PROJECT TITLE: ***Low power field device with integrated SMS-Interface and energy harvester for autonomous sending of measuring data and messages.***

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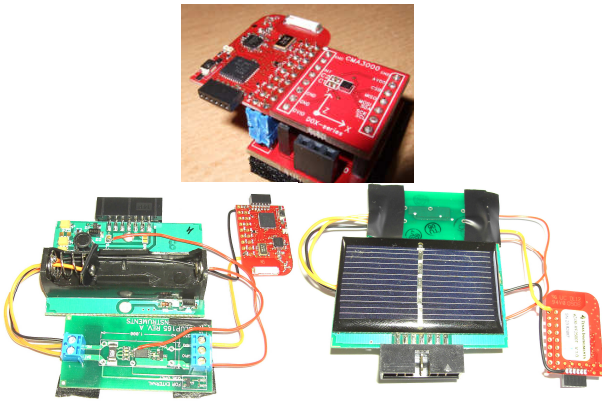
DATE: 26*/06/2010*

TI PARTS USED IN PROJECT: ***Quantity, TI Part Number, TI Website***

Quanti-ty	***TI Part Number***	***TI Website***
2	MSP430F2274	http://focus.ti.com/docs/prod/folders/print/msp430f2274.html
2	CC2500	http://focus.ti.com/docs/prod/folders/print/cc2500.html
1	CC1100	http://focus.ti.com/docs/prod/folders/print/cc1100.html
1	BQ26220	http://focus.ti.com/docs/prod/folders/print/bq26220.html
2	TPS61200	http://focus.ti.com/docs/prod/folders/print/tps61200.html
1	TLV431	http://focus.ti.com/docs/prod/folders/print/tlv431.html
1	OPA379	http://focus.ti.com/docs/prod/folders/print/opa379.html
1	TMP112	http://focus.ti.com/docs/prod/folders/print/tmp112.html
-	TWL3016	Only for high-volume OEMs
-	TRF6150	Only for high-volume OEMs



PROJECT ABSTRACT

Within the scope of the Texas Instruments Analog Design Contest a Low power sensor network is implemented consisting of a base station and several satellites which are used in homely environment for the monitoring. Integrated solar panels provide for the energy supply of the modules, so that these modules can be pursued independent of the public supply mains. The base station owns a GSM modem to be able to send the messages with the help of the predefined "Message Services" like SMS or MMS.

Introduction

The major task of the system is the capture of different data or the monitoring of the surroundings on different environmental aspects like the temperature or security aspects like the movement and the sending the acquired data by means of GSM message services.

The system consists of several satellites and a base station. The satellites are distributed in the rooms and operate as interfaces to different sensors. They process the data and send this further on 2.4 GHz ISM band to the base station. The base station must process these data and inform accordingly the owner on his phone using GSM message services like SMS or MMS.

For the communication between the modules we will use a protocol, which was already developed for such applications from Texas Instruments named SimpliciTI.

All modules have a power supply interface for the battery or for the different energy harvesting technologies. Within the scope of the project it will be used a passive solar power from the solar cells with a energy storage, so that the system can be used autonomous from the public supply mains and in almost every environment.

Motivation for the Project

Everybody wants to live in a safety environment and safety home.
Also the people would like to control any situation even if they are far away from this.
The issue of climate change and global warming is very topical at the moment and interests many people.

We wanted to summarise these subjects into our project and develop an ecologically friendly smart and safety home concept for every household.

Theoretical Background

SimpliciTI™ Network Protocol

The SimpliciTI network protocol is a proprietary, low-power radio-frequency (RF) protocol targeting simple, small RF networks (<100 nodes). The SimpliciTI network protocol is designed for easy implementation with minimal microcontroller resource requirements. The protocol runs out of the box on TI's MSP430 ultra-low-power microcontrollers and multiple RF transceivers.

Small low-power RF networks typically contain battery-operated devices, which require long battery life, low data rate, and low duty cycle, and have a limited number of nodes talking directly to each other. With the SimpliciTI network protocol, MCU resource requirements are minimal, resulting in lower system cost for low-power RF networks. More complex mesh networks that need routing typically require 10 times the program memory and RAM to implement.

Despite the modest resources required, SimpliciTI network protocol supports End Devices in a peer-to-peer network topology, the option to use an Access Point to store and forward messages, and Range Extenders to extend the range of the network up to four hops. Future releases will add more sophisticated features such as frequency agility, an ETSI-compliant listen-before-talk discipline, and a software security routine for message encryption.

The SimpliciTI network protocol supports a wide range of low-power applications including alarm and security (smoke detectors, glass breakage detectors, carbon monoxide sensors, and light sensors), automated meter reading (gas meters and water meters), home automation (appliances, garage door openers, and environmental devices), and active RFID.
The SimpliciTI network protocol is provided as source code under a free license without royalties.

HDQ Protocol

Most battery monitor ICs from TI, such as the BQ2019 and BQ26500, include a single-wire serial data interface (HDQ bus). Host controllers can use this interface to access various on-chip registers to read-out battery capacity, voltage, and other parameters.

The HDQ bus is a master-slave bus system using a simple one-wire, asynchronous, bidirectional, serial interface with a bit-rate of about 5-Kbit/s. The bus line is driven by opencollector devices and therefore requires an external pull-up resistor. The relatively slow bit rate is sufficient for reading out as well as setting registers in battery monitor ICs. The host may only need to communicate at infrequent intervals to update the user with the latest runtime computation, thus minimizing communication and saving power.

The protocol is command-based and data is transferred in blocks of 2 bytes. The first byte is always sent by the host (master) and contains the client register address (7-bit). It also contains the R/W-bit, which determines if the next byte is send by host to the client (R/W = 1) or read from the client by the host (R/W = 0).

Structure & Functions

On the figure 1 there is the full structure of the system:

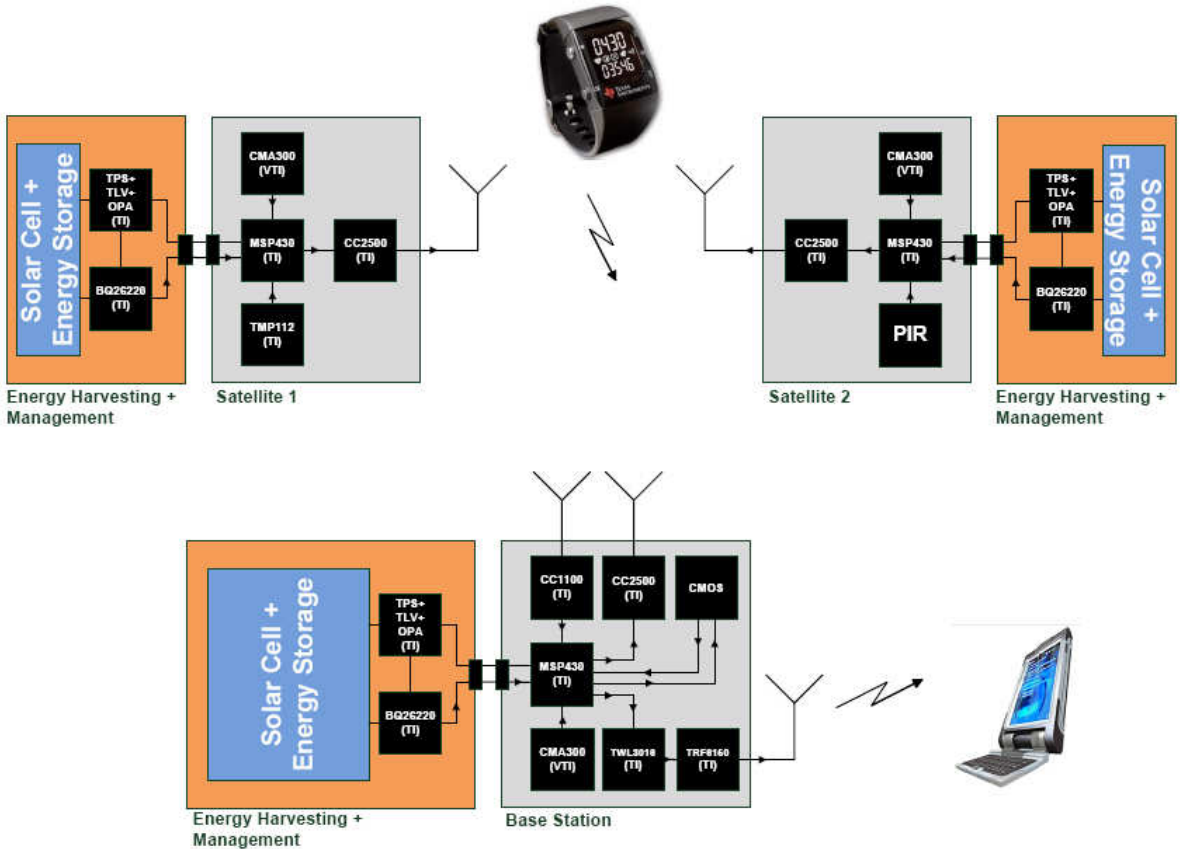


Figure 1: block diagram from the system

Every Board will be supplied from the solar cell and energy storage. The state of the storage will be measured by the BQ26220. Every board has a 3-axis-sensor CMA300 from VTI to register their own movement and CC2500 to communicate with each other. Every Satellite has his own function e.g. temperature measurement with TMP112 (or with MSP) or movement detection with PIR. The Base station has also a CC1100 receiver to communicate with the eZ430-Chronos, a CMOS Chip to make pictures and two TI GSM Chips e.g. TWL3016 and TRF6150 for sending SMSs and MMSs.

There are a lot of functions possible with such construction.

“Monitoring ON/OFF”-Function

The owner can start the special program on the eZ430-Chronos, which is able to activate or deactivate the monitoring network. The base station is able to receive this order using CC1100 receiver.

Special Satellite-Function

Every Satellite has his own function e.g. temperature measurement or movement detection. This can be realized with different sensors like TMP112. There are continuous functions like temperature measurement every minute or interrupt functions like movement detection with passive infrared sensors, which sends the message to the base station, so it can make a picture of the interloper in the house and send this picture to the owner using MMS.

“I am dying”-Function

The BQ26220 is an advanced battery monitoring device designed to accurately measure the charge and discharge currents in rechargeable battery packs. The BQ26220 includes a single-wire HDQ serial data interface to the MSP430. If the battery charge is to low, the MSP430 on the satellite sends the “I am dying” message using SimpliciTI protocol to the base station. The base station sends this message to the owner using SMS.

“I was moved”-Function

Every board has a CMA3000 3-axis ultra low power accelerometer from VTI Technologies. This sensor sends his data to the MSP430. If the board was moved, the MSP430 will detect this and perhaps send the message to the to the base station (if it is satellite) or immediately send a “I was moved” SMS to the owner (if it is a base station).

“I am OK”-Function

Every satellite sends continuous “I am OK” message to the base station to let it know that everything is working like it should.

The benefit of the design are the MSP430 low power modes, so it is possible to use the solar cells for supply. Also it manages all energy for the complex circuits, so it can be possible to use the complex functions regularly for a short period of time without any big energy storage or solid power supply.

The BQ26220, CC1100, CC2500, TMP112 implement very complex analogue functions, but have a very simple digital interface, which allows an enjoyable work with them on the digital side of the design.

Two features of the TPS61200 ideally fit the needs of applications running from a single solar cell. The first and most important feature is the very low start-up voltage. The TPS61200 is able to start from a load of 0.5 V and will run down to voltages below 0.3 V. This feature differentiates this boost converter from other converters and makes it ideal for being supplied by solar cells.
The second feature offers a great advantage for additional circuitry that do not consume much power but needs to be started or running when the main circuit is disabled. The additional circuitry can run from the VAUX output. This output already offers a voltage at very low input voltages (>150 mV typ.) and can drive currents of about 1 mA.

Problems

In the course of the project some problems have appeared. First of all the GSM chips TWL3016 and TRF6150 are only for high-volume OEMs available. The GSM-Modems from other manufacturers are not for solar cell supply and needs more energy than these two chips. Nonetheless we made an order list with the alternative parts we need.

Bezeichnung	Menge	Preis pro St.	Funktion	Hersteller	URL
GM862-GPS	1	76 €	GSM Modem	Telit	http://www.roundsolutions.com/pdf/Price-Modules-GSM.pdf
CMOS Kamera	1	23 €	Kamera für GSM Modem	---	http://www.roundsolutions.com/pdf/Price-Modules-GSM.pdf
GM862 Board 50-Pin	1	$ 29,95	GSM Modem	---	http://www.sparkfun.com/commerce/product_info.php?products_id=277
GPS Antenna	1	$ 12,95	GSM Modem	---	http://www.sparkfun.com/commerce/product_info.php?products_id=464
GSM Antenna	1	$ 7,95	GSM Modem	---	http://www.sparkfun.com/commerce/product_info.php?products_id=675
Cable MMCX to SMA	2	$ 8,95	GSM Modem	---	http://www.sparkfun.com/commerce/product_info.php?products_id=285
CMA3000-D01-PWB	3	40 €	Beschleunigungssensor	VTI Technologies	http://shop.hy-line.de/index.php?cPath=2_35
VTI_MSP430 Adapter	3	15 €	Beschleunigungssensor	---	http://shop.hy-line.de/index.php?cPath=2_35
PIR235	3	$ 4	Pyroelectric Infrared Sensor		http://www.glolab.com/pirparts/pirparts.html
Lens FL65	2	$ 4	FL65 Fresnel Lens		http://www.glolab.com/pirparts/pirparts.html
Lens FL25	2	$ 2,4	FL25 Fresnel lens		http://www.glolab.com/pirparts/pirparts.html
Solarzelle + Akku	3	9,95 €	Versorgung	OLIMEX	http://www.olimex.com/dev/index.html

Figure 2: order list with alternative parts

But after a ~1.5 months waiting for this parts we decided to concentrate our project on the energy harvesting & management board. We decided to develop our own board with own schematic circuit diagram and layout. Also we decided to implement one satellite which measures temperature with intern sensor on MSP430 using our energy harvesting & management board.

Platforms

Texas Instruments offers a wide range of different Development Kits. The core of this project is an eZ430-RF2500 target board, which is the base of the satellite as well as of the base station. The eZ430-RF2500 is a complete USB-based MSP430 wireless development tool that provides all of the hardware and software to evaluate the MSP430F2274 microcontroller and CC2500 2.4-GHz wireless transceiver. The eZ430-RF2500T target board is an out-of-the-box wireless system that may be used with the USB debugging interface, as a stand-alone system with or without external sensors, or incorporated into an existing design.

For Energy Harvesting & Management Board there were used the BQ26220 evaluation board.

As integrated development environment (IDE) for the software there were used a Code Composer studio v4 and IAR Embedded Workbench.

Implementation

For the implementation of the satellite we used a concept of a sensor end device. The satellite should send measuring values to the base station, which is an access point connected with PC for the comfortable debugging, depending on the still available energy.

The energy storage is realized as a battery or large capacitors for the energy collection. The energy comes either from a solar cell, or from other energy sources. So that different sources are possible to use, the measure of the charge amount occurs directly on the storage device.

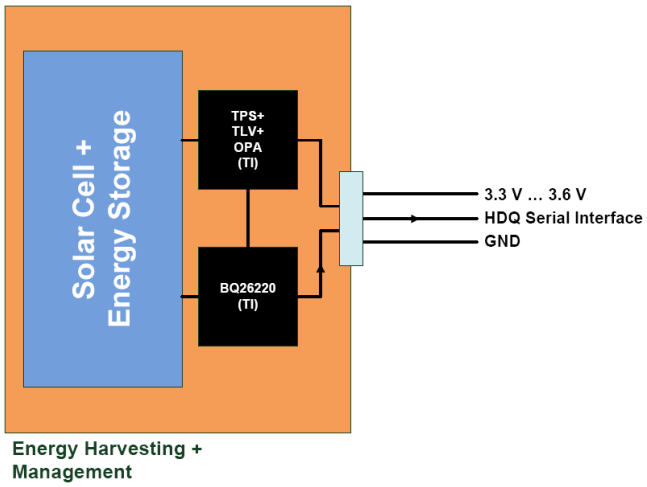


Figure 3: Energy Harvesting & Storage

The satellite has a several 3 working modes.

Normal Mode

In the normal mode the satellite logs the sensor data. The timer period for sending the data or for the low power mode of MSP430 is directly proportional to the charge of the energy storage. The satellite sends his data and the battery charge to the base station.

Energy Saving Mode

In the energy saving mode the satellite does not log the sensor data. It just sends the value of the energy storage. The base station knows that it is *“I am dying”-message* from the satellite and that means that it changes soon his mode in an emergency mode.

Emergency Mode

In this mode there will be only checked whether the energy storage was further loaded again, so that the topical charge state can be send to the base station. To save as lot energy as possible there will be no communication with the base station.

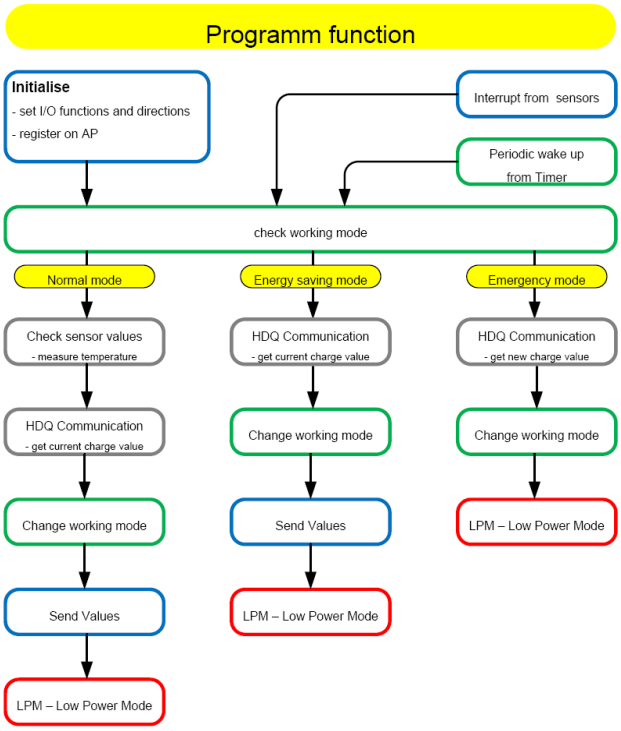


Figure 4: Flowchart

Schematic

The schematic shows the circuit to collect the energy form the Solar Cell and store it. This schematic can be divided in two parts. The part on top describes a simple solar circuit. This circuit reduces the 2.4V from the solar with two diodes to supply the rechargeable NIMH battery. IC6 the TPS61220 convert the 1.2 Volt from the AA cell to 3.3V to supply the RF2500 board and the BQ26220. IC3 the coulomb counter measure the charge and discharge of the AA Cell by the voltage drop on R17.

The second part of the schematic shows a more complex circuit with **M**aximum **P**ower **P**oint control. This circuit consists of a TPS61200 is boosting the input voltage to charge

the supercapacitors. Due to the high conversion ratio which is necessary to boost from about 0.5 V to a suitable supply voltage for the application in a range up to 3 V, the input current is increasing to hundreds of mA. Without additional control, the output voltage of the solar cell collapses. The DC-DC converter basically shorts the solar cell because it tries to draw enough current to maintain its output voltage. This current may be more than the solar cell can provide, and the system latches in this condition. Therefore the TPS61200 VAUX capacitor provides a power source that can be used to drive additional low-power circuits from a low-input voltage and before the main output is operating. To dynamically control the input current, the additional MPP circuit (framed circuit) is added. The operational amplifier is connected to VAUX as well as the additional voltage reference. The selected operational amplifier is a low-power-consuming, rail-to-rail amplifier that is able to work at low supply voltages. Also, the voltage reference has low power consumption.

Because this additional circuit is powered by VAUX, it starts working before the main switch of the converter is turned on and the main power output becomes active. The operational amplifier output is connected to the feedback pin of the TPS61200 to control the output voltage of the converter depending on the supplied input voltage of the solar cell. The operational amplifier is working mainly as a comparator which compares the voltage at the solar cell to a voltage reference. This voltage reference is generated by the TLV431 and can be adjusted by changing the resistor dividers R4 and R5 for different solar cell types and light conditions.

The result is a smooth start-up without overloading the solar cell. In addition, the MPP circuit increases the start-up time depending on the power available from the solar cell. Because of the extreme light changes that can happen for solar cell applications, it is important to use an energy storage device after the TPS61200 boost converter. This is realized by two supercaps each 1F / 5.5V. The time gap that can be bridged depends on the time the chargeable device was charged, the capacity, and finally the leakage of the energy storage device. This is like in the first part measured by the BQ26220 with the voltage drop above R14.

Because of the supply range for the BQ from 2.8V to 4.5V and the MSP from 1.8V to 3.6V, there is only a margin of 0.8V. Therefore it is a second step up converter necessary, to supply the circuit. There are two alternatives available TPS61221 with a low leakage current, and a second TPS61200 with a low start up voltage. So with this circuit the two different solutions of part1 and part2 can be tested.

Layout

The board layout occupies a size of 80mm to 50mm. This includes the place for the solar cell for a size of 50mmx36mm and the complete circuit with the two parts on the top side. On the bottom there you can mount the rechargeable NIMH and the supercaps. On the top side there is also a little extension area for SMD and THT parts available. With jumper you can decide which part of the circuit to operate, the simple or the complex one.

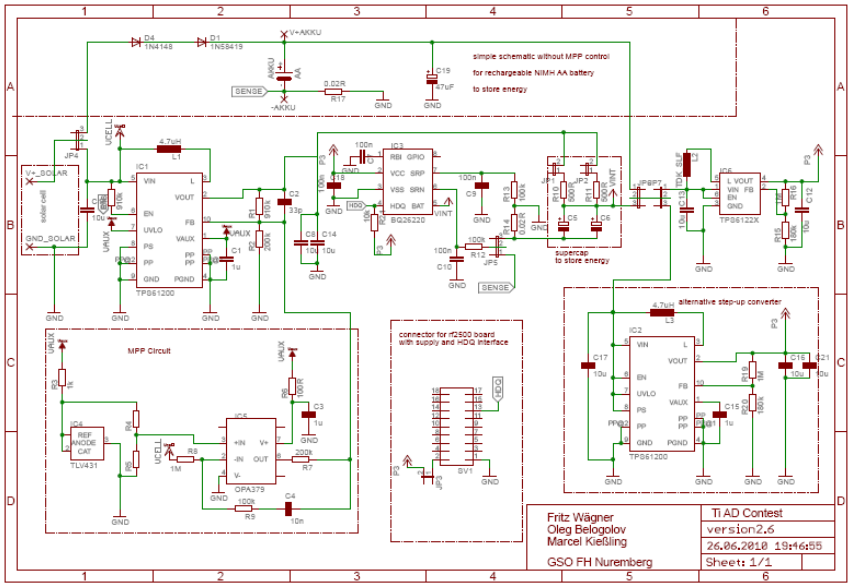


Figure 5: schematic

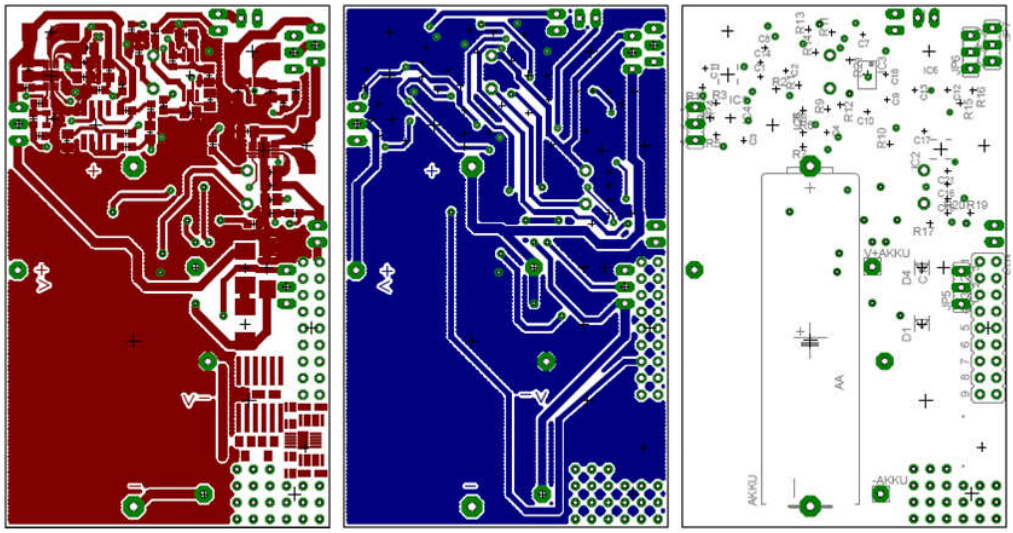


Figure 6: Layout Top Side, Bottom Side, Parts

Summary

The current stage of work is that we were not able to test our software, because there are strange problems with the Code Composer Studio and the SimpliciTI firmware. Our board was not manufactured, so we were able to make just the simple circuit without MPP control using the BQ26220 evaluation board and eZ430-RF2500 target board.