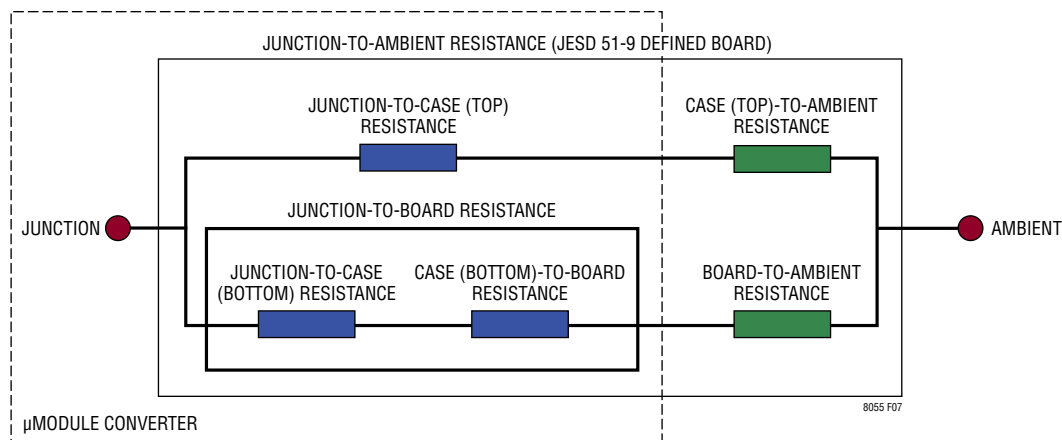


Figure 7

Given these definitions, it should now be apparent that none of these thermal coefficients reflects an actual physical operating condition of a  $\mu$ Module converter. Thus, none of them can be individually used to accurately predict the thermal performance of the product. Likewise, it would be inappropriate to attempt to use any one coefficient to correlate to the junction temperature versus load graphs given in the product's data sheet. The only appropriate way to use the coefficients is when running a detailed thermal analysis, such as FEA, which considers all of the thermal resistances simultaneously.

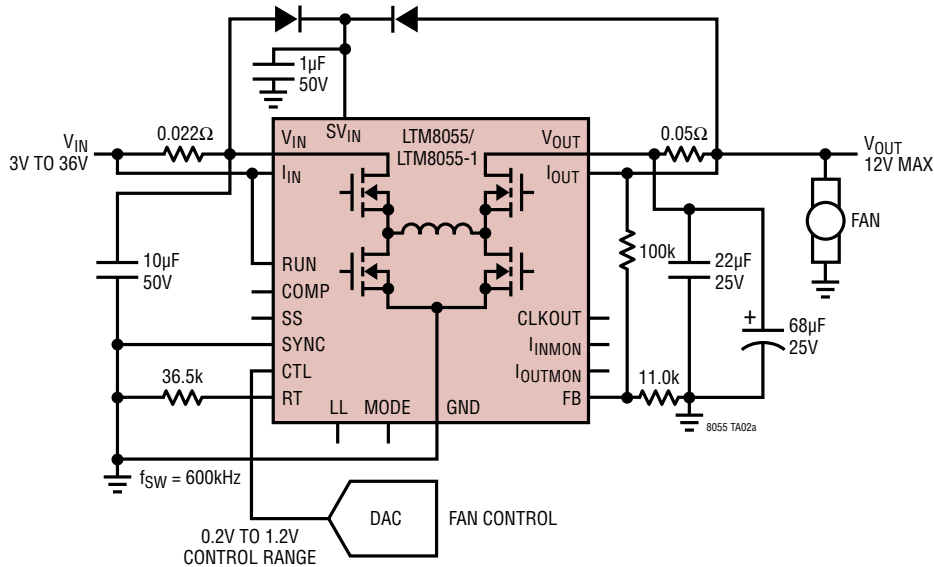
A graphical representation of these thermal resistances is given in Figure 7.

The blue resistances are contained within the  $\mu$ Module converter, and the green are outside.

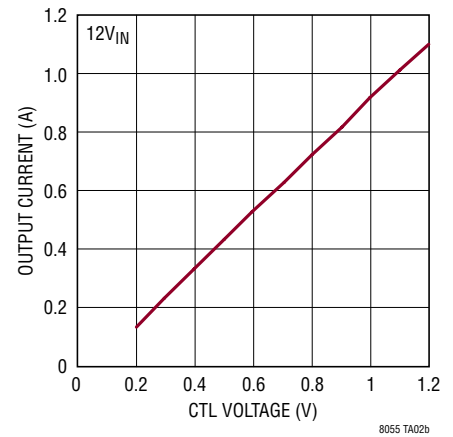
The die temperature of the LTM8055/LTM8055-1 must be lower than the maximum rating of 125°C, so care should be taken in the layout of the circuit to ensure good heat sinking of the LTM8055/LTM8055-1. The bulk of the heat flow out of the LTM8055/LTM8055-1 is through the bottom of the  $\mu$ Module converter and the BGA pads into the printed circuit board. Consequently a poor printed circuit board design can cause excessive heating, resulting in impaired performance or reliability. Please refer to the PCB Layout section for printed circuit board design suggestions.

## TYPICAL APPLICATIONS

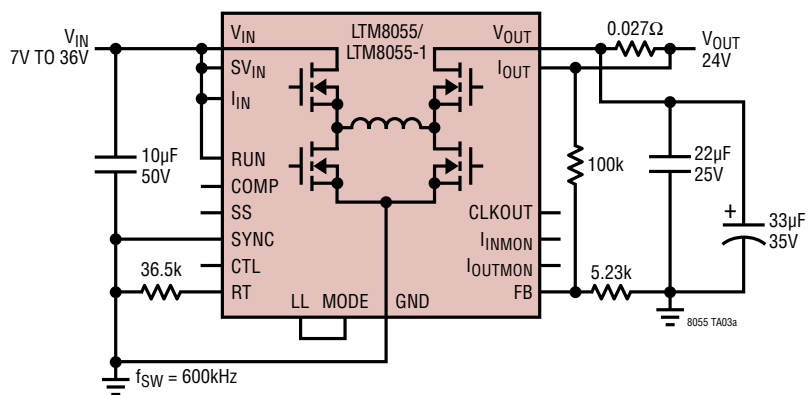
**12V<sub>OUT</sub> Fan Power from 3V<sub>IN</sub> to 36V<sub>IN</sub> with Analog Current Control and 2A Input Current Limiting**



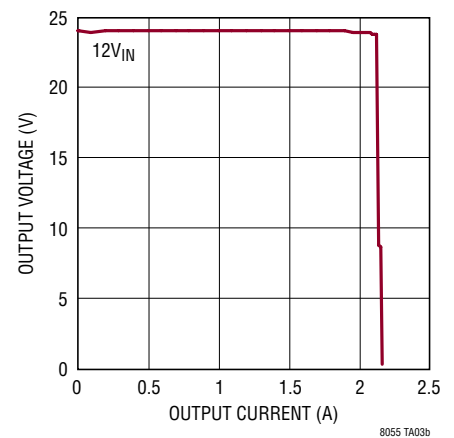
**Maximum Output Current vs CTL Voltage**



**24V<sub>OUT</sub> from 7V<sub>IN</sub> to 36V<sub>IN</sub> with 2.1A Accurate Current Limit**

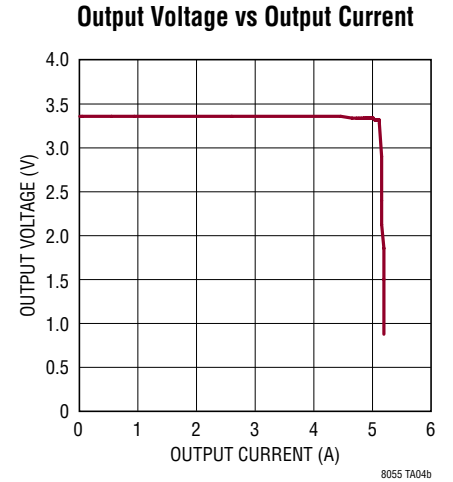
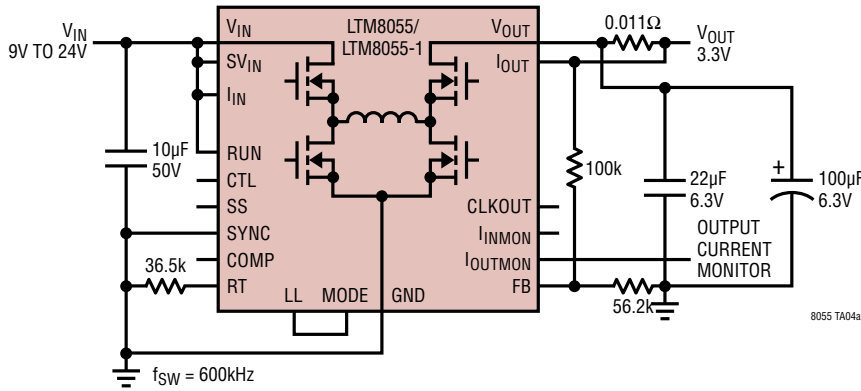


**Output Voltage vs Output Current**

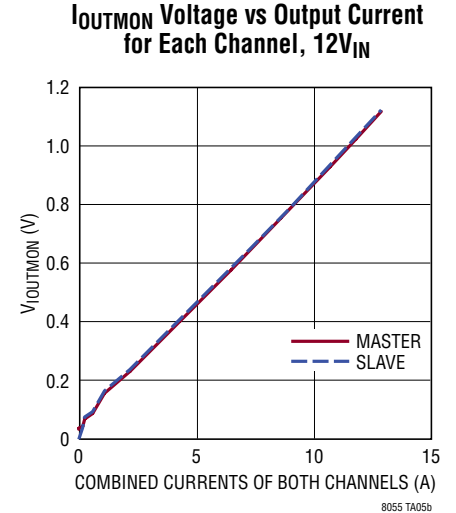
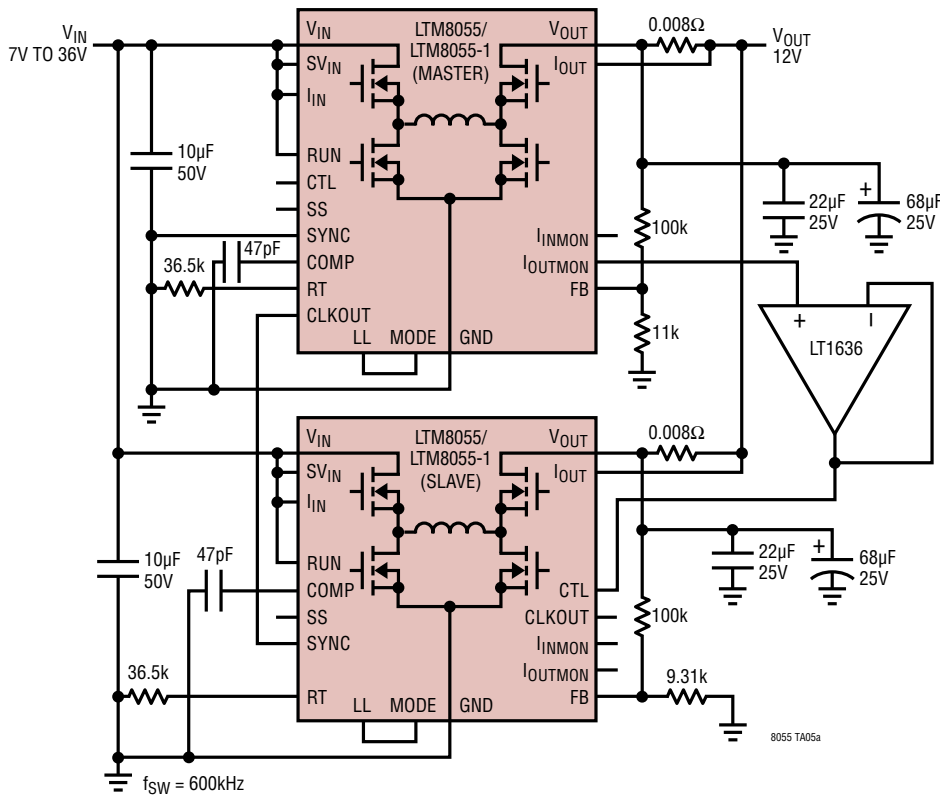


## TYPICAL APPLICATIONS

**3.3V<sub>OUT</sub> from 9V<sub>IN</sub> to 24V<sub>IN</sub> with 5A Accurate Current Limit and Output Current Monitor**

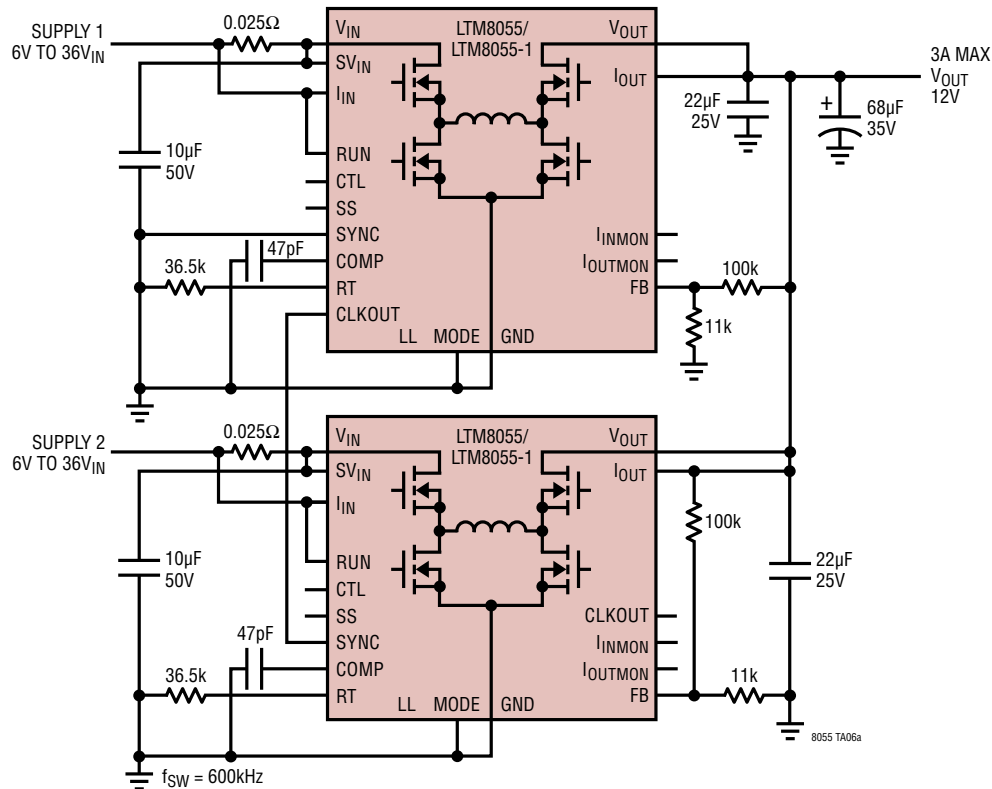


**Two LTM8055/LTM8055-1s Paralleled to Get More Output Current. The Two  $\mu$ Modules Are Synchronized and Switching 180° Out Of Phase**

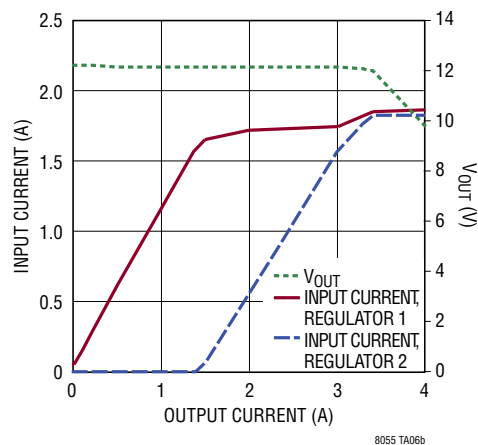


## TYPICAL APPLICATIONS

Two LTM8055/LTM8055-1s Powered from Different Input Sources to Run a Single Load. Each LTM8055/LTM8055-1 Draws No More Than 1.8A from Its Respective Power Source, and Are Synchronized 180° Out Of Phase with Each Other



Input Current and Output Voltage vs  
Output Current 12V<sub>IN</sub>

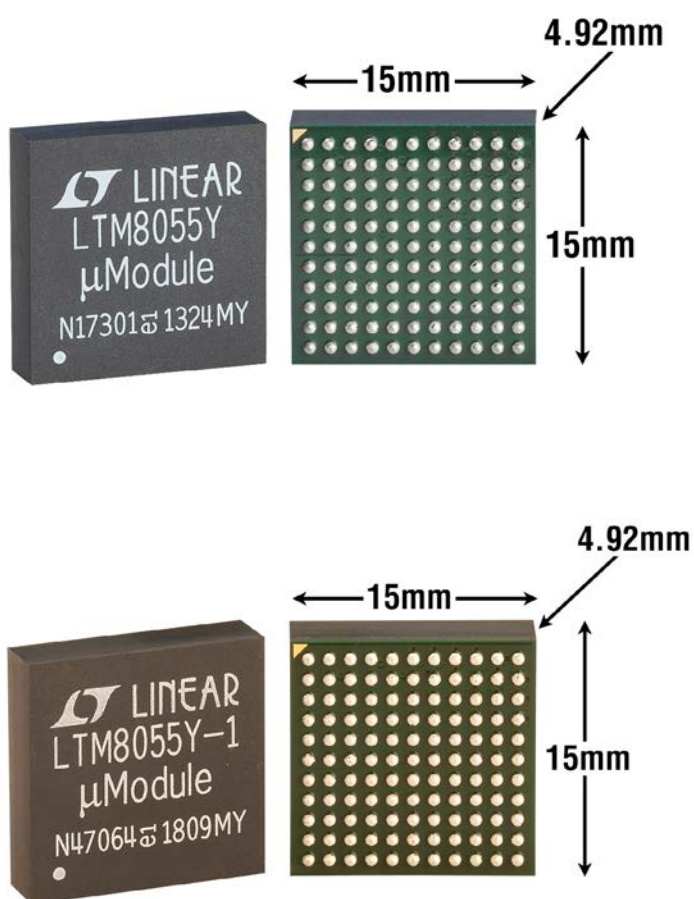


## PACKAGE DESCRIPTION

Table 4. LTM8055/LTM8055-1 Pin Assignment (Arranged by Pin Number)

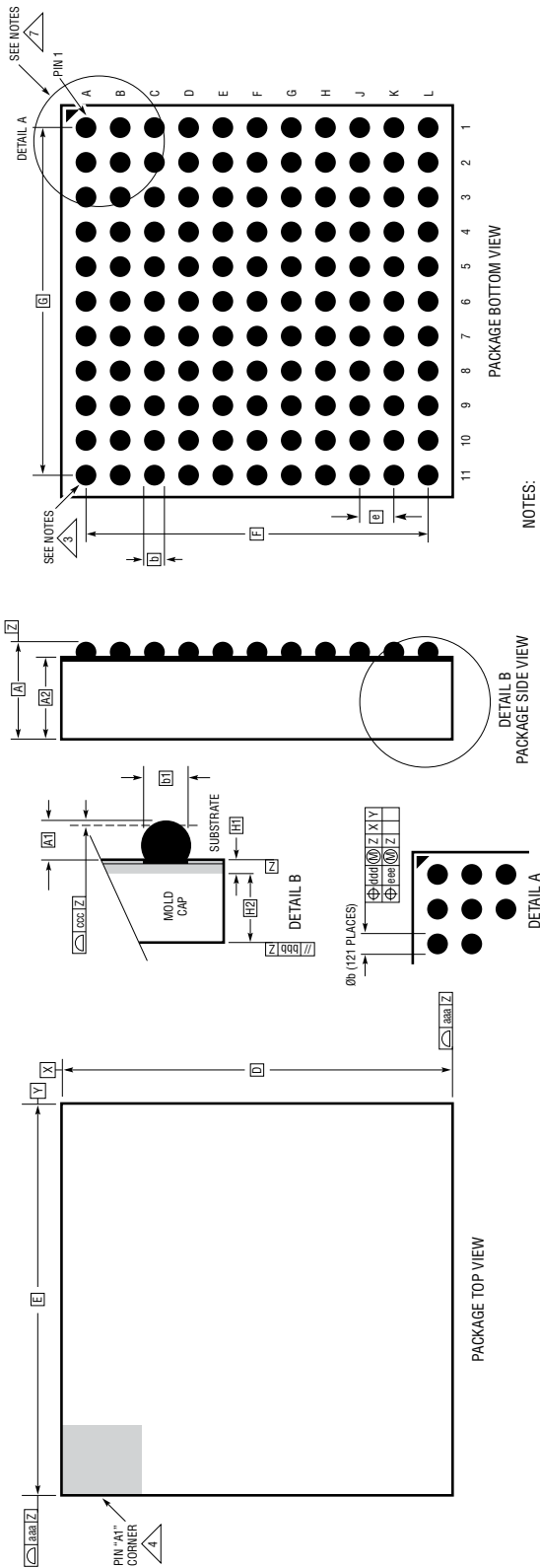
| PIN ID | FUNCTION         | PIN ID | FUNCTION         | PIN ID | FUNCTION         | PIN ID | FUNCTION         | PIN ID | FUNCTION | PIN ID | FUNCTION         |
|--------|------------------|--------|------------------|--------|------------------|--------|------------------|--------|----------|--------|------------------|
| A1     | V <sub>OUT</sub> | B1     | V <sub>OUT</sub> | C1     | V <sub>OUT</sub> | D1     | I <sub>OUT</sub> | E1     | GND      | F1     | LL               |
| A2     | V <sub>OUT</sub> | B2     | V <sub>OUT</sub> | C2     | V <sub>OUT</sub> | D2     | GND              | E2     | GND      | F2     | GND              |
| A3     | V <sub>OUT</sub> | B3     | V <sub>OUT</sub> | C3     | V <sub>OUT</sub> | D3     | GND              | E3     | GND      | F3     | GND              |
| A4     | V <sub>OUT</sub> | B4     | V <sub>OUT</sub> | C4     | V <sub>OUT</sub> | D4     | GND              | E4     | GND      | F4     | GND              |
| A5     | V <sub>OUT</sub> | B5     | V <sub>OUT</sub> | C5     | V <sub>OUT</sub> | D5     | GND              | E5     | GND      | F5     | GND              |
| A6     | V <sub>OUT</sub> | B6     | V <sub>OUT</sub> | C6     | V <sub>OUT</sub> | D6     | GND              | E6     | GND      | F6     | GND              |
| A7     | GND              | B7     | GND              | C7     | GND              | D7     | GND              | E7     | GND      | F7     | GND              |
| A8     | GND              | B8     | GND              | C8     | GND              | D8     | GND              | E8     | GND      | F8     | GND              |
| A9     | GND              | B9     | GND              | C9     | GND              | D9     | GND              | E9     | GND      | F9     | GND              |
| A10    | GND              | B10    | GND              | C10    | GND              | D10    | GND              | E10    | GND      | F10    | SV <sub>IN</sub> |
| A11    | GND              | B11    | GND              | C11    | GND              | D11    | GND              | E11    | GND      | F11    | SV <sub>IN</sub> |

| PIN ID | FUNCTION        | PIN ID | FUNCTION        | PIN ID | FUNCTION        | PIN ID | FUNCTION        | PIN ID | FUNCTION            |
|--------|-----------------|--------|-----------------|--------|-----------------|--------|-----------------|--------|---------------------|
| G1     | CLKOUT          | H1     | RT              | J1     | FB              | K1     | SS              | L1     | GND                 |
| G2     | MODE            | H2     | SYNC            | J2     | COMP            | K2     | CTL             | L2     | I <sub>OUTMON</sub> |
| G3     | GND             | H3     | GND             | J3     | GND             | K3     | GND             | L3     | I <sub>INMON</sub>  |
| G4     | GND             | H4     | GND             | J4     | GND             | K4     | GND             | L4     | RUN                 |
| G5     | GND             | H5     | GND             | J5     | GND             | K5     | GND             | L5     | GND                 |
| G6     | GND             | H6     | GND             | J6     | GND             | K6     | GND             | L6     | GND                 |
| G7     | GND             | H7     | GND             | J7     | GND             | K7     | GND             | L7     | GND                 |
| G8     | GND             | H8     | GND             | J8     | GND             | K8     | GND             | L8     | GND                 |
| G9     | GND             | H9     | GND             | J9     | GND             | K9     | GND             | L9     | I <sub>IN</sub>     |
| G10    | V <sub>IN</sub> | H10    | V <sub>IN</sub> | J10    | V <sub>IN</sub> | K10    | V <sub>IN</sub> | L10    | V <sub>IN</sub>     |
| G11    | V <sub>IN</sub> | H11    | V <sub>IN</sub> | J11    | V <sub>IN</sub> | K11    | V <sub>IN</sub> | L11    | V <sub>IN</sub>     |

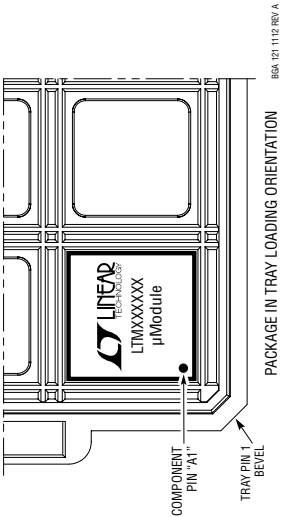
**PACKAGE PHOTO**

PACKAGE DESCRIPTION

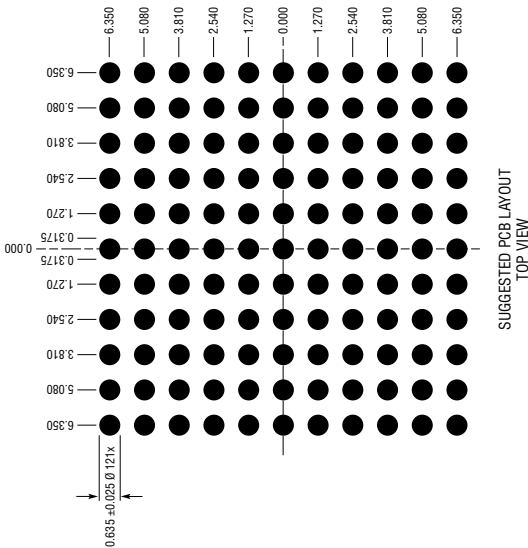
BGA Package  
121-Lead (15.00mm × 15.00mm × 4.92mm)  
(Reference LTC DWG# 05-08-1891 Rev A)



- NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994
  2. ALL DIMENSIONS ARE IN MILLIMETERS
  3. BALL DESIGNATION PER JEDEC MS-028 AND JEP95
  4. DETAILS OF PIN #1 IDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE ZONE INDICATED. THE PIN #1 IDENTIFIER MAY BE EITHER A MOLD OR MARKED FEATURE
  5. PRIMARY DATUM -Z- IS SEATING PLANE
  6. SOLDER BALL COMPOSITION CAN BE 96.5% Sn/3.0% Ag/0.5% Cu OR Sn Pb EUTECTIC
  7. PACKAGE ROW AND COLUMN LABELING MAY VARY AMONG  $\mu$ Module PRODUCTS. REVIEW EACH PACKAGE LAYOUT CAREFULLY



| DIMENSIONS                 |       |       |       | NOTES |  |
|----------------------------|-------|-------|-------|-------|--|
| SYMBOL                     | MIN   | NOM   | MAX   |       |  |
| A                          | 4.72  | 4.92  | 5.12  |       |  |
| A1                         | 0.50  | 0.60  | 0.70  |       |  |
| A2                         | 4.22  | 4.32  | 4.42  |       |  |
| b                          | 0.71  | 0.78  | 0.85  |       |  |
| b1                         | 0.610 | 0.635 | 0.660 |       |  |
| D                          |       | 15.00 |       |       |  |
| E                          |       | 15.00 |       |       |  |
| e                          |       | 1.27  |       |       |  |
| F                          |       | 12.70 |       |       |  |
| G                          |       | 12.70 |       |       |  |
| H1                         | 0.27  | 0.32  | 0.37  |       |  |
| H2                         | 3.95  | 4.00  | 4.05  |       |  |
| aaa                        |       |       | 0.15  |       |  |
| bbb                        |       |       | 0.10  |       |  |
| ccc                        |       |       | 0.20  |       |  |
| ddd                        |       |       | 0.30  |       |  |
| eee                        |       |       | 0.15  |       |  |
| TOTAL NUMBER OF BALLS: 121 |       |       |       |       |  |

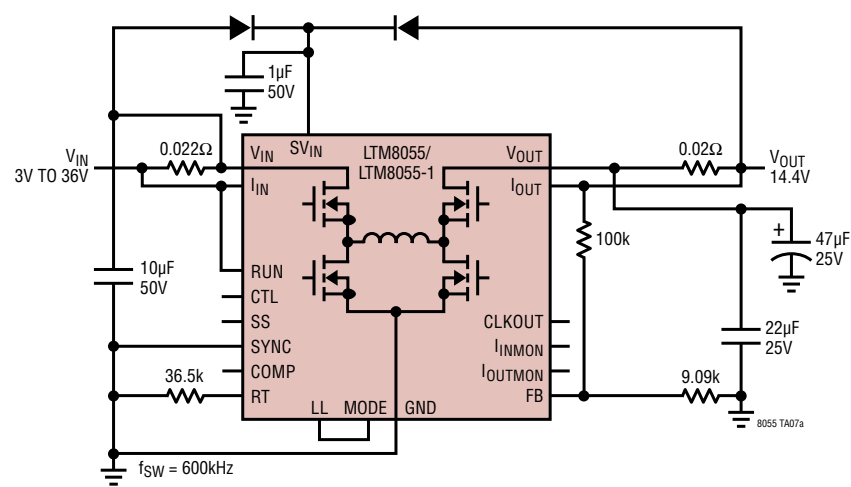


REVISION HISTORY

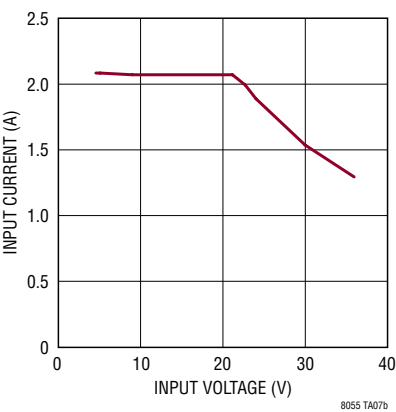
| REV | DATE  | DESCRIPTION                                | PAGE NUMBER           |
|-----|-------|--------------------------------------------|-----------------------|
| A   | 01/16 | Added Buck-Bost Selection Table            | 1                     |
| B   | 05/17 | Added text to I <sub>OUTMON</sub> (pin L2) | 8                     |
| C   | 08/18 | Added LTM8055-1                            | 1, 2, 7, 9, 10,<br>23 |

TYPICAL APPLICATION

14.4V, 3A Lead-Acid Battery Charger Input Current Limited to 2.1A



Input Current vs Input Voltage,  
 $I_{OUT} = 3A$



DESIGN RESOURCES

| SUBJECT                                                    | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                          |
|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <a href="#">μModule Design and Manufacturing Resources</a> | Design: <ul style="list-style-type: none"><li>• Selector Guides</li><li>• Demo Boards and Gerber Files</li><li>• Free Simulation Tools</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Manufacturing: <ul style="list-style-type: none"><li>• Quick Start Guide/Demo Manual</li><li>• PCB Design, Assembly and Manufacturing Guidelines</li><li>• Package and Board Level Reliability</li></ul> |
| <a href="#">μModule Regulator Products Search</a>          | <div><div>1. Sort table of products by parameters and download the result as a spread sheet.</div><div>2. Search using the Quick Power Search parametric table.</div><div><div>Quick Power Search</div><div><div>INPUT  </div><div>OUTPUT  </div><div>FEATURES  </div></div><div><div>V<sub>in</sub>(Min) <input type="text"/> V</div><div>V<sub>in</sub>(Max) <input type="text"/> V</div><div>V<sub>out</sub> <input type="text"/> V</div><div>I<sub>out</sub> <input type="text"/> A</div><div><input type="checkbox"/> Low EMI</div><div><input type="checkbox"/> Ultrathin</div><div><input type="checkbox"/> Internal Heat Sink</div><div>Multiple Outputs</div><div>Search</div></div></div></div> |                                                                                                                                                                                                          |
| <a href="#">Digital Power System Management</a>            | Analog Devices' family of digital power supply management ICs are highly integrated solutions that offer essential functions, including power supply monitoring, supervision, margining and sequencing, and feature EEPROM for storing user configurations and fault logging.                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                          |

RELATED PARTS

| PART NUMBER             | DESCRIPTION                         | COMMENTS                                                                                                     |
|-------------------------|-------------------------------------|--------------------------------------------------------------------------------------------------------------|
| <a href="#">LTM4605</a> | Higher Power Buck-Boost (Up to 60W) | External Inductor, Synchronous Switching Buck-Boost; Up to 36V <sub>IN</sub> , 0.8V ≤ V <sub>OUT</sub> ≤ 16V |
| <a href="#">LTM4607</a> | Higher Power Buck-Boost (Up to 60W) | External Inductor, Synchronous Switching Buck-Boost; Up to 36V <sub>IN</sub> , 0.8V ≤ V <sub>OUT</sub> ≤ 24V |
| <a href="#">LTM4609</a> | Higher Power Buck-Boost (Up to 60W) | External Inductor, Synchronous Switching Buck-Boost; Up to 36V <sub>IN</sub> , 0.8V ≤ V <sub>OUT</sub> ≤ 34V |
| <a href="#">LTM8045</a> | Smaller, Lower Power                | SEPIC and Inverting; 700mA, 6.25mm × 11.25mm × 4.92mm BGA                                                    |
| <a href="#">LTM8046</a> | Isolated, Lower Power               | Flyback Topology, 550mA (5V <sub>OUT</sub> , 24V <sub>IN</sub> ), UL60950, 2KVAC                             |

## Looking for pricing, stock, or lifecycle information?

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 [View LTM8055EY-1#PBF](#) on WIN SOURCE

 [Analog Devices Inc.](#) Information

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-  Global Sourcing Solution
-  Obsolete Management
-  Cost Control Management
-  Shortage Management
-  Alternative Solution
-  Excess Inventory Management