

## Description

The ZL2006 is an integrated mixed-signal power conversion and management IC that combines an efficient step-down DC-DC converter with key power and thermal management functions in a single package. The ZL2006 incorporates current sharing and adaptive efficiency-optimization algorithms to provide a flexible, efficient power IC building block.

The ZL2006EV1 platform is a 4-layer board demonstrating a 15A synchronous buck converter. Sequencing, tracking, margining, plus other features can be evaluated using this board.

A USB to SMBus adapter board can be used to connect the eval board to a PC. The PMBus command set is accessed by using the Zilker Labs PowerNavigator™ evaluation software from a PC running Microsoft Windows.

## Features

- 15A synchronous buck converter
- Optimized for small circuit footprint and dynamic response
- Configurable through SMBus
- Onboard enable switch
- Power good indicator

## Target Specifications

- $V_{IN} = 12\text{ V}$
- $V_{OUT} = 1.2\text{ V} / 15\text{ A}$  (20 A max)
- $f_{sw} = 615\text{ kHz}$
- Efficiency: 86% at 10 A
- Output ripple:  $\pm 1\%$
- Dynamic response:  $\pm 2.5\%$   
(50%-100%-50% load step,  $di/dt = 2.5\text{ A}/\mu\text{s}$ )
- Board temperature:  $25^\circ\text{C}$

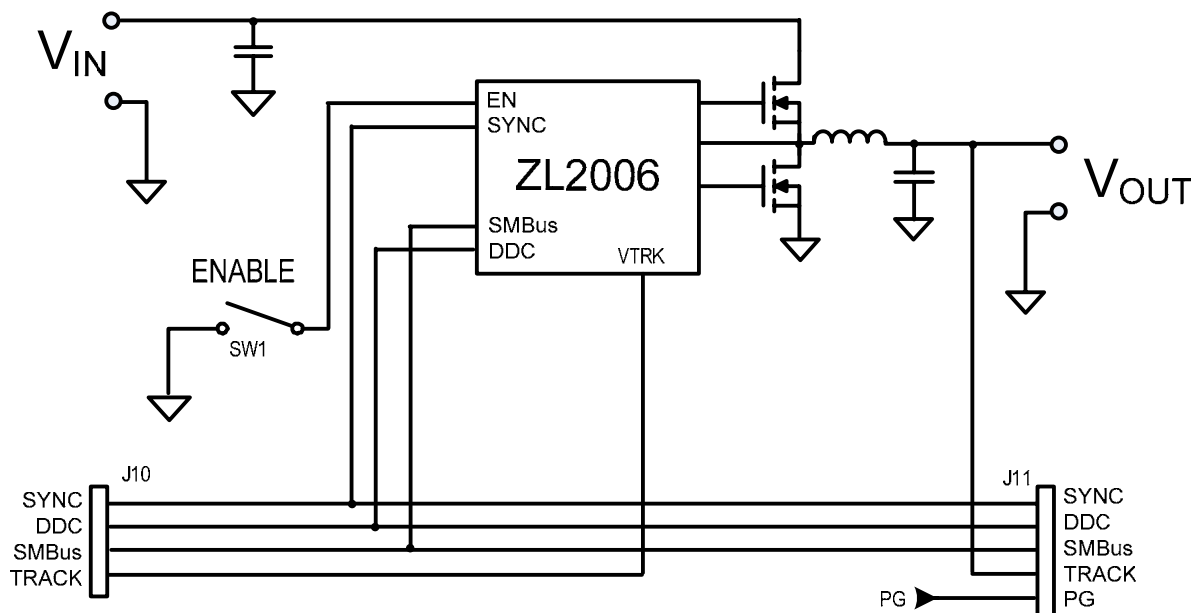


Figure 1. ZL2006EV1 Block Diagram

## Functional Description

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The ZL2006EV1 provides all circuitry required to demonstrate the features of the ZL2006. The ZL2006EV1 has a functionally-optimized ZL2006 circuit layout that allows efficient operation up to the maximum output current. Power and load connections are provided through plug-in sockets.

A majority of the features of the ZL2006 such as soft-start delay and ramp times, supply sequencing, voltage tracking, and voltage margining are available on this evaluation board. For voltage tracking and sequencing evaluation, the board can be connected to any other Zilker Labs evaluation board that supports the Digital DC (DDC) bus.

Figure 1 shows a functional block diagram of the ZL2006EV1 board. The SMBus address is selectable through a jumper on the top side of the board. All power to the board (VIN and I<sup>2</sup>C bus) must be removed before changing the jumpers.

The hardware enable function is controlled by a toggle switch on the ZL2006EV1 board. The power good (PG) LEDs indicate the correct state of PG when external power is applied to the ZL2006EV1 board. The right angle headers at opposite ends of the board are for connecting a USB to SMBus adapter board or for daisy chaining of multiple evaluation boards.

Figure 2 shows the operational circuit. The circuit consists of the ZL2006 IC with its minimal component count to realize a 15 A buck converter. The board layout has been optimized for thermal performance.

Figure 3 is the board interface circuitry. Figure 4 through Figure 8 show the PCB layout for the board including the board fabrication notes.

The bill of materials (BOM) and configuration file are also included for reference.

## Operation

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### PMBus Operation

The ZL2006 utilizes the PMBus protocol. The PMBus functionality can be controlled via USB from a PC running the PowerNavigator evaluation software in a Windows XP or Windows 2000/NT operating system.

Install the evaluation software using the CD included in the ZL2006EV1 kit.

For board operation, connect the included USB-to-SMBus adapter board to J10 of the ZL2006EV1 board. Connect the desired load and an appropriate power supply to the input and connect the included USB cable to the PC running the PowerNavigator evaluation software. Place the ENABLE switch in “DISABLE” and turn on the power.

The evaluation software allows modification of all ZL2006 PMBus parameters. The ZL2006 device on the board has been pre-configured as described in this document, but the user may modify the operating parameters through the eval software or by loading a predefined scenario from a configuration file.

Use the mouse-over pop-ups for PowerNavigator help. Refer to Zilker Labs application note AN33 [2] for PMBus details.

The ENABLE switch can then be moved to “ENABLE” and the ZL2006EV1 board can be tested. Alternately, the PMBus ON-OFF CONFIG and OPERATION commands may be used.

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**Quick Start Guide**

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**Stand Alone Operation**

1. Set ENABLE switch to “DISABLE”
2. Apply load to VOUT+/VOUT-
3. Connect the USB to SMBus adapter board to J10 of ZL2006EV1
4. Connect supplied USB cable from computer to USB to SMBus adapter board
5. Connect power supply to VIN+/VIN- (supply turned off)
6. Turn power supply on
7. Set ENABLE switch to “ENABLE”
8. Monitor ZL2006EV1 board operation using an oscilloscope

**USB (PMBus) Operation**

1. Set ENABLE switch to “DISABLE”
2. Apply load to VOUT+/VOUT-
3. Connect power supply to VIN+/VIN- (supply turned off)
4. Turn power supply on
5. Insert the Zilker Labs Eval Kit CD
6. Connect USB to SMBus adapter board to J10 of ZL2006EV1
7. Connect supplied USB cable from computer to USB to SMBus adapter board
  - a. Upon first-time connection, the Found New Hardware Wizard will appear.
  - b. Windows XP users: Select ‘No’ at prompt to search the Internet for drivers.
  - c. Follow the steps on the screen to install the drivers from the CD.
8. Install the PowerNavigator evaluation software by running setup.exe from the PowerNavigator\_installer folder on the CD.
9. Set ENABLE switch on EVB to “ENABLE”
10. Monitor and configure the ZL2006EV1 board using PMBus commands in the evaluation software
11. Test the ZL2006EV1 operation using an oscilloscope and the evaluation software.

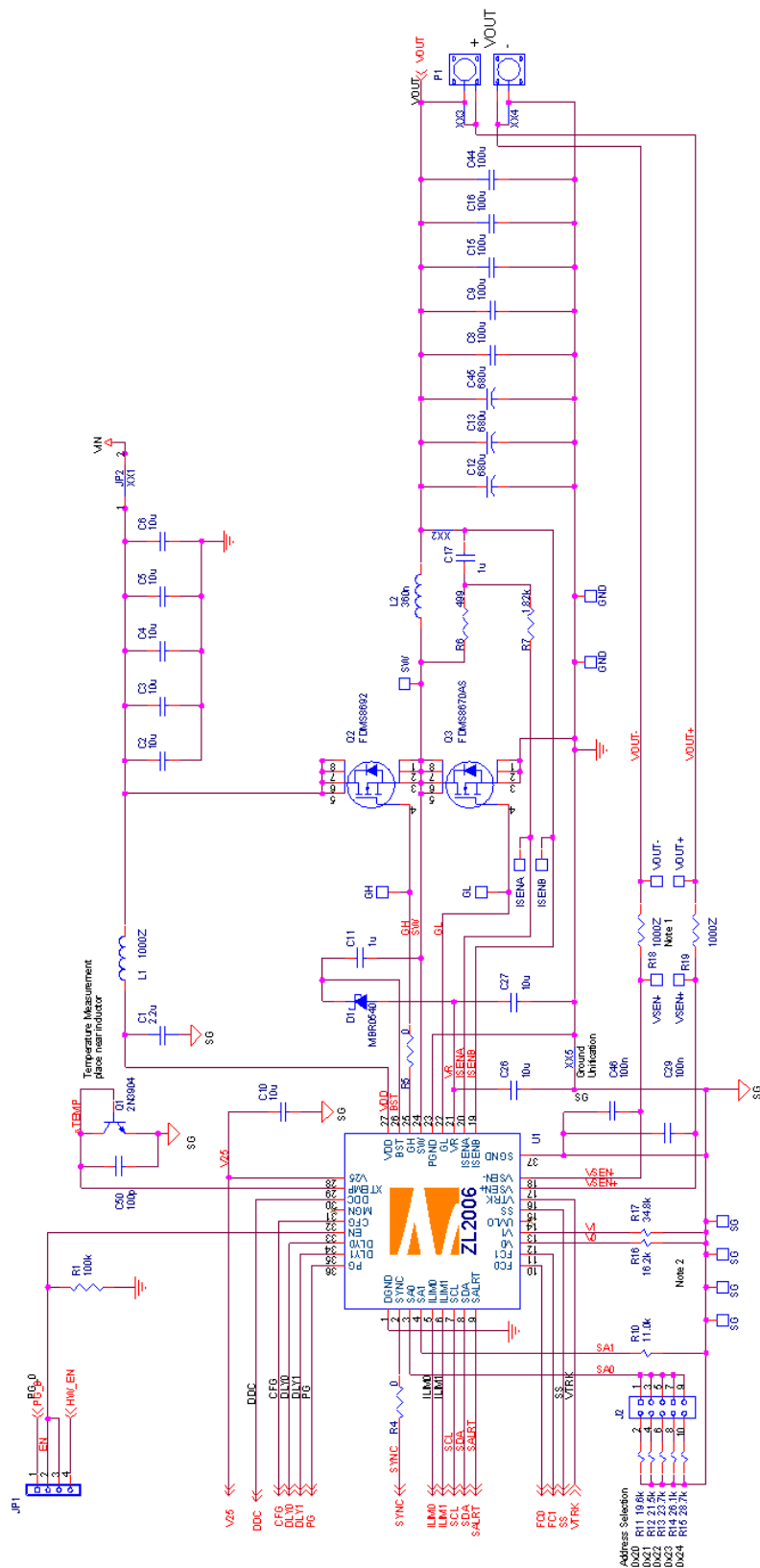
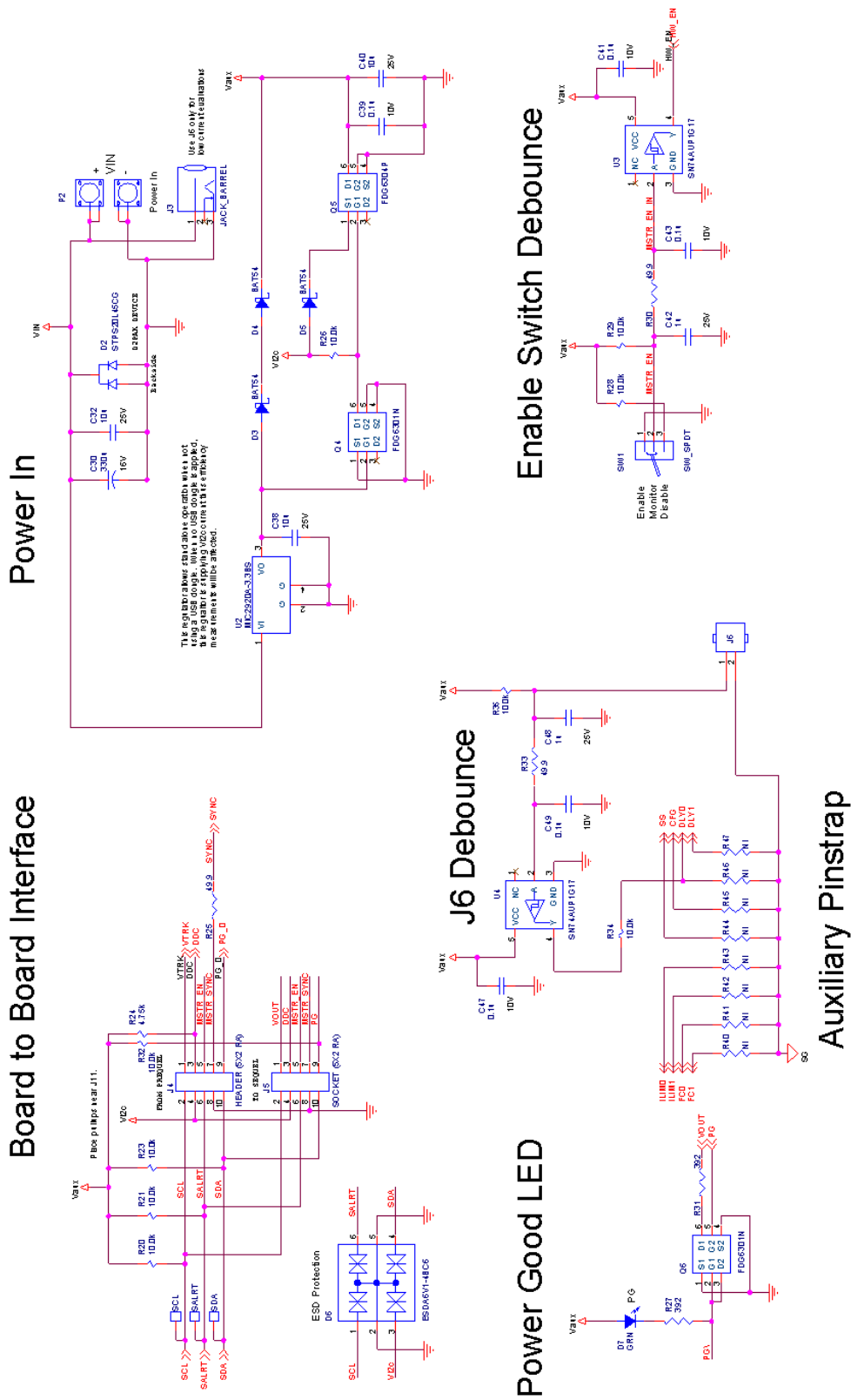


Figure 2. ZL2006EV1 Operational Circuit



### Figure 3. ZL2006EV1 Interface Circuitry

## Board Layout – 4 Layers

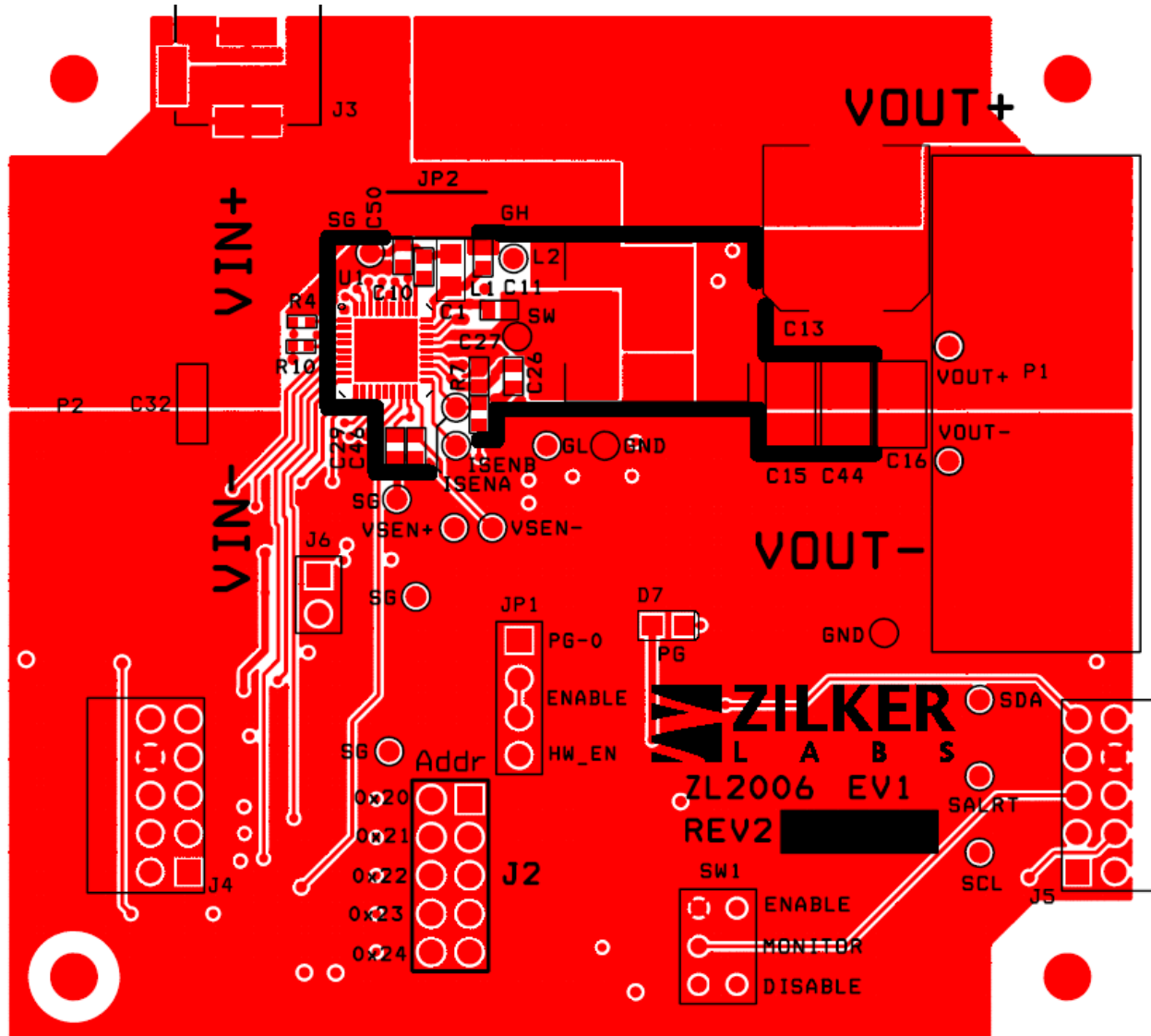


Figure 4. PCB – Top Layer

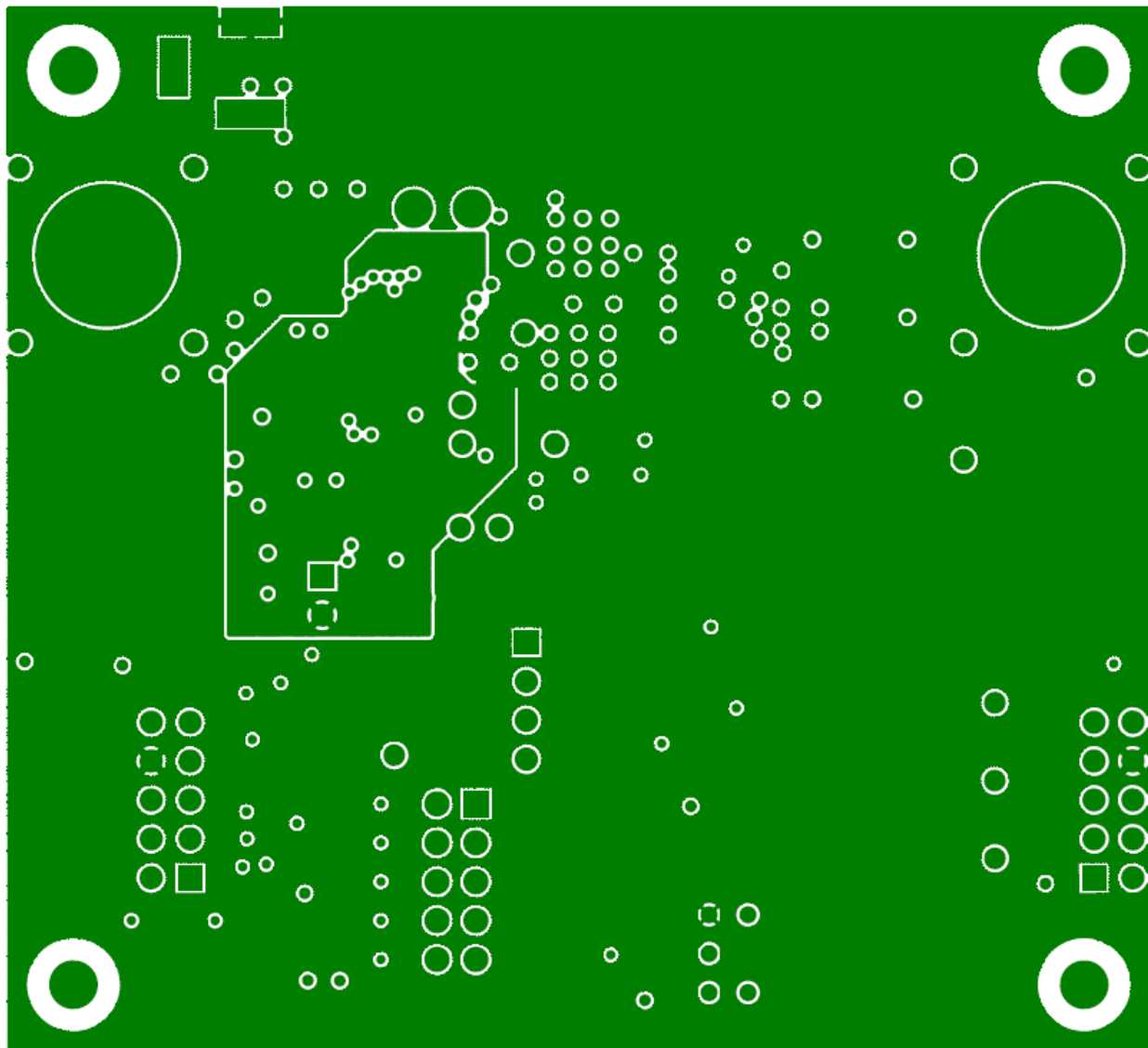


Figure 5. PCB – Inner Layer 1 (Viewed from Top)

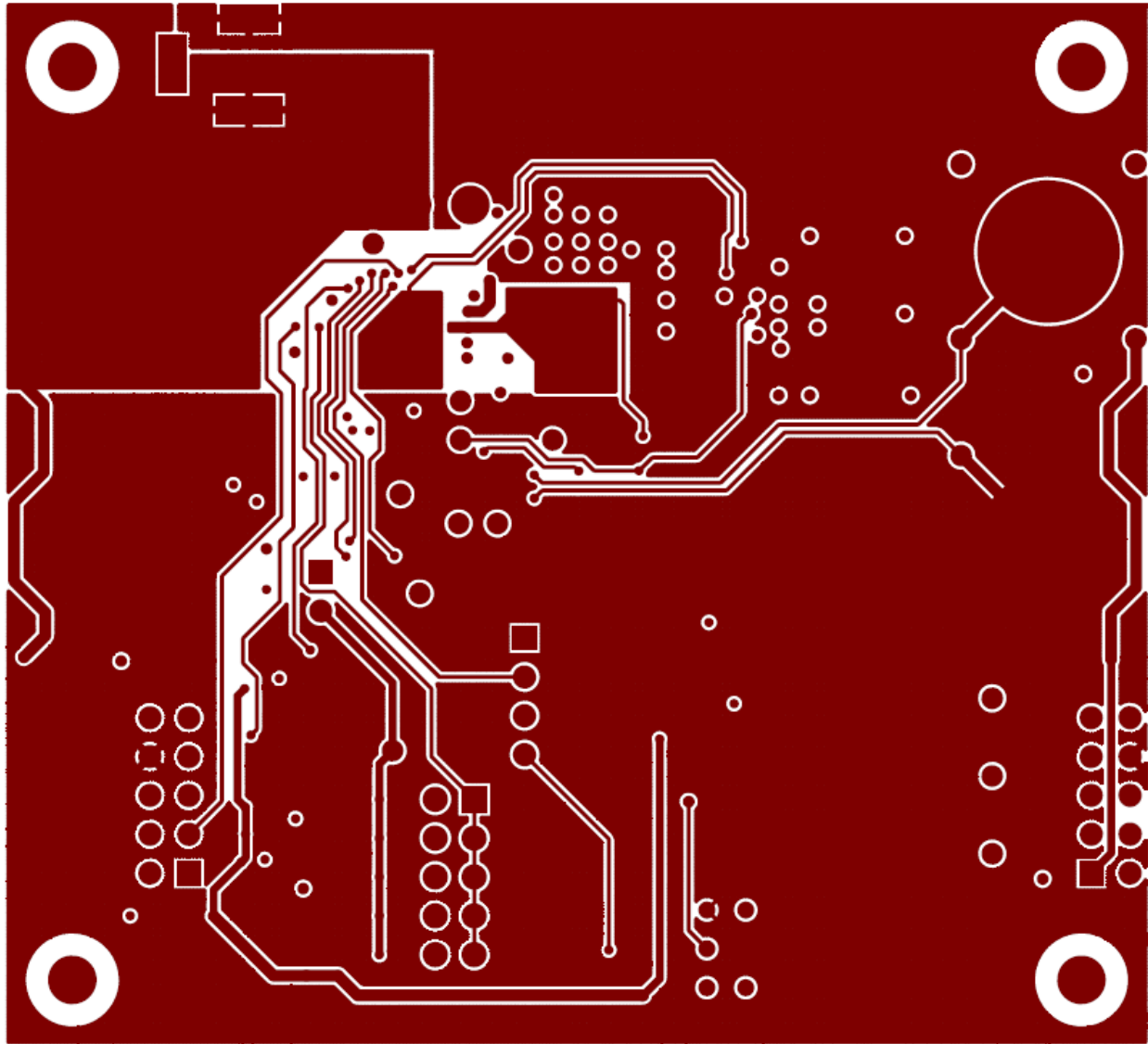


Figure 6. PCB – Inner Layer 2 (Viewed from Top)

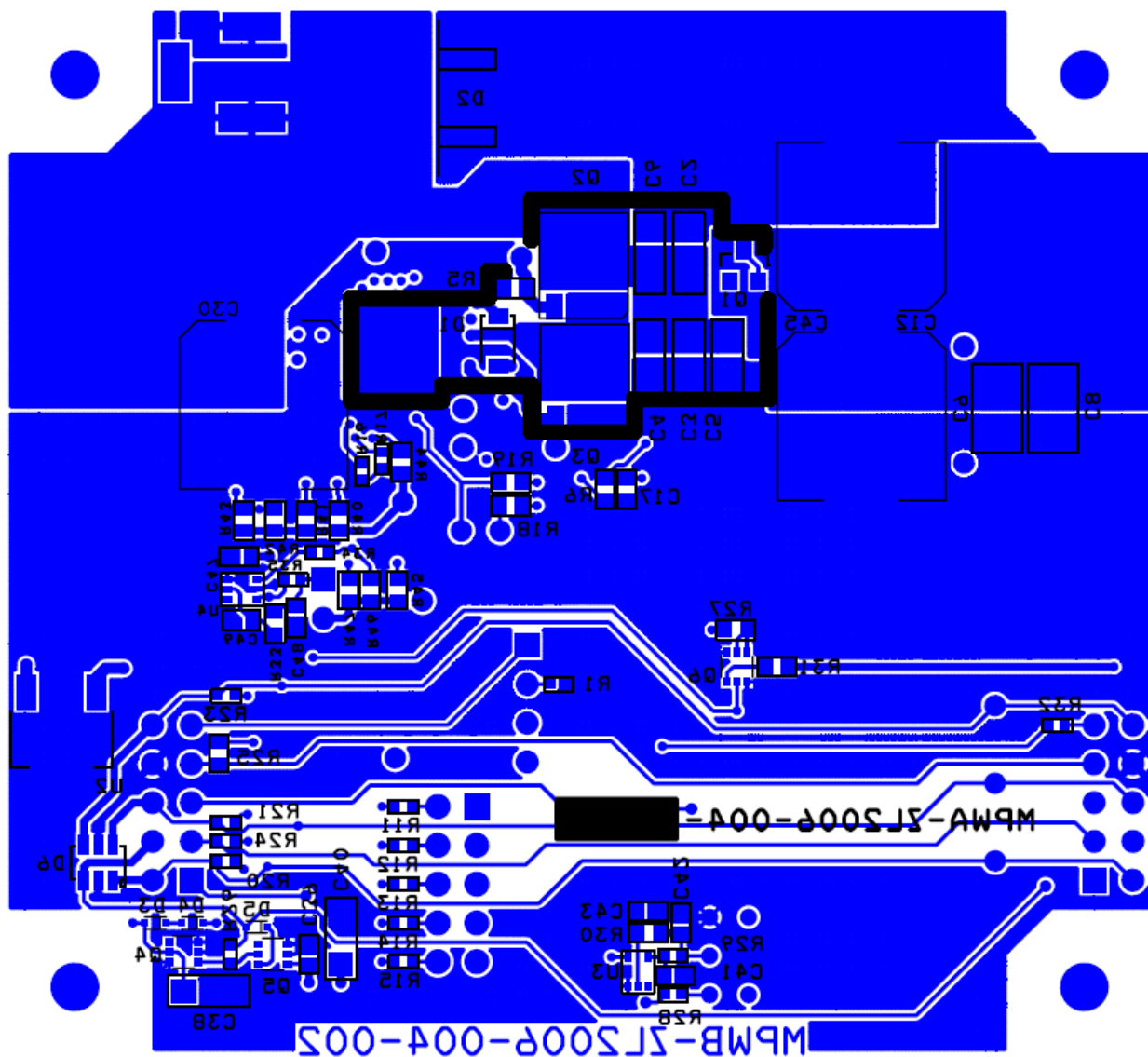


Figure 7. PCB – Bottom Layer (Viewed from Top)

NOTES UNLESS OTHERWISE SPECIFIED:

1. FABRICATE USING ARTWORK AND DRILL FILES PER TABLE BELOW.
2. FINISHED BOARDS MUST CONFORM TO ZILKER LABS QUALITY PROCEDURE SQAS-002-PCBREQ.
3. MATERIAL: NEMA GRADE FR-4; MINIMUM UL FLAMMABILITY RATING 94 V-0  
BOARD LAYER SPACING  
SPACING BETWEEN 1-2 = .013 TO .017  
SPACING BETWEEN 3-4 = .013 TO .017  
TOTAL BOARD THICKNESS = .062
4. COPPER THICKNESS SHALL BE 1 OZ. INNER LAYERS, 1 OZ. PLATED TO 2 OZ. OUTER LAYERS.
5. REFERENCE POINT 0,0 FOR DRILL FILE LISTING.
6. ALL HOLES PLATED THROUGH (UNLESS OTHERWISE NOTED). PLATING IN HOLES PER ZILKER LABS QUALITY PROCEDURE SQAS-002-PCBREQ.
7. BOARD COATING SHALL BE SOLDERMASK OVER BARE COPPER, HOT AIR SOLDER LEVELING.
8. SOLDERMASK PER ZILKER LABS QUALITY PROCEDURE SQAS-002-PCBREQ.
9. VENDOR IDENTIFICATION, UL COMPLIANCE AND DATE CODE TO BE PERMANENTLY AFFIXED AND LOCATED AS SHOWN, ON BOTTOM TRACE LAYER.
10. ELECTRICAL TEST MARK, ON BOTTOM TRACE LAYER, PER ZILKER LABS QUALITY PROCEDURE SQAS-002-PCBREQ.
11. FIDUCIALS TOP AND BOTTOM THESE LOCATIONS.
12. WARNING: THE MANUFACTURING PROCESSES AND THE MATERIALS ASSOCIATED WITH THIS PART MAY REQUIRE SPECIAL SAFETY PRECAUTIONS.

**Figure 8. Board Fabrication Notes**

## Bill of Materials

| ITEM           | QTY | REFDES                                   | VALUE           | TOL        | RATING   | TYPE      | PCB FOOTPRINT   | MFR               | MFR PN              |
|----------------|-----|------------------------------------------|-----------------|------------|----------|-----------|-----------------|-------------------|---------------------|
| 1              | 1   | C1                                       | 2.2u            | 10%        | 16V      | X5R       | SM0805          | MURATA            | GRM21BR61C225KA88L  |
| 2              | 3   | C2,C3,C4                                 | 10u             | 10%        | 25V      | X5R       | SM1206          | PANASONIC-ECG     | ECJ-3YB1E106K       |
| 4              | 5   | C8,C9,C15,<br>C16,C44                    | 100u            | 20%        | 6.3V     | X5R       | SM1210          | TAIYO YUDEN       | JMK325BJ107MY-T     |
| 5              | 3   | C10,C26,C27                              | 10u             | 20%        | 6.3V     | X5R       | SM0603          | PANASONIC-ECG     | ECJ-1VB0J106M       |
| 6              | 3   | C11,C17,C42                              | 1u              | 10%        | 25V      | X5R       | SM0603          | TAIYO YUDEN       | TMK107BJ105KA-T     |
| 7              | 2   | C12,C13                                  | 680u            | 20%        | 6.3V     | AL POLY   | SM10P5X10P5     | UNITED CHEMI-CON  | APXA6R3ARA681MJC0G  |
| 8              | 2   | C29,C46                                  | 100n            | 10%        | 25V      | X7R       | SM0603          | PANASONIC ECG     | ECJ-1VB1E104K       |
| 9              | 1   | C30                                      | 330u            | 20%        | 16V      | AL POLY   | 10.3X10.3_PXA   | UNITED CHEMI-CON  | APXA160ARA331MJC0G  |
| 10             | 3   | C32,C38,C40                              | 10u             | 10%        | 25V      | X7R       | SM1206          | PANASONIC-ECG     | ECJ-13YB1E106K      |
| 11             | 3   | C39,C41,C43                              | 0.1u            | 10%        | 10V      | X7R       | SM0603          | KEMET             | C0603C104K8RACTU    |
| 15             | 1   | C50                                      | 100p            | 5%         | 100V     | NPO       | SM0603          | PANASONIC ECG     | ECJ1VC2A101J        |
| 16             | 1   | D1                                       | MBR0540         |            | 40V      | SCHOTTKY  | SOD123          | ON SEMI           | MBR0540T1           |
| 17             | 1   | D2                                       | STPS20L45CG     |            | 45V-20A  | SCHOTTKY  | D-2PAK          | ST MICRO          | STPS20L45CG         |
| 18             | 3   | D3,D4,D5                                 | BAT54           |            | 30V      | SCHOTTKY  | SOD523          | ON SEMI           | BAT54XV2T10S        |
| 19             | 1   | D6                                       | ESDA6V1-4BC6    |            | 6.1V,80W |           | SOT23_6L        | ST MICRO          | ESDA6V1-4BC6        |
| 20             | 1   | D7                                       | GRN             |            | 2V       | VERT      | SM0805          | CHICAGO MINIATURE | CMD17-21VGC         |
| 21             | 1   | JP1                                      | 4 PIN           |            |          |           | SIP4/100        | TYCO/AMP          | 3-644456-4          |
| 23             | 1   | J2                                       | HEADER 5x2 PIN  |            |          | VERT      | 100X100         | SAMTEC            | TSW-105-07-T-D      |
| 24             | 1   | J3                                       | JACK_BARREL     | 1.5A@18VDC |          | RA        | RA.079PIN       | KOBICONN          | 163-5004-E          |
| 25             | 1   | J4                                       | HEADER (5X2 RA) |            |          | RA        | 100X100         | SAMTEC            | TSW-105-08-T-D-RA   |
| 26             | 1   | J5                                       | SOCKET (5X2 RA) |            |          | RA        | 100X100         | SAMTEC            | SSQ-105-02-T-D-RA   |
| 28             | 3   | L1,R18,R19                               | 1000Z           |            | 50mA     | FERRITE   | SM0603          | MURATA            | BLM18HD102SN1D      |
| 29             | 1   | L2                                       | 360n            | 20%        | 35A      | POWDER    | IHL_P_4040DZ_05 | VISHAY            | IHL_P4040DZERR36M61 |
| 30             | 2   | P1,P2                                    | JACK_BANANA     |            | 15A      |           | .175PLUG/TSTPTS | EMERSON           | 108-0740-001        |
| 31             | 1   | Q1                                       | 2N3904          |            | 40V      | NPN       | SOT-23          | ON SEMI           | MMBT3904LT3G        |
| 32             | 1   | Q2                                       | FDMS8692        |            | 30V      | N-CH      | SO8FL_ALLP      | FAIRCHILD         | FDMS8692            |
| 33             | 1   | Q3                                       | FDMS8670AS      |            | 30V      | N-CH      | SO8FL_ALLP      | FAIRCHILD         | FDMS8670AS          |
| 34             | 2   | Q4,Q6                                    | FDG6301N        |            | 25V      | DUAL N-CH | SC70_6          | FAIRCHILD         | FDG6301N            |
| 35             | 1   | Q5                                       | FDG6304P        |            | 25V      | DUAL P-CH | SC70_6          | FAIRCHILD         | FDG6304P            |
| 36             | 1   | R1                                       | 100k            | 1%         | 63mW     | THK FILM  | SM0402          | VISHAY            | CRCW0402100KFED     |
| 37             | 1   | R4                                       | 0               | 5%         | 63mW     | THK FILM  | SM0402          | ROHM              | MCR01MZPJ000        |
| 38             | 1   | R5                                       | 0               | 5%         | 100mW    | THK FILM  | SM0603          | YAGEO             | RC0603JR-070RL      |
| 39             | 1   | R6                                       | 499             | 1%         | 100mW    | THK FILM  | SM0603          | PANASONIC-ECG     | ERJ-3EKF4990V       |
| 40             | 1   | R7                                       | 1.82k           | 1%         | 100mW    | THK FILM  | SM0603          | PANASONIC-ECG     | ERJ-3EKF1821V       |
| 41             | 1   | R10                                      | 11.0k           | 1%         | 63mW     | THK FILM  | SM0402          | VISHAY            | CRCW040211K0FKED    |
| 42             | 1   | R11                                      | 19.6k           | 1%         | 63mW     | THK FILM  | SM0402          | VISHAY            | CRCW040219K6FKED    |
| 43             | 1   | R12                                      | 21.5k           | 1%         | 63mW     | THK FILM  | SM0402          | VISHAY            | CRCW040221K5FKED    |
| 44             | 1   | R13                                      | 23.7k           | 1%         | 63mW     | THK FILM  | SM0402          | VISHAY            | CRCW040223K7FKED    |
| 45             | 1   | R14                                      | 26.1k           | 1%         | 63mW     | THK FILM  | SM0402          | VISHAY            | CRCW040226K1FKED    |
| 46             | 1   | R15                                      | 28.7k           | 1%         | 63mW     | THK FILM  | SM0402          | VISHAY            | CRCW040228K7FKED    |
| 47             | 1   | R16                                      | 16.2k           | 1%         | 63mW     | THK FILM  | SM0402          | PANASONIC-ECG     | ERJ-2RKF1622X       |
| 48             | 1   | R17                                      | 34.8k           | 1%         | 63mW     | THK FILM  | SM0402          | PANASONIC-ECG     | ERJ-2RKF3482X       |
| 49             | 7   | R20,R21,R23,<br>R26,R28,R29<br>R32       | 10.0k           | 1%         | 63mW     | THK FILM  | SM0402          | YAGEO             | RC0402FR-0710KL     |
| 50             | 1   | R24                                      | 4.75k           | 1%         | 63mW     | THK FILM  | SM0402          | PANASONIC-ECG     | ERJ-2RKF4751X       |
| 51             | 2   | R25,R30                                  | 49.9            | 1%         | 100mW    | THK FILM  | SM0603          | ROHM              | MCR03EZPFX49R9      |
| 52             | 2   | R27,R31                                  | 392             | 1%         | 100mW    | THK FILM  | SM0603          | PANASONIC-ECG     | ERJ-3EKF3920V       |
| 58             | 1   | SW1                                      | SW_SPDT         |            |          | PCB VERT  | ULTRAMIN        | NKK               | G13AP-RO            |
| 73             | 1   | U1                                       | ZL2006          |            |          |           | MLF36_6X6BX     | ZILKER LABS, INC. | ZL2006ALNFT         |
| 74             | 1   | U2                                       | MIC2920A-3.3BS  |            |          |           | SOT223          | MICREL            | MIC2920A-3.3WS      |
| 75             | 1   | U3                                       | SN74AUP1G17     |            |          | TTL       | SC70_5          | TI                | SN74AUP1G17DCKR     |
| 78             | 2   | XX6,XX9<br>XX7,XX10,XX12,<br>XX14        | SHUNT_HDR       |            |          |           | SHUNT_HDR       | TYCO              | 881545-2            |
| 79             | 4   | XX14                                     | STANDOFF        |            |          |           | 4-40            |                   |                     |
| 80             | 4   | XX8,XX11,XX13,<br>XX15<br>XX16,XX17,XX18 | SCREW           |            |          | PHL       | 4-40            | BUILDING FASTENER | PM5 440 0025 PH     |
| 81             | 4   |                                          | CAP_MOLDED      |            |          |           | 0.25ID          | CAPLUGS           | VC-234-8            |
| 82             | 1   | XX20                                     | PCB             |            |          | FR-4      | 2.75HX2.188L    | ZILKER LABS INC   | MPWB-ZL2006-004     |
| NOT INSTALLED: |     |                                          |                 |            |          |           |                 |                   |                     |
| 3              | 2   | C5,C6                                    | 10u             | 10%        | 25V      | X5R       | SM1206          | PANASONIC-ECG     | ECJ-3YB1E106K       |
| 12             | 1   | C45                                      | 680u            | 20%        | 6.3V     | AL POLY   | SM10P5X10P5     | UNITED CHEMI-CON  | APXA6R3ARA681MJC0G  |
| 13             | 2   | C47,C49                                  | 0.1u            | 10%        | 10V      | X7R       | SM0603          | KEMET             | C0603C104K8RACTU    |
| 14             | 1   | C48                                      | 1u              | 10%        | 25V      | X5R       | SM0603          | TAIYO YUDEN       | TMK107BJ105KA-T     |
| 22             | 1   | JP2                                      | JUMPER          |            |          |           | 18AWGX.150LS    |                   |                     |
| 27             | 1   | J6                                       | 2 POS           |            |          | VERT      | SIP2/100        | SAMTEC            | TSW-102-07-L-S      |
| 53             | 1   | R33                                      | 49.9            | 1%         | 100mW    | THK FILM  | SM0603          | ROHM              | MCR03EZPFX49R9      |
| 54             | 2   | R34,R35                                  | 10.0k           | 1%         | 63mW     | THK FILM  | SM0402          | YAGEO             | RC0402FR-0710KL     |
| 55             | 1   | R40                                      | NI              | 1%         | 100mW    | THK FILM  | SM0603          | PANASONIC-ECG     |                     |
| 56             | 6   | R41,R43,R44,<br>R45,R46,R47              | NI              | 1%         | 100mW    | THK FILM  | SM0603          | PANASONIC-ECG     |                     |
| 57             | 1   | R42                                      | NI              | 1%         | 100mW    | THK FILM  | SM0603          | PANASONIC-ECG     |                     |
| 76             | 1   | U4                                       | SN74AUP1G17     |            |          | TTL       | SC70_5          | TI                | SN74AUP1G17DCKR     |
| 77             | 5   | XX1,XX2,XX3,<br>XX4,XX5                  | TIEPT/10WIDE    |            |          |           | TIEPT/10WIDE    |                   |                     |

## Default Configuration Text

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The following text is loaded into the ZL2006 device on the EV1 as default settings. Each PMBus command is loaded via the PowerNavigator software. The # symbol is used for a comment line.

#NOTE: This file is intended for the Rev. 2 ZL2006-EV1

#with L=360nH, Co=5x(100uF/2.0mohm)+(2x680uF/10mohm)

#Erase user store & default store

RESTORE\_FACTORY

STORE\_USER\_ALL

STORE\_DEFAULT\_ALL

#Prepare device for all commands to be added to the DEFAULT store

RESTORE\_DEFAULT\_ALL

#Manufacturer information fields in ASCII:

MFR\_ID Zilker Labs

MFR\_MODEL ZL2006EV1

MFR\_LOCATION Austin

MFR\_REVISION Rev 4.2

#Output Voltage commands

VOUT\_COMMAND 1.200000 #V

OVUV\_CONFIG 0x01 #2 counts

#Output current

IOUT\_CAL\_GAIN 0.920000 #mohms

IOUT\_CAL\_OFFSET 1.4 #A

IOUT\_OC\_FAULT\_LIMIT 30.000000 #A

IOUT\_AVG\_OC\_FAULT\_LIMIT 24.000000 #A

IOUT\_UC\_FAULT\_LIMIT -15.000000 #A

IOUT\_AVG\_UC\_FAULT\_LIMIT -10.000000 #A

#Input Voltage

VIN\_OV\_FAULT\_LIMIT 13.4 #V

VIN\_OV\_WARN\_LIMIT 13.0 #V

VIN\_UV\_WARN\_LIMIT 4.7 #V

VIN\_UV\_FAULT\_LIMIT 4.5 #V

#Other Faults

OT\_FAULT\_LIMIT 120.000000 #deg C

OT\_WARN\_LIMIT 110.000000 #deg C

UT\_WARN\_LIMIT -20.000000 #deg C

UT\_FAULT\_LIMIT -30.000000 #deg C

#General converter commands

TON\_DELAY 5.000000 #ms

TON\_RISE 5.000000 #ms

TOFF\_DELAY 5.000000 #ms

TOFF\_FALL 5.000000 #ms

FREQUENCY\_SWITCH 615.000000 #kHz

PID\_TAPS A=15141.91, B=-29677.9, C=14599.08

MAX\_DUTY 90.000000 #%

DEADTIME 0x3838 #56ns max

DEADTIME\_CONFIG 0x0404 #8ns min, dynamic

INDUCTOR 0.36 #uH

## #Advanced commands

|               |            |                                                         |
|---------------|------------|---------------------------------------------------------|
| MFR_CONFIG    | 0x6A10     | #416ns; 5 count; XTEMP dis; fault on internal           |
| USER_CONFIG   | 0x0000     |                                                         |
| NLR_CONFIG    | 0xCA010200 | #On;1%load;1.5%unload;1toLoad;2toUnload;NoOuter;NoBlank |
| MISC_CONFIG   | 0x0480     | #Precise dis; Adaptive dis;                             |
| INTERLEAVE    | 0x0000     |                                                         |
| SEQUENCE      | 0x0000     |                                                         |
| TEMPCO_CONFIG | 0x28       | #4000PPM/°C internal                                    |

STORE\_DEFAULT\_ALL  
RESTORE\_DEFAULT\_ALL

## Measured Data

The following data was acquired using a ZL2006EV1 rev 2 evaluation board.

### Efficiency

Adaptive diode emulation and adaptive frequency modes are disabled for these efficiency measurements.

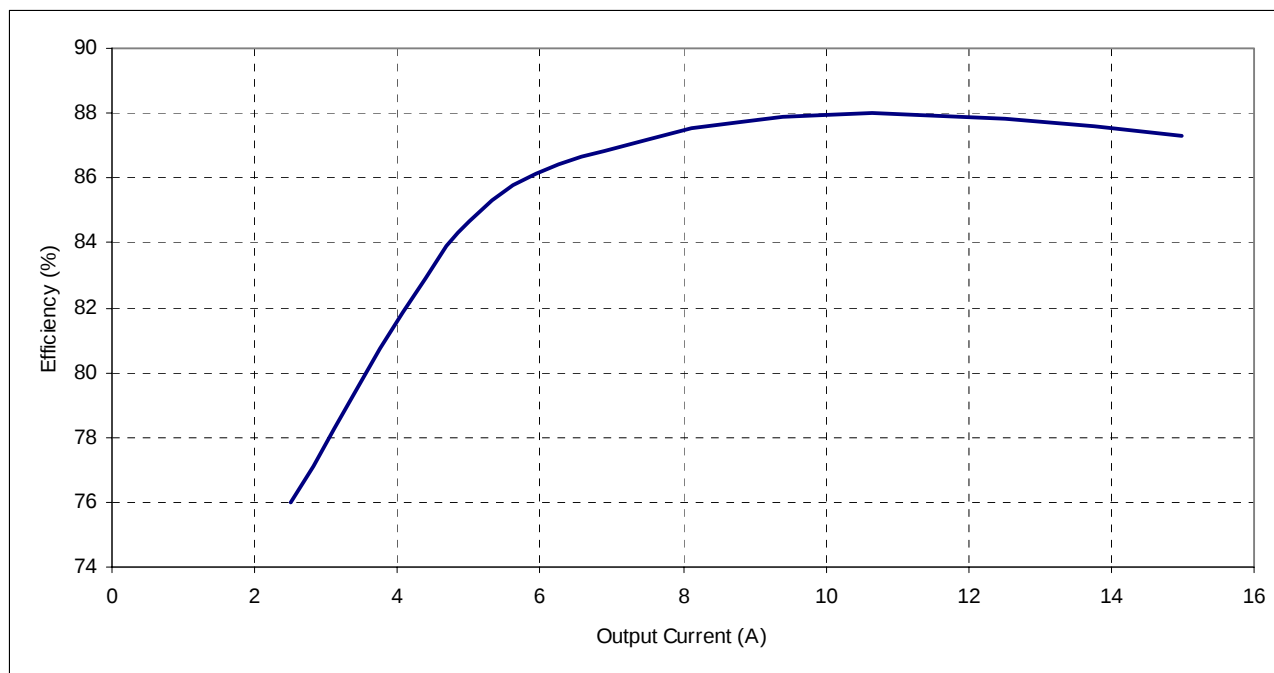
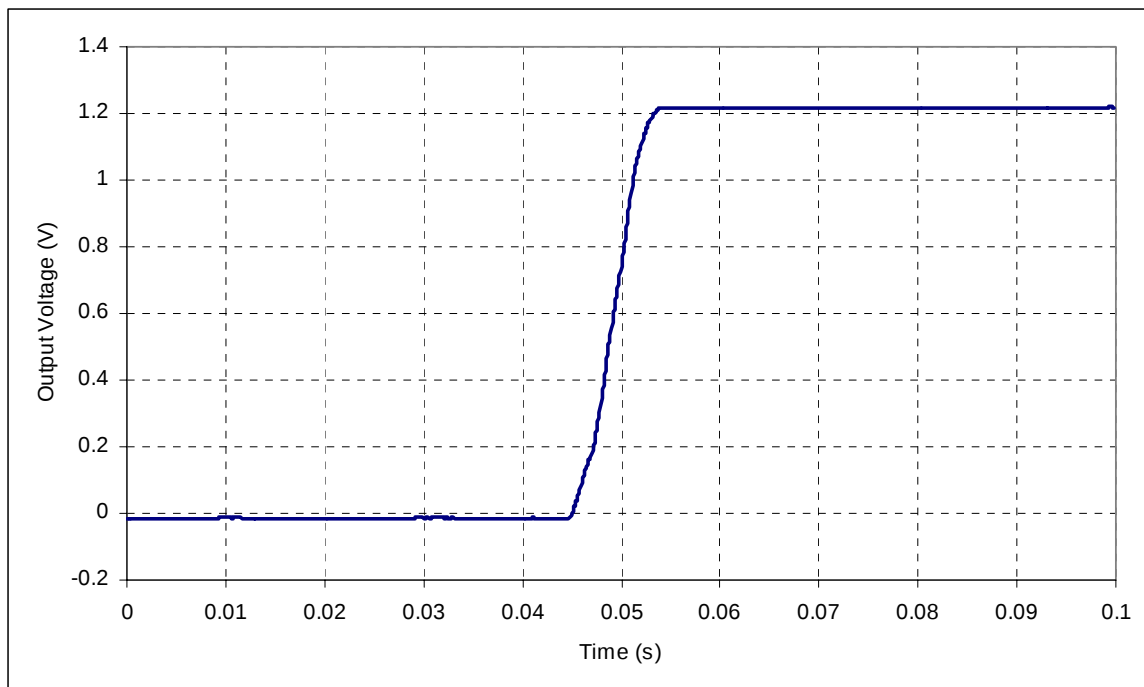
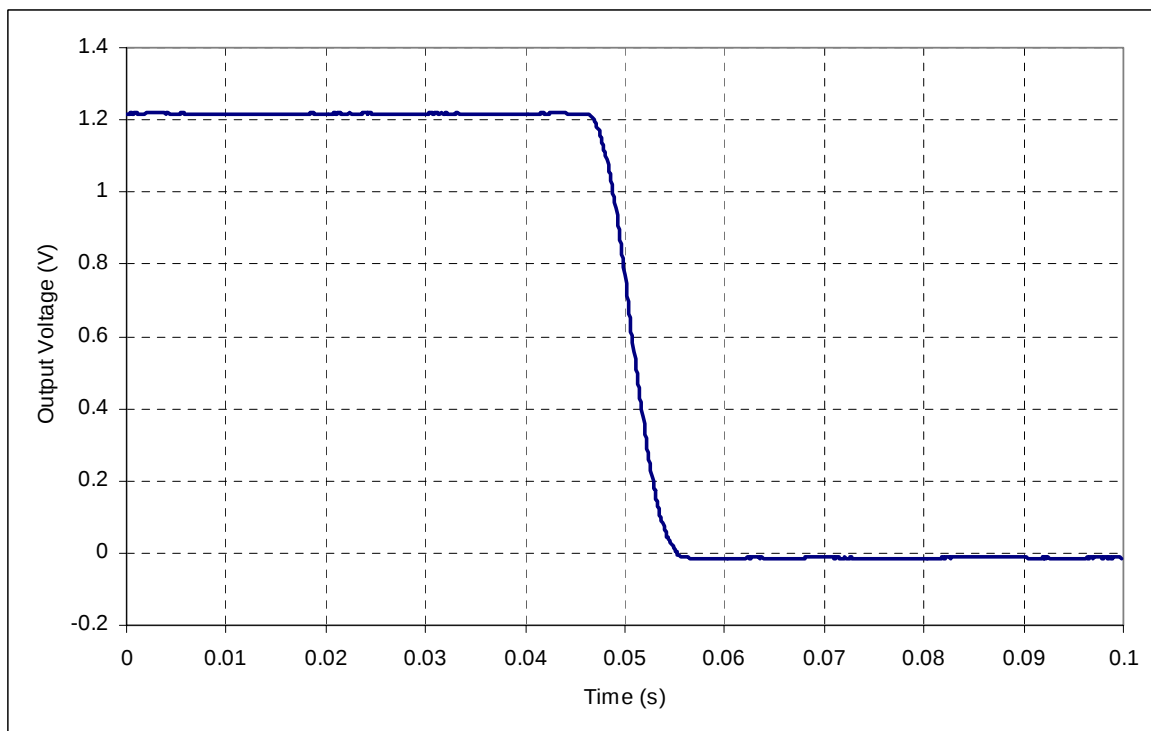


Figure 9. Efficiency,  $V_{in}=12V$ ,  $V_{out}=1.2V$

**Ramp-up / Ramp-down Characteristics****Figure 10. Ramp Up****Figure 11. Ramp Down**

## Dynamic Load Response

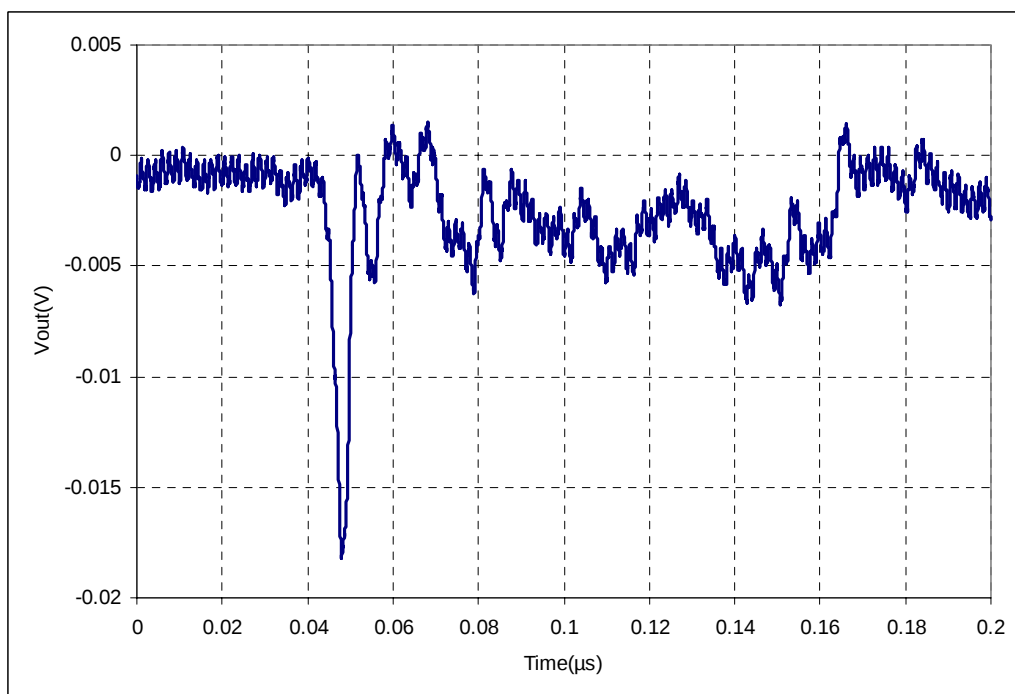


Figure 12. Dynamic Response, 7A to 15A Load Step

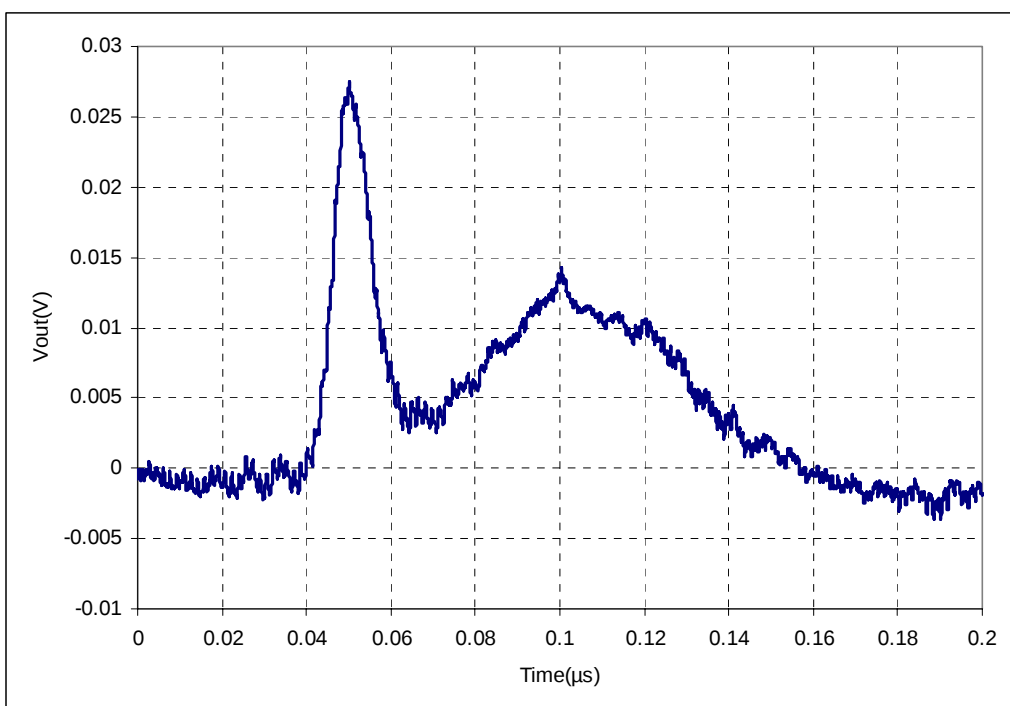


Figure 13. Dynamic Response, 15A to 7A Load Step

## References

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- [1] ZL2006 Data Sheet, Zilker Labs, Inc., 2008.
- [2] AN33 – PMBus™ Command Set, Zilker Labs, Inc., 2008.

## Ordering Information

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| Orderable Part Number | Description                                               |
|-----------------------|-----------------------------------------------------------|
| ZL2006EVK1            | ZL2006 Evaluation Kit (EVB, USB Adapter, Cable, Software) |
| ZL2006EV1             | ZL2006 Evaluation board only                              |

## Revision History

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| Date          | Rev. # | Description                      |
|---------------|--------|----------------------------------|
| February 2009 | 2.0    | Initial release with board rev 2 |
|               |        |                                  |
|               |        |                                  |
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