

## LTM4650EY-1 High Efficiency, PolyPhase 200A Step-Down Power $\mu$ Module<sup>®</sup> Regulator 4 $\times$ LTM4650EY-1, 200A

### DESCRIPTION

Demonstration Circuit 2455A-C features PolyPhase<sup>®</sup> design using the LTM<sup>®</sup>4650EY-1 (B-grade), the high efficiency, high density, dual 25A, switch mode step-down power module regulator. The input voltage is from 4.5V to 15V. The output voltage is jumper selectable from 0.9V to 1.8V. DC2455A-C can deliver nominal 200A output current. As explained in the data sheet, output current de-rating is necessary for certain  $V_{IN}$ ,  $V_{OUT}$ , and thermal conditions. The LTM4650-1 on DC2455A-C always operate in continuous conduction mode. The switching frequency can be programmed through a resistor or can be synchronized to an external clock signal. The board allows the user to program how its output voltage ramps up and down through the

TRACK pin. The output voltage is tightly regulated between “ $V_0^+$ ” and “ $V_0^-$ ” through remote output voltage sensing which improves output voltage regulation at heavy loads. These features and the availability of the LTM4650EY-1 in a compact 16mm  $\times$  16mm  $\times$  5.01mm BGA package make it ideal for use in many high-density point-of-load regulation applications. The LTM4650-1 data sheet must be read in conjunction with this demo manual for working on or modifying the demo circuit DC2455A-C.

**Design files for this circuit board are available at <http://www.linear.com/demo/DC2455A-C>**

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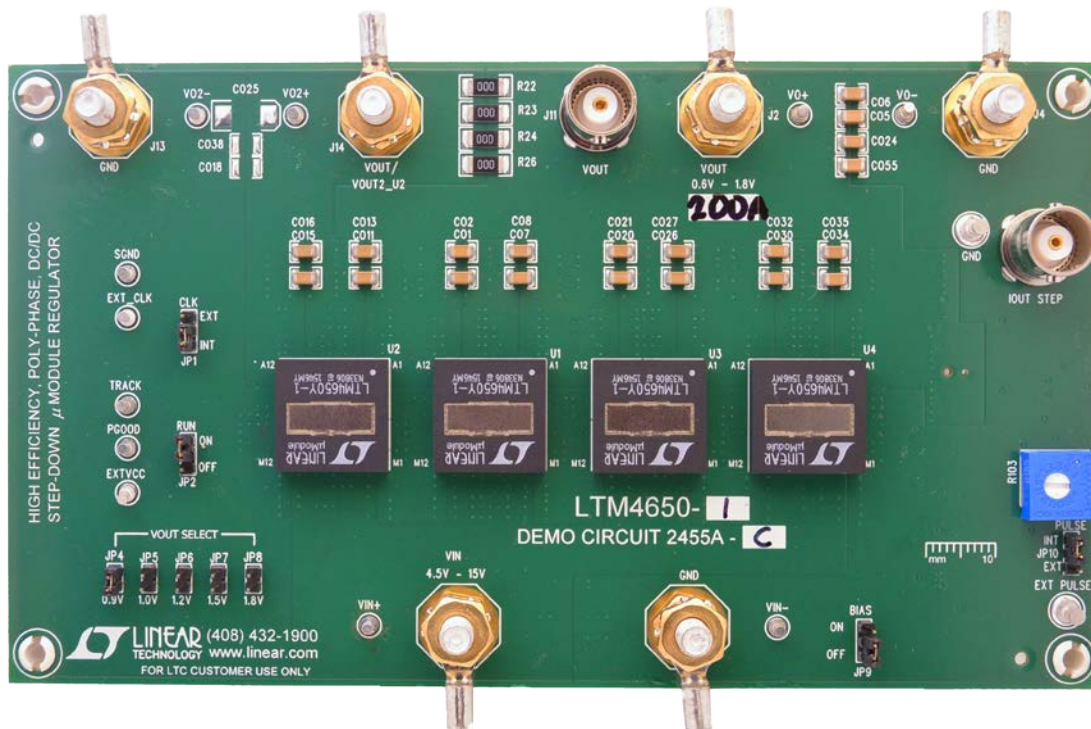


Figure 1. 4 $\times$  LTM4650-1, 200A PolyPhase LTM4650-1/DC2455A-C Demo Board

# DEMO MANUAL DC2455A-C

## PERFORMANCE SUMMARY Specifications are at $T_A = 25^\circ\text{C}$

| PARAMETER                             | CONDITIONS / NOTES                                                                                         | VALUE                                     |
|---------------------------------------|------------------------------------------------------------------------------------------------------------|-------------------------------------------|
| Input Voltage Range                   |                                                                                                            | 4.5V ~ 15V                                |
| Output Voltage $V_{OUT}$              | $V_{IN} = 4.5\text{V to } 15\text{V}$ , $I_{OUT} = 0\text{A to } 200\text{A}$ , JP5: 1.0V                  | $1.0\text{V} \pm 1.5\%$ (0.985V ~ 1.015V) |
| Maximum Continuous Output Current     | De-rating is necessary for certain $V_{IN}$ , $V_{OUT}$ and thermal conditions, see data sheet for detail. | 200A                                      |
| Default Operating Frequency           |                                                                                                            | 500kHz                                    |
| Resistor Programmable Frequency Range |                                                                                                            | 400kHz – 780kHz                           |
| External Clock Sync. Frequency Range  |                                                                                                            | 400kHz – 780kHz                           |
| Efficiency                            | $V_{IN} = 12\text{V}$ , $V_{OUT} = 1.0\text{V}$ , $I_{OUT} = 200\text{A}$ , $f_{SW} = 500\text{kHz}$       | 86.1% See Figure 3                        |
| Load Transient                        | $V_{IN} = 12\text{V}$ , $V_{OUT} = 1.0\text{V}$ , $I_{STEP} = 100\text{A to } 150\text{A}$                 | < 53mV, See Figure 4                      |

## QUICK START PROCEDURE

Demonstration circuit DC2455A-C is easy to set up to evaluate the performance of PolyPhase operation of the LTM4650EY-1. Due to the high input/output current, user should select the proper input supply/load/cable which can sustain the full load operation. It's recommended to pull load current from J2 and J4. The load current pulled from J5 and J6 shouldn't exceed 25A. Please refer to Figure 2 for proper measurement setup and follow the procedure below:

1. Place jumpers in the following positions for a typical 1.0V<sub>OUT</sub> application:

|            |            |                               |
|------------|------------|-------------------------------|
| JP1        | JP2        | JP4~JP8                       |
| <b>CLK</b> | <b>RUN</b> | <b>V<sub>OUT</sub> SELECT</b> |
| INT        | OFF        | ON JP5 / 1.0V                 |

2. With power off, connect the input power supply, load and meters as shown in Figure 2. Preset the load to 0A and  $V_{IN}$  supply to 12V.
3. Turn on the power supply at the input. Place JP2 to ON position. The output voltage between “V<sub>O+</sub>” and “V<sub>O-</sub>” should be  $1.0\text{V} \pm 1.5\%$  (0.985V~1.015V).
4. Once the proper output voltage is established, adjust the load within the operating range and observe the output

voltage regulation, output voltage ripple, efficiency and other parameters. Output voltage ripple should be measured at J11 with BNC cables. 50 $\Omega$  termination should be set on the oscilloscope or BNC cables.

5. (Optional) For optional load transient test, apply an adjustable pulse signal between “IOSTEP CLK” and “GND” test point. Pulse amplitude (3V~3.5V) sets the load step current amplitude. The output transient current can be monitored at the BNC connector J12 (5mV/A). The pulse signal should be very small duty cycle (<10%) to limit the thermal stress on the transient load circuit.
6. (Optional) LTM4650-1 can be synchronized to an external clock signal. Place the JP1 jumper on EXT and apply a clock signal (0V~5V, square wave) on the “EXT\_CLK” test point.
7. (Optional) The outputs of LTM4650-1 can track another supply. The output voltage tracks the voltage on TRACK when a valid signal is applied on the test point.
8. (Optional) DC2455A-C can be configured to a dual outputs configuration with V<sub>O</sub> at 175A load current and V<sub>O2</sub> at 25A load current. Stuff 0 $\Omega$  resistor on R61 and 0.1 $\mu\text{F}$  on C14. Remove R22, R23, R24, R26, R27, R28, R32, R33, R35. Output voltage V<sub>O2</sub> is set by R37 based on the equation  $V_{O2} = 0.6\text{V}(1+60.4\text{k}/\text{R}37)$ .

## QUICK START PROCEDURE

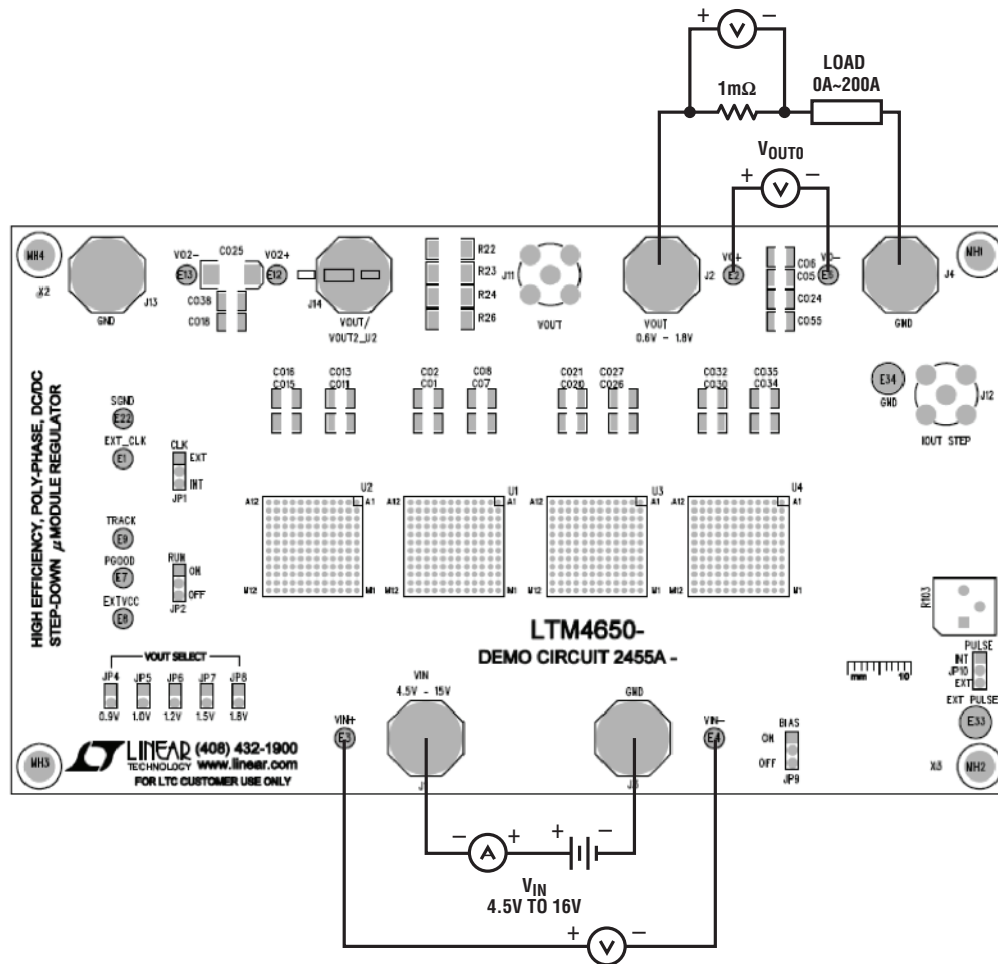


Figure 2. Test Setup of DC2455A-C

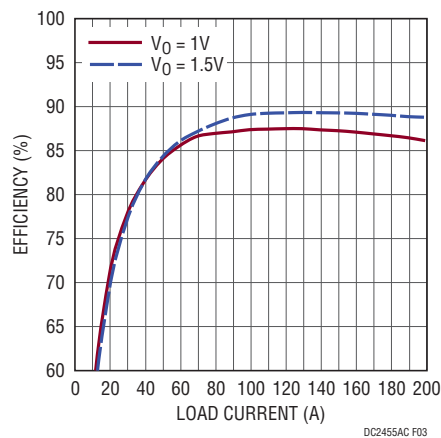


Figure 3. Measured Efficiency  $V_{IN} = 12V$ ,  $f_{SW} = 500kHz$

QUICK START PROCEDURE

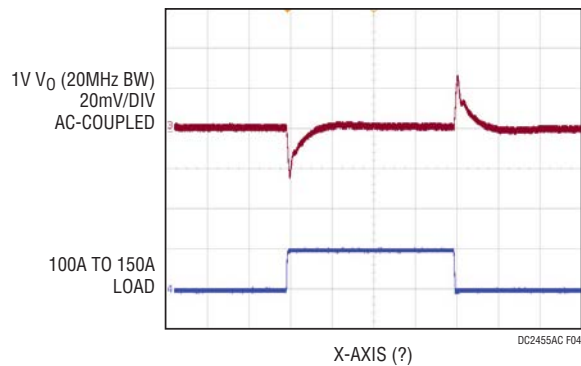


Figure 4. Load Transient 100A to 150A  
( $V_{IN} = 12V$ ,  $V_{OUT1} = 1V$ ,  $f_{SW} = 500kHz$ )

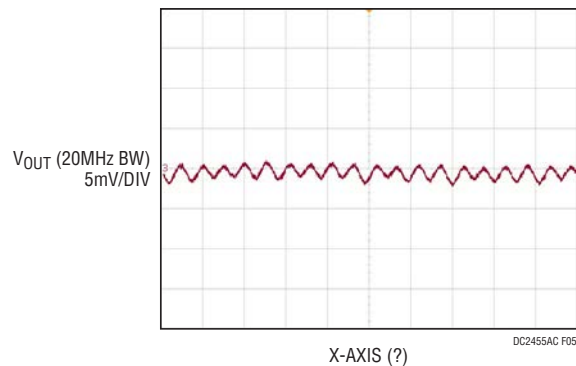


Figure 5. Output Voltage Ripple ( $V_{IN} = 12V$ ,  
 $V_{OUT1} = 1V$ ,  $I_{OUT} = 200A$ ,  $f_{SW} = 500kHz$ )

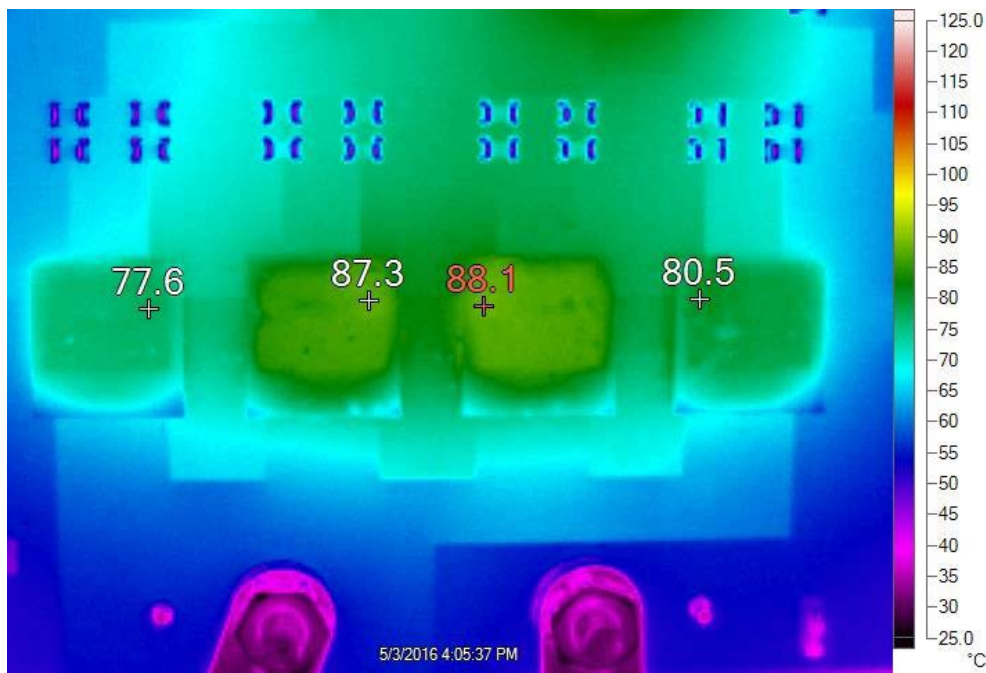


Figure 6. Thermal Performance at  $V_{IN} = 12V$ ,  $V_{OUT} = 1V$ ,  $I_{OUT} = 200A$ ,  $T_A = 23.8^{\circ}C$ , 400LFM Air Flow

## PARTS LIST

| ITEM                               | QTY | REFERENCE                                                                                      | PART DESCRIPTION             | MANUFACTURER/PART NUMBER     |
|------------------------------------|-----|------------------------------------------------------------------------------------------------|------------------------------|------------------------------|
| <b>Required Circuit Components</b> |     |                                                                                                |                              |                              |
| 1                                  | 1   | CIN1                                                                                           | CAP, 150μF 25% 25V ALUM      | SUN ELECT., 25HVH150M        |
| 2                                  | 2   | CIN2, CIN11                                                                                    | CAP, 1206 1μF 10% 25V X5R    | TAIYO YUDEN, TMK316BJ105KD-T |
| 3                                  | 8   | CIN3-CIN10                                                                                     | CAP, 1210 22μF 10% 25V X5R   | AVX, 12103D226KAT2A          |
| 4                                  | 8   | CIN12-CIN19                                                                                    | CAP, 1210 22μF 10% 25V X5R   | AVX, 12103D226KAT2A          |
| 5                                  | 16  | C01, C02, C05, C06, C07, C08, C011, C013, C015, C016, C024, C055, C056, C057, C058, C059       | CAP, 1206 220μF 20% 4V X5R   | MURATA, GRM31CR60G227ME11L   |
| 6                                  | 16  | C020, C021, C022, C026, C027, C028, C030, C032, C033, C034, C035, C036, C048, C050, C052, C054 | CAP, 1206 220μF 20% 4V X5R   | MURATA, GRM31CR60G227ME11L   |
| 7                                  | 1   | C1                                                                                             | CAP, 0603 330pF 10% 50V X7R  | AVX, 06035C331KAT2A-CT       |
| 8                                  | 4   | C4, C10, C18, C22                                                                              | CAP, 0603 4.7μF 20% 10V X5R  | TAIYO YUDEN, LMK107BJ475MA-T |
| 9                                  | 7   | C6, C11, C19, C23, COUT26, C42, C43                                                            | CAP, 0603 1μF 10% 10V X7R    | TAIYO YUDEN, LMK107BJ105KA-T |
| 10                                 | 1   | C7                                                                                             | CAP, 0603 0.1μF 10% 25V X7R  | AVX, 06033C104KAT2A          |
| 11                                 | 1   | C31                                                                                            | CAP, 0603 15nF 10% 50V X7R   | AVX, 06035C153KAZ2A          |
| 12                                 | 1   | C39                                                                                            | CAP, 0603 100nF 10% 100V X7R | MURATA, GRM188R72A104KA35D   |
| 13                                 | 1   | C40                                                                                            | CAP, 0603 150pF 5% 50V C0G   | AVX, 06035A151JAT2A          |
| 14                                 | 2   | C41, C48                                                                                       | CAP, 1210 100μF 10V X5R      | MURATA, GRM32ER61A107ME20L   |
| 15                                 | 8   | C41, C44, C45, C48, C52, C53, C54, C55                                                         | CAP, 1210 100μF 10% 6.3V X5R | MURATA, GRM32ER60J107ME20L   |
| 16                                 | 1   | C46                                                                                            | CAP, 1210 10μF 16V X5R       | MURATA, GRM32DR61C106KA01L   |
| 17                                 | 1   | C47                                                                                            | CAP, 0603 220pF 10% 50V X7R  | AVX, 06035C221KAT2A          |
| 18                                 | 1   | C49                                                                                            | CAP, 0603 47nF 10% 50V X7R   | AVX, 06035C473KAZ2A          |
| 19                                 | 1   | L1                                                                                             | IND, 68μH, CDRH105           | SUMIDA CDRH105RNP-680N       |
| 20                                 | 2   | Q1, Q2                                                                                         | MOSFET, N-CH D-S 40V TO252   | VISHAY, SUD50N04-8M8P-4GE3   |
| 21                                 | 4   | R1, R3, R25, R29                                                                               | RES, 0603 10Ω 5% 1/10W       | VISHAY, CRCW060310R0JNEA     |
| 22                                 | 9   | R2, R9, R14, R21, R31, R39, R43, R47, R51                                                      | RES, 0603 121kΩ 1% 1/10W     | VISHAY, CRCW0603121KFKEA     |
| 23                                 | 4   | R4, R36, R41, R98                                                                              | RES, 0603 10kΩ 5% 1/10W      | VISHAY, CRCW060310K0JNEA     |
| 24                                 | 1   | R11                                                                                            | RES, 0603 1.74kΩ 1% 1/10W    | VISHAY, CRCW06031K74FKEA     |
| 25                                 | 1   | R15                                                                                            | RES, 0603 90.9kΩ 1% 1/10W    | VISHAY, CRCW060390K9FKEA     |
| 26                                 | 1   | R16                                                                                            | RES, 0603 60.4kΩ 1% 1/10W    | VISHAY, CRCW060360K4FKEA     |
| 27                                 | 1   | R17                                                                                            | RES, 0603 40.2kΩ 1% 1/10W    | VISHAY, CRCW060340K2FKEA     |
| 28                                 | 1   | R18                                                                                            | RES, 0603 30.1kΩ 1% 1/10W    | VISHAY, CRCW060330K1FKEA     |
| 29                                 | 1   | R89                                                                                            | RES, 0603 2Ω 1% 1/10W        | VISHAY, CRCW06032R00FNEA     |
| 30                                 | 1   | R92                                                                                            | RES, 0603 3.3Ω 1% 1/10W      | VISHAY, CRCW06033R3FKEA      |
| 31                                 | 1   | R93                                                                                            | RES, 0603 154kΩ 1% 1/10W     | VISHAY, CRCW0603154KFKEA     |
| 32                                 | 1   | R94                                                                                            | RES, 0603 1MΩ 5% 1/10W       | VISHAY, CRCW06031M00JNEA     |
| 33                                 | 3   | R95, R96, R107                                                                                 | RES, 0603 20kΩ 5% 1/10W      | VISHAY, CRCW060320K0JNTA     |
| 34                                 | 1   | R97                                                                                            | RES, 0603 681kΩ 1% 1/10W     | VISHAY, CRCW0603681KFKEA     |
| 35                                 | 1   | R99                                                                                            | RES, 0603 301Ω 1% 1/10W      | VISHAY, CRCW0603301RFKEA     |
| 36                                 | 1   | R100                                                                                           | RES, 0603 82.5Ω 1% 1/10W     | VISHAY, CRCW060382R5FKEA     |
| 37                                 | 2   | R101, R102                                                                                     | RES, 2512 0.010Ω 1% 1W       | VISHAY, WSL2512R01000FEA     |
| 38                                 | 1   | R103                                                                                           | RES POT, 5k                  | BOURNS 3386P-1-502-LF        |



# DEMO MANUAL DC2455A-C

## PARTS LIST

| ITEM | QTY | REFERENCE      | PART DESCRIPTION                  | MANUFACTURER/PART NUMBER        |
|------|-----|----------------|-----------------------------------|---------------------------------|
| 39   | 1   | R104           | RES, 0603 1k $\Omega$ 1% 1/10W    | VISHAY, CRCW06031K00FKEA        |
| 40   | 1   | R105           | RES, 0603 105k $\Omega$ 1% 1/10W  | VISHAY CRCW0603105KFKEA         |
| 41   | 1   | R106           | RES, 0603 80.6k $\Omega$ 1% 1/10W | VISHAY CRCW060380K6FKEA         |
| 42   | 4   | U1, U2, U3, U4 | IC, VOLTAGE REGULATOR, BGA        | LINEAR TECH., LTM4650EY-1#PBF   |
| 43   | 1   | U5             | IC, TimerBlox®                    | LINEAR TECH., LTC6992IS6-1B#PBF |
| 44   | 1   | U6             | IC, OP-AMP, SINGLE, BIPOLAR       | LINEAR TECH., LT1803IS5#PBF     |
| 45   | 1   | U7             | IC, LTC3630EMSE                   | LINEAR TECH., LTC3630EMSE#PBF   |

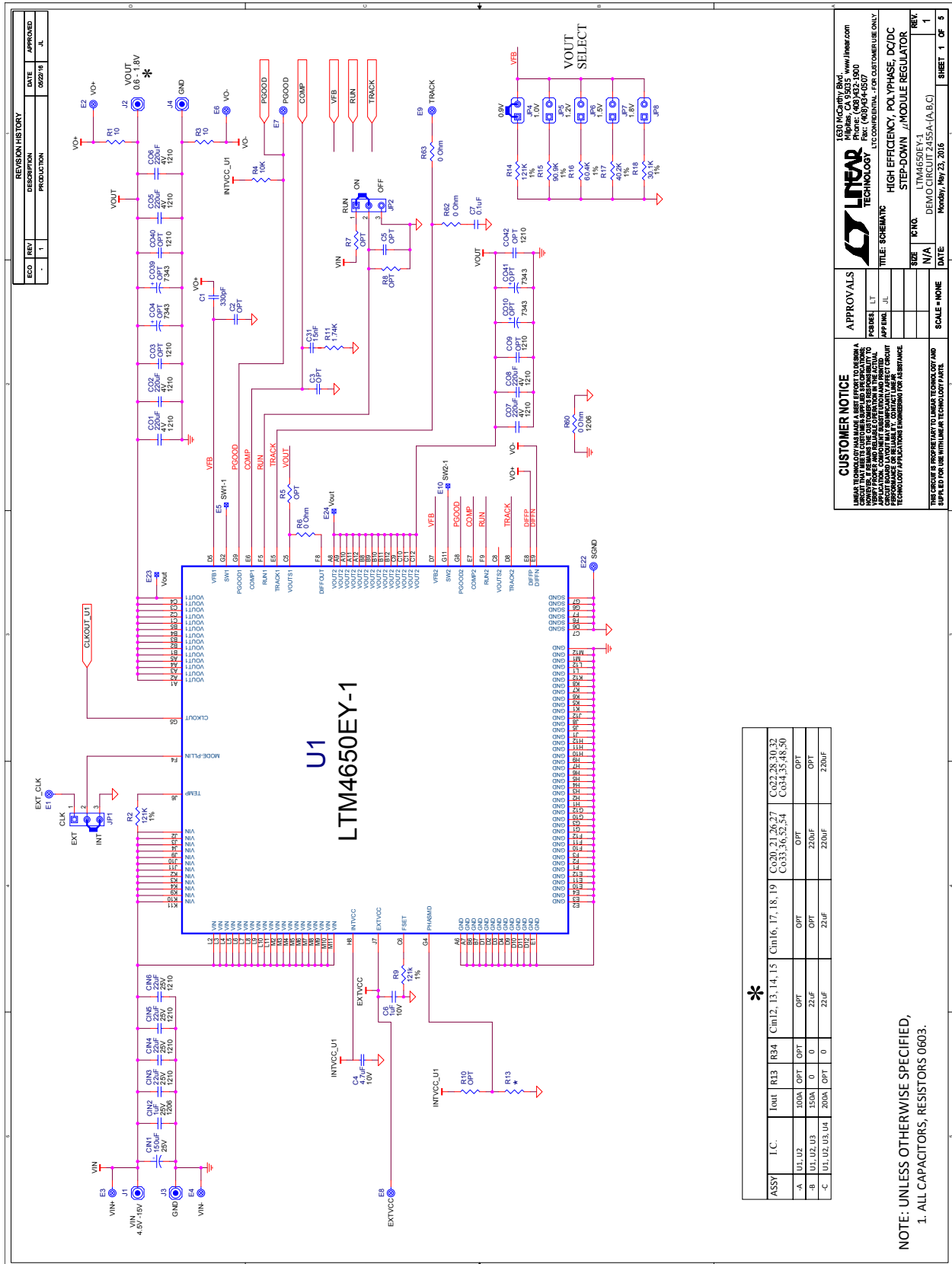
### Additional Demo Board Circuit Components

|   |    |                                                                                                     |                             |                          |
|---|----|-----------------------------------------------------------------------------------------------------|-----------------------------|--------------------------|
| 1 | 0  | C03, C09, C014, C017, C018, C038, C040, C042, C045, C046                                            | CAP, 1210 OPTION            | OPTION                   |
| 2 | 0  | C04, C010, C012, C019, C023, C025, C029, C031, C037, C039, C041, C043, C044, C047, C049, C051, C053 | CAP, 7343 OPTION            | OPTION                   |
| 3 | 0  | C2, C3, C5, C8, C9, C12, C17, C20, C21, C29, C30, C32                                               | CAP, 0603 OPTION            | OPTION                   |
| 4 | 0  | R5, R7, R8, R10, R30, R37, R38, R42, R44, R48, R49, R50, R52, R53, R55, R61, R64, R87               | RES, 0603 OPTION            | OPTION                   |
| 5 | 13 | R6, R19, R20, R27, R28, R32, R33, R35, R40, R45, R62, R63, R91                                      | RES, 0603 0 OHMS JUMPER     | VISHAY, CRCW06030000Z0EA |
| 6 | 0  | R13                                                                                                 | RES, 0603 OPTION            | OPTION                   |
| 7 | 1  | R34                                                                                                 | RES, 0603 0 $\Omega$ JUMPER | VISHAY, CRCW06030000Z0EA |
| 8 | 4  | R22, R23, R24, R26                                                                                  | RES, 2010 0 $\Omega$ JUMPER | VISHAY, CRCW20100000ZEA9 |
| 9 | 1  | R60                                                                                                 | RES, 1206 0 $\Omega$ JUMPER | VISHAY, CRCW12060000Z0EA |

### Hardware: For Demo Board Only

|    |    |                                                                               |                              |                                   |
|----|----|-------------------------------------------------------------------------------|------------------------------|-----------------------------------|
| 1  | 11 | E1-E4, E6-E9, E12, E13, E22                                                   | TESTPOINT, TURRET, .063"     | MILL MAX, 2308-2-00-80-00-00-07-0 |
| 2  | 0  | E5, E10, E11, E14, E15, E16, E17, E18, E23, E24, E25, E26, E27, E28, E29, E30 | TEST PAD SMD                 |                                   |
| 3  | 2  | E33, E34                                                                      | TESTPOINT, TURRET, .094"     | MILL MAX, 2501-2-00-80-00-00-07-0 |
| 4  | 4  | JP1, JP2, JP9, JP10                                                           | HEADER, 3 PIN 2mm SINGLE ROW | WURTH ELEKTRONIK, 620-003-111-21  |
| 5  | 5  | JP4, JP5, JP6, JP7, JP8                                                       | HEADER, 2 PIN 2mm SINGLE ROW | WURTH ELEKTRONIK, 620-002-111-21  |
| 6  | 6  | J1, J2, J3, J4, J13, J14                                                      | STUD, TEST PIN               | PEM, KFH-032-10                   |
| 7  | 12 | J1, J2, J3, J4, J13, J14 (x2)                                                 | NUT, BRASS PL # 10-32        | ANY, 10-32M/S BR PL               |
| 8  | 6  | J1, J2, J3, J4, J13, J14                                                      | LUG RING, #10                | KEYSTONE, 8205                    |
| 9  | 6  | J1, J2, J3, J4, J13, J14                                                      | WASHER, TIN PLATED BRASS     | ANY, #10EXT BZ TN                 |
| 10 | 2  | J11, J12                                                                      | CON, BNC, 5 PINS             | CONNEX, 112404                    |
| 11 | 5  | XJP1, XJP2, XJP4, XJP9, XJP10                                                 | SHUNT 2mm                    | WURTH ELEKTRONIK, 608-002-134-21  |
| 12 | 4  | MTGS AT 4 CORNERS                                                             | STAND-OFF, NYLON             | KEYSTONE, 8833                    |

## SCHEMATIC DIAGRAM



## 8

[illegible]



## SCHEMATIC DIAGRAM



## SCHEMATIC DIAGRAM





# DEMO MANUAL DC2455A-C

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