

## LTC4359HDCB 12V/20A Ideal Diode with Reverse Input Protection

### DESCRIPTION

Demonstration circuit 1502A showcases the LTC®4359 ideal diode controller with reverse input protection. The board includes two independent LTC4359 ideal diode circuits, sharing a common ground and operating over a 4.5V to 28V range.

Each channel is capable of carrying 20A. Through-hole pads are included to permit modification for even higher currents, using an off board power stage.

**Design files for this circuit board are available at <http://www.linear.com/demo>**

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### PERFORMANCE SUMMARY Specifications are at T<sub>A</sub> = 25°C

| PARAMETER                 | CONDITIONS      | MIN | TYP | MAX | UNITS |
|---------------------------|-----------------|-----|-----|-----|-------|
| Input Voltage Limits      | Operating       | 4.5 |     | 28  | V     |
|                           | DC Survival     | -40 |     | 90  | V     |
|                           | 1ms Transient   | -60 |     | 250 | V     |
|                           | VIN-VOUT        | -60 |     |     | V     |
| Output Current Capability | 4.5V ≤ VIN ≤ 8V |     |     | 10  | A     |
|                           | VIN > 8V        |     |     | 20  | A     |

## QUICK START PROCEDURE

### Overview

DC1502A features two independent LTC4359 ideal diode circuits sharing a common ground. Each channel handles up to 20A at room temperature, with no air flow. The board is double-sided. Reference designators are duplicated for the two sections of the board; the upper section is suffixed A while the lower section is suffixed B.

### Voltage Capability and Onboard Clamps

The voltage capability of DC1502A is clearly stated on the top side silkscreen and on the schematic. Several factors contribute to the listed ranges. First, there are the limits of the LTC4359 which has a specified operating range of 4V to 80V, and an absolute maximum rating for the IN,  $\overline{\text{SHDN}}$  and SOURCE pins of  $-40\text{V}$  to  $100\text{V}$ .

Second, there is the  $60\text{V}$   $\text{BV}_{\text{DSS}}$  rating of MOSFET Q1 that limits the VIN–VOUT rating of the board to  $-60\text{V}$  maximum. Higher excursions are made possible by operating Q1 in avalanche, or by replacing it with a higher voltage device.

Third, there are the clamp diodes D1 and D2. Clamping is necessary to rein in commutation spikes—the LTC4359 behavior is no different in this respect from ordinary rectifiers.

Fourth, there is the dissipation capability of R1, a component which has been chosen for its pulse capability. It becomes the limiting factor for DC conditions when the input voltage exceeds the breakdown of D1 or D2.

These factors combine to produce the INPUT VOLTAGE LIMITS table shown on the schematic and silkscreened on to the circuit board. Always bear in mind the VIN–VOUT limit of  $-60\text{V}$  which may further restrict the survival and transient limits.

### Current Capability

DC1502A is designed to carry 20A per channel, provided the LTC4359s are enabled. In the disabled state the associated Q1 MOSFET is turned off, and any forward current flows through the  $0.7\text{V}$  body diode. This limits the current

capability in the disabled state to  $\approx 1\text{A}$ . Do not attempt to pass 20A forward current in the disabled state, or Q1 will be destroyed.

The 10A and 20A current limitations in the enabled state result from MOSFET and board self heating, and from connector capability.

### Circuit Resistances

Typical  $R_{\text{DS(ON)}}$  for the BCS028N06NS MOSFET is  $2.5\text{m}\Omega$ , dropping  $50\text{mV}$  and dissipating about  $1\text{W}$  at  $20\text{A}$ . This produces a junction temperature rise of  $25^\circ\text{C}$  with the board lying on a bench top and deprived of air flow.

The circuit traces leading to and from Q1 and the interface between the board and the banana jacks amounts to  $500\mu\Omega$ , adding  $200\text{mW}$  dissipation at  $20\text{A}$ . The ground path measures about  $350\mu\Omega$ , which contributes an additional  $140\text{mW}$  dissipation. The total board+MOSFET dissipation for one channel driven is  $1.3\text{W}$  and with both channels driven, the total dissipation approaches  $3\text{W}$ . The ground copper loss may be eliminated by using a single power ground connection to DC1502A.

The best banana test leads (such as Pomona Model B banana plug) are rated to only  $10\text{A}$  to  $15\text{A}$ . For this reason, and to minimize self heating, all banana connections should be doubled up and kept as short as possible.

Banana plugs represent a substantial loss. Typical drop measured from the point where the wire exits a Pomona B-12 banana plug to the shoulder of the DC1502A banana jack is in excess of  $20\text{mV}$  at  $20\text{A}$ , or about  $1\text{m}\Omega$ . If each of the eight banana jacks is used to carry  $20\text{A}$ , they will add over  $3\text{W}$ , doubling the total dissipation.

If the turrets are removed,  $12\text{ AWG}$  bus wire can be installed in the vacated holes to virtually eliminate any voltage drop or dissipation associated with connections to the board. The dissipation is reduced to about  $20\text{mW}$  ( $50\mu\Omega$ ) per connection. Use the banana jacks for Kelvin meter connections.

## QUICK START PROCEDURE

At 20A even 12 AWG wire has its limitations: the resistance is  $\approx 1.6\text{m}\Omega/\text{foot}$ ; one foot dissipates a surprising 640mW at 20A. Some of this heat is conducted into the circuit board.

Another means of making connections is to attach ring terminals or copper terminal lugs to the banana jacks, using 8-32 screws. A Blackburn/Thomas&Betts BTC1014 terminal lug, enlarged for a number eight screw with a #15 drill, accepts up to 10 AWG stranded wire; BTC0614 accepts up to 6 AWG wire and needs no machining.

Various typical circuit resistances are summarized in the Various Voltage Drops Measured at 10A Load Current table.

### Modifying for Higher Current

The resistance issues discussed in the previous section make obvious that modification of the demo board itself for higher current is futile. Nevertheless, an off board power stage may be constructed and connected to DC1502A by using the SOURCE, DRAIN and GATE test pads. Snub the MOSFET with a  $100\Omega$ , 10nF series network directly across the device's drain and source terminals. Do not pass load current through the DC1502A ground terminals.

### Modifying for Other Applications

Pads are provided so that the board may be modified to match any of the data sheet diode applications. Components used in other applications include D3, D5 and D6, all located on the bottom of the board.  $R_{\text{SNUB}}$  and  $C_{\text{SNUB}}$  are useful for certain MOSFETs that exhibit parasitic stability issues, such as the FDMS86101.

### Shutdown

The LTC4359 may be shut down by moving the  $\overline{\text{SHDN}}$  jumper to the OFF position, which pulls  $\overline{\text{SHDN}}$  to VSS through  $100\text{k}\Omega$  (R5). Shutdown reduces the quiescent current to  $\approx 14\mu\text{A}$ . In the ON position the  $\overline{\text{SHDN}}$  pin floats; an internal  $2\mu\text{A}$  pull up asserts it high, enabling the LTC4359. In the EXT position, the  $\overline{\text{SHDN}}$  pin is connected through R5 to the  $\overline{\text{SHDN}}$  turret. If the  $\overline{\text{SHDN}}$  turret is left open, the

LTC4359 is enabled. To disable, connect the  $\overline{\text{SHDN}}$  turret to the neighboring VSS turret.  $\overline{\text{SHDN}}$  pin level shift circuits are shown in data sheet Figure 3.

Because the  $\overline{\text{SHDN}}$  pin is high impedance, it is subject to capacitive coupling. A 10nF noise bypass capacitor, CF, works with R5 to keep noise out of the  $\overline{\text{SHDN}}$  pin. R5 also helps protect the  $\overline{\text{SHDN}}$  pin against inadvertent overvoltage conditions that might arise from use of the  $\overline{\text{SHDN}}$  turret.

It is important to note that shutting down the LTC4359 does not interrupt the forward current path. Even when the LTC4359 is in the shutdown state and Q1 is off, Q1's body diode is still present and will conduct forward current. Do not shut down the LTC4359 when the MOSFET is carrying a forward current of more than 1A. High dissipation will result in rapid destruction of Q1.

### How to Operate DC1502A

A simple demonstration of DC1502A's operation is as follows (see Figure 1). Connect two adjustable power supplies, each set to 12V. Connect one to VIN A and nearby GND, the second to VIN B and its associated GND. Place the  $\overline{\text{SHDN}}$  jumpers in the ON position. Join the outputs of VOUT A and VOUT B together at the input of a DC load of up to 20A. Slowly adjust one power supply up and down relative to the other while monitoring the power supply currents. The higher supply will carry the load current, with a narrow transition region where the voltages are nearly identical and the supplies droop share. If one supply is shorted, the output voltage will not collapse—the other supply will carry the load.

The forward characteristics of the LTC4359 can be tested without using a high power load and using only a low voltage 20A supply, as shown in Figure 2. First, DC1502A is biased with a 12V supply. This supply provides quiescent current for the two channels, totaling less than 1mA. Second, connect the two channels in series (VOUT A connected to VIN B), and connect a 20A, current-limited low voltage ( $\approx 1\text{V}$ ) supply to VIN A and VOUT B.

# DEMO MANUAL DC1502A

## QUICK START PROCEDURE

Turn on the 12V bias supply first, and then turn on the 20A supply. 20A will flow from the input of channel A, through Q1A, to the input of channel B, through Q1B, and back out to the 20A power supply. This arrangement eliminates the need for high power supplies, eliminates the need for a second high current supply and eliminates the need for a high power load, yet the forward behavior of the LTC4359 and the board, connector and MOSFET voltage drops are readily examined as though the board was fully loaded with each channel carrying 20A. Always remember that the 12V supply must be present whenever forward current is flowing.

The 20A supply may be adjusted from zero to 20A and the 12V supply may be adjusted from 8.5V to 28V, to observe operation under any operating condition. At 10A, the 12V supply may be adjusted to as low as 4.5V.

When powering down, turn off the 20A supply first and then turn off the 12V supply. Using this sequence precludes passing 20A through the body diodes of Q1A and Q1B.

Various Voltage Drops Measured at 10A Load Current

| PATH   | MEASURED VOLTAGE DROP AT 10A | COMPUTED RESISTANCE | COMPUTED DISSIPATION AT 20A |
|--|------------------------------|---------------------|-----------------------------|
| Banana Tip to Banana Jack Shoulder (Input)       | 5.6mV                        | 560μΩ               | 224mW                       |
| Banana Jack Shoulder to SOURCE Pad               | 0.6mV                        | 60μΩ                |                             |
| Banana Jack Shoulder to Center Source Lead       | 2.6mV                        | 260μΩ               | 104mW                       |
| Center Source Lead to Drain Lead                 | 28.1mV                       | 2.81mΩ              | 1.12W                       |
| Drain Lead to Banana Jack Shoulder               | 1.8mV                        | 180μΩ               | 72mW                        |
| Banana Jack Shoulder to Banana Lead Tip (Output) | 2.8mV                        | 280μΩ               | 112mW                       |
| SOURCE Pad to DRAIN Pad                          | 31.4mV                       | 3.14mΩ              |                             |
| LTC4359 IN to OUT Pins                           | 30.5mV                       | 3.05mΩ              |                             |
| Shoulder to Shoulder (Total Board Drop)          | 32.7mV                       | 3.27mΩ              | 1.31W                       |

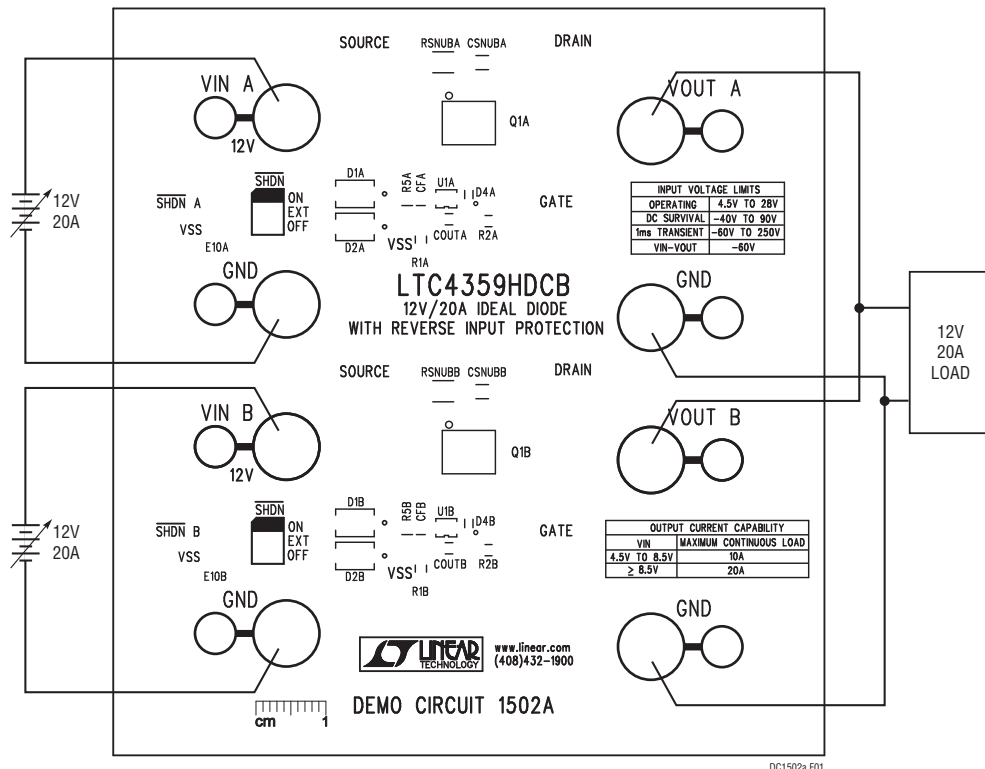


Figure 1. Basic Operation of DC1502A

QUICK START PROCEDURE

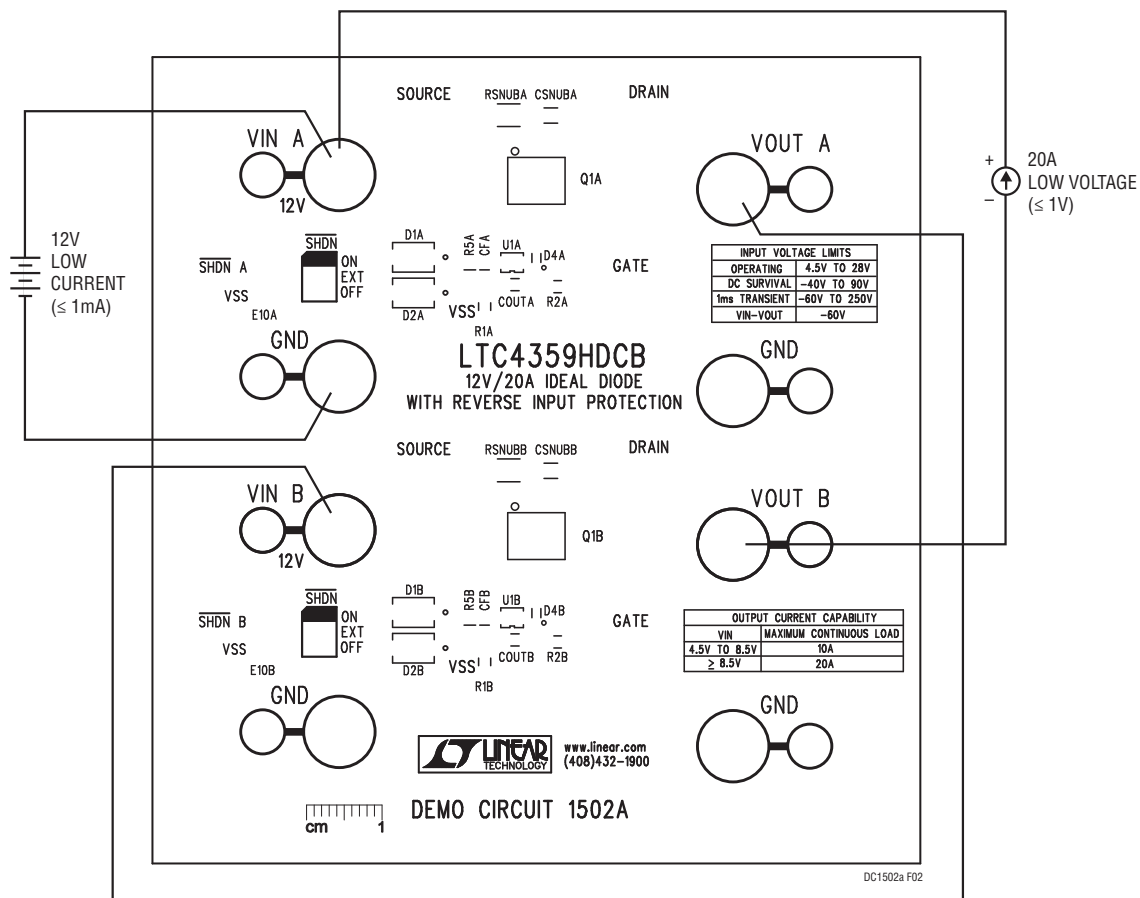


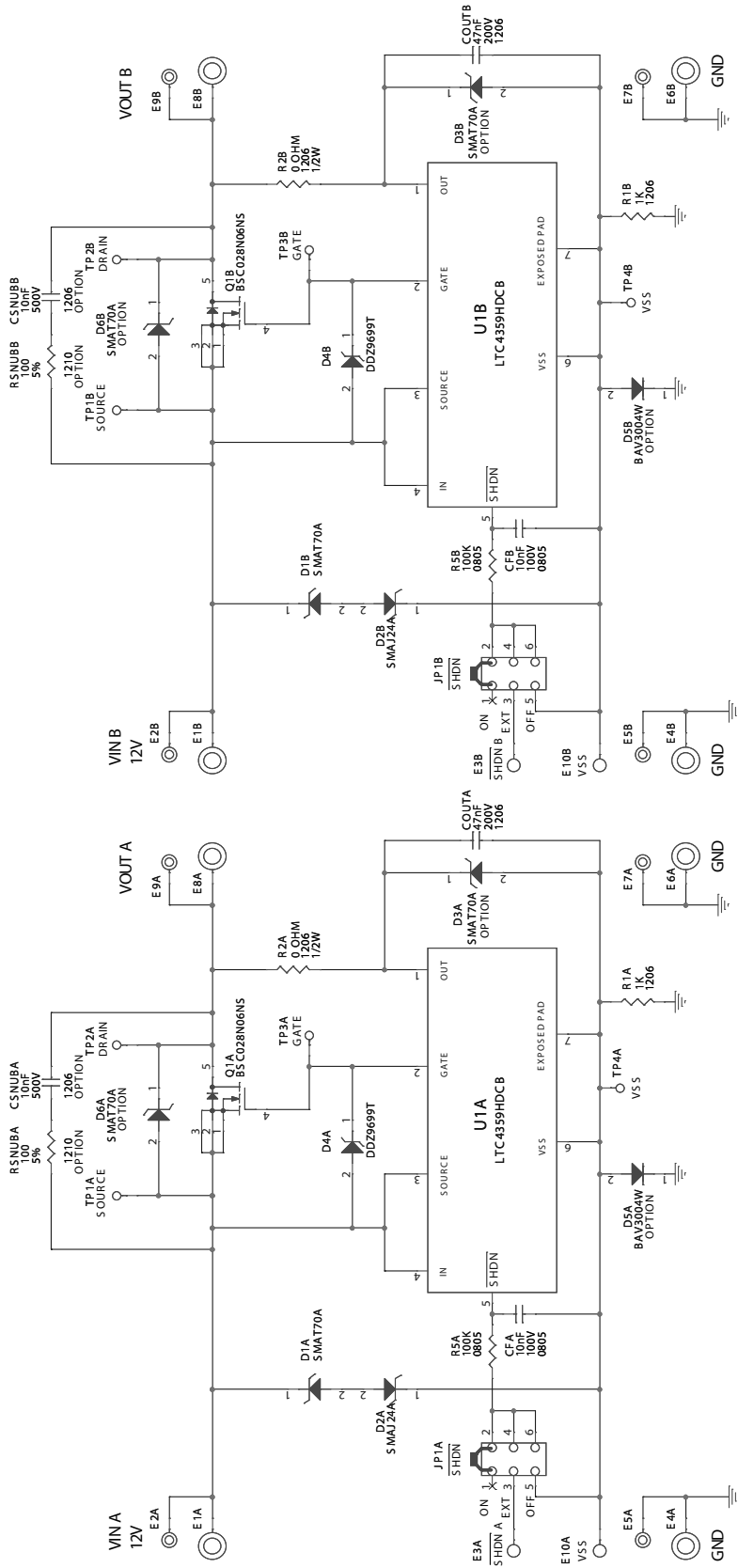
Figure 2. Testing Voltage Drops at High Current without the Need for High Power Supplies

# DEMO MANUAL DC1502A

## PARTS LIST

| ITEM                               | QTY | REFERENCE                              | PART DESCRIPTION                                 | MANUFACTURER/PART NUMBER           |
|------------------------------------|-----|--|--|------------------------------------|
| <b>Required Circuit Components</b> |     |  |  |                                    |
| 1                                  | 2   | CFB, CFA                               | CAP, X7R, 10nF, 100V 20% 0805                    | AVX, 08051C103MAT2A                |
| 2                                  | 2   | COU7B, COU7A                           | CAP, X7R, 47nF, 200V 20% 1206                    | AVX, 12062C473MAT2A                |
| 3                                  | 0   | CSNUBB, CSNUBA                         | CAP, X7R, 10nF, 500V 20% 1206, OPTION            | AVX, 12067C103MAT2A                |
| 4                                  | 2   | D1B, D1A                               | DIODE, TVS, 70V, SMA                             | DIODES INC/ZETEX, SMAT70A-13-F     |
| 5                                  | 2   | D2B, D2A                               | DIODE, TVS, 24V, SMA                             | DIODES INC/ZETEX, SMAJ24A-13-F     |
| 6                                  | 0   | D3B, D3A, D6B, D6A                     | DIODE, TVS, 70V, SMA, OPTION                     | DIODES INC/ZETEX, SMAT70A-13-F     |
| 7                                  | 2   | D4B, D4A                               | DIODE, ZENER 12V 150mW SOD-523                   | DIODES INC/ZETEX, DDZ9699T-7       |
| 8                                  | 0   | D5B, D5A                               | DIODE, SWITCHING, 300V, SOD-123, OPTION          | DIODES INC/ZETEX, BAV3004W-7-F     |
| 9                                  | 8   | E1B, E1A, E4B, E4A, E6B, E6A, E8B, E8A | BANANA JACK, NON-INSULATED                       | KEYSTONE, 575-4                    |
| 10                                 | 8   | E2B, E2A, E5B, E5A, E7B, E7A, E9B, E9A | TEST POINT, TURRET, 0.094, PBF                   | MILL-MAX, 2501-2-00-80-00-00-07-0  |
| 11                                 | 4   | E3B, E3A, E10B, E10A                   | TEST POINT, TURRET, 0.061, PBF                   | MILL-MAX, 2308-2-00-80-00-00-07-0  |
| 12                                 | 2   | JP1B, JP1A                             | HEADER, 2X3 PIN, 0.079CC                         | SAMTEC, TMM-103-02-L-D             |
| 13                                 | 6   | MH1 TO MH6                             | STANDOFF, NYLON 0.5"                             | KEYSTONE, 8833 (SNAP ON)           |
| 14                                 | 2   | Q1B, Q1A                               | TRANSISTOR, POWER MOSFET, N-CH 60V, 100A TDSON-8 | INFINEON, BSC028N06NS              |
| 15                                 | 0   | RSNUBB, RSNUBA                         | RES, CHIP, 100Ω, 1/2W, 5%, 1210, OPT             | NIC, NRCP25J101TRF                 |
| 16                                 | 2   | R1B, R1A                               | RES, CHIP, HIGH POWER, 1k, 1/2W, 5% 1206         | VISHAY, CRCW12061K00JNEAHP         |
| 17                                 | 2   | R2B, R2A                               | RES, CHIP, HIGH POWER, 0Ω, 1/2W, 5% 1206         | VISHAY, CRCW12060000Z0EAHP         |
|                                    |     |  | R2 PART OPTION 2k, 1/2W 5% 1206                  | VISHAY, CRCW12062K00FKEAHP         |
| 18                                 | 2   | R5B, R5A                               | RES, CHIP, 100k, 1/8W, 5% 0805                   | VISHAY, CRCW0805100KJNEA           |
| 19                                 | 2   | U1B, U1A                               | IC, 28V IDEAL DIODE, DFN-6L                      | LINEAR TECHNOLOGY, LTC4359HDCB#PBF |
| 20                                 | 2   | XJP1B, XJP1A                           | SHUNT, 2MM                                       | SAMTEC, 2SN-BK-G                   |

## SCHEMATIC DIAGRAM



NOTE: LTC-4359HDCB TOP MARK LFKF

| OUTPUT CURRENT CAPABILITY |                         |
|---------------------------|-------------------------|
| VIN                       | MAXIMUM CONTINUOUS LOAD |
| 4.5V TO 8V                | 10A                     |
| ≥8V                       | 20A                     |

| INPUT VOLTAGE LIMITS |              |
|----------------------|--------------|
| OPERATING            | 4.5V TO 28V  |
| DC SURVIVAL          | -40V TO 90V  |
| 1ms TRANSIENT        | -60V TO 250V |
| VIN - VOUT           | -60V         |

- MH1   MH2   MH3   MH4   MH5   MH6
- ○   ○   ○   ○   ○
- SNAP-IN STANDOFFS ON PC BOARD

# DEMO MANUAL DC1502A

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