Lit Number: TIDUAQ7
Date: September 2015

TI Designs
Fast Response, Small Size Power Solution Reference Design for GPRS Module

TEXAS INSTRUMENTS

TI Designs

TI Designs provide the foundation that you need including methodology, testing and design files to quickly evaluate and customize the system. TI Designs help **you** accelerate your time to market.

Design Resources

TIDA-00685	Design Folder
LP38501-ADJ	Product Folder

TI E2E™ Community

Ask The Analog Experts
WEBENCH® Design Center

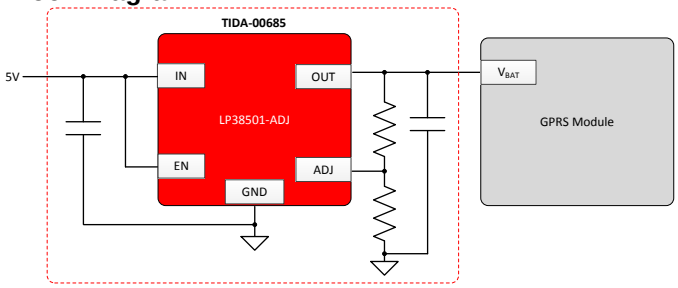
Design Features

- Large output current capability
- Fast load transient response
- Small size solution
- Cost optimized solution

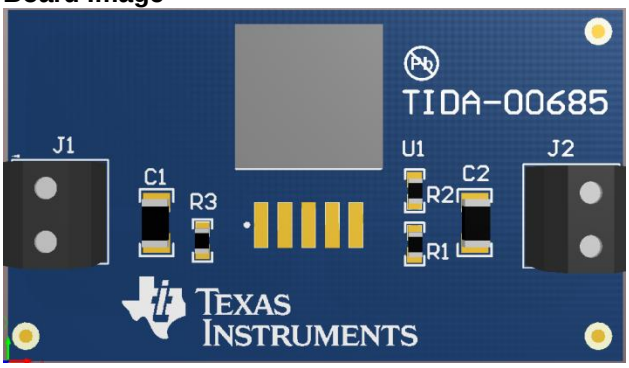
Featured Applications

- GPRS Module Power Supply
- ASIC Power Supplies
- DSP and FPGA Power Supplies
- SMPS Regulator

Block Diagram



Board Image



Copyright © 2015, Texas Instruments Incorporated

1 Key System Specifications

Table 1 System Specifications

PARAMETERS	SPECIFICATION	DETAILS
GPRS Module	Power supply recommendations for GPSR Module	Section 4.2
Design Implementation	Design implementation guidelines	Section 5

2 System Description

The TIDA-00685 reference design provides a power management solution for industry data transmit system using the voltage regulator LP38501 to provide the appropriate voltage level to power GPRS module.

The TIDA-00685 is mainly focused in power management section and provides test data, schematic and Gerber files. This power management can be used as a reference for industry data transmit application such as GPRS module, 3G/4G module.

The highlights for this design are:

- Large output current capability
- Fast load transient response
- Small size power management solution
- Cost optimized solution

2.1 Device selection considerations

The highlighted design considerations for the device selection are output current, load transient response, and size.

When the GPRS module works in data transmit mode, the internal power amplifier current reaches 2A flowing with a ratio of 1/8 of time, around 577us every 4.615ms. The following figure shows VBAT voltage (GPRS module supply voltage) drop during maximum power transmitting burst, the voltage drop will be less in 3G and 4G network.

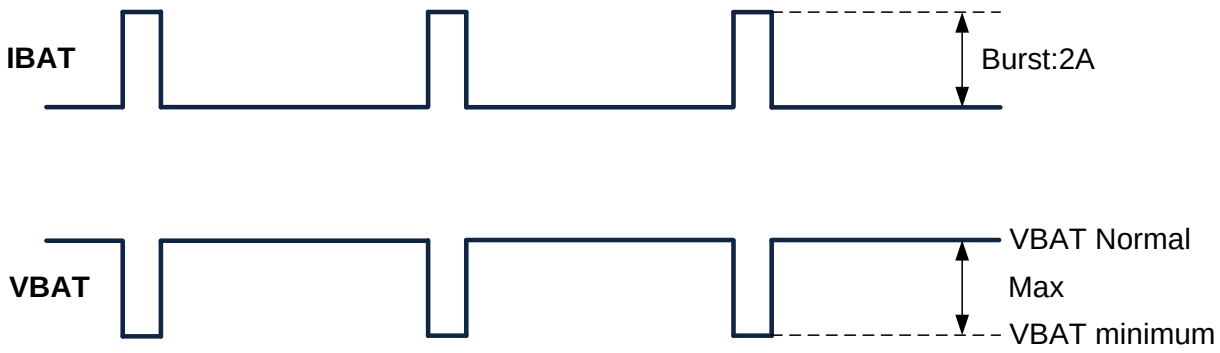


Figure 1 Ripple in Supply Voltage during Transmit Burst

The transmit burst can cause obvious voltage drop at the module supply voltage, thus the supply must be capable of providing sufficient current up to 2A, and must be designed to provide fast load transient response to keep VBAT above minimum voltage.

Copyright © 2015, Texas Instruments Incorporated

Normally, the voltage difference between the input source and the desired output (VBAT normal) is not large; a LDO power supply would be preferable for its smaller size and cost.

Copyright © 2015, Texas Instruments Incorporated

3 Block Diagram

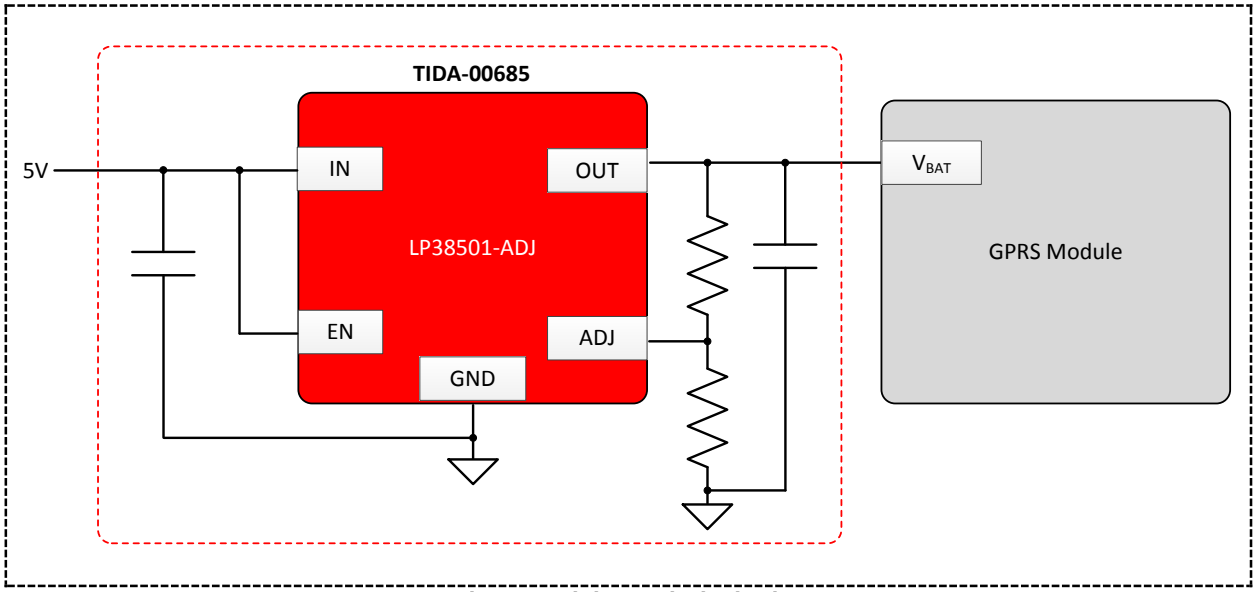


Figure 2 High Level Block Diagram

Figure 2 gives a high level block diagram of the system. The red block represents the focus component of this document. The grey block is non TI components.
Grey component is mentioned in this document and its power requirement is defined and taken into consideration to specify the system requirements and test parameters; however this component was not design into the TIDA-00685 evaluation board and some of its application specific requirements are not mentioned, it is recommended to review their datasheet for additional application implementation requirements.

3.1 Highlighted TI Products

TIDA-00685 features the following Texas Instruments (TI) regulator. This device was chosen taking into account the power requirements of GPRS module.

LP38501-ADJ: 3A, Low Dropout Linear Regulator

3.1.1 LP38501-ADJ

The LP38501-ADJ is a 3A low dropout linear regulator, which operates from a 2.7V to 5.5V input supply. This ultra-low dropout linear regulator responds very quickly to step change in load, which makes it suitable for low voltage application. Developed on a CMOS process, (utilizing a PMOS pass transistor), the LP38501-ADJ has low quiescent current that changes little with load current.

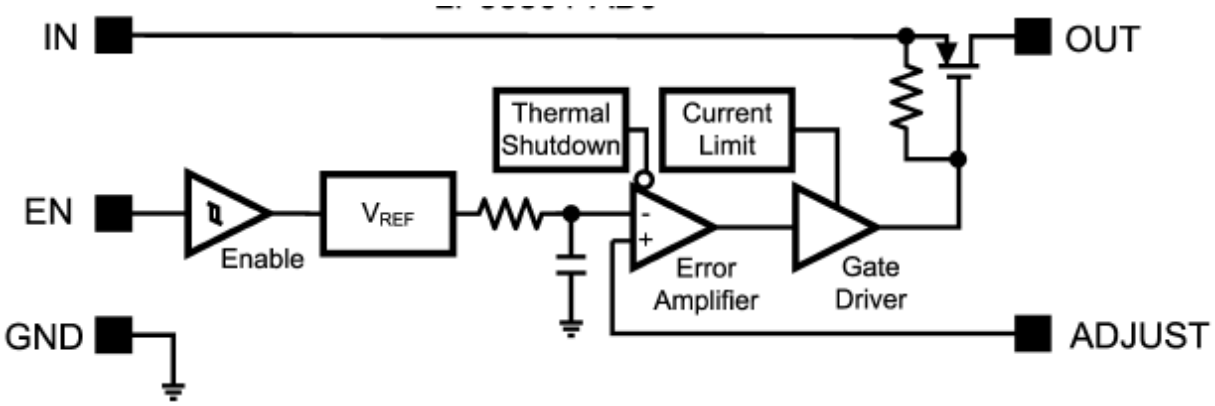


Figure 3 LP38501-ADJ Functional Block Diagram

Copyright © 2015, Texas Instruments Incorporated

The LP38501-ADJ has below features:
Simplified Compensation: Stable with any type of output capacitor, regardless of ESR.

Load transient Response: The LP38501 employs an internal feedforward design which makes the load transient response much faster than would be predicted simply by loop speed, this forward means any voltage changes appearing on the output are coupled through to the high-speed driver used to control the gate of the pass FET along a signal path using very fast FET devices. Because of this, the pass transistor's current can change very quickly.

Copyright © 2015, Texas Instruments Incorporated

4 Design Considerations

This section gives an overview of GPRS module operation mode, the GPRS module usually transfers between different modes according to system requirement. Different modes acquire different current from supply.

4.1 GPRS Operation Mode

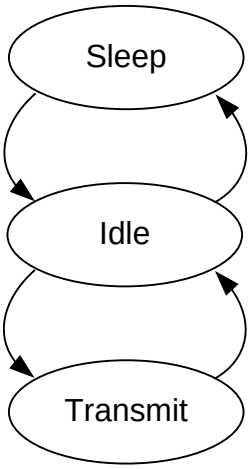


Figure 4 GPRS Operation Mode Flow

Figure 4 shows GPRS operation modes transferring flow.

Sleep Mode: in this mode, the module can receive paging message and SMS from the system normally; the current consumption of module will reduce to the minimal level.

Idle Mode: In this mode, the module is not registered to GPRS network. The module is not reachable through GPRS channel. During idle mode, the current consumption is much small.

Transmit Mode: in this mode, the module is registered to GPRS network, the PDP (packet data protocol) context is active, and the module is going on receiving or transmitting GPRS data. During this mode, the maximum current consumption can be up to 2A.

4.2 GPRS Power Supply Requirements

This section provides power supply requirements of a typical GPRS module. The M10 GPRS module from Quectel is used as an example to show the power requirements of a typical GPSR module.

Table 2 shows the current consumption of GPRS module operation mode, for detail information about application implementation, please refer to M10 datasheet, it can be obtained from Quectel Technologies Corp.

Table 2 M10 Module Specifications

PARAMETERS		M10 (Quectel)
V_{BAT} (V)	Min	3.4
	Type	3.8
	Max	4.5
I_{SLEEP} (mA)		1.1
I_{IDLE} (mA)		12
$I_{TRANSMIT}$ (A)		2

Copyright © 2015, Texas Instruments Incorporated

5 Design Implementation Guidelines

This section gives design implementation based on above section GPRS module specifications.

5.1 Input and Output Capacitor

The LP38501 requires that at least 10uF capacitors be used at the input and output pins located within one cm of IC. Larger capacitors may be used without limit on size for both CIN and COUT. Capacitor tolerances such as temperature variation and voltage loading effects must be considered when selecting capacitors to ensure that they will provide the minimum required amount of capacitance under all operating conditions for the application.
In general, ceramic capacitors are best for noise bypassing and transient response because of their ultra-low ESR. It must be noted that if ceramics are used, only the types with X5R or X7R dielectric ratings should be used.

5.1.1 Input Capacitor

To ensure proper loop operation, the ESR of the capacitor used for C_{IN} must not exceed 0.5ohm. Any good quality ceramic capacitor will meet this requirement.

5.1.2 Output Capacitor

Any type of capacitor may be used for COUT, with no limitations on minimum or maximum ESR, as long as the minimum amount of capacitance is present. The amount of capacitance can be increased without limit. Increasing the size of COUT typically will give improved load transient response.

5.2 Setting the Output Voltage

The output voltage of LP38501-ADJ is set to 3.8V using two external resistors shown as R1 and R2 in Figure 5.

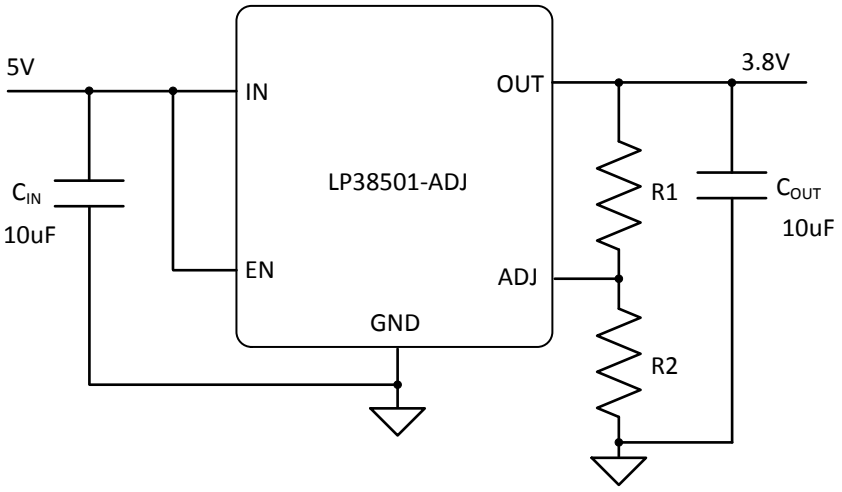


Figure 5 LP38501-ADJ Design Circuit

The value of R2 should be always be less than or equal to 10kΩ for good loop compensation. R1 is selected for 3.8V using the following formula:

$$V_{OUT} = V_{ADJ} \times \left(1 + \frac{R1}{R2}\right) + I_{ADJ} \times R_1 \quad (1)$$

Where, V_{ADJ} is the adjust pin voltage, I_{ADJ} is the bias current flowing into the adjust pin, for LP38501-ADJ, V_{ADJ} is 0.6V, I_{ADJ} is 50nA.
If R2 is selected as 10kΩ, then R1 is selected as 53kΩ.

Copyright © 2015, Texas Instruments Incorporated

6 Test Data

The test data in this section only applies to the parameters mentioned in this document, for alternative configuration it is recommended to review the datasheet of the cited devices.

6.1 Test Equipment

The following table shows the test equipment used in this sections.

Table 3 Test Equipment

Test Equipment	Part Number
Linear Voltage Supply	Agilent E3631A
Oscilloscope	TekDPO5104B
Multi-meter	Agilent E34401A

6.2 Load Regulation

As GPRS module works in different mode, it requires different current consumption; the power supply output should be within GPRS module range.

Table 4 shows the GPRS supply output voltage in different mode.

Table 4 Power Supply Voltage under Different Mode

Mode	GPRS Supply Output Voltage
Sleep Mode	3.838V
Idle Mode	3.836V
Transmit Mode	3.829V

6.3 Load Transient

During mode transferring, the power supply should not drop out of GPRS module range.

Figure 6 Transient Response during Transfer between SLEEP and IDLE Mode

Copyright © 2015, Texas Instruments Incorporated

Figure 6 shows power supply output voltage during mode transfer between Sleep and Idle mode, the output shows a little overshot and undershot.

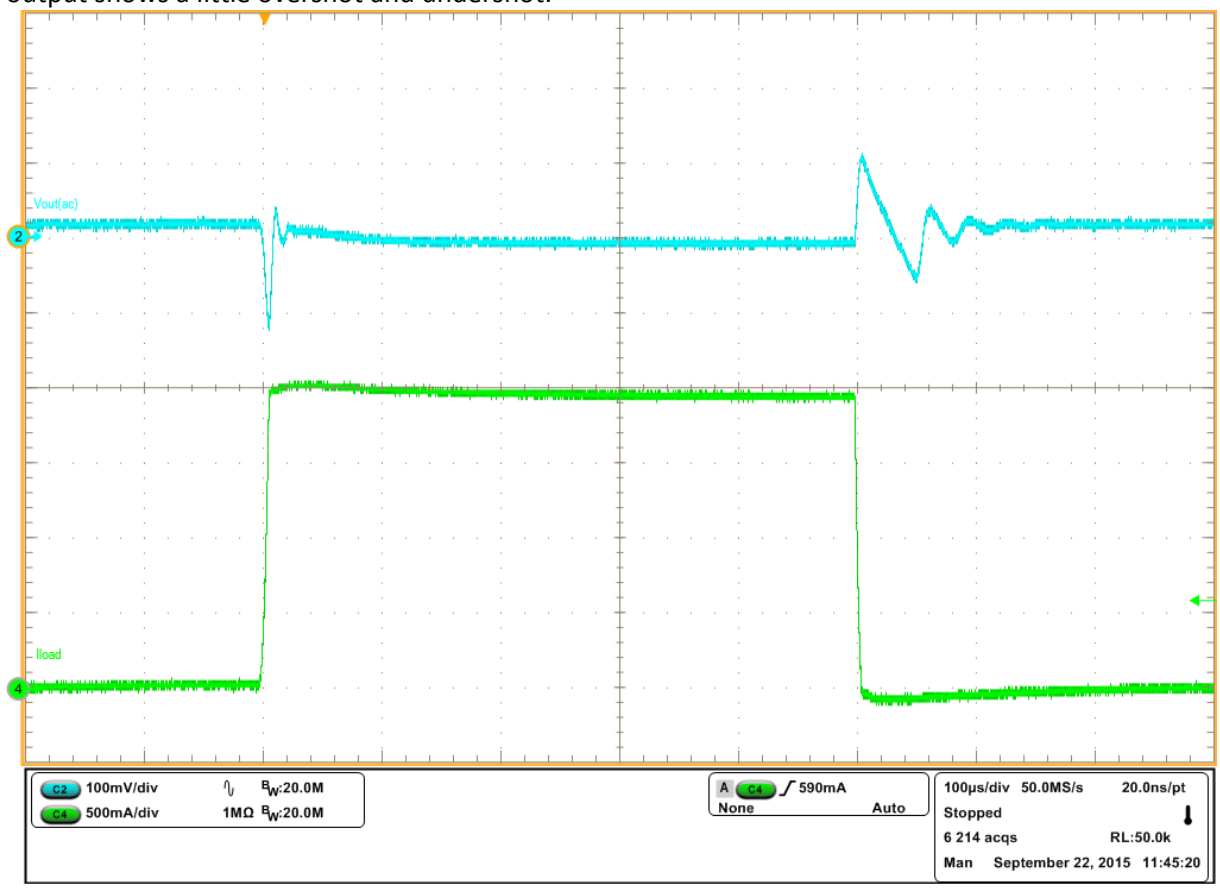


Figure 7 Transient Response during Transfer between IDLE and TRANSMIT Mode

Figure 7 shows power supply output voltage during mode transfer between IDLE and TRANSMIT mode, the output shows 120mV undershot and 120mV overshot, within GPRS module range.

6.4 Load Transient Improved

For better load transient response, it can be achieved by increasing output cap.

Figure 8 shows load transient response by increasing output capacitor to 22uF, the output shows 110mV undershot and 100mV overshot, while if keep increasing output capacitor to 47uF, the output shows 100mV undershot and 80mV overshot as in Figure 9.

Copyright © 2015, Texas Instruments Incorporated

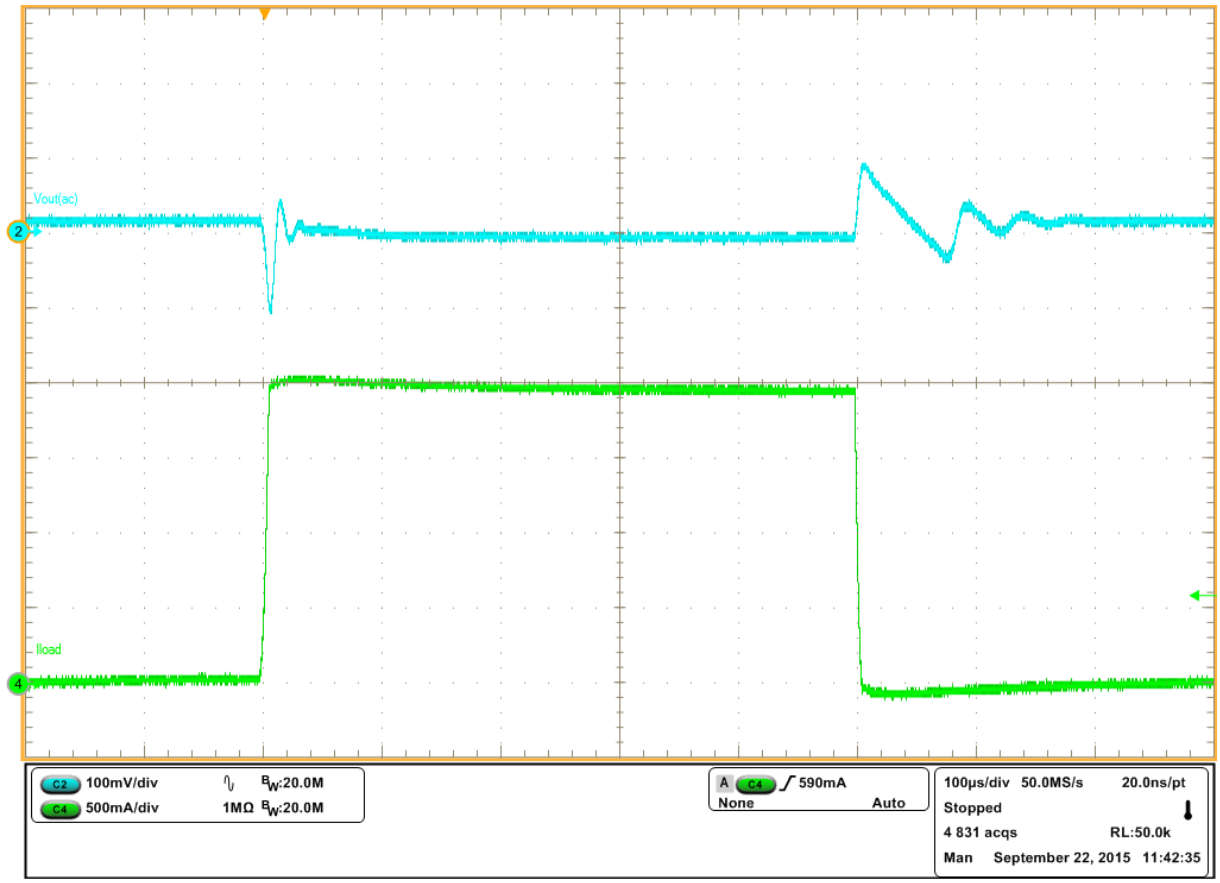


Figure 8 Transient Response during Transfer between IDLE and TRANSMIT Mode with 22uF Cap

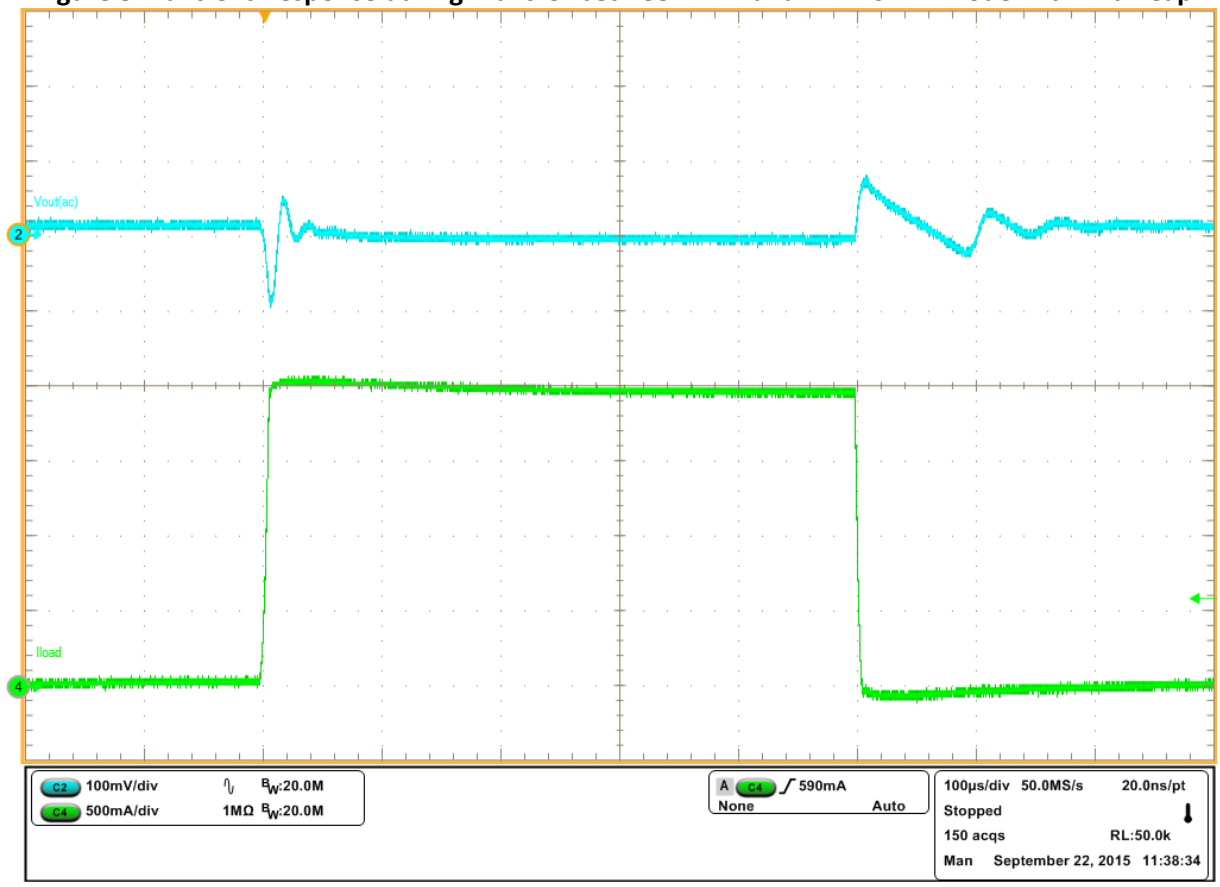


Figure 9 Transient Response during Transfer between IDLE and TRANSMIT Mode with 47uF Cap

Copyright © 2015, Texas Instruments Incorporated

7 Design Files

7.1 Schematics

To download the Schematics for each board, see the design files at http://www.ti.com/tool/TIDA-00685

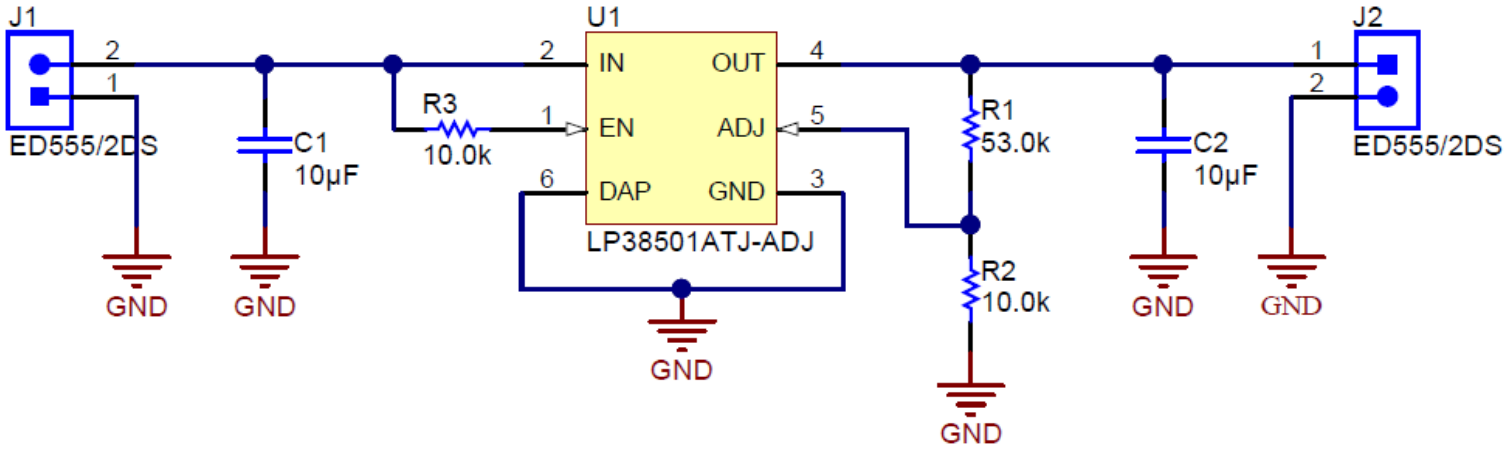


Figure 10: TIDA-00685 Schematic

Copyright © 2015, Texas Instruments Incorporated

7.2 PCB Layout Recommendations

7.2.1 Layout Guidelines

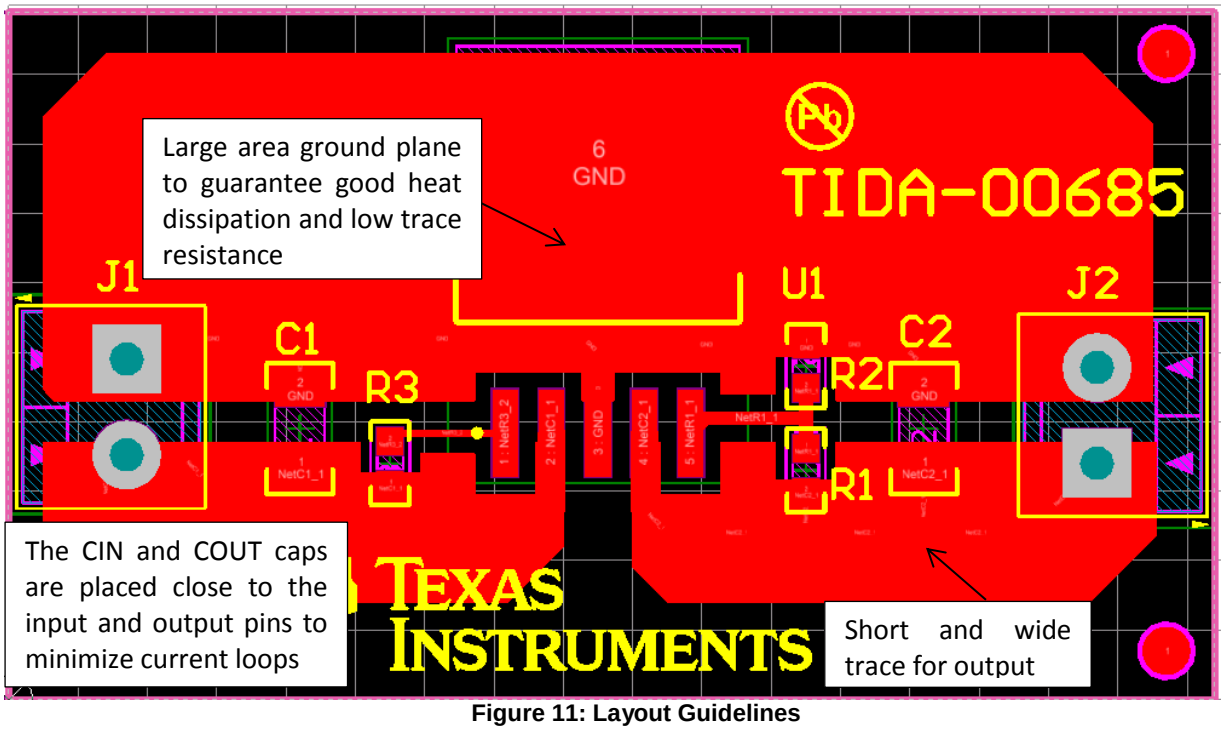


Figure 11: Layout Guidelines

Copyright © 2015, Texas Instruments Incorporated

7.2.2 Altium Project

To download the Altium project files for each board, see the design files at.
http://www.ti.com/tool/TIDA-00685

- Gerber and NC-drills
- Bill of Materials (BOM)
- Assembly Drawings

8 References

1. Quectel, Hardware Design, M10 Hardware Design, 2010

9 Terminology

TI Glossary: SLYZ022 This glossary lists and explains terms, acronyms, and definitions.

10 About the Author

Hank Cao
Is a System Engineer at Texas Instruments on the RF power group at Texas Instruments.

Copyright © 2015, Texas Instruments Incorporated

IMPORTANT NOTICE FOR TI REFERENCE DESIGNS

Texas Instruments Incorporated ("TI") reference designs are solely intended to assist designers (“Buyers”) who are developing systems that incorporate TI semiconductor products (also referred to herein as “components”). Buyer understands and agrees that Buyer remains responsible for using its independent analysis, evaluation and judgment in designing Buyer’s systems and products.

TI reference designs have been created using standard laboratory conditions and engineering practices. **TI has not conducted any testing other than that specifically described in the published documentation for a particular reference design.** TI may make corrections, enhancements, improvements and other changes to its reference designs.

Buyers are authorized to use TI reference designs with the TI component(s) identified in each particular reference design and to modify the reference design in the development of their end products. HOWEVER, NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY THIRD PARTY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT, IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI REFERENCE DESIGNS ARE PROVIDED "AS IS". TI MAKES NO WARRANTIES OR REPRESENTATIONS WITH REGARD TO THE REFERENCE DESIGNS OR USE OF THE REFERENCE DESIGNS, EXPRESS, IMPLIED OR STATUTORY, INCLUDING ACCURACY OR COMPLETENESS. TI DISCLAIMS ANY WARRANTY OF TITLE AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, QUIET ENJOYMENT, QUIET POSSESSION, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS WITH REGARD TO TI REFERENCE DESIGNS OR USE THEREOF. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY BUYERS AGAINST ANY THIRD PARTY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON A COMBINATION OF COMPONENTS PROVIDED IN A TI REFERENCE DESIGN. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, SPECIAL, INCIDENTAL, CONSEQUENTIAL OR INDIRECT DAMAGES, HOWEVER CAUSED, ON ANY THEORY OF LIABILITY AND WHETHER OR NOT TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, ARISING IN ANY WAY OUT OF TI REFERENCE DESIGNS OR BUYER’S USE OF TI REFERENCE DESIGNS.

TI reserves the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques for TI components are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

Reproduction of significant portions of TI information in TI data books, data sheets or reference designs is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards that anticipate dangerous failures, monitor failures and their consequences, lessen the likelihood of dangerous failures and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in Buyer’s safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed an agreement specifically governing such use.

Only those TI components that TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components that have ***not*** been so designated is solely at Buyer's risk, and Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2015, Texas Instruments Incorporated