

## DESCRIPTION

Demonstration circuit 551 is a complete constant-current/constant-voltage battery charger designed to charge one Lithium-Ion cell. Programmed for 3A charge current, this board features a 500kHz step down switching regulator controller driving a P-channel MOSFET. A fixed 3 hour timer is included for charge termination in addition to a charge status LED to indicate a near-full-charge condition and a thermistor connection for battery temperature charge qualification. Because of the heat generated by the circuit, the thermistor must not be mounted

on this board. A 10k resistor (R3) is used instead of a thermistor on this board.

The LTC®4002 on this board is in a tiny 3 X 3 mm 10 pin DFN package. All surface mount components are used to minimize board space and height with the circuitry occupying approximately 0.5 square inches of board space although additional pc-board copper is needed for heat dissipation.

**Design files for this circuit board are available. Call the LTC factory.**

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LTC is a registered trademark of Linear Technology Corporation

### Other Features include:

- Preset float voltages of 4.2V  $\pm$ 1%
- 3A Constant Current (can be programmed for other charge currents)
- 3 Hour charge termination timer
- NTC Thermistor input for sensing battery temperature
- Undervoltage Lockout
- Manual Shutdown
- Low battery drain current when input supply is removed
- C/10 Trickle charge for deeply discharged batteries
- Auto recharge when battery voltage drops below preset threshold
- C/5 Charge LED indicator (CHRG)

# QUICK START GUIDE FOR DEMONSTRATION CIRCUIT 551

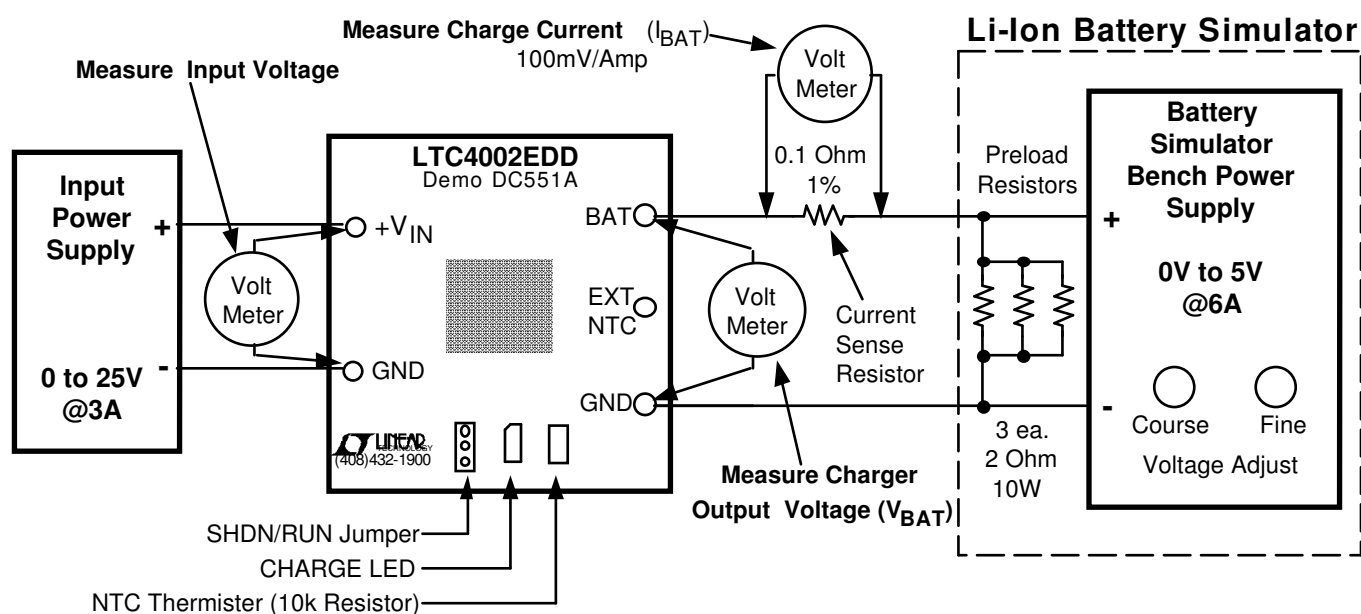
## LITHIUM-ION BATTERY CHARGER WITH CHARGE TERMINATION

### Typical Demo Board Specifications

|                                                      |                 |
|------------------------------------------------------|-----------------|
| Input Voltage Range ( $V_{IN}$ )                     | 5.2V to 24V     |
| Charge Voltage ( $V_{BAT}$ ) (constant voltage mode) | 4.2V $\pm$ 1%   |
| Charge Current $I_{BAT}$ (constant current mode)     | 3A $\pm$ 8%     |
| Charge Current $I_{BAT}$ (trickle current mode)      | 350mA $\pm$ 20% |
| C/5 CHRГ LED Threshold Level                         | 750mA $\pm$ 25% |
| Trickle Charge Threshold Voltage                     | 2.9V            |
| Battery Drain Current with $V_{IN}$ Removed          | <20 $\mu$ A *   |

\* Main cause of drain current is due to Schottky diode leakage current.

Figure 1. Test Setup



### Test Equipment Required for Demo Board Evaluation

|                                                                |                               |
|----------------------------------------------------------------|-------------------------------|
| Lab power supply for input power                               | 0 to 25V @ 3A                 |
| Digital multimeter for measuring input voltage ( $V_{IN}$ )    | 3-1/2 digits                  |
| Digital multimeter for measuring battery voltage ( $V_{BAT}$ ) | 4-1/2 digits                  |
| Digital multimeter for measuring charge current                | 3-1/2 digits                  |
| Li-Ion cell or * <b>Battery Simulator</b>                      | 4.2V Rechargeable Li-Ion Cell |

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### \*Battery Simulator consists of;

|                                                                  |              |
|------------------------------------------------------------------|--------------|
| Power supply with coarse and fine output voltage adjust controls | 0 to 5V @ 6A |
| Power resistors (preload for power supply)                       | 3ea 2• 10W   |

### Battery Simulator

A battery simulator can be very useful for evaluating a battery charger. A simple battery simulator consists of a lab power supply with coarse and fine (or a multi-turn) voltage adjust controls and a power resistor connected to the power supply output terminals. With the resistor load connected, the power supply can source and sink current, similar to an actual battery. Any level of charge from a fully discharged to fully charged battery can be quickly simulated by simply

changing the battery simulator power supply voltage. A fully discharged Li-Ion cell will be approx. 2.6V to 3V and a fully charged cell will be either 4.1V or 4.2V depending on the battery chemistry. When the cell is nearly fully charged, small changes in battery voltage will result in large changes in charge current.

Of course, there are times when an actual battery is needed, for example when plotting a complete charge cycle from start to finish.

## QUICK START PROCEDURE

With both power supplies set to 0V, connect the demo board to power supplies and meters as shown in Figure 1. The electrical connections between the charger output and the battery simulator must be high quality and a  $0.1\Omega$  sense resistor is recommended for the charge current measurement. The dc resistance in the charge current path should be kept to a minimum.

**Undervoltage Lockout and Trickle Charge** - After placing jumper (JP1) in the "RUN" position, begin increasing the input power supply voltage. At approximately 4.3V, the LTC4002 undervoltage lockout will allow the charger to start and the charge current will abruptly rise to approximately 300mA (30mV on the meter). This is the trickle charge current for a deeply discharged battery ( $V_{BAT} < 2.9V$ ). Adjust the input supply to approximately 6V.

**Trickle Charge Threshold and Constant Current Charge** - Begin increasing the battery simulator power supply ( $V_{BAT}$ ), observing the charger output voltage on the DVM. When the voltage exceeds

approximately 2.9V, the charger will suddenly enter the Constant Current portion of the charge cycle resulting in an abrupt increase in charge current to the programmed value of approximately 3A (300mV on the charge current DVM). This is the constant current mode. The CHRG LED will also turn on.

**Constant Voltage Charge and CHRG LED Indicator** - Continue slowly increasing the battery simulator power supply, thus simulating a battery accepting charge. The charge current should remain at the programmed value of 3A until the charger output voltage is within approximately 10mV of the preset charge voltage ( $4.2V \pm 1\%$ ), at which time the charge current will begin to decrease. This is the beginning of the Constant Voltage portion of the charge cycle.

Continue very slowly increasing the battery simulator power supply until the CHRG LED turns off, and note the charge current level when it went off. The current level should be approximately 750mA  $\pm 25\%$ . The LED is an indicator that the battery is approaching full charge. It is not a charge complete indication. The charge cycle will continue until the 3 hour timer ends. (Note: when the LED

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turns off, it remains off until a new battery is installed, the input power is cycled, or the charger is momentarily shut down).

Continue increasing the battery simulator power supply until the charge current drops to approximately 300mA (30mV on the charge current DVM), then read the charger output voltage on the DVM. This reading is the charger float voltage of  $4.200V \pm 40mV$ . Note: small changes in battery simulator voltage will result in large changes in charge current. Adjusting the simulator power supply to 4.2V will drop the charge current to 0mA.

**Sleep Mode** - To verify battery drain current in the sleep mode, remove the input supply voltage or shut the supply off, replace the  $0.1\Omega$  current sense resistor with a  $1k\Omega$ , and set the battery simulator power supply to approximately 4V. The charge current DVM will now read battery drain current with  $1mV/\mu A$ .

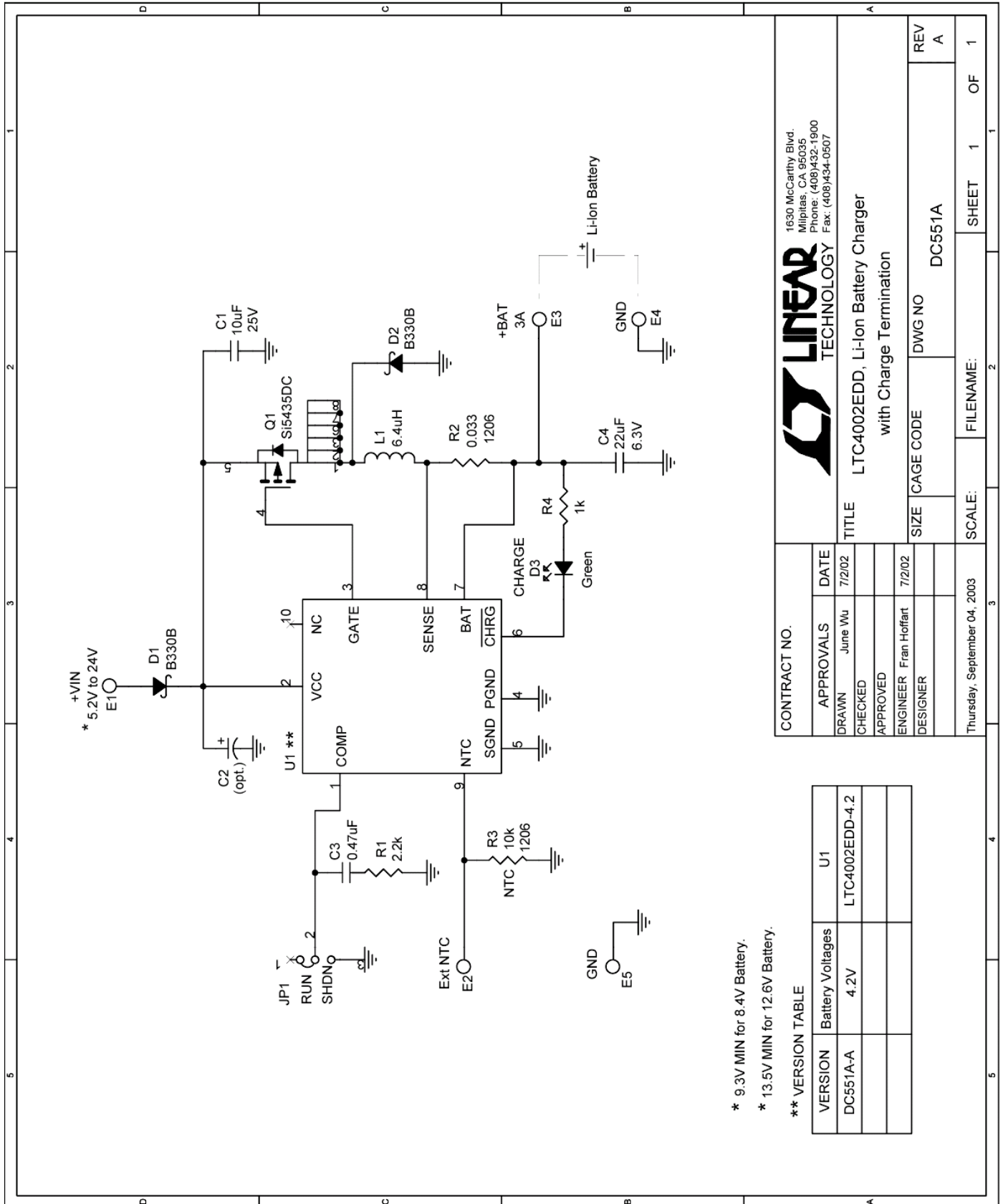
**Misc** - The input voltage can range from 5.2V to 24V with negligible effect on charge current or charge voltage specs. When applying input voltage greater than 20V, a solid tantalum capacitor is recommended in parallel with the existing ceramic input bypass capacitor to minimize voltage transients due to ringing when the input power is hot switched. Install a  $10\mu F$  or larger, 35V tantalum capacitor at location C2 on the demo board.

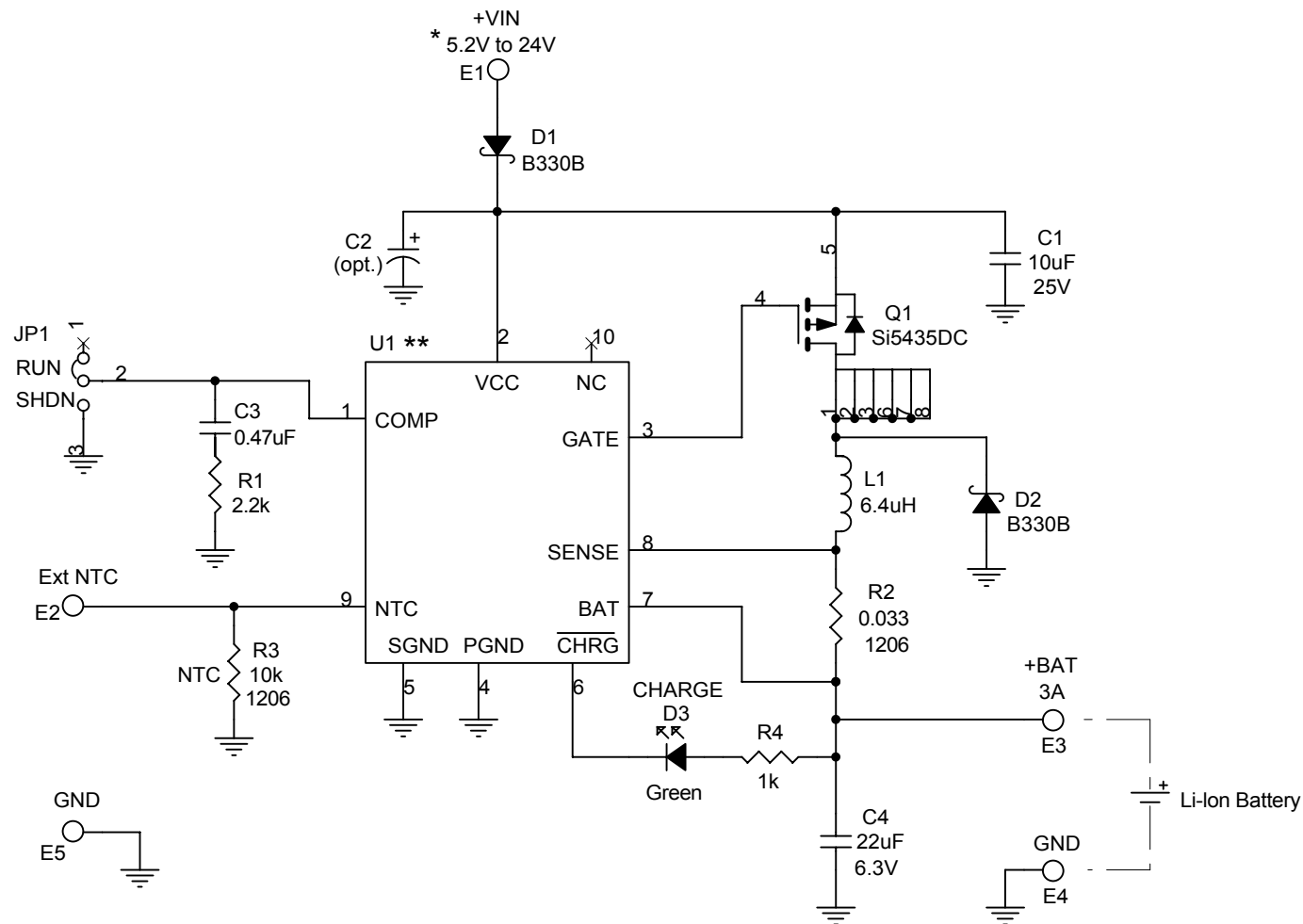
The charger can be shutdown by moving the jumper (J1) from the "RUN" position to the "SHDN" position.

To verify the temperature qualification feature, remove the 10k resistor R3 and connect a resistor substitution box to the "EXT NTC" terminals. Refer to the LTC4002 data sheet for resistor values that will either allow the charger to provide charge current or stop charging because of temperature extremes. If an actual thermistor is used, it must be mounted near the battery, not on the board.

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## LITHIUM-ION BATTERY CHARGER WITH CHARGE TERMINATION





\* 9.3V MIN for 8.4V Battery.

\* 13.5V MIN for 12.6V Battery.

# \*\* VERSION TABLE

| VERSION  | Battery Voltages | U1             |
|----------|------------------|----------------|
| DC551A-A | 4.2V             | LTC4002EDD-4.2 |
|          |                  |                |
|          |                  |                |

|                              |        |                                                                                                                                                                               |           |         |      |
|------------------------------|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|---------|------|
| CONTRACT NO.                 |        |  1630 McCarthy Blvd.<br>Milpitas, CA 95035<br>Phone: (408)432-1900<br>Fax: (408)434-0507 |           |         |      |
| APPROVALS                    | DATE   |                                                                                                                                                                               |           |         |      |
| DRAWN June Wu                | 7/2/02 | TITLE LTC4002EDD, Li-Ion Battery Charger<br>with Charge Termination                                                                                                           |           |         |      |
| CHECKED                      |        |                                                                                                                                                                               |           |         |      |
| APPROVED                     |        | SIZE                                                                                                                                                                          | CAGE CODE | DWG NO  | REV  |
| ENGINEER Fran Hoffart        | 7/2/02 |                                                                                                                                                                               |           | DC551A  | A    |
| DESIGNER                     |        |                                                                                                                                                                               |           |         |      |
| Thursday, September 04, 2003 |        | SCALE:                                                                                                                                                                        | FILENAME: | SHEET 1 | OF 1 |

6/17/2005

| <b>Item</b> | <b>Qty</b> | <b>Reference</b> | <b>Part Description</b>           | <b>Manufacture / Part #</b>    |
|-------------|------------|------------------|-----------------------------------|--------------------------------|
|             |            |                  |                                   |                                |
|             |            |                  |                                   |                                |
|             |            |                  |                                   |                                |
| 1           | 1          | C1               | CAP., X5R, 10uF, 25V, 20% 1210    | Taiyo Yuden, TMK325BJ106MM     |
| 2           | 0          | C2 (OPT)         | CAP., TANT., 7343                 | OPT.                           |
| 3           | 1          | C3               | CAP., X5R, 0.47uF, 6.3V, 20% 0603 | AVX, 06036D474MAT2A            |
| 4           | 1          | C4               | CAP., X5R, 22uF, 6.3V, 20% 1210   | Taiyo Yuden, JMK325BJ226MM     |
| 5           | 2          | D1,D2            | Schottky Rec., B330B SMB          | DIODES INC., B330B-13          |
| 6           | 1          | D3               | LED, Green                        | Panasonic, LN1351C-(TR)        |
| 7           | 5          | E1-E5            | TESTPOINT, TURRET, .094"          | MILL-MAX, 2501-2               |
| 8           | 1          | JP1              | 0.079 SINGLE ROW HEADER, 3 PIN    | COMM CON, 2802S-03-G1          |
| 9           | 1          | SHUNT (1-2)      | SHUNT,                            | COMM CON, CCIJ2MM-138G         |
| 10          | 1          | L1               | INDUCTOR, 6.4uH, D104C            | TOKO, 919AS-6R4M               |
| 11          | 1          | Q1               | P-MOSFET, Si5435DC 1206-8         | Vishay Siliconix, Si5435DC-T1  |
| 12          | 1          | R1               | RES., CHIP, 2.2K, 1/16W, 5% 0603  | AAC, CR16-222JM                |
| 13          | 1          | R2               | RES., CHIP, 0.033, 1/2W, 1% 1206  | THIN FILM TECH., RL1632R-R033F |
| 14          | 1          | R3               | RES., CHIP, 10k, 1/4W, 5% 1206    | AAC, CR18-103JM                |
| 15          | 1          | R4               | RES., CHIP, 1k, 1/16W, 5% 0603    | AAC, CR16-102JM                |
| 16          | 1          | U1               | I.C., LTC4002EDD DFN10            | Linear Tech. LTC4002EDD        |
| 17          | 1          |                  | PRINTED CIRCUIT BOARD             | DEMO CIRCUIT #551A-A           |
| 18          | 1          |                  | STENCIL                           | STENCIL #551A-A                |