

# QUICK START GUIDE FOR DEMONSTRATION CIRCUIT 616

## 4MHZ, POLYPHASE HIGH EFFICIENCY SYNCHRONOUS BOOST CONVERTER

LTC3425EUH

### DESCRIPTION

Demonstration Circuit 616 is a synchronous, 4-phase boost converter using the LTC3425. It is capable of operating below 1V input. DC616A is set for 3.3V output. DC616B is set for 5V output. On each demo board, the left circuit gives higher efficiency and current rating; while the right circuit has smaller size and lower cost.

The switching frequency is set at 1MHz per phase, minimizing inductor and capacitor size. A single resistor at RT pin sets the frequency. If desired, the LTC3425 can be synchronized to an external clock.

Long wires run from input sources (such as wall adaptors) can cause large voltage spikes during initial plug-in. C5 and C15 are installed on DC616 to damp the possible voltage spikes. They are not required for applications where input source is close to the regulator. Please refer to Application Note 88 for details.

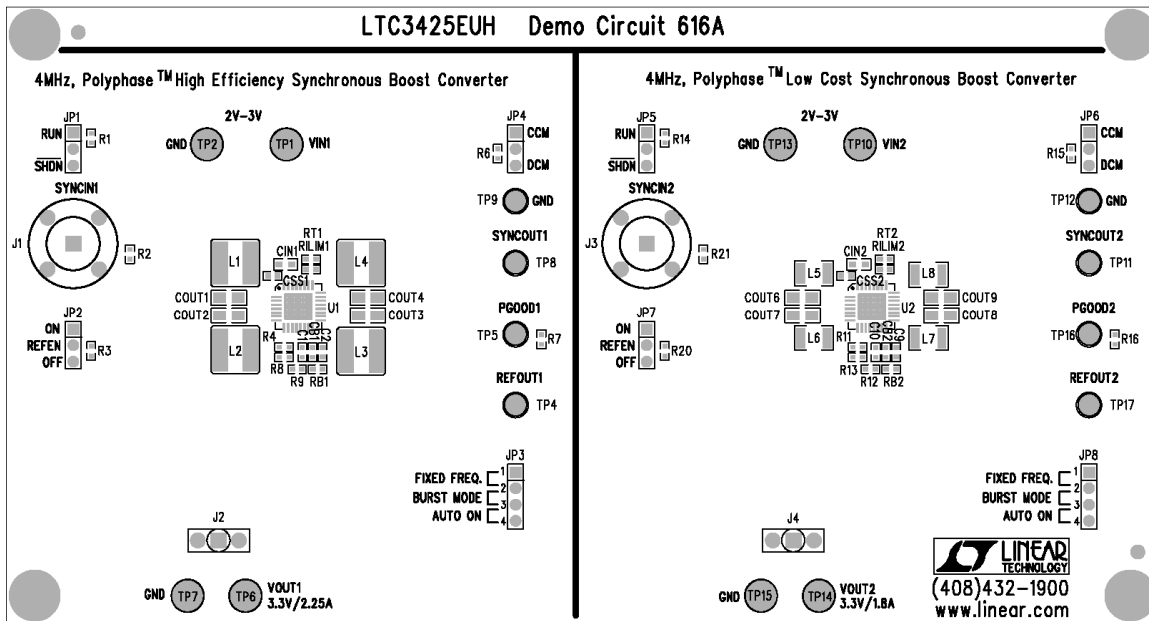
**Design files for this circuit board are available. Call the LTC factory.**

**Table 1. DC616A Performance Summary ( $T_A = 25^\circ\text{C}$  unless otherwise noted)**

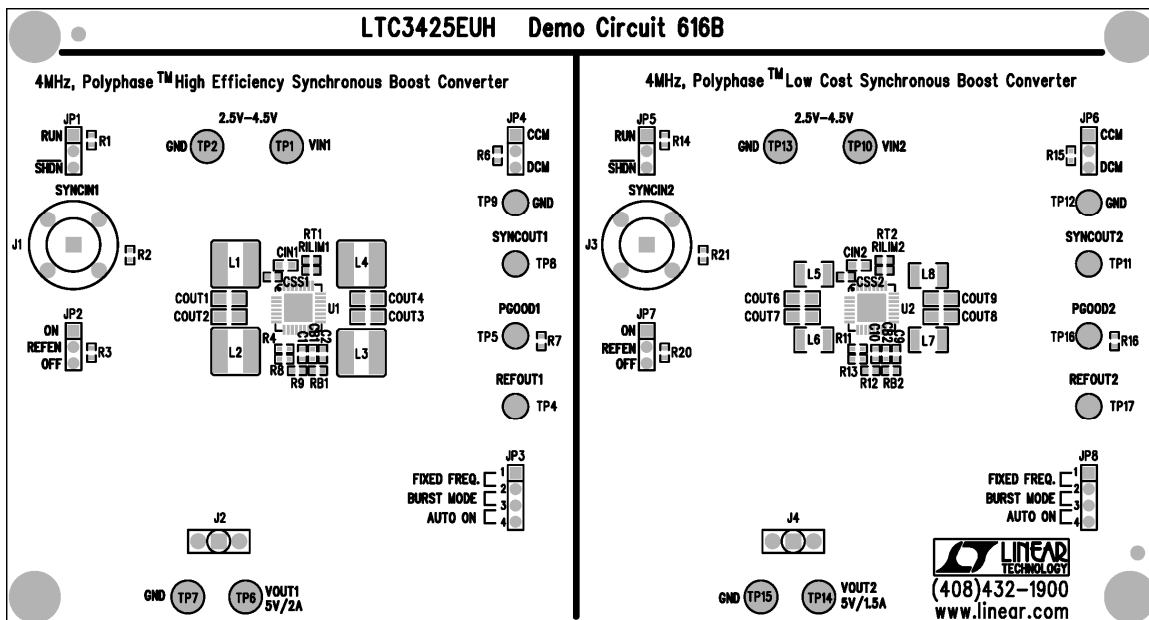
| PARAMETER                                           | CONDITION                                                                             | VALUE          |
|-----------------------------------------------------|---------------------------------------------------------------------------------------|----------------|
| Minimum Input Voltage (Start-Up)                    |                                                                                       | 1V             |
| Output Voltage $V_{OUT1}$ (High Efficiency Circuit) | $V_{IN} = 2V$ to $3V$ , $I_{OUT1} = 0A$ to $2.25A$                                    | $3.3V \pm 4\%$ |
| Output Voltage $V_{OUT2}$ (Low Cost Circuit)        | $V_{IN} = 2V$ to $3V$ , $I_{OUT2} = 0A$ to $1.8A$                                     | $3.3V \pm 4\%$ |
| Maximum Output Current (High Efficiency Circuit)    | $V_{IN} = 2V$ to $3V$                                                                 | $2.25A$        |
| Maximum Output Current (Low Cost Circuit)           | $V_{IN} = 2V$ to $3V$                                                                 | $1.8A$         |
| Typical Output Ripple $V_{OUT}$                     | $V_{IN} = 2.4V$ , $I_{OUT} = 1.8A$ (20MHz BW)                                         | $28mV_{p-p}$   |
| Typical Switching Frequency (each phase)            |                                                                                       | 1MHz           |
| Efficiency (High Efficiency Circuit)                | $V_{IN} = 2.4V$ , $I_{OUT1} = 0.5A$                                                   | 93.0% Typical  |
|                                                     | $V_{IN} = 2.4V$ , $I_{OUT1} = 2A$                                                     | 88.6% Typical  |
| On/Off Control                                      | Logic Low Voltage-Off, $-40^\circ\text{C}$ to $85^\circ\text{C}$                      | 0.25V MAX      |
|                                                     | Logic High Voltage-On (Initial Start-Up), $-40^\circ\text{C}$ to $85^\circ\text{C}$   | 1V MIN         |
|                                                     | Logic High Voltage-On ( $V_{OUT} > 2.4V$ ), $-40^\circ\text{C}$ to $85^\circ\text{C}$ | 0.65V MIN      |

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## 4MHZ, POLYPHASE HIGH EFFICIENCY SYNCHRONOUS BOOST CONVERTER



**Demo Circuit 616A = 3.3Vout@2.25A or 1.8A**



**Demo Circuit 616B = 5Vout@2.0A or 1.5A**

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**Table 2. DC616B Performance Summary ( $T_A = 25^\circ\text{C}$  unless otherwise noted)**

| PARAMETER                                           | CONDITION                                                                                   | VALUE               |
|-----------------------------------------------------|---------------------------------------------------------------------------------------------|---------------------|
| Minimum Input Voltage (Start-Up)                    |                                                                                             | 1V                  |
| Output Voltage $V_{OUT1}$ (High Efficiency Circuit) | $V_{IN} = 2.5\text{V to } 4.5\text{V}$ , $I_{OUT1} = 0\text{A to } 2\text{A}$               | $5\text{V} \pm 4\%$ |
| Output Voltage $V_{OUT2}$ (Low Cost Circuit)        | $V_{IN} = 2.5\text{V to } 4.5\text{V}$ , $I_{OUT2} = 0\text{A to } 1.5\text{A}$             | $5\text{V} \pm 4\%$ |
| Maximum Output Current (High Efficiency Circuit)    | $V_{IN} = 2.5\text{V to } 4.5\text{V}$                                                      | 2A                  |
| Maximum Output Current (Low Cost Circuit)           | $V_{IN} = 2.5\text{V to } 4.5\text{V}$                                                      | 1.5A                |
| Typical Output Ripple $V_{OUT}$                     | $V_{IN} = 3.3\text{V}$ , $I_{OUT} = 1.5\text{A}$ (20MHz BW)                                 | 33mV <sub>P-P</sub> |
| Typical Switching Frequency (each phase)            |                                                                                             | 1MHz                |
| Efficiency (High Efficiency Circuit)                | $V_{IN} = 3.3\text{V}$ , $I_{OUT1} = 0.5\text{A}$                                           | 93.0% Typical       |
|                                                     | $V_{IN} = 3.3\text{V}$ , $I_{OUT1} = 2\text{A}$                                             | 92.3% Typical       |
| On/Off Control                                      | Logic Low Voltage-Off, $-40^\circ\text{C to } 85^\circ\text{C}$                             | 0.25V MAX           |
|                                                     | Logic High Voltage-On (Initial Start-Up), $-40^\circ\text{C to } 85^\circ\text{C}$          | 1V MIN              |
|                                                     | Logic High Voltage-On ( $V_{OUT} > 2.4\text{V}$ ), $-40^\circ\text{C to } 85^\circ\text{C}$ | 0.65V MIN           |

## QUICK START PROCEDURE

Demonstration circuit 616 is easy to set up to evaluate the performance of the LTC3425. Refer to Figure 1 for proper measurement equipment setup and follow the procedure below:

**NOTE:** When measuring the input or output voltage ripple, care must be taken to avoid a long ground lead on the oscilloscope probe. Measure the input or output voltage ripple by touching the probe tip directly across the Vin or Vout and GND terminals. See Figure 2 for proper scope probe technique.

1. Place jumpers in the following positions:

**JP1, JP5**    RUN  
**JP2, JP7**    ON  
**JP4, JP6**    DCM  
**JP3, JP8**    AUTO ON.

2. With power off, connect the input power supply to VIN1 and GND or VIN2 and GND.
3. Turn on the power at the input.

**NOTE:** Make sure that the input voltage does not exceed 4.5V.

4. Check for the proper output voltage.
5. If there is no output, temporarily disconnect the load to make sure that the load is not set too high.

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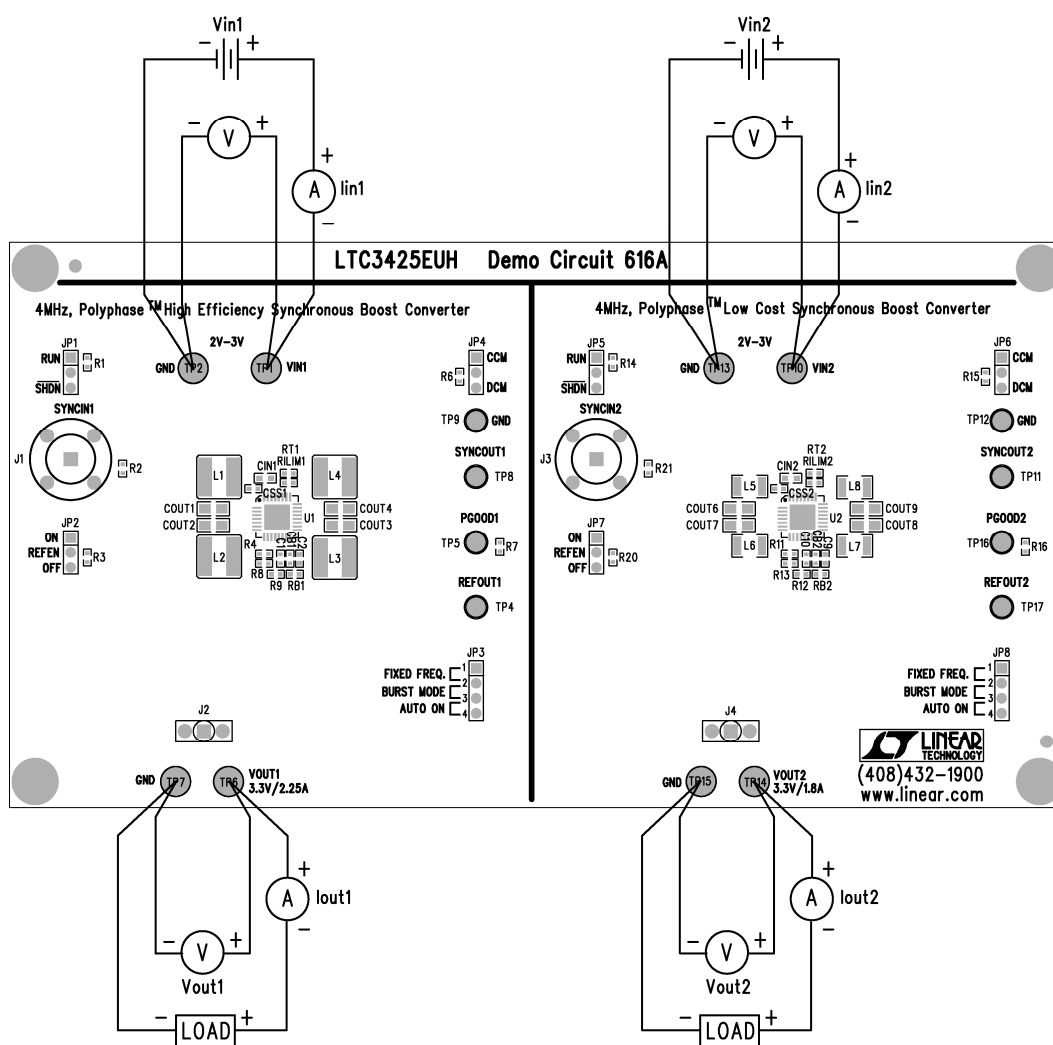
- Once the proper output voltage is established, adjust the load within the operating range and observe the output voltage regulation, ripple voltage, efficiency and other parameters.
- Different operating modes can be selected according to the following table:

**Table 3. LTC3425 Operating Modes**

| OPERATING MODE                                           | JP3, JP8 POSITION | JP4, JP6 POSITION |
|----------------------------------------------------------|-------------------|-------------------|
| Forced Burst                                             | BURST MODE        | DCM               |
| Automatic Burst (Operating Mode is Load Dependent)       | AUTO ON           | DCM               |
| Forced Fixed Frequency with Pulse Skipping at light load | FIXED FREQ        | DCM               |
| Forced Fixed Frequency, Low Noise (No Pulse Skipping)    | FIXED FREQ        | CCM               |

- The active clamping circuits are installed on DC616B to prevent the voltages at switch nodes from exceeding the maximum rating (refer to data sheet "Applications Where  $V_{OUT} > 4.3V$ " section for details). If there is any momentary short-circuit condition, please add a  $10\Omega$  in series with Q1.

## GRAPHIC



**Figure 1. Proper Measurement Equipment Setup**

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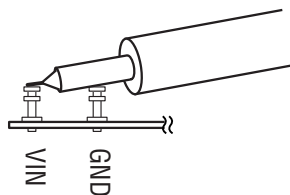


Figure 2. Measuring Input or Output Ripple

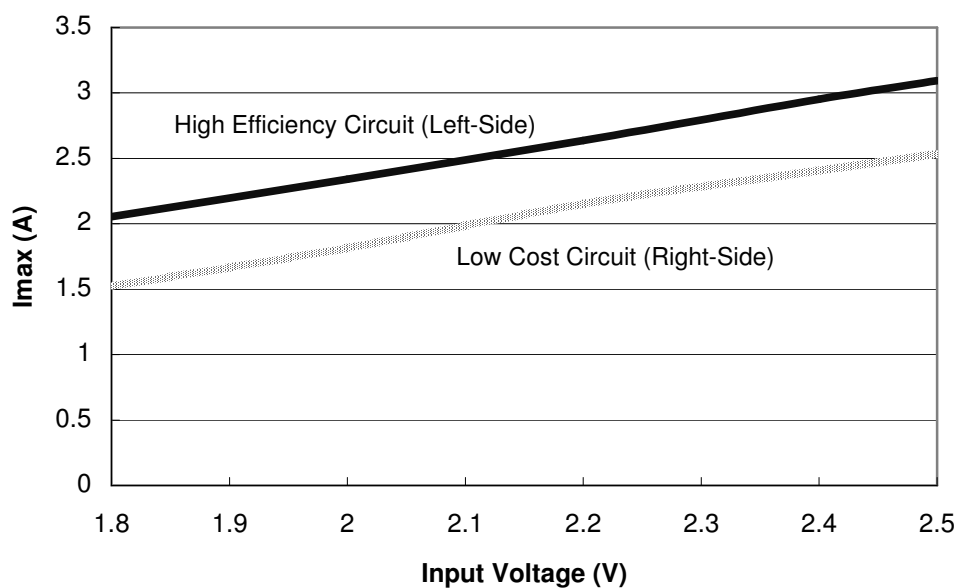


Figure 3. Maximum Output Current vs Input Voltage for 3.3V Output (DC616A)

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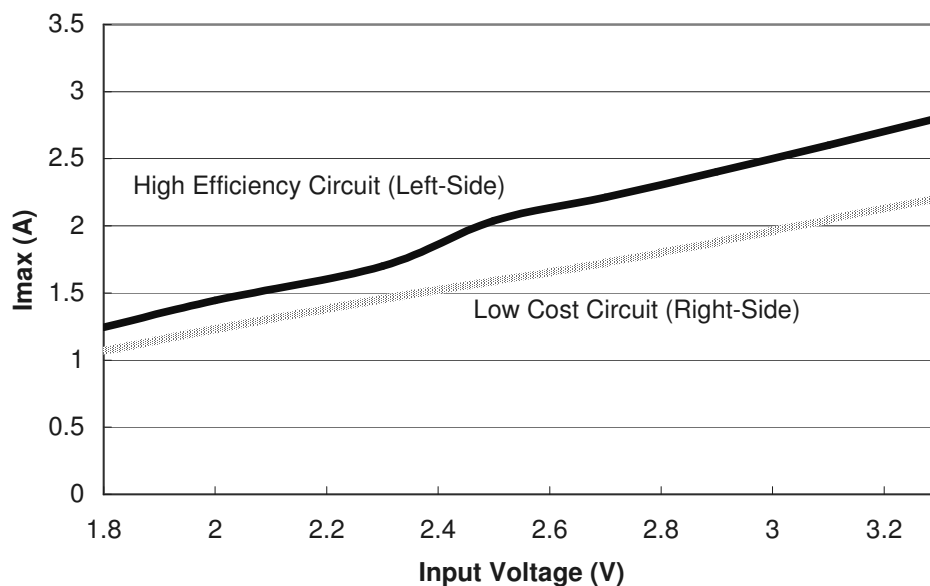


Figure 4. Maximum Output Current vs Input Voltage for 5V Output (DC616B)

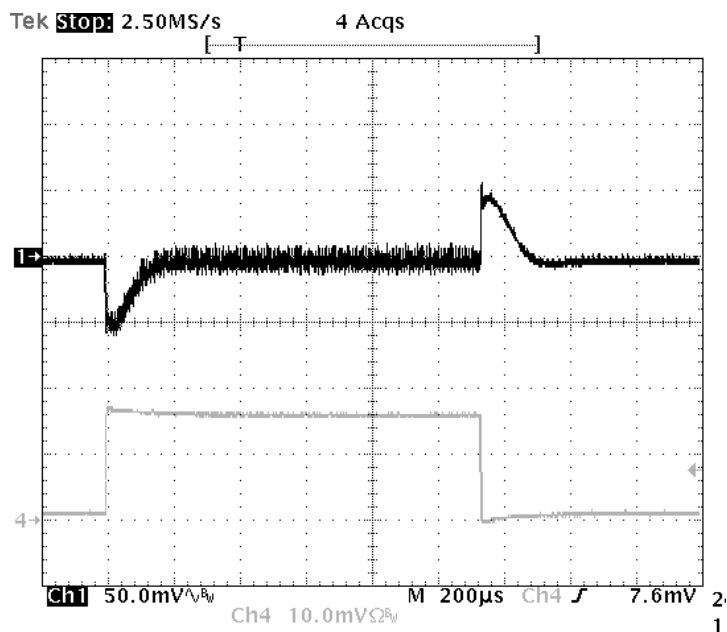


Figure 5. DC616A Load Transient Response ( $V_{in}=2.4V$ ; Channel 1: Vout1; Channel 2: Iout: load step from 0.2A to 2.25A)

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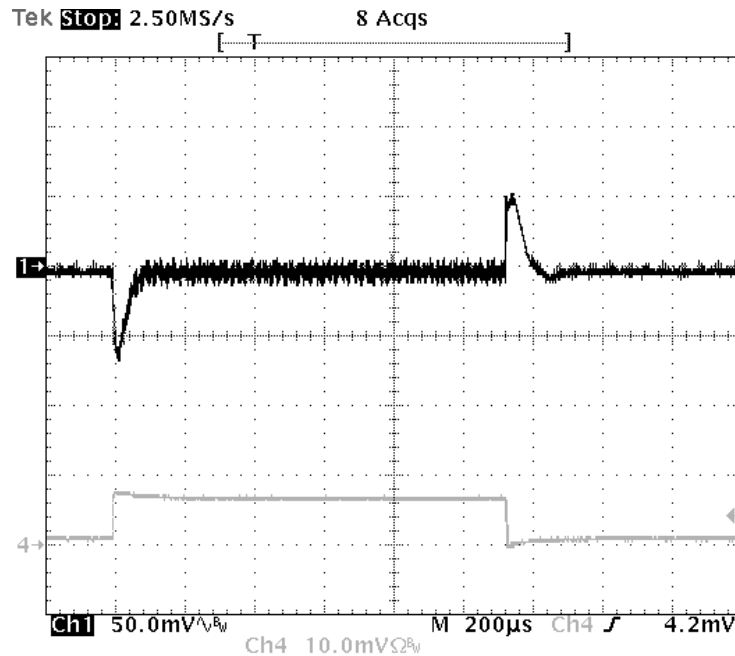


Figure 6. DC616B Load Transient Response ( $V_{in}=4.2V$ ; Channel 1:  $V_{out1}$ ; Channel 2:  $I_{out1}$ : load step from 0.2A to 2A)



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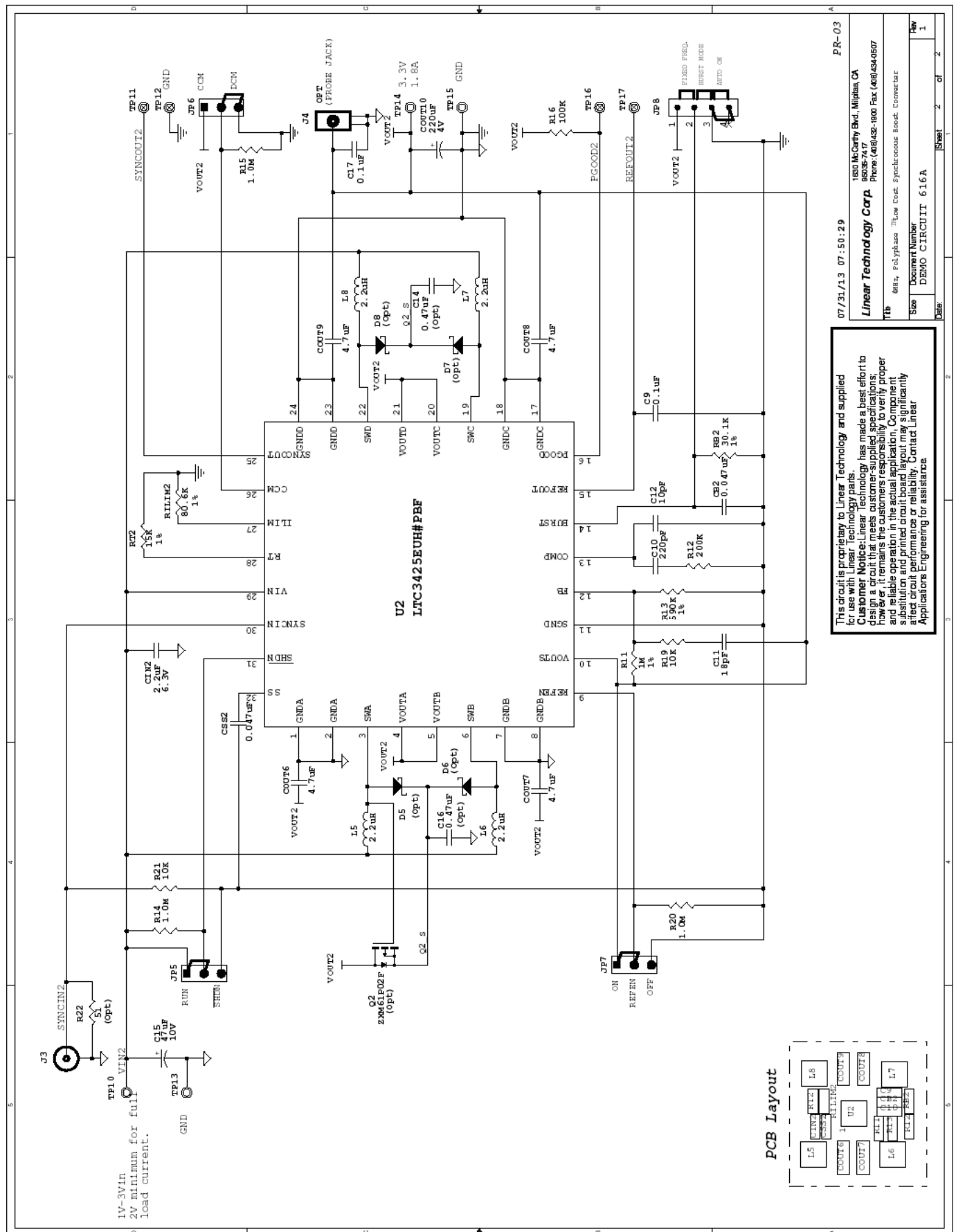
**Vin=1V to 3V**

**Vout=3.3V@2.25A**

| Item | Qty | Ref - Des           | Part Description                             | Manufacturer's Part Number        |
|------|-----|---------------------|----------------------------------------------|-----------------------------------|
| 1    | 2   | CB1,CSS1            | Cap., X5R 0.047uF 16V 20%                    | AVX 0402YD473MAT2A                |
| 2    | 1   | CIN1                | Cap., X5R 2.2uF 6.3V 10%                     | TAIYO YUDEN JMK107BJ225KA-T       |
| 3    | 4   | COU1,COU2,COU3,COU4 | Cap., X5R 4.7uF 6.3V 20%                     | TAIYO YUDEN JMK212ABJ475MG-T      |
| 4    | 1   | COU5                | Cap., SP-CAP 220uF 4V .009 ohm, case size D2 | PANASONIC EEF5X0G221ER            |
| 5    | 1   | C1                  | Cap., NPO 330pF 25V 10%                      | AVX 04023A331KAT2A                |
| 6    | 2   | C2,C8               | Cap., X5R 0.1uF 10V 10%                      | TDK C1005X5R1A104K                |
| 7    | 1   | C3                  | Cap., NPO 10pF 25V 10%                       | AVX 04023A100KAT2A                |
| 8    | 1   | C4                  | Cap., NPO 18pF 25V 10%                       | AVX 04023A180KAT2A                |
| 9    | 1   | C5                  | Cap., Tant. 47uF 10V 20%                     | AVX TAJB476M010RNJ                |
| 10   | 0   | C6,C7 (Opt)         | Cap., X5R 0.47uF 10V 10%                     | Taiyo Yuden LMK107BJ474KA-T       |
| 11   | 0   | D1,D2,D3,D4 (Opt)   | Schottky Diode, UPS5817                      | Microsemi UPS5817                 |
| 12   | 3   | JP1,JP2,JP4         | Headers, 3 Pins 2mm Ctrs.                    | SULLINS NRPN031PAEN-RC            |
| 13   | 1   | JP3                 | Headers, Commcon2802s04g2                    | SULLINS NRPN041PAEN-RC            |
| 14   | 1   | J1                  | BNC Connector                                | Connex 112404                     |
| 15   | 0   | J2 (Opt)            | Test Jacks, Shielded                         | Johnson Components 129-0701-201   |
| 16   | 4   | L1,L2,L3,L4         | Inductor, 2.2uH                              | COILCRAFT XAL5030-222MEC          |
| 17   | 0   | Q1 (Opt)            | P-Channel, 20V                               | ZETEX ZXM61P02F                   |
| 18   | 1   | RB1                 | Res., Chip 30.1K 0.06W 1%                    | VISHAY CRCW040230K1FKED           |
| 19   | 1   | R1LIM1              | Res., Chip 69.8K 0.06W 1%                    | VISHAY CRCW040269K8FKED           |
| 20   | 1   | RT1                 | Res., Chip 15K 0.06W 1%                      | VISHAY CRCW040215K0FKED           |
| 21   | 3   | R1,R3,R6            | Res., Chip 1.0M 1/16W 5%                     | VISHAY CRCW04021M00JNED           |
| 22   | 2   | R5,R2               | Res., Chip 10K 0.06W 5%                      | VISHAY CRCW040210K0JNED           |
| 23   | 1   | R4                  | Res., Chip 1M 1/16W 1%                       | VISHAY CRCW04021M00FKED           |
| 24   | 1   | R7                  | Res., Chip 100K 0.06W 5%                     | VISHAY CRCW0402100KJNED           |
| 25   | 1   | R8                  | Res., Chip 590K 0.06W 1%                     | VISHAY CRCW0402590KFKED           |
| 26   | 1   | R9                  | Res., Chip 200K 0.06W 5%                     | VISHAY CRCW0402200KJNED           |
| 27   | 0   | R10 (Opt)           | Res., Chip 51 0.06W 5%                       | VISHAY CRCW040251R0JNED           |
| 28   | 4   | TP1,TP2,TP6,TP7     | Turret, Testpoint                            | MILL-MAX 2501-2-00-80-00-00-07-0  |
| 29   | 4   | TP4,TP5,TP8,TP9     | Turret, Testpoint                            | MILL-MAX 2308-2-00-80-00-00-07-0  |
| 30   | 1   | U1                  | I.C., Polyphase Switching Reg.               | LINEAR TECH. CORP. LTC3425EUH#PBF |

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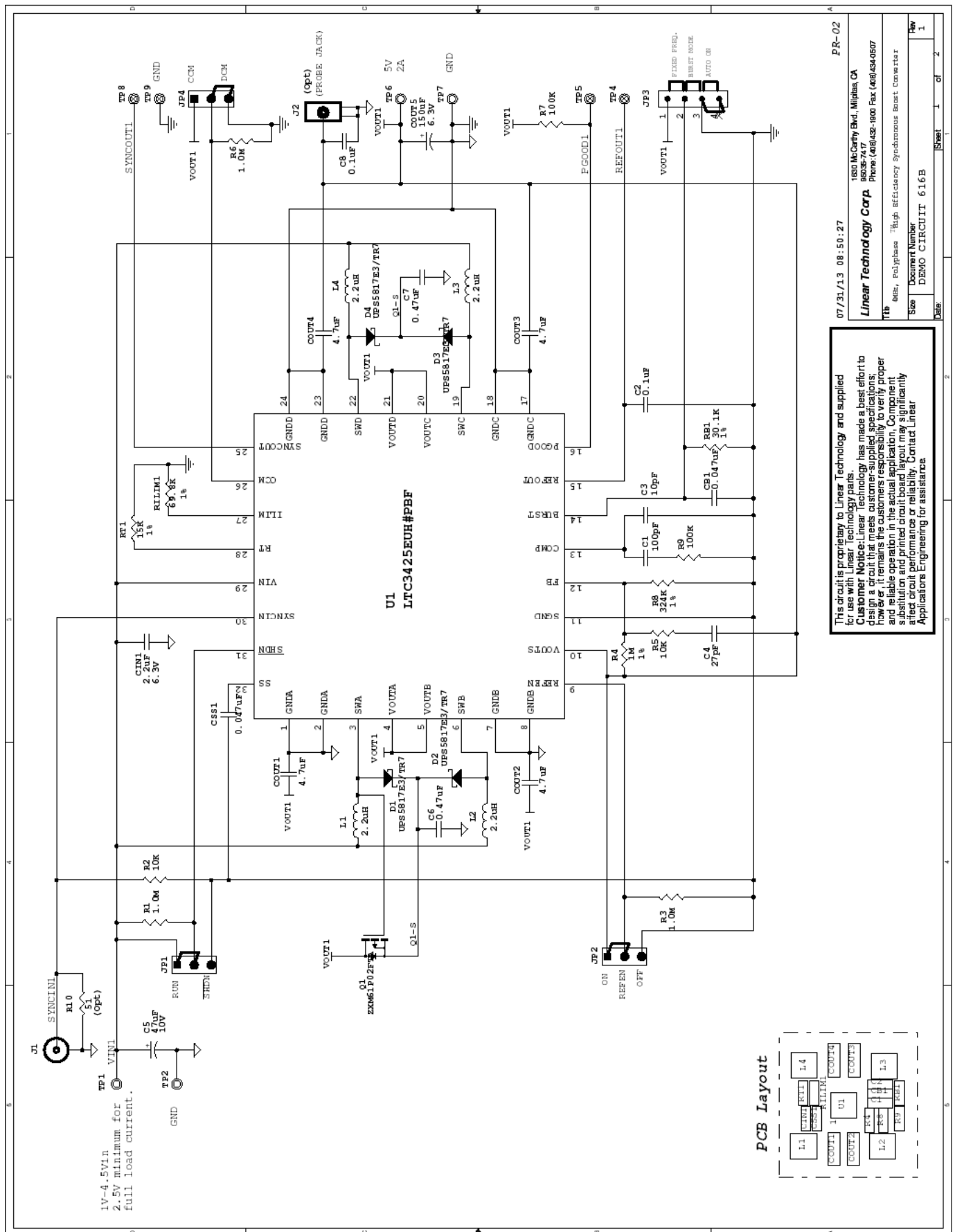
**Vin=1V to 3V**

**Vout=3.3V@1.8A**

| Item | Qty | Ref - Des               | Part Description                            | Manufacturer's Part Number        |
|------|-----|-------------------------|---------------------------------------------|-----------------------------------|
| 1    | 2   | CSS2,CB2                | Cap., X5R 0.047uF 16V 20%                   | AVX 0402YD473MAT2A                |
| 2    | 1   | CIN2                    | Cap., X5R 2.2uF 6.3V 10%                    | Taiyo Yuden JMK107BJ225KA-T       |
| 3    | 4   | COUT6,COUT7,COUT8,COUT9 | Cap., X5R 4.7uF 6.3V 20%                    | TAIYO YUDEN JMK212ABJ475MG-T      |
| 4    | 1   | COUT10                  | Cap, SP-CAP 220uF 4V .009 ohm, case size D2 | PANASONIC EEFSX0G221ER            |
| 5    | 2   | C17,C9                  | Cap., X5R 0.1uF 10V 10%                     | TDK C1005X5R1A104K                |
| 6    | 1   | C10                     | Cap., NPO 220pF 25V 10%                     | AVX 04023A221KAT2A                |
| 7    | 1   | C11                     | Cap., NPO 18pF 25V 10%                      | AVX 04023A180KAT2A                |
| 8    | 1   | C12                     | Cap., NPO 10pF 25V 10%                      | AVX 04023A100KAT2A                |
| 9    | 0   | C16,C14 (Opt)           | Cap., X5R 0.47uF 10V 10%                    | Taiyo Yuden LMK107BJ474KA-T       |
| 10   | 1   | C15                     | Cap., Tant. 47uF 10V 20%                    | AVX TAJB476M010RNJ                |
| 11   | 4   | D5,D6,D7,D8 (Opt)       | Schottky Diode, UPS5817                     | Microsemi UPS5817                 |
| 12   | 3   | JP5,JP6,JP7             | Headers, 3 Pins 2mm Ctrs.                   | SULLINS NRPN031PAEN-RC            |
| 13   | 1   | JP8                     | Headers, Commcon2802s04g2                   | SULLINS NRPN041PAEN-RC            |
| 14   | 1   | J3                      | BNC Connector                               | Connex 112404                     |
| 15   | 0   | J4 (Opt)                | Test Jacks, Shielded                        | Johnson Components 129-0701-201   |
| 16   | 4   | L5,L6,L7,L8             | Inductor, 2.2uH                             | muRata LQH32CN2R2M53              |
| 17   | 0   | Q2 (Opt)                | P-Channel, 20V                              | ZETEX ZXM61P02F                   |
| 18   | 1   | RB2                     | Res., Chip 30.1K 0.06W 1%                   | VISHAY CRCW040230K1FKED           |
| 19   | 1   | RILIM2                  | Res., Chip 80.6K 0.06W 1%                   | VISHAY CRCW040269K8FKED           |
| 20   | 1   | RT2                     | Res., Chip 15K 0.06W 1%                     | VISHAY CRCW040215K0FKED           |
| 21   | 1   | R11                     | Res., Chip 1M 1/16W 1%                      | VISHAY CRCW04021M00FKED           |
| 22   | 1   | R12                     | Res., Chip 200K 0.06W 5%                    | VISHAY CRCW0402200KJNED           |
| 23   | 1   | R13                     | Res., Chip 590K 0.06W 1%                    | VISHAY CRCW0402590KFKED           |
| 24   | 3   | R14,R15,R20             | Res., Chip 1.0M 1/16W 5%                    | VISHAY CRCW04021M00JNED           |
| 25   | 1   | R16                     | Res., Chip 100K 0.06W 5%                    | VISHAY CRCW0402100KJNED           |
| 26   | 2   | R21,R19                 | Res., Chip 10K 0.06W 5%                     | VISHAY CRCW040210K0JNED           |
| 27   | 0   | R22 (Opt)               | Res., Chip 51 0.06W 5%                      | VISHAY CRCW040251R0JNED           |
| 28   | 4   | TP10,TP13,TP14,TP15     | Turret, Testpoint                           | MILL-MAX 2501-2-00-80-00-00-07-0  |
| 29   | 4   | TP11,TP12,TP16,TP17     | Turret, Testpoint                           | MILL-MAX 2308-2-00-80-00-00-07-0  |
| 30   | 1   | U2                      | I.C., Polyphase Switching Reg.              | LINEAR TECH. CORP. LTC3425EUH#PBF |

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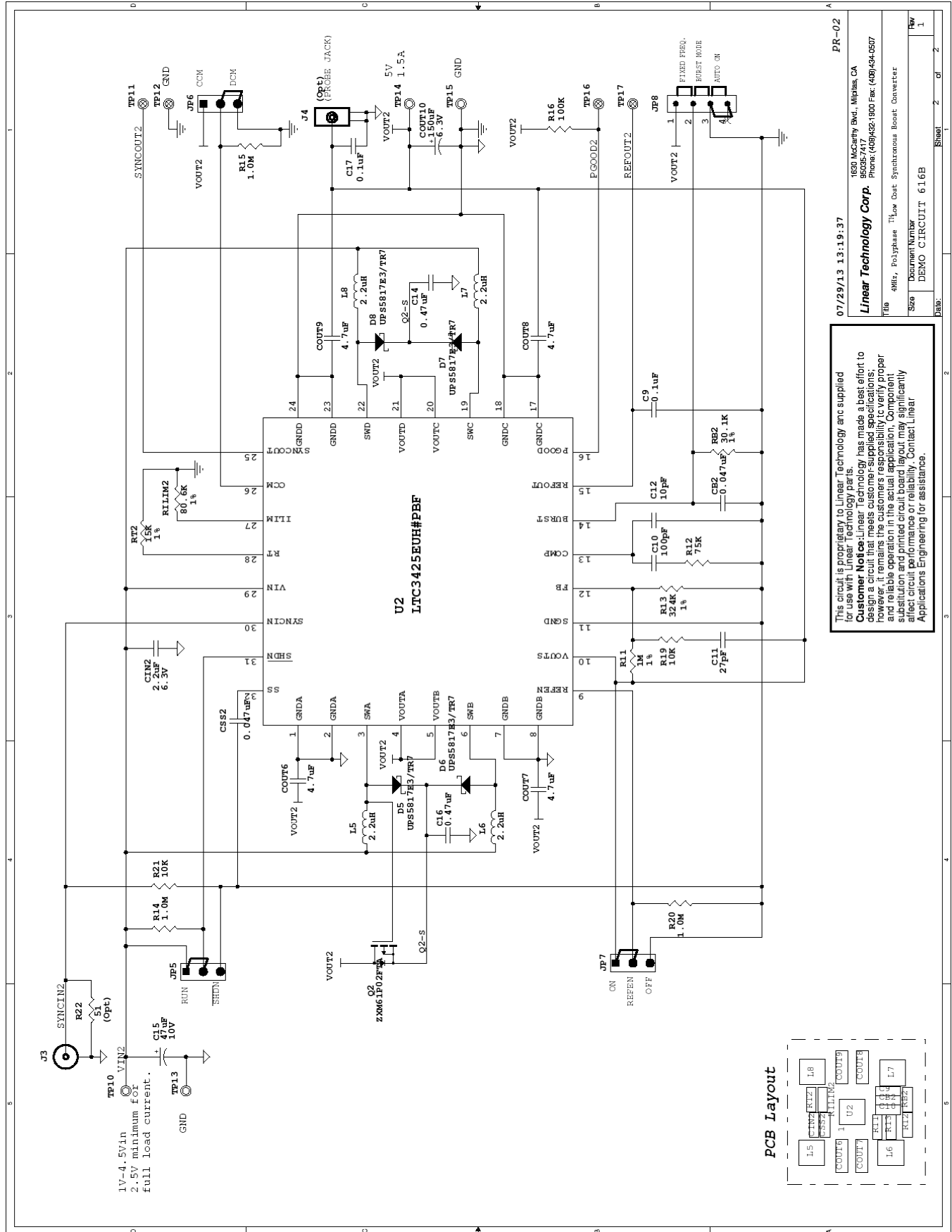
**V<sub>in</sub>=2.5V to 4.5V**

**V<sub>out</sub>=5V@2A**

| Item | Qty | Ref - Des               | Part Description               | Manufacture's Part Number         |
|------|-----|-------------------------|--------------------------------|-----------------------------------|
| 1    | 2   | CB1,CSS1                | Cap., X5R 0.047uF 16V 20%      | AVX 0402YD473MAT2A                |
| 2    | 1   | CIN1                    | Cap., X5R 2.2uF 6.3V 10%       | Taiyo Yuden JMK107BJ225KA-T       |
| 3    | 4   | COUT1,COUT2,COUT3,COUT4 | Cap., X5R 4.7uF 6.3V 20%       | TAIYO YUDEN JMK212ABJ475MG-T      |
| 4    | 1   | COUT5                   | Cap., POSCAP 150uF 6.3V 20%    | PANASONIC 6TPE150M                |
| 5    | 1   | C1                      | Cap., NPO 100pF 25V 10%        | AVX 04023A101KAT2A                |
| 6    | 2   | C8,C2                   | Cap., X5R 0.1uF 10V 10%        | TDK C1005X5R1A104K                |
| 7    | 1   | C3                      | Cap., NPO 10pF 25V 10%         | AVX 04023A100KAT2A                |
| 8    | 1   | C4                      | Cap., NPO 27pF 25V 10%         | AVX 04023A270KAT2A                |
| 9    | 1   | C5                      | Cap., Tant. 47uF 10V 20%       | AVX TAJB476M010RNJ                |
| 10   | 2   | C6,C7                   | Cap., X5R 0.47uF 10V 10%       | TAIYO YUDEN LMK107BJ474KA-T       |
| 11   | 4   | D1,D2,D3,D4             | Schottky Diode, UPS5817        | MICROSEMI. UPS5817E3/TR7          |
| 12   | 3   | JP1,JP2,JP4             | Headers, 3 Pins 2mm Ctrs.      | SULLINS NRPN031PAEN-RC            |
| 13   | 1   | JP3                     | Headers, 4 Pins 2mm Ctrs.      | SULLINS NRPN041PAEN-RC            |
| 14   | 1   | J1                      | BNC Connector                  | Connex 112404                     |
| 15   | 0   | J2 (Opt)                | Test Jacks, Shielded           | Johnson Components 129-0701-201   |
| 16   | 4   | L1,L2,L3,L4             | Inductor, 2.2uH                | COILCRAFT XAL5030-222MEC          |
| 17   | 1   | Q1                      | P-Channel, 20V                 | ZETEX ZXM61P02FTA                 |
| 18   | 1   | RB1                     | Res., Chip 30.1K 0.06W 1%      | VISHAY CRCW040230K1FKED           |
| 19   | 1   | RILIM1                  | Res., Chip 69.8K 0.06W 1%      | VISHAY CRCW040269K8FKED           |
| 20   | 1   | RT1                     | Res., Chip 15K 0.06W 1%        | VISHAY CRCW040215K0FKED           |
| 21   | 3   | R1,R3,R6                | Res., Chip 1.0M 1/16W 5%       | VISHAY CRCW04021M00JNED           |
| 22   | 2   | R5,R2                   | Res., Chip 10K 0.06W 5%        | VISHAY CRCW040210K0JNED           |
| 23   | 1   | R4                      | Res., Chip 1M 1/16W 1%         | VISHAY CRCW04021M00FKED           |
| 24   | 2   | R7,R9                   | Res., Chip 100K 0.06W 5%       | VISHAY CRCW0402100KJNED           |
| 25   | 1   | R8                      | Res., Chip 324K 1/16W 1%       | VISHAY CRCW0402324KFKED           |
| 26   | 0   | R10 (Opt)               | Res., Chip 51 0.06W 5%         | VISHAY CRCW040251R0JNED           |
| 27   | 4   | TP1,TP2,TP6,TP7         | Turret, Testpoint              | MILL-MAX 2501-2-00-80-00-00-07-0  |
| 28   | 4   | TP4,TP5,TP8,TP9         | Turret, Testpoint              | MILL-MAX 2308-2-00-80-00-00-07-0  |
| 29   | 1   | U1                      | I.C., Polyphase Switching Reg. | LINEAR TECH. CORP. LTC3425EUH#PBF |

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**Vin=2.5V to 4.5V**

**Vout=5V@1.5A**

| Item | Qty | Ref - Des               | Part Description                            | Manufacturer's Part Number        |
|------|-----|-------------------------|---------------------------------------------|-----------------------------------|
| 1    | 2   | CSS2,CB2                | Cap., X5R 0.047uF 16V 20%                   | AVX 0402YD473MAT2A                |
| 2    | 1   | CIN2                    | Cap., X5R 2.2uF 6.3V 10%                    | Taiyo Yuden JMK107BJ225KA-T       |
| 3    | 4   | COUT6,COUT7,COUT8,COUT9 | Cap., X5R 4.7uF 6.3V 20%                    | TAIYO YUDEN JMK212ABJ475MG-T      |
| 4    | 1   | COUT10                  | Cap, SP-CAP 220uF 4V .009 ohm, case size D2 | PANASONIC EEF5X0G221ER            |
| 5    | 2   | C17,C9                  | Cap., X5R 0.1uF 10V 10%                     | TDK C1005X5R1A104K                |
| 6    | 1   | C10                     | Cap., NPO 220pF 25V 10%                     | AVX 04023A221KAT2A                |
| 7    | 1   | C11                     | Cap., NPO 18pF 25V 10%                      | AVX 04023A180KAT2A                |
| 8    | 1   | C12                     | Cap., NPO 10pF 25V 10%                      | AVX 04023A100KAT2A                |
| 9    | 0   | C16,C14 (Opt)           | Cap., X5R 0.47uF 10V 10%                    | Taiyo Yuden LMK107BJ474KA-T       |
| 10   | 1   | C15                     | Cap., Tant. 47uF 10V 20%                    | AVX TAJB476M010RNJ                |
| 11   | 4   | D5,D6,D7,D8 (Opt)       | Schottky Diode, UPS5817                     | Microsemi UPS5817                 |
| 12   | 3   | JP5,JP6,JP7             | Headers, 3 Pins 2mm Ctrs.                   | SULLINS NRPN031PAEN-RC            |
| 13   | 1   | JP8                     | Headers, Commcon2802s04g2                   | SULLINS NRPN041PAEN-RC            |
| 14   | 1   | J3                      | BNC Connector                               | Connex 112404                     |
| 15   | 0   | J4 (Opt)                | Test Jacks, Shielded                        | Johnson Components 129-0701-201   |
| 16   | 4   | L5,L6,L7,L8             | Inductor, 2.2uH                             | muRata LQH32CN2R2M53              |
| 17   | 0   | Q2 (Opt)                | P-Channel, 20V                              | ZETEX ZXM61P02F                   |
| 18   | 1   | RB2                     | Res., Chip 30.1K 0.06W 1%                   | VISHAY CRCW040230K1FKED           |
| 19   | 1   | R1LIM2                  | Res., Chip 80.6K 0.06W 1%                   | VISHAY CRCW040269K8FKED           |
| 20   | 1   | RT2                     | Res., Chip 15K 0.06W 1%                     | VISHAY CRCW040215K0FKED           |
| 21   | 1   | R11                     | Res., Chip 1M 1/16W 1%                      | VISHAY CRCW04021M00FKED           |
| 22   | 1   | R12                     | Res., Chip 200K 0.06W 5%                    | VISHAY CRCW0402200KJNED           |
| 23   | 1   | R13                     | Res., Chip 590K 0.06W 1%                    | VISHAY CRCW0402590KFKED           |
| 24   | 3   | R14,R15,R20             | Res., Chip 1.0M 1/16W 5%                    | VISHAY CRCW04021M00JNED           |
| 25   | 1   | R16                     | Res., Chip 100K 0.06W 5%                    | VISHAY CRCW0402100KJNED           |
| 26   | 2   | R21,R19                 | Res., Chip 10K 0.06W 5%                     | VISHAY CRCW040210K0JNED           |
| 27   | 0   | R22 (Opt)               | Res., Chip 51 0.06W 5%                      | VISHAY CRCW040251R0JNED           |
| 28   | 4   | TP10,TP13,TP14,TP15     | Turret, Testpoint                           | MILL-MAX 2501-2-00-80-00-00-07-0  |
| 29   | 4   | TP11,TP12,TP16,TP17     | Turret, Testpoint                           | MILL-MAX 2308-2-00-80-00-00-07-0  |
| 30   | 1   | U2                      | I.C., Polyphase Switching Reg.              | LINEAR TECH. CORP. LTC3425EUH#PBF |