LTC3676EUJ-1
Power Management Solution for Application Processors with DDR

DESCRIPTION

Demonstration circuit 1976A-B is a multioutput power supply with a pushbutton controller and I²C, featuring the LTC®3676EUJ-1. The LTC3676EUJ-1 has four synchronous buck regulators, an always-on LDO and three LDO regulators. The input voltage range of the LTC3676EUJ-1 is ideal for single-cell Li-Ion/Polymer battery applications.

The switching regulator settings, such as enables, feedback voltages, operating modes and other functions, can be controlled via I²C. All of the regulators, except the always-on LDO1 and LD04, can also be enabled via external enable pins. After the first regulator is enabled, the remaining enable pins use a precision threshold to allow hardwired power-up sequences. All the regulators, except LDO1, can also be enabled via the I²C.

The LTC3676EUJ-1 has three status registers, PGSTATL, PGSTATR and IRQSTAT, that can be used to determine the current state of the device.

The three status registers, which can be read via I²C, indicate which regulators are in regulation and if a UV or OT event occurred. The command registers, which are used to control the switching regulators and program the special functions, can also be read back via I²C to assure the correct data was received.

The LTC3676-1 has a ±1.5A buck regulator configured to support DDR termination plus a VTTR reference output.

Refer to the LTC3676EUJ-1 data sheet for more details on the electrical and timing specifications and for an explanation of the different device options.

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

LT, LTC, LTM, Linear Technology and the Linear logo are registered trademarks and QuikEval is a trademark of Linear Technology Corporation. All other trademarks are the property of their respective owners.

PERFORMANCE SUMMARY

Specifications are at T_A = 25°C

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{IN}	Input Voltage Range		2.7		5.5	V
V_{BUCK1}	Buck Regulator 1 Output Voltage	Buck 1 Enabled, I_{BUCK1} = 0 ~ 1.5A	0.95 • V_{BUCK4}/2	V_{BUCK4}/2	1.05 • V_{BUCK4}/2	V
V_{BUCK2}	Buck Regulator 2 Output Voltage	Buck 2 Enabled, I_{BUCK2} = 0 ~ 1.5A	0.76	1.38	1.58	V
V_{BUCK3}	Buck Regulator 3 Output Voltage	Buck 3 Enabled, I_{BUCK3} = 0 ~ 2.5A	0.76	1.38	1.58	V
V_{BUCK4}	Buck-Boost Regulator Output Voltage	Buck4 Enabled, I_{BUCK4} = 0 ~ 2.5A	0.82	1.50	1.71	V
V_{LDO1}	LDO1 Regulator Output Voltage	LDO1 Is Always On, I_{LDO1} = 0 ~ 25mA	2.92	3.01	3.10	V
V_{LDO2}	LDO2 Regulator Output Voltage	LDO2 Enabled, I_{LDO2} = 0 ~ 300mA	2.73	2.81	2.89	V
V_{LDO3}	LDO3 Regulator Output Voltage	LDO3 Enabled, I_{LDO3} = 0 ~ 300mA	1.75	1.80	1.85	V
V_{LDO4}	LDO4 Regulator Output Voltage	LDO4 Enabled, I_{LDO4} = 0 ~ 300mA	1.16	1.20	1.24	V

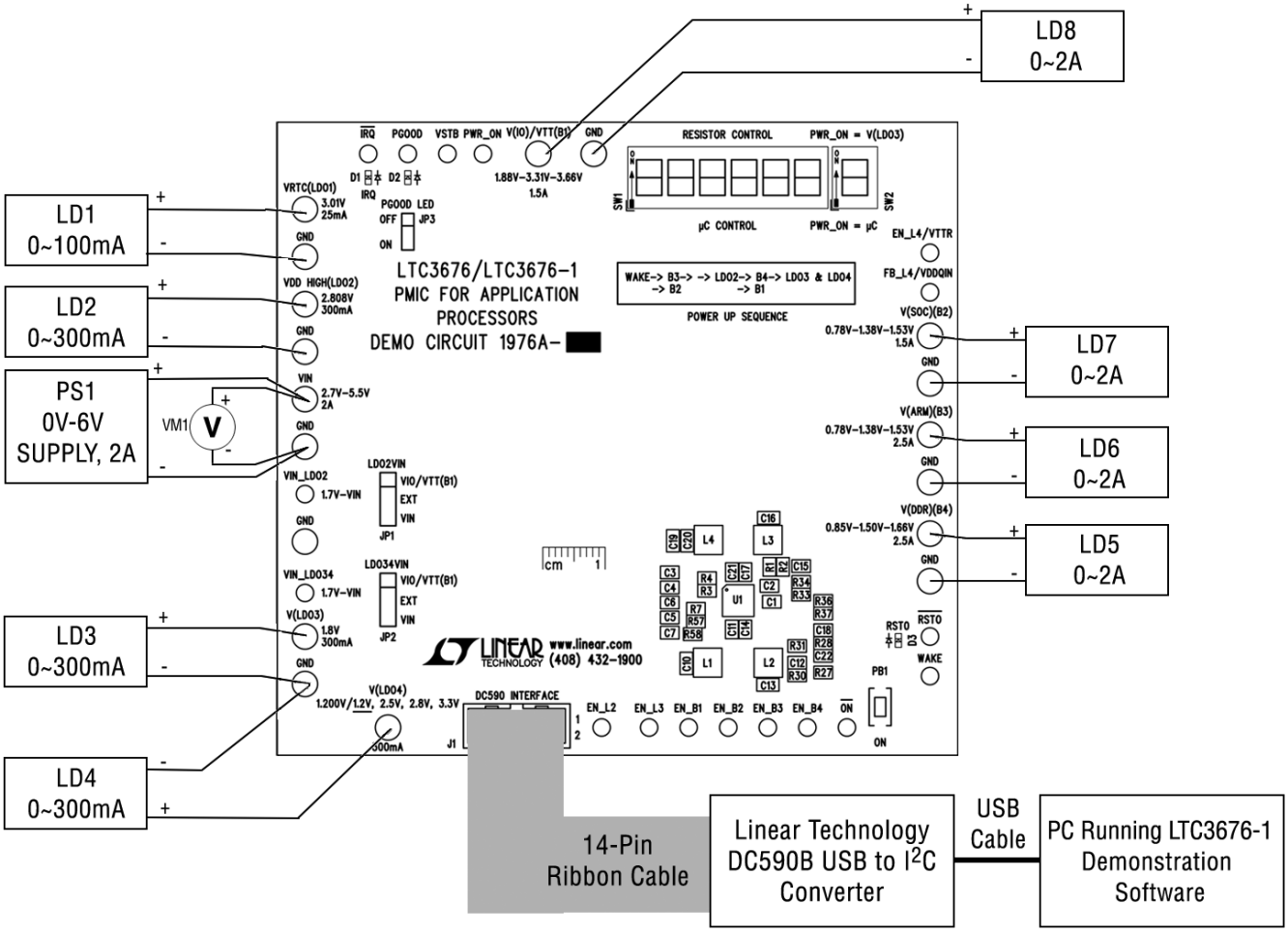
QUICK START PROCEDURE

1. Ensure that JP1 to JP3, SW1 and SW2 are in their default positions, as shown in Figure 1. Set PS1 to 5V and turn on. The RST0 LED should light until LDO1 comes on, and the PGOOD LED should come on and stay on

NOTE: The DV_{CC} voltage level may be selected on the DC590B. This is done by setting the V_{CCIO} jumper, JP6, on the DC590B board to one of the following settings: 3.3V, 5V, removed for 2.7V, or set to external if an external supply is used. Please set DV_{CC} to 5V.

2. Start the Linear Technology QuikEval™ program. This program should automatically detect the presence of the LTC3676EUJ-1 demo board (DC1976A-B) and activate the appropriate GUI, as seen in Figure 3. The GUI reads back the current voltages of the regulators. LDO1 should read 3V, and V_{IN} should read 5V; all others should be 0V.
3. Press the PB1 button on the DC1976A-B for more than 0.5s; all of the power supplies should come up and the displayed GUI page should match Figure 3. The sequencing for these supplies was set by Linear Technology, using resistor divider networks from the supply outputs to control the ENx lines.
4. Each of the supplies can be loaded to test the regulators, but be aware that LDO2~4 are powered from V_{IN}, and the dissipation can be significant. If significant current is desired from these regulators, care with input voltage selection will be required.
5. Press and hold the PB1 button for more than 5s, and all of the regulators, except LDO1, will shut down. The GUI will show the voltages for all regulators, other than always-on LDO1, as 0V.
6. Refer to the Using the LTC3676EUJ-1 Software section for more information on how to control the device using the LTC3676EUJ-1 control window.
7. Refer to the LTC3676EUJ-1 data sheet for more details on how the LTC3676EUJ-1 operates.
8. When done, close the LTC3676EUJ-1 GUI and turn off all loads and power supplies.

QUICK START PROCEDURE



Note: All connections from equipment should be Kelvin connected directly to the board pins to which they are connected on this diagram. Any input or output leads should be twisted-pair.

Figure 1. Proper Measurement Equipment Setup

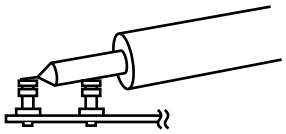


Figure 2. Measuring Input or Output Ripple

USING THE LTC3676EUJ-1 SOFTWARE

Introduction

The LTC3676EUJ-1 GUI provides control of most aspects of operation of the LTC3676EUJ-1. The LTC3676EUJ-1 GUI also provides a means to manage the feedback divider resistors, turn the regulators on and off manually, and even to experiment with sequencing.

The LTC3676EUJ-1 GUI is composed of four forms:

- The LTC3676 (DC1976A-B) form (Figure 3) is brought up by the QuikEval program.
- The Manage Resistors form (Figure 4) is brought up by pressing the Change Resistor Divider Networks button on the LTC3676 form.
- The Advanced Settings form (Figure 5) is brought up by pressing the Advanced Settings button on the LTC3676 form.
- The Sequencing form is brought up by pressing the Change LTC3676 Sequencing button.

The sequencing form, in turn, contains three tabs: Direct (Figure 6), Table (Figure 7) and Shutdown (Figure 8). These allow direct control and table based sequencing, respectively, and the shutdown sequence.

SW1, positions 1 to 6, sets the source of the ENx signals to the preselected resistor networks or to the on-board microcontroller. SW1 should be set to Resistor Control for normal mode, and µC Control for sequence modes (Direct and Table).

SW2 controls the source of PWR_ON. Resistor Control, PWR_ON = V_{LDO3}, makes the source the LDO3 regulator output. PWR_ON = µC makes it controlled by the on-board microcontroller. This switch should be set to Resistor Control for normal mode and µC Control for sequence modes.

View the LTC3676EUJ-1 Product Page

This button opens your default Internet browser, and searches the Linear Technology Corporation website for information on the LTC3676EUJ-1 when an Internet connection is available.

Buck2 ~ Buck4 and LDO2~LDO4 Sections

These sections control most aspects of the regulator operation. Some of the controls for the regulators are on the Advanced Settings form. Please consult the data sheet for operation of these bits.

Whenever the DAC sliders are changed or the regulator is switched between normal and standby, the appropriate control registers are changed.

If the text box has a grey background, it cannot be directly edited. A good example of this is the command registers SCR1, OVEN, SCR2, etc., at the bottom of the LTC3676 form. These registers are changed by the various controls on the form.

The Auto Readback Enabled button determines if the IRQSTAT, PGSTATL and PGSTATR values are automatically read back. If automatic readback is disabled, the Readback button will do a one-time readback.

The Auto Update Enabled button determines if the command registers are automatically sent to the LTC3676 on change, and if the values of these registers are automatically read back. If automatic update is disabled, the Update All button will update all the command registers and read back the values.

For all the automatic update modes, an internal 100ms timer is used, so all values will be updated every 100ms, if enabled.

USING THE LTC3676EUJ-1 SOFTWARE

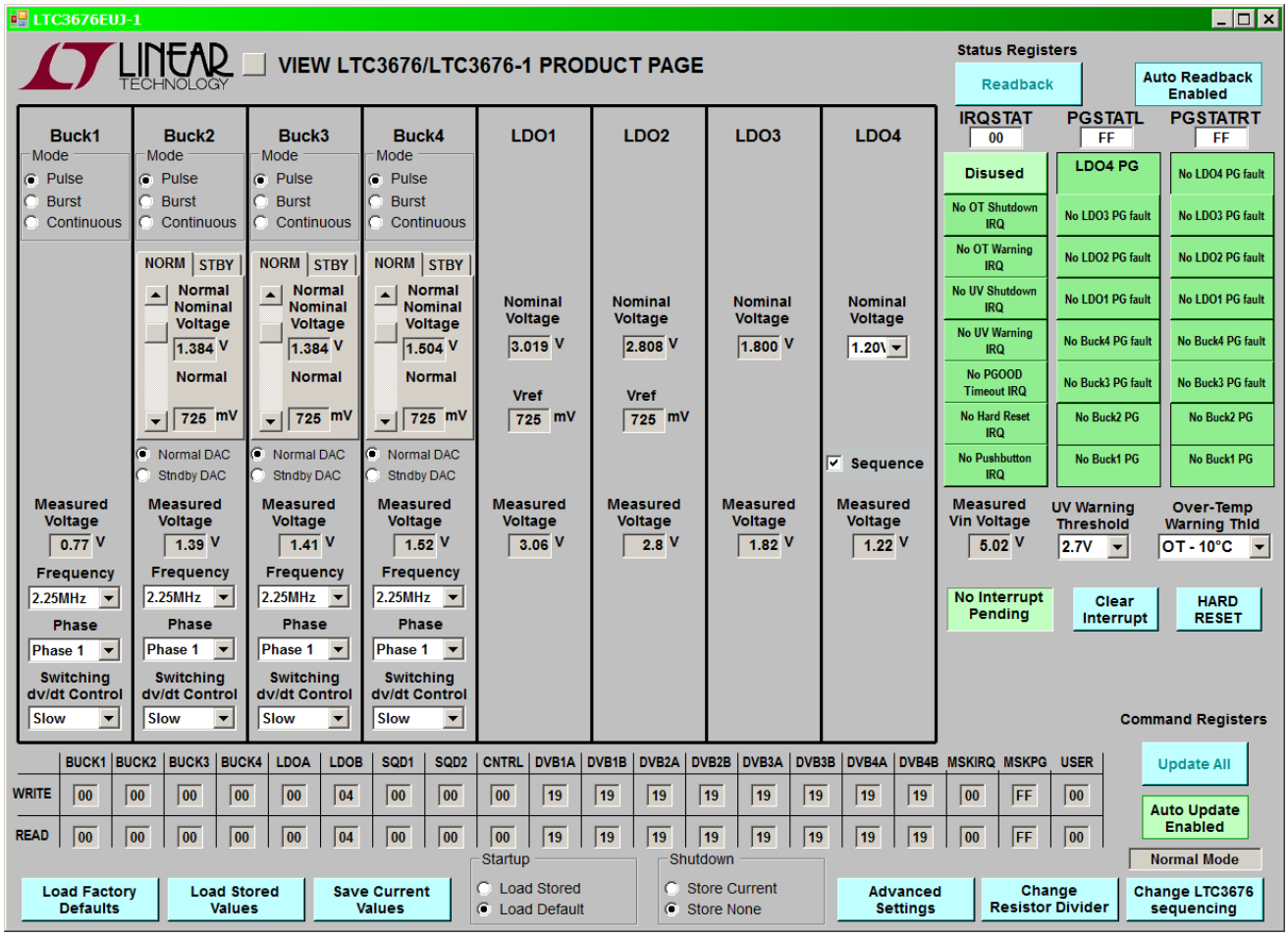


Figure 3. Main Form

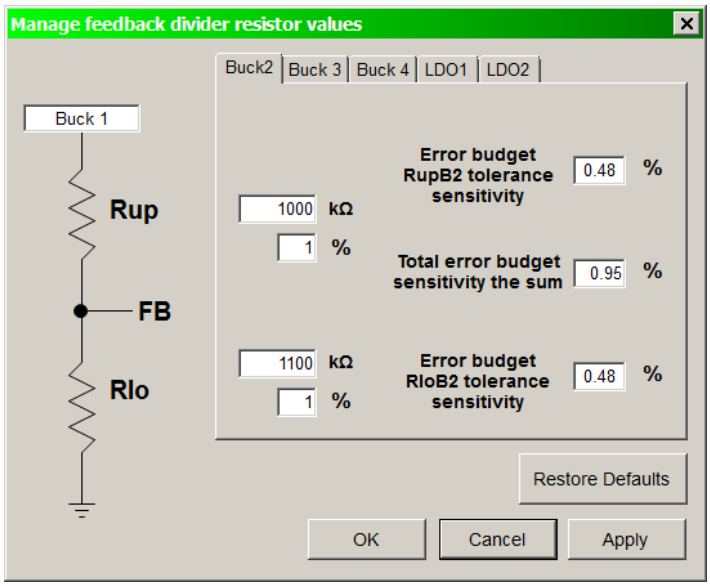


Figure 4. Manage Resistors Form

USING THE LTC3676EUJ-1 SOFTWARE

Interrupts and Status

The current state of IRQSTAT, PGSTATL and PGSTATR are displayed on the right. If an interrupt is pending, the IRQ LED (D1) on the DC1976A-B demo board will light. The interrupt box will change color to red, and indicate Interrupt Pending. To clear the interrupt, press the Clear Interrupt button.

Advanced Settings Button

This button brings up the Advanced Settings form (Figure 5), which allows the control of several less used bits. Any changes made in this form will immediately be reflected in the appropriate command registers on the LTC3676 form. However, if Auto Update Enabled is disabled, the value will not be sent to the LTC3676EUJ-1 until auto update is re-enabled or Update All is pressed.

Mode Display

This box displays the current operating mode. The value of this box can be changed in the sequence form.

Load Factory Defaults

The factory default values for the command registers, regulator resistors and auto update states are immediately loaded.

Load Stored Values

The state of the command registers, regulator resistors and auto update states can be saved to a file and reused. This button causes the saved states to be loaded immediately.

Save Current Values

Immediately saves the state of the command registers, regulator resistors and auto update states to file.

Start-Up

The start-up section determines what the GUI will do at start-up, load default or stored command register, regulator resistors and auto update states.

Shutdown

The shutdown section determines what the GUI will do at shutdown, store the current command register, regulator resistor resistors and auto update values or not.

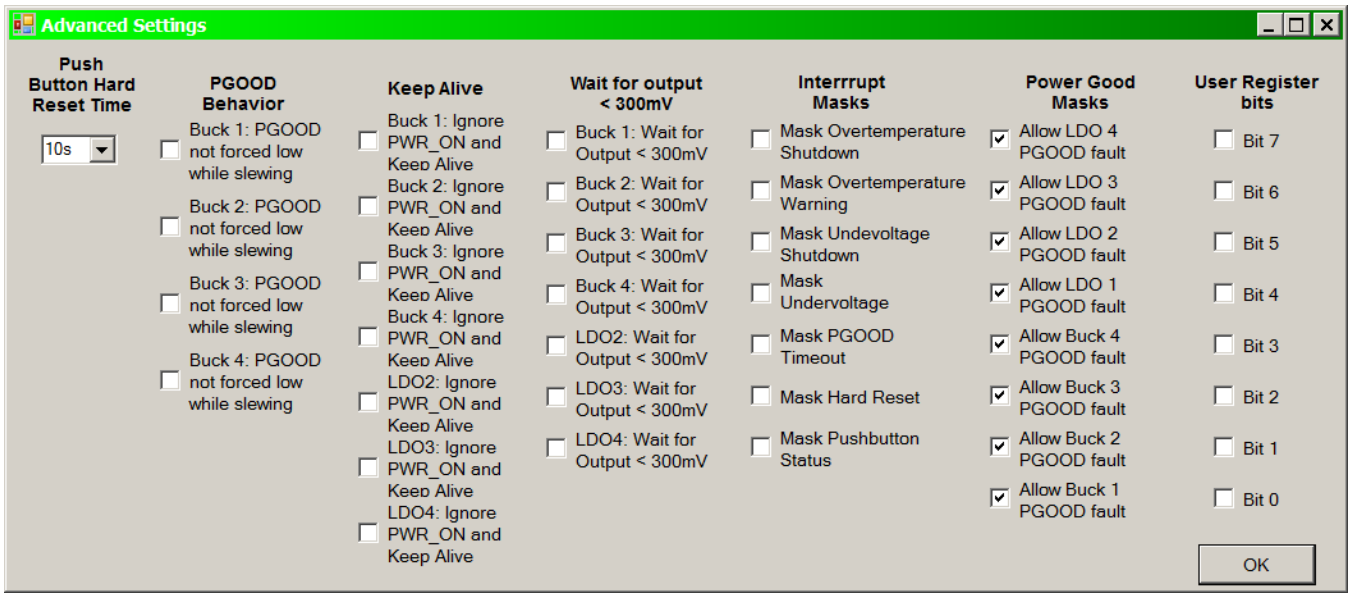


Figure 5. DC1976A-B (LTC3676EUJ-1) Advanced Settings Form

USING THE LTC3676EUJ-1 SOFTWARE

Change Resistor Divider Networks Button

This button brings up the Manage Feedback Divider Resistor Values form (Figure 4), which allows for different feedback divider resistor values. Any changes made in this form will immediately be reflected in the appropriate voltage value boxes on the LTC3676 form. It is the user's responsibility to ensure that the values in this form are the same as the values of the actual resistors on the demo board.

Change LTC3676 Sequencing Button

This brings up the sequencing form which has two tabs Direct (Figure 6) and Table (Figure 7).These allow the direct control of the regulator on/off (Direct tab), or set up a sequence that will be downloaded to the on-board microcontroller to set the regulator sequencing (Table tab).

Both the direct and the table modes require that all positions of the SW1 dipswitch be in the µC Control position.

Neither direct nor sequence mode can be enabled from the other mode. You must be in normal mode to enable direct or sequence mode.

Returning to normal mode explicitly, by using a button to disable direct or sequence modes, resets the regulator states to the default. However, if you return to normal mode by completing a downloaded sequence, the regulator states are not reset.

Direct

To directly control the on/off state of the regulators, choose the Direct tab, enable direct mode (the mode display on the LTC3676 form should change to direct). Ensure that the dipswitch positions are in the correct state and check the appropriate boxes. The regulators can now be turned on and off directly.

The Measured Voltage boxes are live and update on the 100ms update timer.

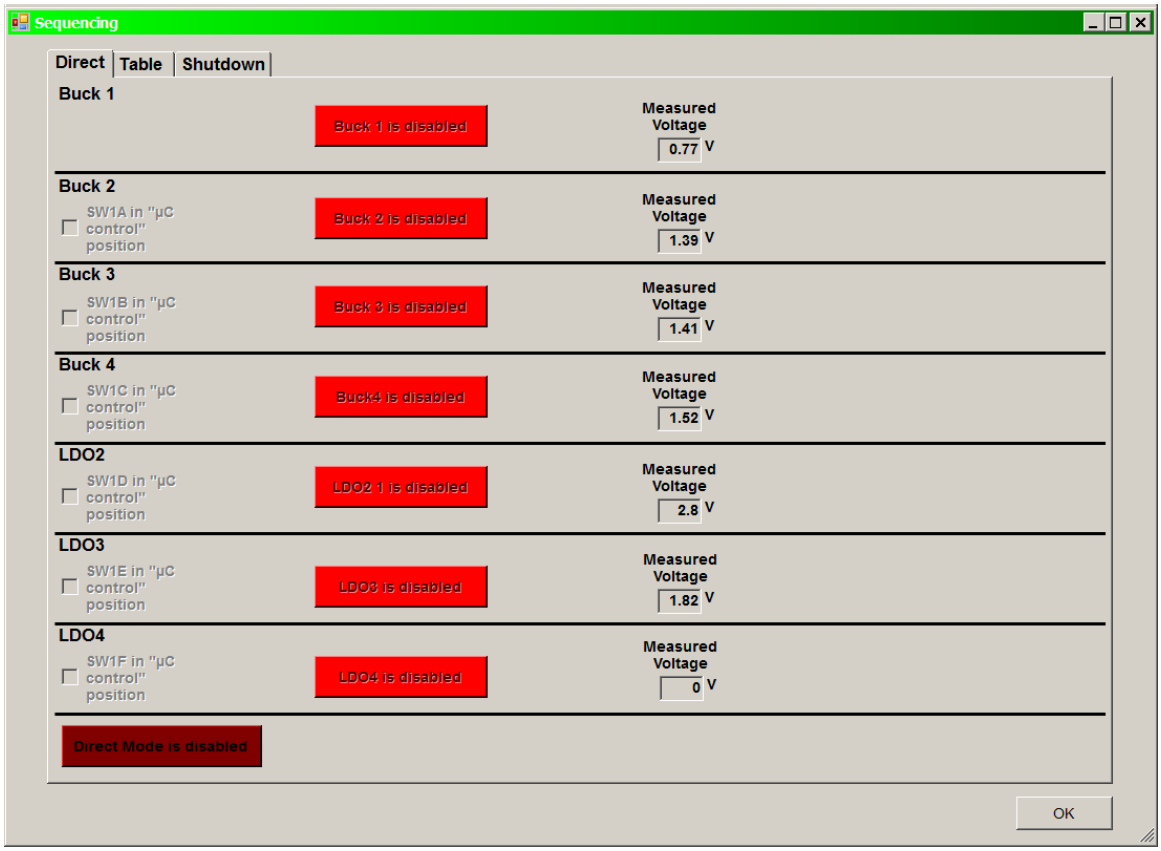


Figure 6. Sequence, Direct Form

USING THE LTC3676EUJ-1 SOFTWARE

Table

To set up a sequence for the power supplies to power up, choose the Table tab. Do not enable sequence mode until a sequence table has been downloaded. Sequence tables can only be downloaded in normal mode.

Some error checking is done on the table before downloading, such as ensuring that at least one regulator is controlled by WAKE, but in general, the user must ensure that the sequence table is reasonable.

In particular, always ensure that one regulator is controlled by WAKE and that at least one regulator is used in the particular sequence controls PWR_ON. It is not necessary that you use all regulators, nor that only one regulator is controlled at a time. For example, WAKE could start all regulators, or just one. If PWR_ON is not asserted in the sequence, the sequence will execute, but the regulators will shut down after 5s.

Once a sequence has been downloaded, and sequence mode has been set, press the PB1 button to start the sequence. In sequence mode it is not necessary to press the PB1 button for 0.5s.

The level of the WAKE signal is the same as the level of the V_{IN} signal, that is, if V_{IN} is 3V, WAKE will assert at 3V. So, when choosing the threshold voltage for WAKE, make sure that you do not set it higher than the V_{IN} voltage. In fact, you should choose a voltage that is ≈ $V_{IN/2}$.

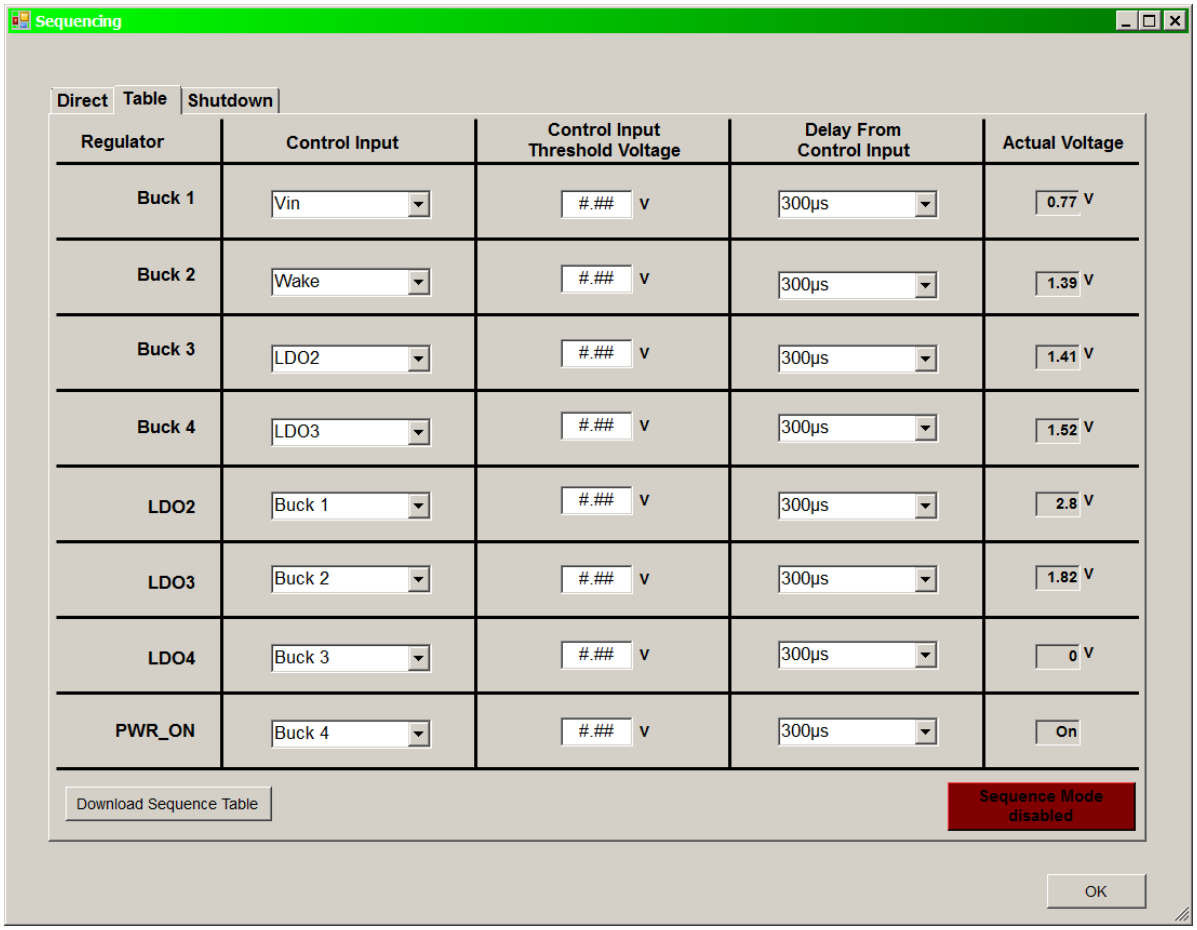


Figure 7. Sequence, Table Form

USING THE LTC3676EUJ-1 SOFTWARE

When PWR_ON is asserted in the sequence, the on-board microcontroller determines that the sequence is done and sets the state to normal (without resetting the states of the regulators). The sequence / table form can now be closed. If you wish to rerun the sequence, hold down PB1 for more than 5s, until the regulators shut off. Go to the sequence / table form, and enable sequence mode. It is not necessary to download the sequence table again, as it is still the in the on-board microcontroller's memory. Now, just press the PB1 button to restart the sequence.

Shutdown

Choose Sequencing for shutdown. To activate shutdown, hold MON (PB1) down for more than 10s.

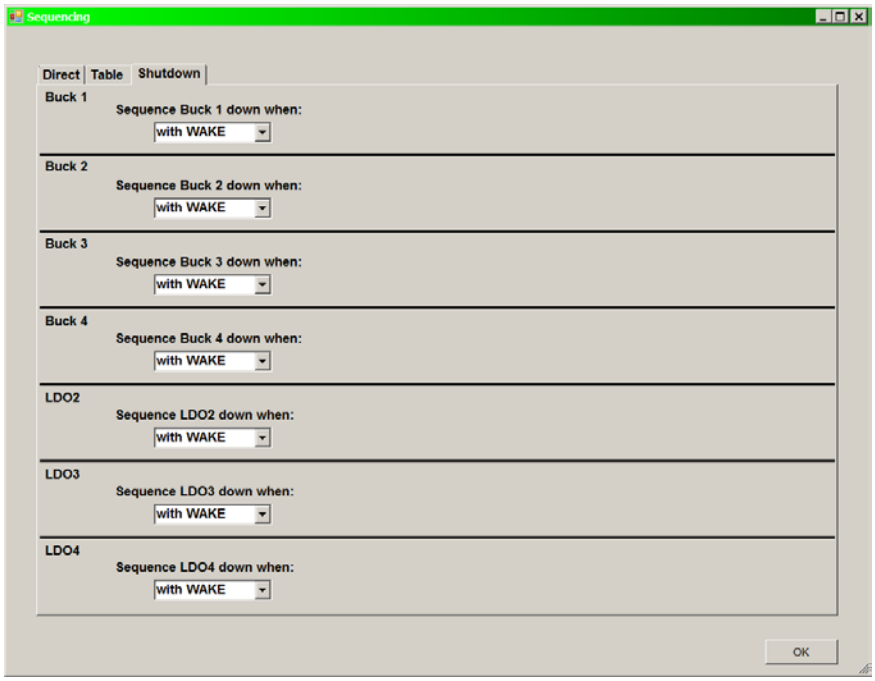


Figure 8. Shutdown Sequencing Form

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	5	C1, C11, C14, C17, C21	CAP, CHIP, X5R, 10µF, ±20%, 6.3V, 0603	TDK, C1608X5R0J106M
2	6	C2, C3, C4, C5, C6, C7	CAP, CHIP, X5R, 1µF, ±10%, 10V, 0402	MURATA, GRM155R61A105KE15D
3	4	C10, C13, C16, C19	CAP, CHIP, X5R, 47µF, ±20%,6.3V, 0805	SAMSUNG, CL21A476MQYNNNB
4	4	C12, C15, C18, C22	CAP, CHIP, C0G, 10pF, ±0.5pF, 50V, 0402	VISHAY, VJ0402A4R7
5	4	L1, L2, L3, L4	IND, SMT,1.5µH, 36mΩ, ±20%, 5.8A, 4.2mm × 4.2mm	COILCRAFT, XFL4020-152ME
6	5	R1, R3, R28, R31, R34	RES, CHIP, 1M, ±1%, 1/16W, 0402	VISHAY, CRCW04021M00FKED
7	1	R2	RES, CHIP, 316k, ±1%, 1/16W, 0402	VISHAY, CRCW0402316KFKED
8	1	R4	RES, CHIP, 332k, ±1%, 1/16W, 0402	VISHAY, CRCW0402332KFKED
9	1	R27	RES, CHIP, 931k, ±1%, 1/10W, 0402	VISHAY, CRCW0402931KFKED
10	4	R29, R32, R35, R38	RES, CHIP, 20Ω, ±5%, 1/16W, 0402	VISHAY, CRCW040220R0JNED
11	2	R30, R33	RES, CHIP, 1.10M, ±1%, 1/16W, 0402	VISHAY, CRCW04021M10FKED
12	2	R43, R60	RES, CHIP, 6.49k, ±1%, 1/16W, 0402	VISHAY, CRCW04026K49FKED
13	7	R44, R46, R48, R50, R52, R54, R59	RES, CHIP, 10k, ±1%, 1/16W, 0402	VISHAY, CRCW040210K0FKED
14	1	R45	RES, CHIP, 7.15k, ±1%, 1/10W, 0402	VISHAY, CRCW04027K15FKED
15	2	R47, R49	RES, CHIP, 2.67k, ±1%, 1/16W, 0402	VISHAY, CRCW04022K67FKED
16	2	R51, R53	RES, CHIP, 22.1k, ±1%, 1/16W, 0402	VISHAY, CRCW040222K1FKED
17	1	R55	RES, CHIP, 511k, ±1%, 1/16W, 0402	VISHAY, CRCW0402511KFKED
Additional Demo Board Circuit Components				
1	4	C8, C9, C25, C27	CAP, CHIP, X7R, 0.1µF, ±10%, 16V, 0402	MURATA, GRM155R71C104KA88D
2	0	C20	CAP, CHIP, 0805	Customer defined
3	2	C26, C28	CAP, CHIP, C0G, 1000pF, ±5%, 50V, 0402	TDK, GRM1555C1H102J
4	2	C23, C24	CAP, CHIP, X5R, 2.2µF, ±20%, 6.3V, 0402	MURATA, GRM155R60J225ME15D
5	2	D1, D3	DIODE, LED, RED, SMT, 0603	LITEON, LTST-C193KRKT-5A
6	1	D2	DIODE, LED, ORANGE, RECT, CLEAR, 0603	LITEON,LTST-C193KFKT-5A
7	1	D4	DIODE, SCHOTTKY, SMT, 20V, 0.5A, SOD123	ON SEMICONDUCTOR, MBR0520LG
8	1	D5	DIODE, Si SWITCHING, 100V, 80mA, SOD123	ON SEMICONDUCTOR, MMSD4148G
9	1	M1	MOSFET, 60V, 10Ω, 115A, SOT-23	FAIRCHILD, 2N7002L
10	1	PB1	SWITCH, WS-TRS, TACT , SMD, 6mm × 3.8mm	WÜRTH, 434 111 025 826
11	1	Q1	BITRANS., GP SS NPN 40V, SOT-23	ON SEMICONDUCTOR, MMBT3904LT1G
12	4	R5, R10, R39, R56	RES, CHIP, 1k, ±5%, 1/16W, 0402	VISHAY, CRCW04021K00JNED
13	4	R6, R8, R9, R40	RES, CHIP, 100k, ±5%, 1/16W, 0402	VISHAY, CRCW0402100KJNED
14	11	R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21	RES, CHIP, 10k, 5%, 1/16W, 0402	VISHAY, CRCW040210K0JNED
15	3	R22, R23, R25	RES, CHIP, 5.1k, 5%, 1/16W, 0402	VISHAY, CRCW04025K10JNED
16	2	R24, R26	RES, CHIP, 4.7k, ±5%, 1/16W, 0402	VISHAY, CRCW04024K70JNED
17	2	R41, R42	RES,CHIP, 100k , ±1%, 1/16W, 0402	VISHAY, CRCW0402100KFKED
18	1	SW1	SWITCH, SMT, SPDT, 6 POS. DIP, 37mm × 8mm	CTS ELECTROCOMPONENTS, 204-126ST
19	1	SW2	SWITCH, SMT, SPDT, 1 POS. DIP, 7mm × 8mm	CTS ELECTROCOMPONENTS, 204-121-LPST
20	1	U2	I^2C EEPROM	MICROCHIP, 24LC025-I/ST

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
21	1	U3	PIC MICROCONTROLLER, 6mm × 6mm QFN-16	MICROCHIP, PIC16F722-I/ML
22	1	U4	LOW NOISE REGULATED CHARGE PUMP IN 2mm × 2mm DFN	LINEAR TECH., LTC3204BEDC-5
Hardware For Demo Board Only				
1	18	E1-E4, E6, E7, E9-E12, E28-E35	TURRET, 0.09 DIA	MILL-MAX, 2501-2-00-80-00-00-07-0
2	17	E5, E8, E13-E27	TURRET, 0.061 DIA	MILL-MAX, 2308-2-00-80-00-00-07-0
3	1	J1	CONN, HEADER 14POS 2MM VERT GOLD	MOLEX, 87831-1420
4	1	J2	HEADER, 2mm × 3mm, 0.079 DOUBLE ROW	SAMTEC, TMM-103-02-L-D
5	2	JP1, JP2	HEADER, 1mm × 4mm PIN 0.079 SINGLE ROW	SAMTEC, TMM-104-02-L-S
6	1	JP3	HEADER, 1mm × 3mm PIN 0.079 SINGLE ROW	SAMTEC, TMM-103-02-L-S
9	1		FAB, PRINTED CIRCUIT BOARD	DC1976A-5-A/B
Required Circuit Components				
1	0	R7	NO LOAD	
2	0	R36	NO LOAD	
3	1	R37	RES, CHIP, 0Ω JUMPER, 1/16W, 0402	VISHAY, CRCW04020000Z0ED
4	0	R57	NO LOAD	
5	1	R58	RES, CHIP, 0Ω JUMPER, 1/16W, 0402	VISHAY, CRCW04020000Z0ED
6	0	R61	NO LOAD	
7	1	U1	PMIC FOR APPLICATION PROCESSORS	LINEAR TECH., LTC3676EUJ-1

SCHEMATIC DIAGRAM

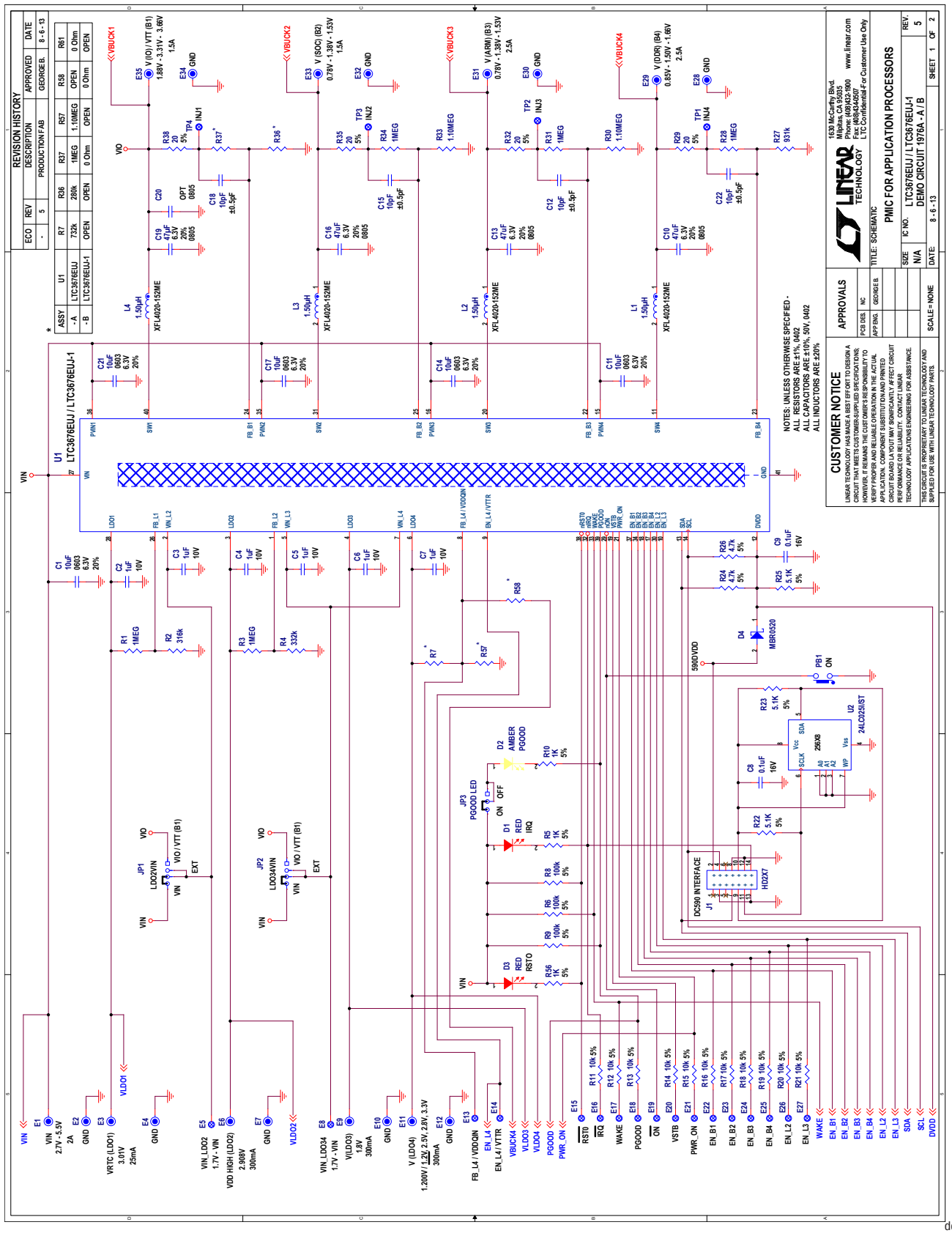


Figure 9. PMIC for Application Processors

SCHEMATIC DIAGRAM

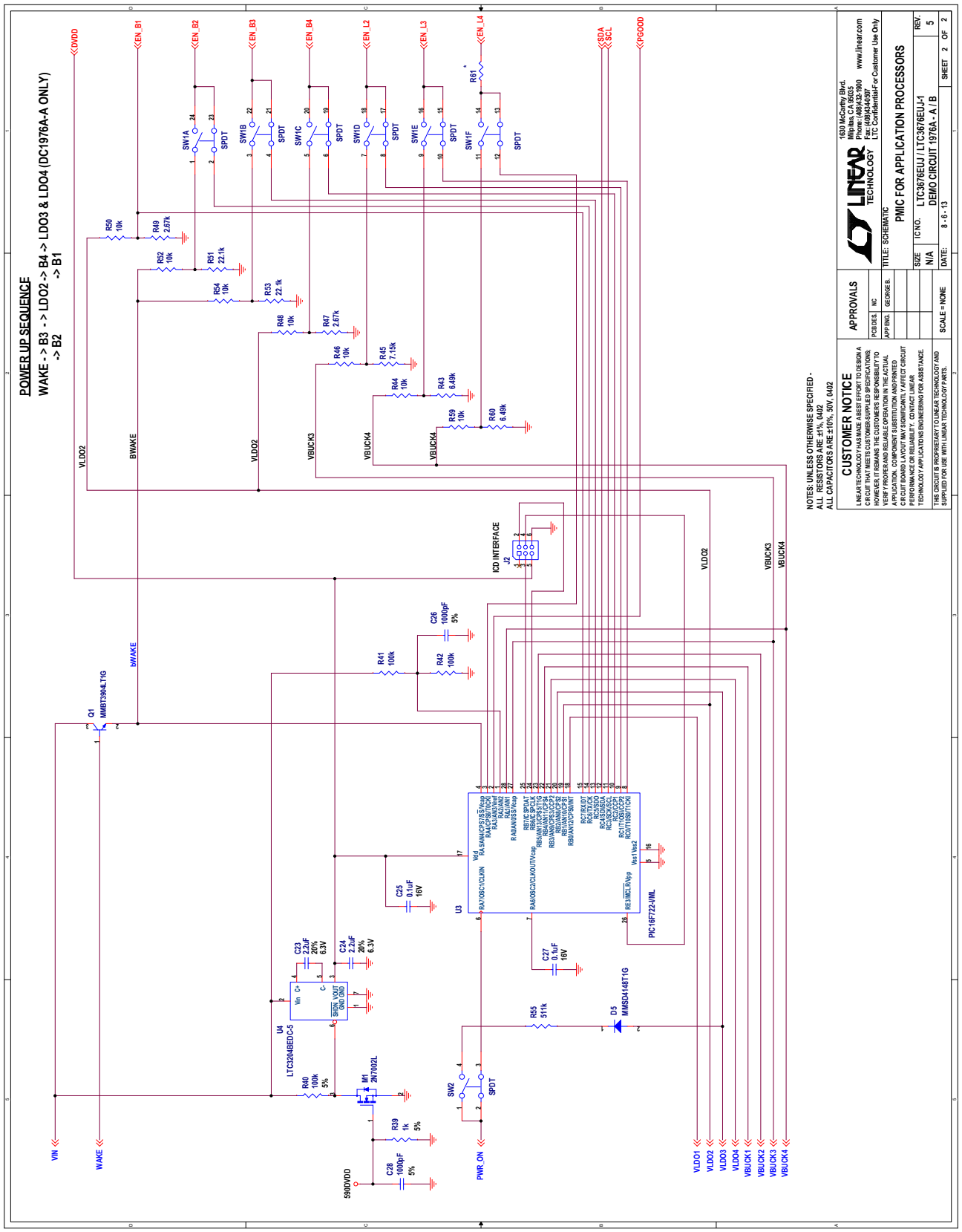


Figure 10. PMIC for Application Processors

Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.

DEMONSTRATION BOARD IMPORTANT NOTICE

Linear Technology Corporation (LTC) provides the enclosed product(s) under the following **AS IS** conditions:

This demonstration board (DEMO BOARD) kit being sold or provided by Linear Technology is intended for use for **ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY** and is not provided by LTC for commercial use. As such, the DEMO BOARD herein may not be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including but not limited to product safety measures typically found in finished commercial goods. As a prototype, this product does not fall within the scope of the European Union directive on electromagnetic compatibility and therefore may or may not meet the technical requirements of the directive, or other regulations.

If this evaluation kit does not meet the specifications recited in the DEMO BOARD manual the kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY THE SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THIS INDEMNITY, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user releases LTC from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge. Also be aware that the products herein may not be regulatory compliant or agency certified (FCC, UL, CE, etc.).

No License is granted under any patent right or other intellectual property whatsoever. **LTC assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or any other intellectual property rights of any kind.**

LTC currently services a variety of customers for products around the world, and therefore this transaction **is not exclusive**.

Please read the DEMO BOARD manual prior to handling the product. Persons handling this product must have electronics training and observe good laboratory practice standards. **Common sense is encouraged**.

This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact a LTC application engineer.

Mailing Address:

Linear Technology
1630 McCarthy Blvd.
Milpitas, CA 95035

Copyright © 2004, Linear Technology Corporation

© LINEAR TECHNOLOGY CORPORATION 2013