Project Necromancer
Design Document

Sponsored By: The Rainforest Connection (RFCx)

Submitted By: Joe Gibson gibsjose@mail.gvsu.edu
David Adlof adlofd@mail.gvsu.edu
Kalee Stutzman stutzmak@mail.gvsu.edu
Jesse Millwood millwooj@mail.gvsu.edu

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Executive Summary

Software, electrical, and hardware enhancements to Rainforest Connection's currently used device are proposed in this paper. The electrical enhancements include the addition of a new PCB that contains power regulation and battery charging circuitry, along with current, voltage, temperature, and humidity sensors. The software enhancements include sending sensor measurements to an Android cellphone. Sending measurements from the PCB to the phone will allow for diagnostic feedback that can be used for laboratory testing and verification as well as field statistics. The point of this project is not to entirely redesign the existing device but rather to provide modular enhancements and improvements to specific components.

Power consumption is a major concern and a key area for improvement on the existing device. We will use *Max Point Power Tracking*(MPPT) ICs in the design of the power regulation and solar panel interface to ensure maximum efficiency from the solar panels. In addition we will use Lithium-Ion battery management ICs to ensure that the batteries are properly charge, properly discharge, and to prevent overheating. A switching power regulator will boost the voltage from either the batteries or the solar panel to charge the phone and a linear dropout regulator will provide 3.3V to the regulation and diagnostic circuitry on the PCB.

Temperature is another major concern. To mitigate the heat produced by the phone, the power circuitry, and the environment, a heatsink will be attached to the PCB with direct thermal contact with the phone. The heatsink will extend outside of the enclosure, transferring heat outside of the device enclosure.

Sending diagnostics will be achieved using an 8-bit Atmel ATmega328P microcontroller. Power, temperature, and humidity data will be sent from the microcontroller to the cell phone via USB, where it will be received and displayed by an Android application.

Keywords

Rain forest, Recycling, RFCx, Rainforest Connection, cellphone, Android, logging

Grand Valley State University

1 Introduction and Design Background

Rainforest Connection (RFCx) is a non-profit organization that is dedicated to stopping illegal logging and deforestation in rainforests throughout the world. The destruction of tropical rainforests is a leading cause of CO2 emission, and much of it is caused by illegal activities. RFCx combats illegal logging by using re-purposed cellphones strategically placed in trees in remote areas. These cell phones listen and record audio streams at all times, using their data connection to periodically send audio data to the RFCx server, where it is processed. Digital signal processing algorithms are used to detect the sound of chainsaws and engines at a distance of up to $\frac{2}{3}$ of a mile, because the sheer size of the area covered by a single human makes it impractical, if not impossible, to properly monitor the forests for illegal activities without the aid of technology. If a chainsaw is detected, a real-time alert is sent to pre-existing ground patrols, who can react to the situation and combat the threat. In addition to man-made sounds, the RFCx platform is also used to record the sounds of animals in the forest. These sounds can be used to gain information about certain species of animals and are open to anyone to use and analyze.

RFCx Project Necromancer is a project involving the design of new hardware, as well as upgrades to the existing hardware. The principal objective is to merge all of the external electronics into a custom printed circuit board. This involves integrating the regulation circuitry, photovoltaic battery charge controller, sensors (temperature, power, etc.), microcontroller, and other supporting electronics into a single board. Power, temperature, and humidity diagnostics will be sent from the microcontroller to the Android phone. Relaying the collected diagnostic data to the server is possible with the existing framework but outside of the scope of this project. Instead, the collected data will be displayed for testing and verification purposes.

On the PCB, an ATMega328P microcontroller (28) will be used. An SPV1040 Max Point Power Tracker (MPPT)(38) will be used to obtain the maximum power from the solar panels and to efficiently charge the Lithium-Ion batteries(32). Current and voltage measurements on both the solar panel inputs as well as the output to the batteries will be measured by using an external ADC. The ADC chosen is a low-power TI ADS1015(27), which has four single-ended analog inputs, and draws as little as 150uA under worst case conditions. Two options were considered for temperature, one also providing humidity measurements. The single temperature sensor is the NXT LM75BD(33), which is a super low power temperature sensor with an accuracy of $\pm 2^{\circ}C$, communicating over I2C. It uses less around 300uA during peak transmission, and costs under $1. The combined temperature and humidity sensor is the Honeywell HIH6130(31), which is a low-power sensor with 14-bit resolution for both humidity and temperature, low-current operation, from 1uA in sleep mode to under 1mA worst case draw. The HIH6130 chip also has its own internal ADC, EEPROM, and oscillator, but costs nearly $14. The LM75BD will be used to cut costs but the HIH6130 footprint will be included but unpopulated on the final PCB as an option to the end user. All sensor ICs communicate with the microcontroller via the I2C protocol. For communication with the Android phone, the ATMega328P serial port will be interfaced through FTDI(39) to an on-board USB connector.
On the phone, the RFCx Sentinel App monitors the incoming diagnostics, displaying them to a screen, logging them to a file, and possibly transmitting them along with the audio data to the server. The RFCx Sentinel Application was developed for this project.

1.1

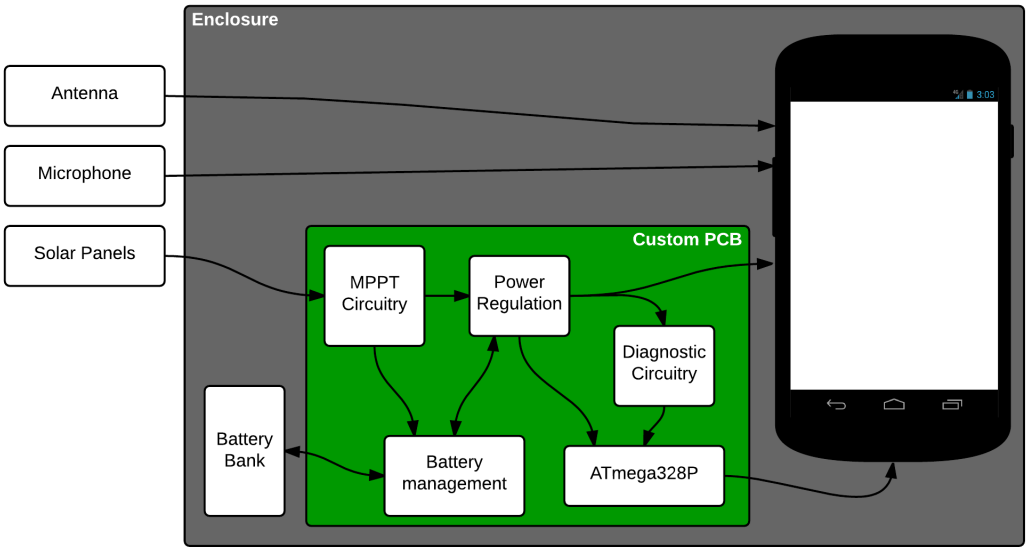

Figure 1: High Level Functional Diagram of the Major Components

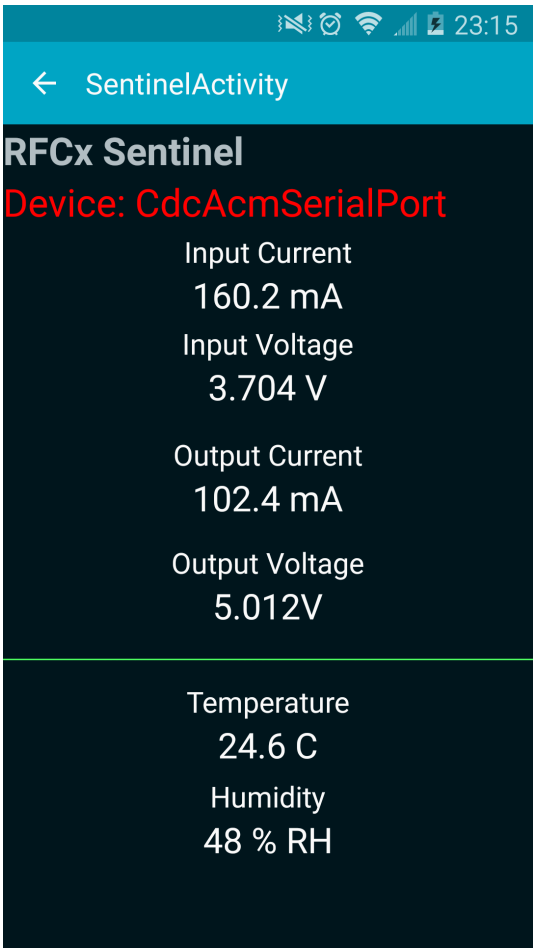

Figure 2: Actual RFCx Sentinel App Screenshot

2 Requirements and Functional Specifications

2.1 External Interfaces Requirements

This section addresses the requirements of the enhanced device pertaining to its external interfaces. External interfaces are defined as components of the device interacting with something outside of the device enclosure.

2.1.1 Hardware

Requirement 2.1.1.1. The device shall not exceed the existing power consumption and should reduce power consumption by at least 10%.

Requirement 2.1.1.2. The interface with the phone shall consist of a USB connection for power and data, a microphone connection via the standard audio jack, and a connection to the external antenna.

Requirement 2.1.1.3. The interface with the phone shall consist of a USB connection for power and data, a microphone connection via the standard audio jack, and a connection to the external antenna.

Requirement 2.1.1.4. Shielding techniques should be investigated to reduce the GSM audio interference noted by Topher White in the audio recordings.

Requirement 2.1.1.5. The microphone shall be interfaced via the standard audio jack on the Android phone.

Requirement 2.1.1.6. Camouflage color scheme may be used to conceal the device from loggers. Additional camouflage features may be added so long as those features do not cover the solar panels.

Requirement 2.1.1.7. A simple assembly process shall be well documented with illustrations.

To verify **Requirement 2.1.1.7.**. a sample group of people with varying skill levels will be asked to provide feedback on the assembly process and will be timed.

Requirement 2.1.1.8. The assembly and installation documentation may be translated into Spanish, French, and/or Portuguese.

2.1.2 Software

Requirement 2.1.2.1. The algorithm used to compress the audio signal may be compared to other existing algorithms and may be changed as such depending on the outcomes of comparative testing.

To verify **Requirement 2.1.2.1.**, audio will be recorded and compressed using multiple algorithms including the current algorithm. An infographic hosted on RFCx's website, shown in Figure 2 illustrates the flow of data that is collected from the phone and analyzed on the server.

2.2 Internal Device Requirements

This section addresses the requirements of the enhanced device pertaining to its internal interfaces and software. Internal here is defined as anything inside of the device enclosure.

2.2.1 Hardware

Requirement 2.2.1.1. The PCB shall consist of battery management circuitry, the power regulation circuitry, power interface to the phone, power monitoring circuitry, as well as the microphone interface.

To verify **Requirement 2.2.1.1.**, SPICE will be used to simulate the power charging circuitry to obtain power consumption and efficiency calculations. The manufactured and assembled board will then be subjected to a load test in a lab setting.

Requirement 2.2.1.2. The device shall use the existing external microphone and antennae

Requirement 2.2.1.3. There should be a low power microcontroller included on the PCB that communicates with the Android phone. This will be used to monitor power consumption and provide external control of peripherals through the Android Debug Bridge protocol over USB. Extra general purpose IO pins of the microcontroller should be easily accessible for interfacing with future hardware.

To verify **Requirement 2.2.1.3.**, simple packets will be sent from the microcontroller to the phone. These packets can be verified with debug tools or simple programs on the microcontroller and the phone. A debug serial port may be included as a peripheral to the microcontroller to aid in debugging. Any analog values read by the microcontroller will be verified with shop equipment.

Requirement 2.2.1.4. The monetary cost of the device, not including the solar panels, shall not exceed 25% more than the current device cost, also not including the solar panels. The current cost of the solar panels has been quoted at $200 and the rest of the device has been quoted at $200. Increases in monetary cost above the current cost and below 125% of the current cost are for enhancements in functionality (i.e. the PCB, etc.) and reductions in assembly time.

2.2.2 Software

Requirement 2.2.2.1. The microcontroller software should be capable of bi-directional communication between itself and the Android phone.

Requirement 2.2.2.2. The microcontroller software should be capable of communicating power usage diagnostics to the phone over the ADB protocol.

Requirement 2.2.2.3. An Android companion application may be capable of reporting power diagnostics from the microcontroller for testing and debugging.

Requirement 2.2.2.4. There shall be a header on the PCB to program to reprogram the microcontroller.

3 System Architecture

3.1 Hardware Specifications

PCB
The following is a list of the main IC's that make up the design of this PCB

•**Atmel ATMega328P** : 8-bit AVR microcontroller

•**SPV1040 Max Point Power Tracker** : Solar power controller and lithium-ion battery charger

•**ADS1015** : External 4-input 12-bit Analog-to-Digital Converter, I2C communication

•**LM75BD** : Ultra Low Power Temperature Sensor,$\pm 2°C$, I2C communication

•**(Optional) HIH6130** : 14-bit resolution Humidity and Temperature Sensor with accuracy of ±4% Relative Humidity and $\pm 1°C$, I2C communication

•**FT230X** : FTDI USB-UART interface for USB serial communication

•**bq2057CTS** : Linear Battery Charge Management IC

•**LM61428** : Simple Switcher Boost Controller IC

•**SM72238** : Micropower Fixed 3.3V LDO

•**LTC6800** : Rail-To-Rail Input and Output Instrumentation Amplifier

•**LTC4412** : Low loss powerpath controller

3.1.1 Hardware Design

Power Sources
The system is powered from 8 solar cells that have been manufactured by RFCx. These solar panels have been reported to have an open circuit voltage of 1.6V and produce 0.75W each. The other power source on board is two 2-cell 4400mA/Hr lithium-ion (Li-ion) battery packs. The solar panels are going to be configured in a way that a pair may be wired in either series or parallel, which will be wired in parallel with the other three pairs. The pairs will be wired how the end user would like them and the remaining wires will be connected to a terminal block with screw/leaf spring wire termination on the PCB board, which will be powering the MPPT controllers. This is illustrated in the figure 3.

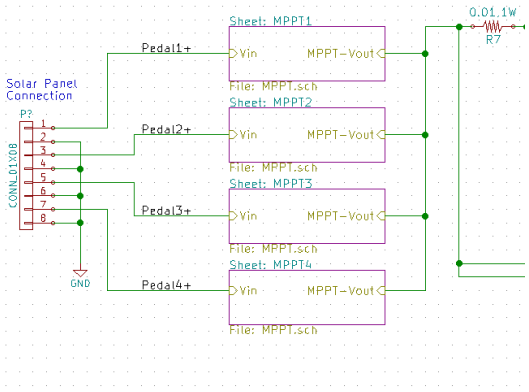

Figure 3: MPPT and Solar Panel Interface

This configuration was chosen because the end user may decide to change the panel configuration at a later date. The optimal configuration is when each pair is in parallel. Multiple MPPT chips are required for solar panels wired together because without them the worst performing panel would dictate the output power of the whole bank of solar panels. In this configuration the output voltage will be the same and the output current will be the sum of the output current from each of the MPPT regulated series solar cells. **Solar Charging**
Instead of the currently used solar power regulator (MCP73871 on an Adafruit board), the SPV1040 Max Point Power Tracker(MPPT) will be used. The MCP73871 is a linear battery charger and management IC that is meant to charge a single cell Li-ion battery, however there are 4 in this system. The MCP73871 is also only available in a QFN package, which will make assembly harder for the end user. An MPPT increases efficiency by adjusting the current and voltage of the output to achieve the maximum power. The MPPT IC will regulate the solar cell voltage up to 5.2V. From the MPPT IC, the battery management circuitry, the 3.3V line, and the 5V line is powered.The SPV1040 was chosen for two reasons: RFCx currently has a multitude of them in stock, and suggested that we use them, and they require less control and I/O than the Solar Magic SM72442, a similar MPPT chip that was also considered, but which requires more power and more control from the MCU via an I2C interface.
Battery Management The BQ2057CTS is a charge management IC designed for single and dual cell Li-ion battery packs. Battery management is very important because if a battery is damaged by over or under charging and it goes unnoticed it could sink current from the other batteries or discharge into the other batteries causing more damage and possibly catch fire. This system is meant to be mounted in remote and hot climates, so safe battery management is a concern. One of these IC's are used for each of the two 2-cell battery packs. This battery management IC combines current and voltage regulation, charge status indication, and charge rate auto compensation. It also comes in an easy to use surface mount package. The charge rate auto compensation feature allows the batteries to charge faster by compensating for internal impedance of the battery pack. This IC was chosen for its charging features, its ability to handle two cells, its indication capabilities, as well as the package it comes in. The following figure shows the battery management circuitry for one of the 2-cell battery packs.

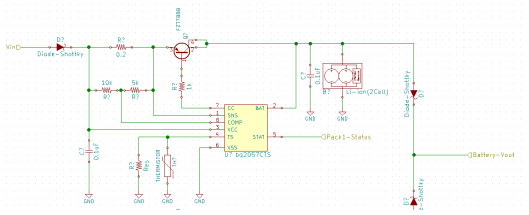

Figure 4: Battery Management Circuitry

The calculations for the component selection for the battery management circuitry is included in the Appendix.
Voltage Regulation
A diode-ORed power path management circuit was used to switch the power source that feeds the 3.3V and 5V regulation circuitry. This circuit is shown below.

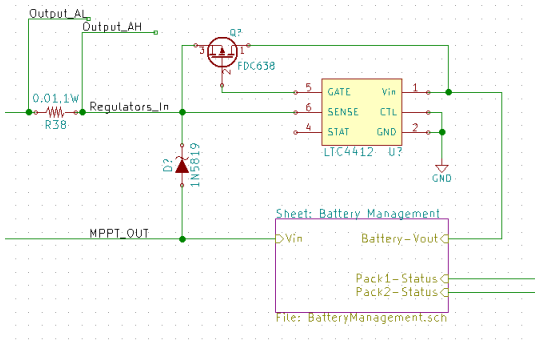

Figure 5: Diode Ored Circuit

The reason this circuit was chosen is because power path switching happens in under 100us and there is no dip in the output voltage. This dip was observed in a simulation of a different power path switching topology that involved only the FET and the diode. The two circuits were simulated with LTSpice and can be seen in figure x. The same diode and transistor were used in each simulation. A load of 550mA was used because this is more than the calculated worst case current draw from the circuit.

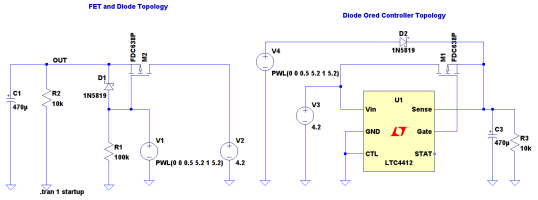

Figure 6: Simulation of Diode Ored Circuit

The transient simulation results of the diode and transistor topology can be seen in the following figure.

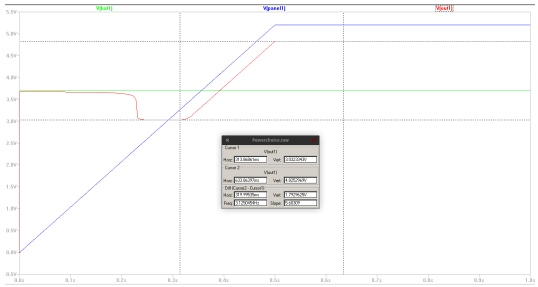

Figure 7: Simulation Result of Old Diode Ored Circuit

It can be seen that as the panel voltage is rising, there is a considerable dip to around 3.0V. If this occured, the 3.3V linear drop out regulator would not be able to regulate properly and the 3.3V line would be deactivated. The diode-ored controller topology simulation result can be seen in the following figure.

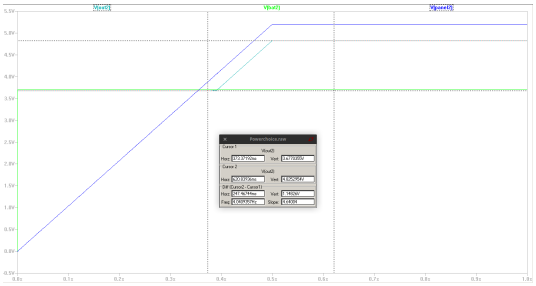

Figure 8: Simulation Result of Current Diode Ored Circuit

Here it can be seen that there is a very small drop in voltage when powered only from battery and a reasonable drop when powered from the solar panel. This is the desired behavior. The supporting components were chosen because they were suggested in the LTC4412 data sheet and they were in reasonable packages for the end user to assemble with.
The LM61428 is a step-up voltage regulator that is configured to boost the input voltage to 5V and an output current of up to 1A. The reason for this voltage is to charge the cell phone battery. The calculations for the surrounding components can be seen in the Appendix. The layout of the 5V boost regulator can be seen in the following figure.

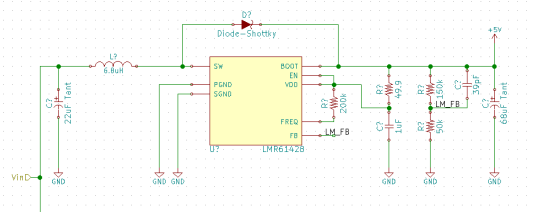

Figure 9: 5V Voltage Regulation

A Texas Instruments SM72238 Micropower fixed 3.3V LDO is used to regulate the 3.3V line. This was chosen over a switching regulator because the minimum voltage of 3.7 and the output voltage of 3.3V were too close together, causing the duty cycle calculations to come out to negative or not meet certain regulator's requirements. The SM72238 has very low dropout, which is in range for the need of this application. The only external components required by the LDO are two low ESR 1uF capacitors on the input and output.
Input and Output Current and Voltage Sensing The ADS1015 is a 12-bit ADC that can communicate over I2C with the microcontroller. An external ADC is used here because fewer I/O lines are used on the microcontoller and this has a higher resolution.
The LTC6800 instrumentation amplifier is used to sense the voltage across a known sense resistor. This is so that the ADC can read the output and the current that is being drawn by the circuit can be calculated by the microcontroller. The input current sense circuit is configured to have a gain of around 80.5. The sense resistor has been selected to be 0.01 Ohms. With this configuration the ADC will be able to sense the current with a resolution of 1mA/bit. The calculations for this section can be seen in the Appendix. The configuration of the current sense amplifier can be seen in the following figure.

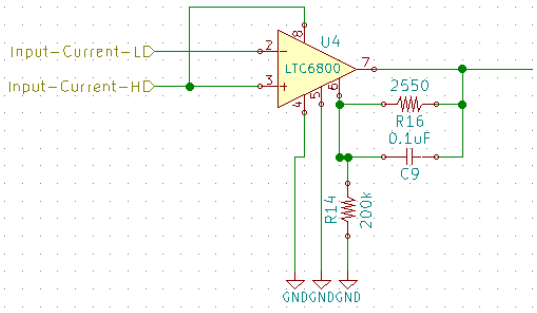

Figure 10: Current Sense Amplifier

The LTC6800 is used to sense the input and the output current. The input and output voltage are sensed with simple resistor dividers that are fed to the ADC.

Microcontroller

The purpose of having a microcontroller on board was to be able to relay diagnostic information of the environment to the phone so that it may take the information into consideration with its own calculations. The common Atmel ATmega328P and an FTDI IC were chosen to be the interface between the phone and the on board diagnostic circuitry.

Three other microcontrollers were considered. Two ARM M0+ low power micro controllers were considered. The Atmel ATSAM ARM M0+ was not chosen because it drew more current than the 328P and was decided to be over kill for this application. Some nice features were that it had a built in USB module and required no external tools to program it. The Freescale KL25Z was also decided to be overkill for this application and was not chosen because the programming interface of the end user would have been difficult as it required a JTAG programmer. The other microcontroller was a Texas Instruments 16-bit RISC MSP430. This microcontroller was the most expensive, drew the highest current in active and sleep modes, and requires an external tool to program. The ATmega328P does require an external tool to program but it does have low power sleep modes, it is cheap, its is simple, and it is well documented not only by Atmel but by a very large community. It is felt that this would benefit the end user the most in the future.

Temperature and Humidity

A temperature sensor (LM75BD) and a humidity/temperature sensor(HIH6130) are going to be designed onto this board. It is not intended that they both be populated at the same time but it does give the end user an option in case humidity is not a concern or the HIH6130 is too expensive. Both ICs are low power and communicate with the microcontroller over I2C. The schematic connections of the two ICs is shown in the following figure.

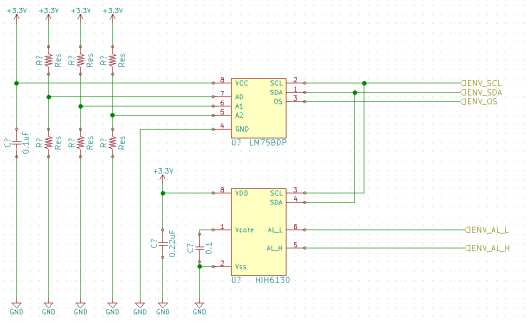

Figure 11: Temperature and Humidity Sensors

Connectors

The USB connection consists of a standard USB Micro A connector, soldered directly onto the board and is secured to the board as a strain-relief mechanism. A standard 3.5mm audio cable is used to connect the microphone. A standard GSM antenna adapter is used to interface with the phone's onboard GSM module.

GSM Interface

The use of X2Y TDMA filtering capacitors will be tested to reduce the noise produced by the stopping and starting of GSM packets, which is in the audible range at 217Hz. A pass-through 3.5mm microphone interface will be included to test the X2Y capacitors. In addition, a large heatsink will be attached to a large ground plane on one side of the board, and the phone will be attached to the same ground plane, which should help with some shielding.

PCB Size

Two size options were proposed for the PCB, including having only enough space for the components and having a long open space on the PCB for attaching the phone. Having a long PBC with space for the phone was chosen to simplify the assembly process for the device. The length of the open space is long enough to accommodate large phones, and variable length mounting holes in the PCB allow for any size phone to be securely mounted to the PCB using snap-fit mounting screws. A micro-USB cable is used to interface the phone to the rest of the board. Using a cable instead of a connector allows the use of any size phone in the device. Having the PCB only large enough to fit the electrical components on it requires a separate mounting mechanism for the phone, which complicates the assembly of the device.

Heat Dissipation Multiple alternatives were explored for dissipating heat built up in the enclosure, including drilling holes into the enclosure, putting fans in the enclosure to control airflow in and out of the enclosure, and using a heat sink. Using a heat sink was chosen as the best design alternative for heat dissipation. Drilling holes in the enclosure can allow water, insects and dust to enter the enclosure. A wire mesh over the holes could be used to keep insects out of the enclosure, but water and dust could still get into the enclosure and damage the electronics. Running fans in the device creates a sound in a similar frequency range to the chainsaw noise the device is trying to detect. This can cause false detection of a chainsaw by the RFCx server. A heat sink also requires a hole to be drilled into the enclosure for the heat sink to reach outside of the enclosure. This opening is sealed with caulk or by other methods to prevent water, insects and dust from entering the enclosure. The battery cover on the phone is removed and thermal paste is used between the phone battery and the PBC, and between the PCB and the heat sink. This allows heat to dissipate out of the enclosure and help keep the phone attached to the PCB and the PCB attached to the heat sink. Vias in the PCB help heat to transfer more readily through the board instead of trying to transfer the heat through the fiberglass the board is made of.

3.1.2 Hardware Implementation

Heat Sink A heat sink, as described in Section 3.1.1 is shown in Figure 1.4. The current design calls for a rectangular opening to be cut into the front face of the enclosure so that the heat sink may pass through. The shape of the heat sink will be optimized for reduced interior air temperature through heat transfer calculations.

3.2 Software Specifications

The software used in the design will consists of C and C++ code running on the ATMega328P microcontroller, as well as a companion app (RFCx Sentinel) written in Java, running on the Android phone.

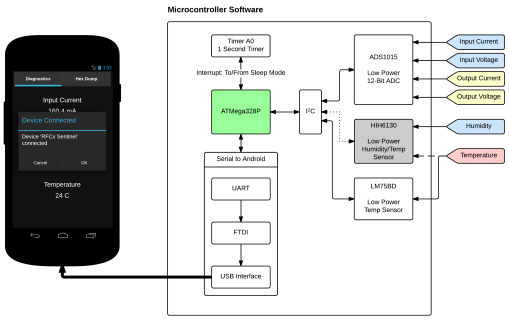

Figure 12: Software UML Diagram

3.2.1 Software Design

The microcontroller software gathers data from a humidity/temperature sensor, and input/output current and voltage. This data is sent via the ATMega328P serial port to the Android phone via the FTDI chip on the PCB and the usb-serial-for-android libraries on the phone. Listing 1 describes the basic functionality of the microcontroller software.

Listing 1: MCU Flow Code Snippet

```
void wakeFromSleep() {
    //Get sensor measurements
    GetDiagnostics(&Diagnostics);
    //Send sensor measurements to phone
    SendDiagnostics(Diagnostics);
    //Go to sleep
    enterSleep();
}
```

3.2.2 Software Implementation

An ATMega328P microcontroller is be used to take measurements from the sensors. The temperature (and possibly humidity) measurements are sent digitally via I2C to the microcontroller. On the same I2C bus is the ADS1015, which has four single-ended analog inputs for reading the input current, input voltage, output current, and output voltage. This data is be sent to the phone using the standard AVR UART serial library.
The data, once sent to the phone, is be monitored by the RFCx Sentinel app. This app is written in Java in Android Studio, and uses the open-source usb-serial-for-android library. The app opens a connection upon discovering a compatible device (FTDI is compatible), and allows the user to view a streamlined interface with relevant data, as well as a tab for the raw hex dump of incoming serial data. The data may or may not be transmitted along with audio data to the RFCx server for real-time monitoring.

4 Verification

4.1 Hardware Verification

To verify the power consumption of the devices in **Requirement 2.1.1.1.**. the voltage applied and current drawn by the both the enhanced device and the current device will be measured over the course of 1 hour during a realistic usage scenario. The average power will be verified to not exceed 90% of the existing device's usage.
To verify **Requirement 2.1.1.6.**. a visual inspection by volunteers will qualify camouflage schemes. A successful inspection will be one in which more than 80% of the volunteers are unable to find the device within a 2 minute inspection window.
To verify **Requirement 2.1.1.7.**. a sample group of people with varying skill levels will be asked to provide feedback the on assembly process.

4.2 Software Verification

To verify **Requirement 2.1.2.1.**., audio will be recorded and compressed using multiple algorithms including the current algorithm. An infographic hosted on RFCx's website, shown in Figure 2 illustrates the flow of data that is collected from the phone and analyzed on the server.
To verify **Requirement 2.2.1.3.**, simple packets will be sent from the microcontroller to the phone. These packets can be verified with debug tools or simple programs on the microcontroller and the phone. A debug serial port may be included as a peripheral to the microcontroller to aid in debugging. Any analog values read by the microcontroller will be verified with shop equipment.

5 Validation

Requirement 2.2.1.2., **Requirement 2.1.1.2.**, and **Requirement 2.1.1.4.** can be validated by inspecting the components on the PCB to ensure all required components are present on the board. Requirements **Requirement 2.1.1.7.** and **Requirement 2.1.1.8.** can be validated by handing the assembly instructions out to a sample group of people with varying skill levels and receiving feedback on the set of instructions from them. People with the ability to read other languages can be used if the documents have been translated from English into other languages.
Requirement 2.2.1.4. can be validated by inspecting the total cost printed on the BOM for the enhanced device.
Requirement 2.2.1.1., **Requirement 2.1.1.1.**, and **Requirement 2.2.1.3.** can be validated by current and voltage measurements taken in the lab using a DMM. The power calculations made based on those measurements can be compared to similar calculations based on measurements taken from the current device. SPICE simulation data and values displayed on the RFCx Sentinel app will be compared to the actual power consumption of the new device.
Requirement 2.2.2.1., **Requirement 2.2.2.2.**, **Requirement 2.2.2.3.**, and **Requirement 2.2.1.3.** can be validated by comparing the values reported in the RFCx Sentinel app to the calculated power consumption of the enhanced device.
Requirement 2.1.1.3. can be validated by changing the scale factor in the microcontroller program, reprogramming the microcontroller from the PCB header and comparing the values displayed on the RFCx Sentinel app to the previous displayed values. The new values displayed on the RFCx Sentinel app should reflect the change to the scale factor in the microcontroller program.
Requirement 2.1.1.3., **Requirement 2.2.2.3.**, and **Requirement 2.1.2.1.** can be validated during a field test. The enhance device can be mounted at eye level in a tree and turned on to allow the device to start sending audio data to the RFCx server. Requirement **Requirement 2.1.1.6.** can be validated by having a volunteer outside of the project search for the device in a wooded area without knowing what it looks like to see if it sticks out. A chainsaw can be turned on 0.25 miles from the device to trigger an alert and validate that the enhanced device can communicate with the RFCx server. The size of the audio recording sent to the RFCx server after employing the audio compression algorithm can be compared to the size of audio data sent to the RFCx server by the current device to determine the audio compression ratio of this algorithm. Both audio recordings can be played back to determine the level of audio interference created by GSM transmission.

6 Project Budget and Schedule

6.1 Budget

This project will require minor funding for manufacturing and populating the PCB, and the materials to construct a new enclosure, as well as general testing and component costs. As RFCx is a non-profit organization working solely on grant money, this budget is not expected to be covered by them.

- $400 = 4 x $100 for PCB manufacturing
- $320 = 4 x $80 for PCB components
- $200 = 1 x $200 for general needs
- Estimated Total: $920

7 Schedule

The schedule in Figure 6.2 is the proposed schedule for all phases of the project. This will be used as a general timeline for guidance throughout the project.

Appendix A: Electrical Schematics

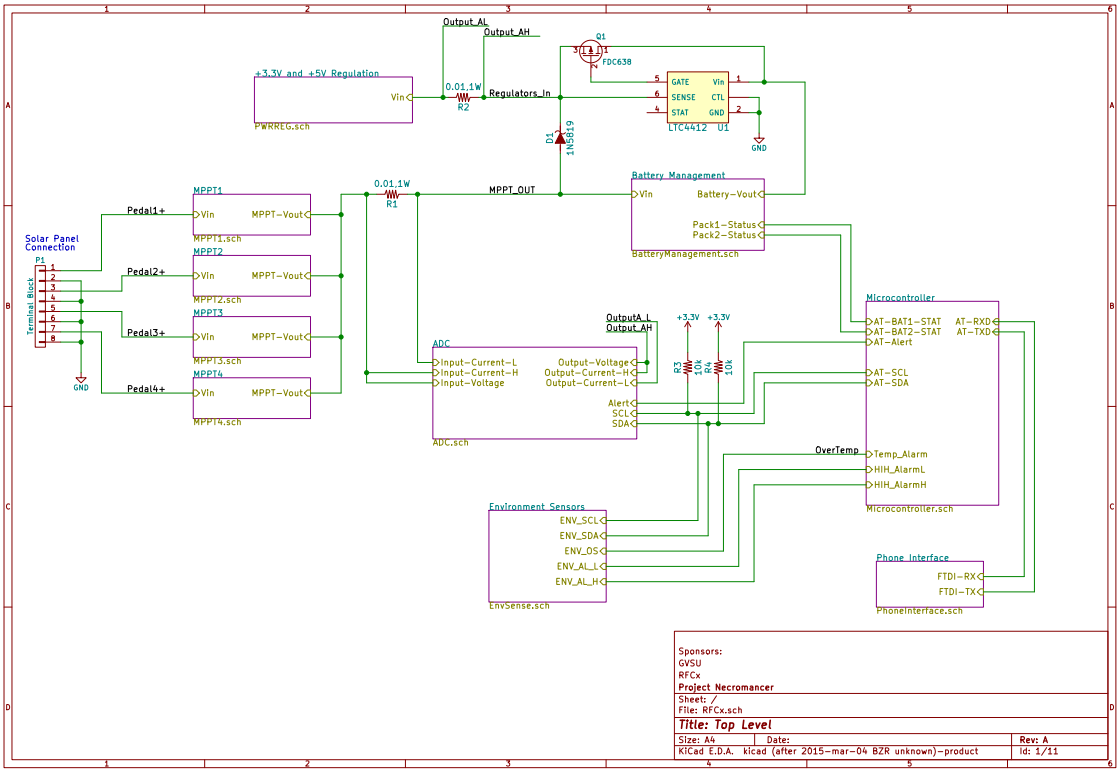

Figure 13

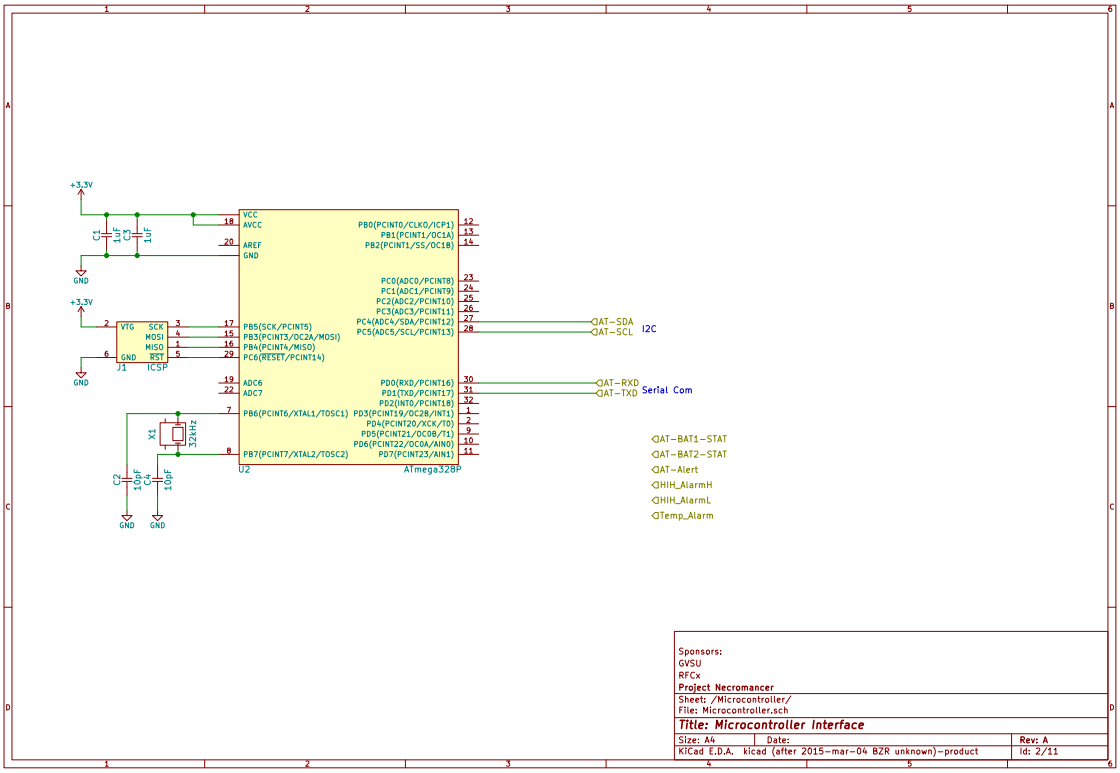
+3.3V
C1
1uF
C3
1uF
GND
VCC
AVCC
AREF
GND
PB0(PCINT0/CLKO/ICP1)
PB1(PCINT1/OC1A)
PB2(PCINT1/SS/OC1B)
PC0(ADC0/PCINT8)
PC1(ADC1/PCINT9)
PC2(ADC2/PCINT10)
PC3(ADC3/PCINT11)
PC4(ADC4/SDA/PCINT12)
PC5(ADC5/SCL/PCINT13)
AT-SDA
AT-SCL
I2C
VTG
SCK
MOSI
MISO
GND
RST
J1
ICSP
PB5(SCK/PCINT5)
PB3(PCINT3/OC2A/MOSI)
PB4(PCINT4/MISO)
PC6(RESET/PCINT14)
ADC6
ADC7
PD0(RXD/PCINT16)
PD1(TXD/PCINT17)
PD2(INT0/PCINT18)
PD3(PCINT19/OC2B/INT1)
PD4(PCINT20/XCK/T0)
PD5(PCINT21/OC0B/T1)
PD6(PCINT22/OC0A/AIN0)
PD7(PCINT23/AIN1)
AT-RXD
AT-TXD
Serial Com
PB6(PCINT6/XTAL1/TOSC1)
PB7(PCINT7/XTAL2/TOSC2)
X1
32kHz
C2
10pF
C4
10pF
GND
GND
U2
ATmega328P
AT-BAT1-STAT
AT-BAT2-STAT
AT-Alert
HIH_AlarmH
HIH_AlarmL
Temp_Alarm
Sponsors:
GVSU
RFCx
Project Necromancer
Sheet: /Microcontroller/
File: Microcontroller.sch
Title: Microcontroller Interface
Size: A4
Date:
Rev: A
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product
Id: 2/11

Figure 14

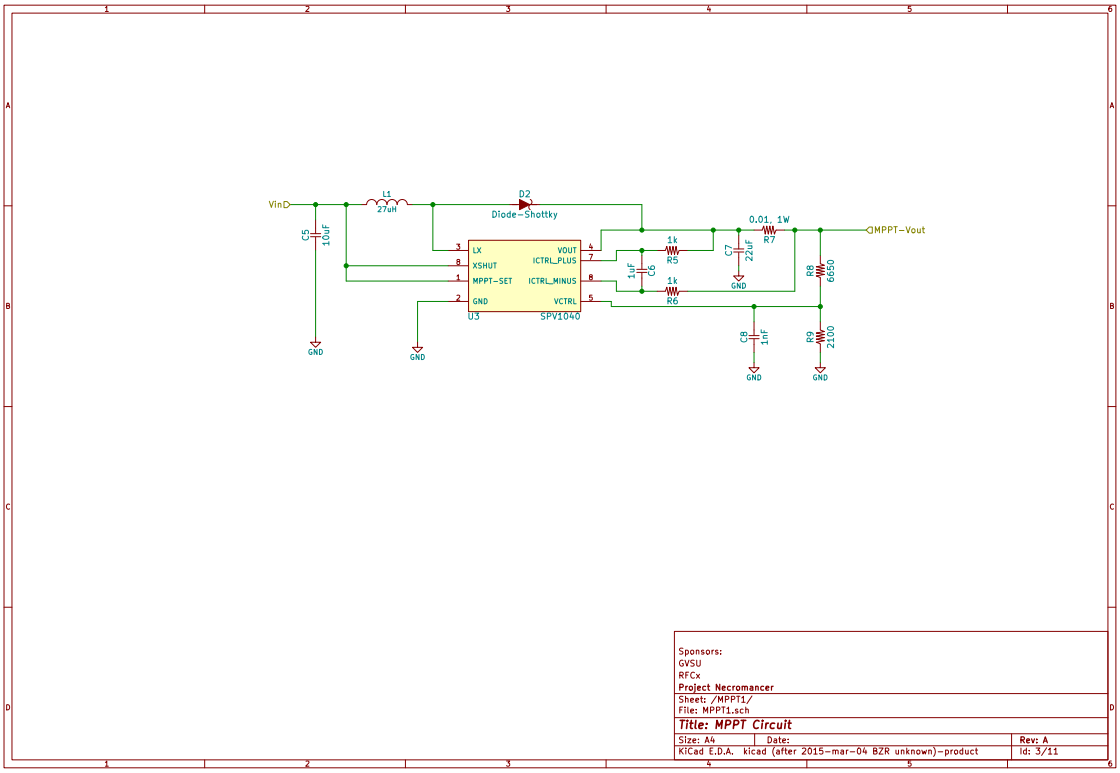
VinD
L1
27uH
D2
Diode-Shottky
C5
10uF
GND
LX
XSHUT
MPPT-SET
GND
VOUT
ICTRL_PLUS
ICTRL_MINUS
VCTRL
U3
SPV1040
1uF
C6
1k
R5
1k
R6
C7
22uF
GND
0.01, 1W
R7
MPPT-Vout
R8
6650
C8
1nF
GND
R9
2100
GND
Sponsors:
GVSU
RFCx
Project Necromancer
Sheet: /MPPT1/
File: MPPT1.sch
Title: MPPT Circuit
Size: A4
Date:
Rev: A
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product
Id: 3/11

Figure 15

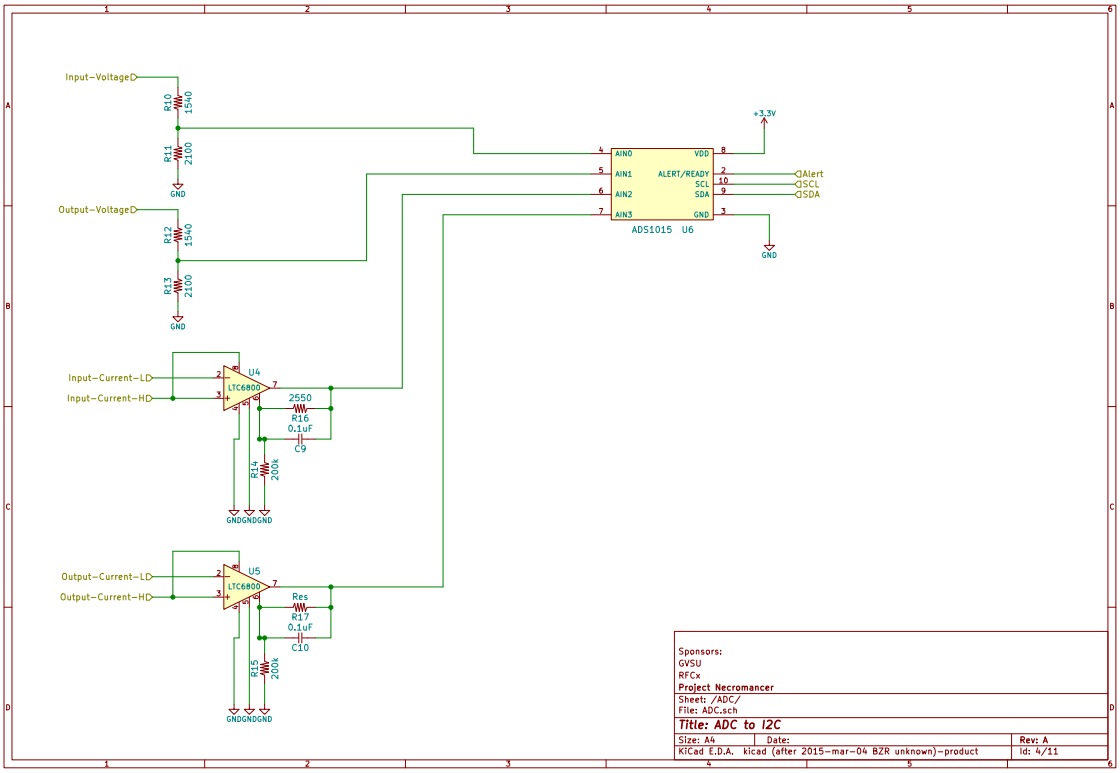
Input-Voltage
R10
1M
1540
R11
1M
2100
GND
Output-Voltage
R12
1M
1540
R13
1M
2100
GND
+3.3V
AIN0
AIN1
AIN2
AIN3
VDD
ALERT/READY
SCL
SDA
GND
ADS1015 U6
Alert
SCL
SDA
Input-Current-LD
Input-Current-HD
U4
LTC6800
2550
R16
0.1uF
C9
R14
200k
GNDGNDGND
Output-Current-LD
Output-Current-HD
U5
LTC6800
Res
R17
0.1uF
C10
R15
200k
GNDGNDGND
Sponsors:
GVSU
RFCx
Project Necromancer
Sheet: /ADC/
File: ADC.sch
Title: ADC to I2C
Size: A4
Date:
Rev: A
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product
Id: 4/11

Figure 16

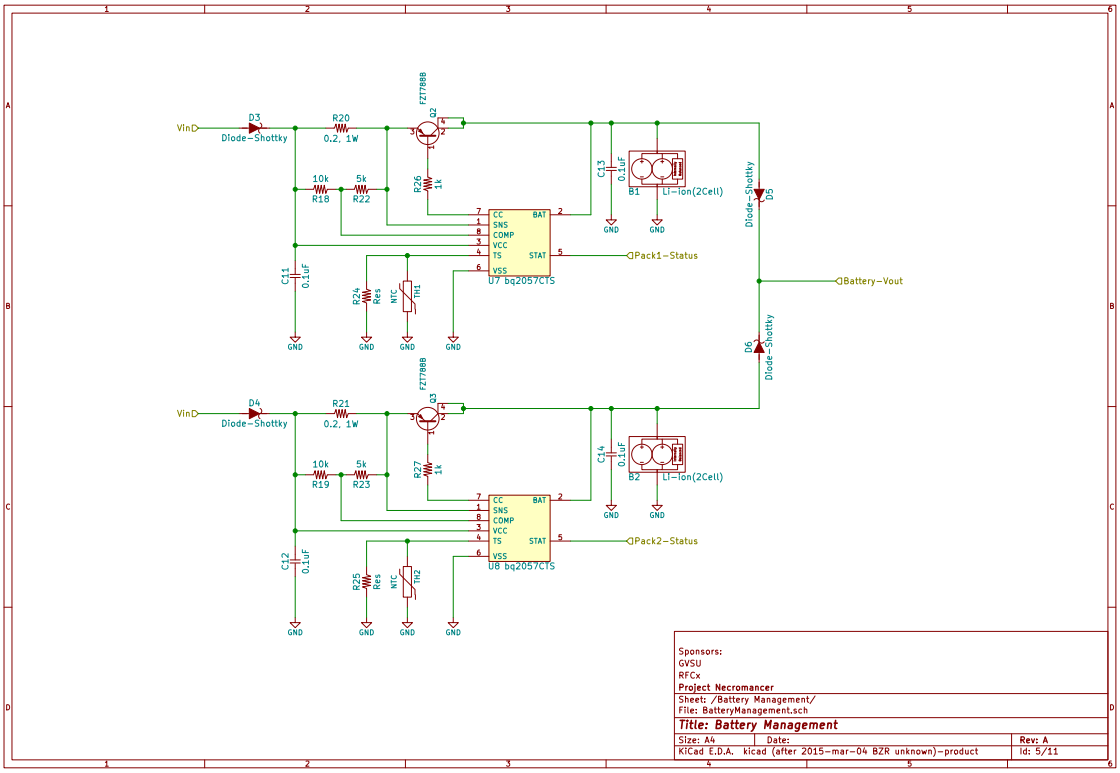
Vin
D3
Diode-Shottky
R20
0.2, 1W
FZT788B
Q2
10k
R18
5k
R22
R26
1k
C13
0.1uF
B1
Li-Ion(2Cell)
Diode-Shottky
D5
CC
SNS
COMP
VCC
TS
VSS
BAT
STAT
U7 bq2057CTS
Pack1-Status
C11
0.1uF
R24
Res
NTC
TH1
Battery-Vout
D6
Diode-Shottky
Vin
D4
Diode-Shottky
R21
0.2, 1W
FZT788B
Q3
10k
R19
5k
R23
R27
1k
C14
0.1uF
B2
Li-Ion(2Cell)
U8 bq2057CTS
Pack2-Status
C12
0.1uF
R25
Res
NTC
TH2
GND
Sponsors:
GVSU
RFCx
Project Necromancer
Sheet: /Battery Management/
File: BatteryManagement.sch
Title: Battery Management
Size: A4
Date:
Rev: A
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product
Id: 5/11

Figure 17

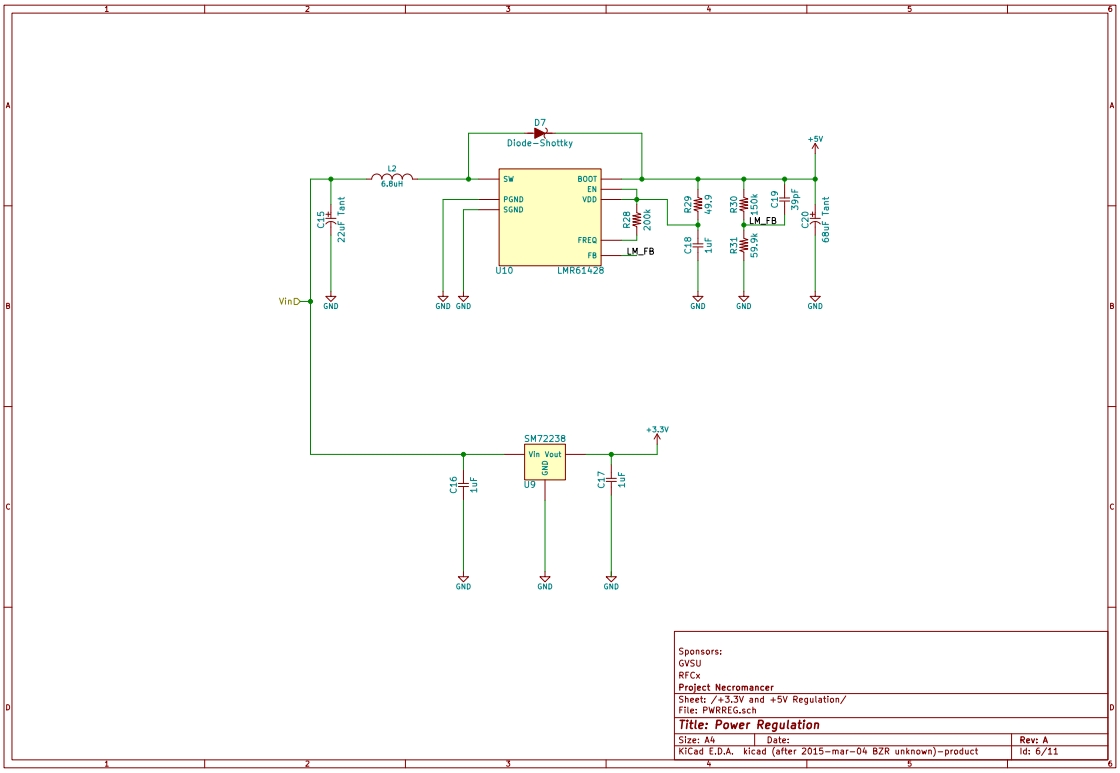
D7
Diode-Shottky
L2
6.8uH
C15
22uF Tant
SW
PGND
SGND
BOOT
EN
VDD
FREQ
FB
U10
LMR61428
R28
200k
LM_FB
R29
49.9
R30
150k
C19
39pF
R31
59.9k
C18
1uF
C20
68uF Tant
+5V
VinD
GND
SM72238
Vin Vout
GND
U9
C16
1uF
C17
1uF
+3.3V
Sponsors:
GVSU
RFCx
Project Necromancer
Sheet: /+3.3V and +5V Regulation/
File: PWRREG.sch
Title: Power Regulation
Size: A4
Date:
Rev: A
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product
Id: 6/11

Figure 18

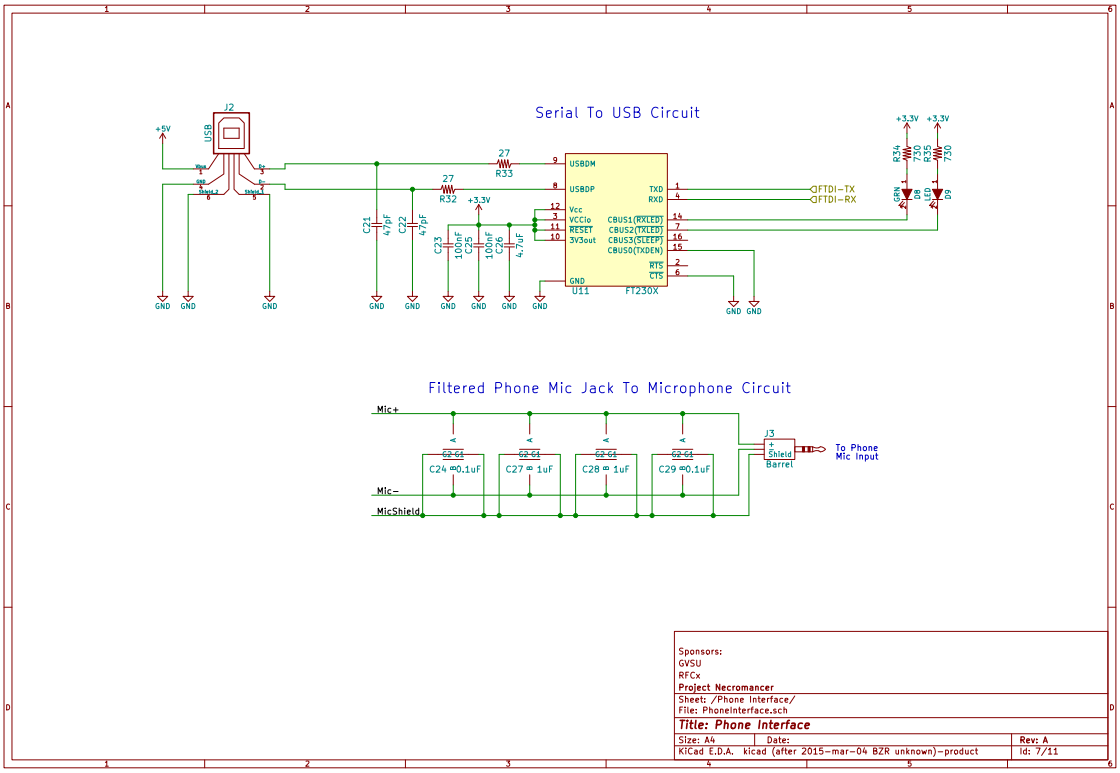
Serial To USB Circuit
Filtered Phone Mic Jack To Microphone Circuit
Mic+
Mic−
MicShield
To Phone
Mic Input
FT230X
Sponsors:
GVSU
RFCx
Project Necromancer
Sheet: /Phone Interface/
File: PhoneInterface.sch
Title: Phone Interface
Size: A4
Date:
Rev: A
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product
Id: 7/11

Figure 19

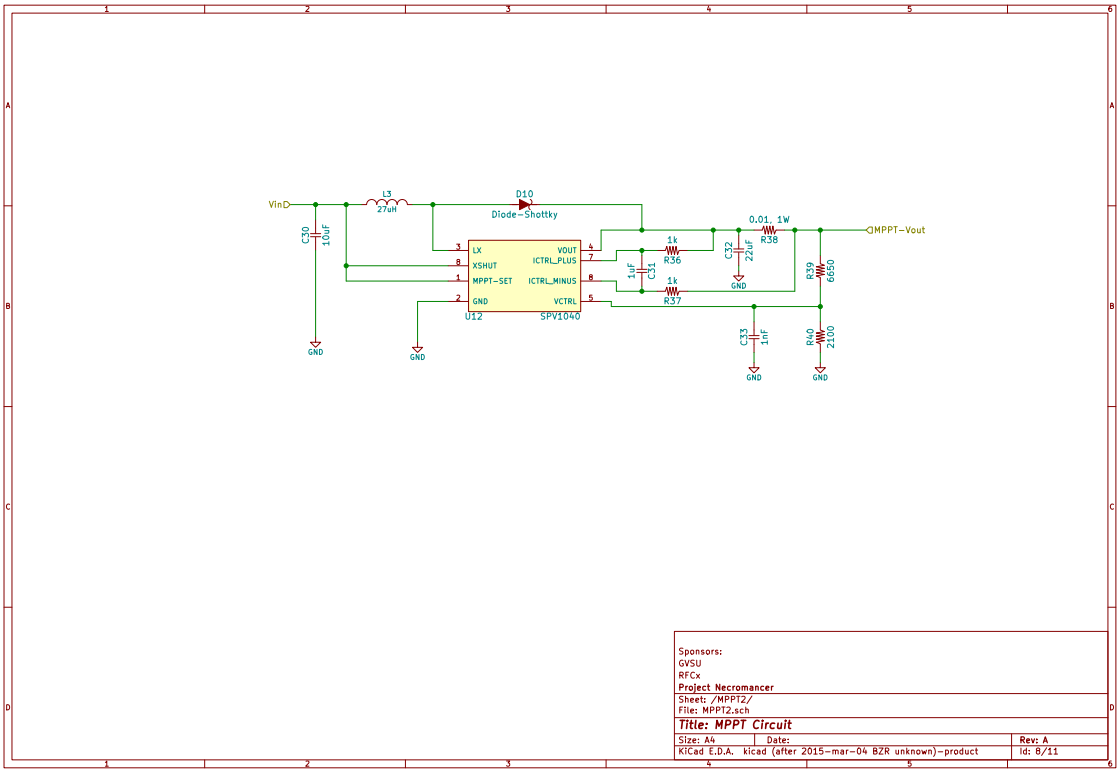
VinD
L3
27uH
D10
Diode_Shottky
C30
10uF
LX
XSHUT
MPPT_SET
GND
VOUT
ICTRL_PLUS
ICTRL_MINUS
VCTRL
U12
SPV1040
1uF
C31
1k
R36
1k
R37
C32
22uF
0.01, 1W
R38
R39
6650
MPPT_Vout
C33
1nF
R40
2100
GND
Sponsors:
GVSU
RFCx
Project Necromancer
Sheet: /MPPT2/
File: MPPT2.sch
Title: MPPT Circuit
Size: A4
Date:
Rev: A
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product
Id: 6/11

Figure 20

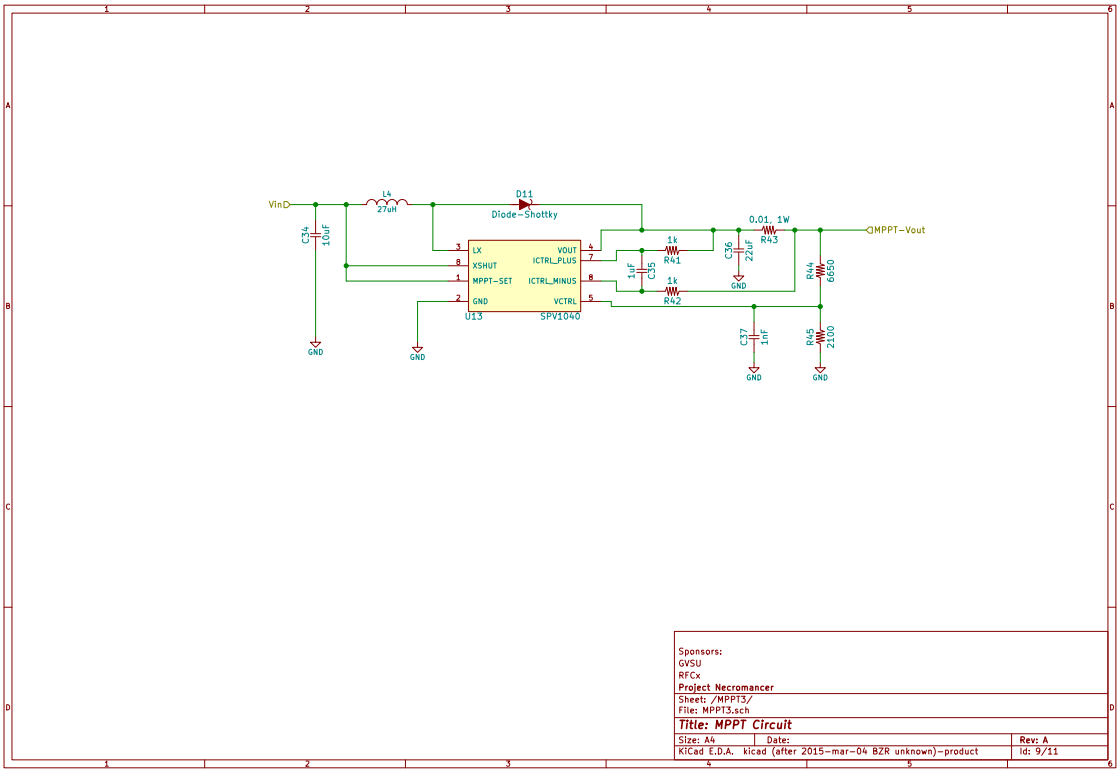
VinD
L4
27uH
D11
Diode_Shottky
C34
10uF
LX
XSHUT
MPPT_SET
GND
VOUT
ICTRL_PLUS
ICTRL_MINUS
VCTRL
U13
SPV1040
1uF
C35
1k
R41
1k
R42
C36
22uF
0.01, 1W
R43
MPPT_Vout
R44
6650
C37
1nF
R45
2100
GND
Sponsors:
GVSU
RFCx
Project Necromancer
Sheet: /MPPT3/
File: MPPT3.sch
Title: MPPT Circuit
Size: A4
Date:
Rev: A
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product
Id: 9/11

Figure 21

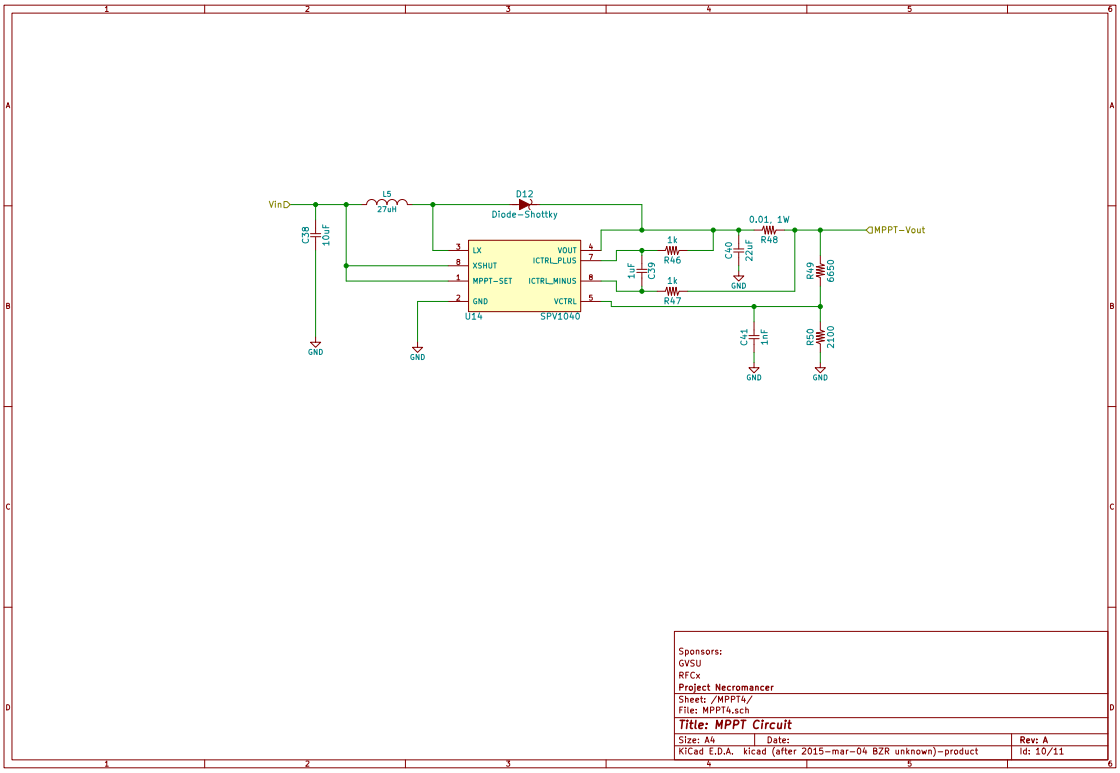
VinD
L5
27uH
D12
Diode-Shottky
C38
10uF
LX
XSHUT
MPPT-SET
GND
VOUT
ICTRL_PLUS
ICTRL_MINUS
VCTRL
U14
SPV1040
1uF
C39
1k
R46
1k
R47
C40
22uF
0.01, 1W
R48
R49
6650
MPPT-Vout
C41
1nF
R50
2100
GND
Sponsors:
GVSU
RFCx
Project Necromancer
Sheet: /MPPT4/
File: MPPT4.sch
Title: MPPT Circuit
Size: A4
Date:
Rev: A
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product
Id: 10/11

Figure 22

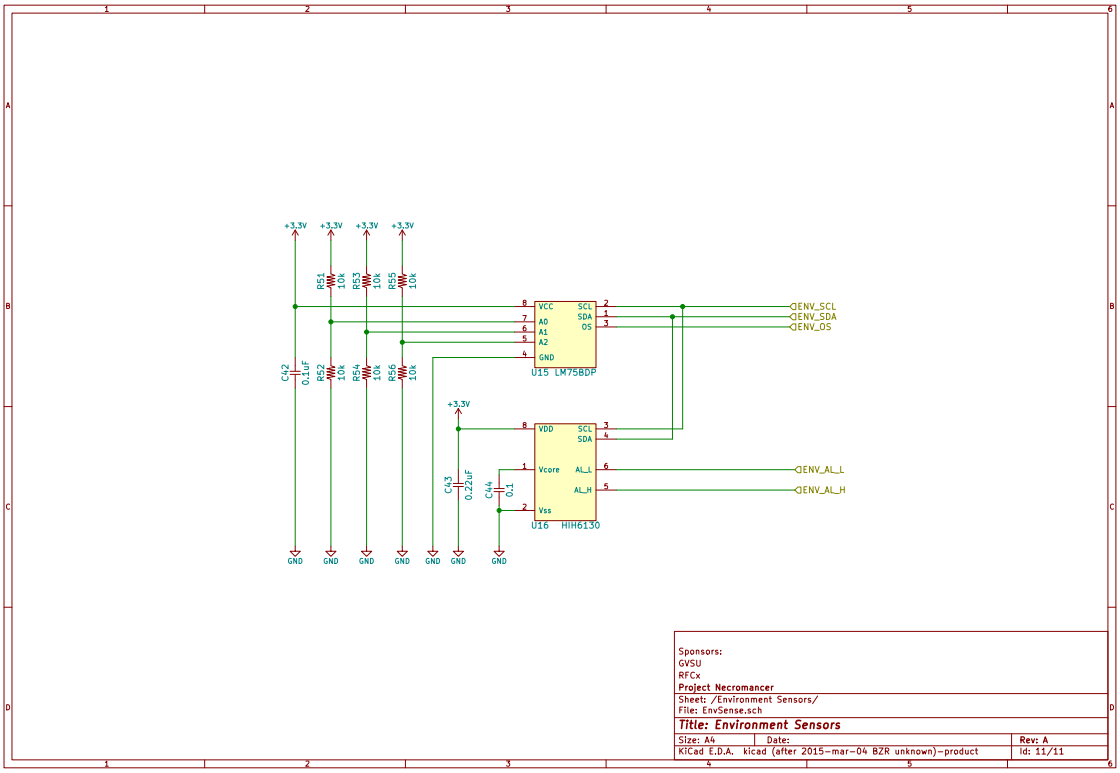
+3.3V
R51 10k
R53 10k
R55 10k
C42 0.1uF
R52 10k
R54 10k
R56 10k
GND
VCC
A0
A1
A2
GND
SCL
SDA
OS
U15 LM75BDP
ENV_SCL
ENV_SDA
ENV_OS
VDD
Vcore
Vss
AL_L
AL_H
C43 0.22uF
C44 0.1
U16 HIH6130
ENV_AL_L
ENV_AL_H
Sponsors:
GVSU
RFCx
Project Necromancer
Sheet: /Environment Sensors/
File: EnvSense.sch
Title: Environment Sensors
Size: A4
Date:
Rev: A
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product
Id: 11/11

Figure 23

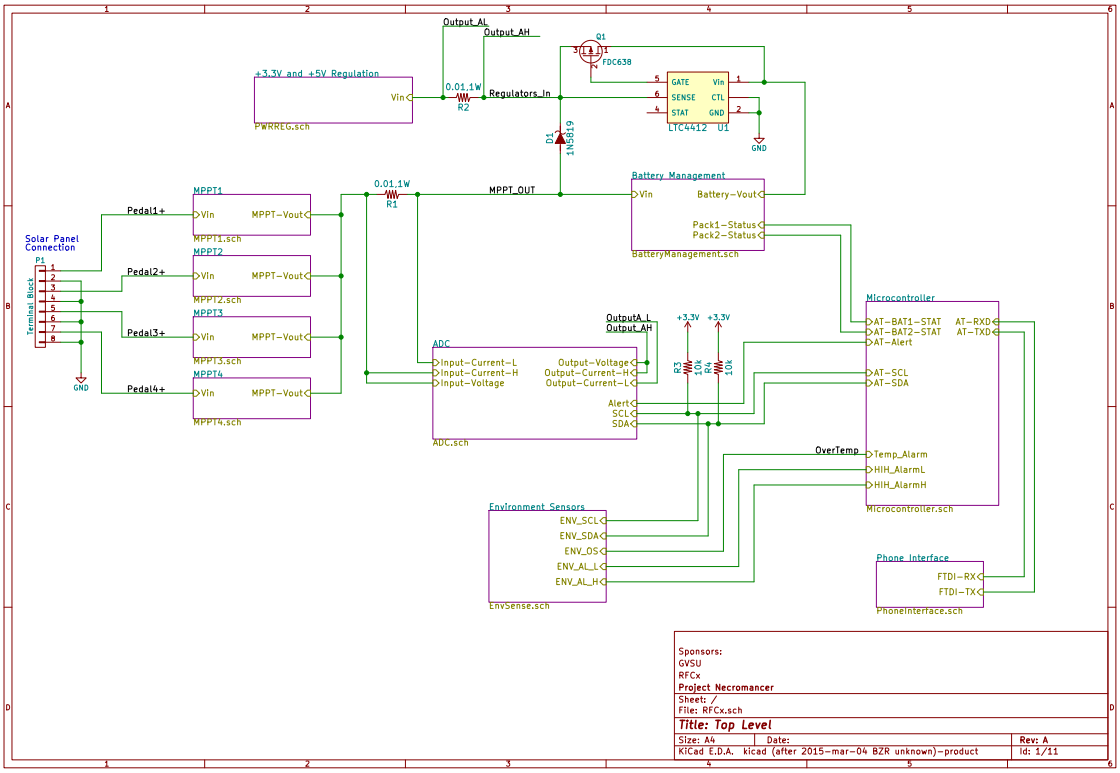
Output_AL
Output_AH
Q1
FDC638
+3.3V and +5V Regulation
Vin
PWRREG.sch
0.01,1W
R2
Regulators_In
D1
1N5819
GATE
SENSE
STAT
Vin
CTL
GND
LTC4412 U1
GND
Battery Management
Vin
Battery-Vout
Pack1-Status
Pack2-Status
BatteryManagement.sch
0.01,1W
R1
MPPT_OUT
MPPT1
MPPT2
MPPT3
MPPT4
Vin
MPPT-Vout
MPPT1.sch
MPPT2.sch
MPPT3.sch
MPPT4.sch
Pedal1+
Pedal2+
Pedal3+
Pedal4+
Solar Panel Connection
P1
Terminal Block
GND
ADC
Input-Current-L
Input-Current-H
Input-Voltage
Output-Voltage
Output-Current-H
Output-Current-L
Alert
SCL
SDA
ADC.sch
OutputA_L
Output_AH
+3.3V
+3.3V
R3
10k
R4
10k
Microcontroller
AT-BAT1-STAT
AT-BAT2-STAT
AT-Alert
AT-SCL
AT-SDA
AT-RXD
AT-TXD
Microcontroller.sch
OverTemp
Temp_Alarm
HIH_AlarmL
HIH_AlarmH
Environment Sensors
ENV_SCL
ENV_SDA
ENV_OS
ENV_AL_L
ENV_AL_H
EnvSense.sch
Phone Interface
FTDI-RX
FTDI-TX
PhoneInterface.sch
Sponsors:
GVSU
RFCx
Project Necromancer
Sheet: /
File: RFCx.sch
Title: Top Level
Size: A4
Date:
Rev: A
KiCad E.D.A. kicad (after 2015-mar-04 BZR unknown)-product
Id: 1/11

Figure 24

Appendix B: Bill Of Materials

RFCx_BOM

Project: RFCx
Tool: kicad
Number of Parts 145

Reference	Quantity	Value	Distributor	Distributor #	Single Quantity Price	Extended Price
Q1	1	FDC638	DigiKey	FDC638PCT-ND	$0.55	$0.55
C2,C4	2	10pF	DigiKey	709-1168-1-ND	$0.10	$0.20
C3,C1,C6,C18,C17,C16,C31,C35,C39	9	1uF	DigiKey	1276-1275-1-ND	$0.10	$0.90
C5,C30,C34,C38	4	10uF	DigiKey	587-1312-1-ND	$0.17	$0.68
C7,C32,C36,C40	4	22uF	DigiKey	1276-1822-1-ND	$0.53	$2.12
C8,C33,C37,C41	4	1nF	DigiKey	399-1147-1-ND	$0.10	$0.40
C9,C10,C11,C13,C12,C14,C29,C24,C42,C25,C23,C44	12	0.1uF	DigiKey	311-1245-1-ND	$0.57	$6.84
R20,R21	2	0.2, 1W	DigiKey	989-1049-1-ND	$0.61	$1.22
Q2,Q3	2	FZT788B	DigiKey	FZT788BCT-ND	$1.01	$2.02
C15	1	22uF Tant	DigiKey	511-1506-1-ND	$1.03	$1.03
C19	1	39pF	DigiKey	1276-1769-1-ND	$0.10	$0.10
C20	1	68uF Tant	DigiKey	478-8414-1-ND	$1.08	$1.08
C26	1	4.7uF	DigiKey	1276-1065-1-ND	$0.21	$0.21
C22,C21	2	47pF	DigiKey	1276-1832-1-ND	$0.10	$0.20
C28,C27	2	1uF	DigiKey	709-1108-1-ND	$0.74	$1.48
C43	1	0.22uF	DigiKey	587-1287-1-ND	$0.12	$0.12
R1,R2,R7,R38,R43,R48	6	0.01,1W	DigiKey	RHM.010ASCT-ND	$0.69	$4.14
R3,R4,R18,R19,R52,R54,R56,R55,R53,R51	10	10k	DigiKey	P10KACT-ND	$0.10	$1.00
R5,R6,R26,R27,R36,R37,R41,R42,R46,R47	10	1k	DigiKey	P1.0KACT-ND	$0.10	$1.00
R8,R39,R44,R49	4	6650	DigiKey	P6.65KCCT-ND	$0.10	$0.40
R9,R40,R45,R50,R11,R13	6	2100	DigiKey	P2.10KCCT-ND	$0.10	$0.60
R10,R12	2	1540	DigiKey	P1.54KCCT-ND	$0.10	$0.20
R16,R17	2	2550	DigiKey	311-2.55KCRCT-ND	$0.10	$0.20
R14,R15,R28	3	200k	DigiKey	P200KACT-ND	$0.10	$0.30
R24,R25	2	Res	NA	NA		$0.00
R22,R23	2	5k	DigiKey	P4.99KCCT-ND	$0.10	$0.20
R29	1	49.9	DigiKey	P49.9CCT-ND	$0.10	$0.10
R30	1	150k	DigiKey	P150KCCT-ND	$0.10	$0.10
R31	1	49.9k	DigiKey	P49.9KCCT-ND	$0.10	$0.10
D8	1	GRN	DigiKey	754-1939-1-ND	$0.58	$0.58
D9	1	LED	DigiKey	511-1293-1-ND	$0.46	$0.46
R34,R35	2	730	DigiKey	P732CCT-ND	$0.10	$0.20
R33,R32	2	27	DigiKey	P27ACT-ND	$0.10	$0.20
X1	1	32kHz	DigiKey	300-8744-1-ND	$1.18	$1.18

Page 1

Figure 25

RFCx_BOM

D2,D3,D4,D5,D6,D7,D10,D11,D12,D1	10	1N5819	DigiKey	1N5819HW-FDICT-ND	$0.52	$5.20
L1,L3,L4,L5	4	27uH	DigiKey	SRR1260-270MCT-ND	$0.99	$3.96
L2	1	6.8uH	DigiKey	SRN6045-6R8YCT-ND	$0.43	$0.43
P1	1	Terminal Block	DigiKey	ED2615-ND	$1.31	$1.31
U1	1	LTC4412	DigiKey	LTC4412ES6#TRPBFC	$3.07	$3.07
U2	1	ATmega328P	DigiKey	ATMEGA328P-AU-ND	$3.58	$3.58
J1	1	ICSP	DigiKey	S2011EC-03-ND	$0.36	$0.36
U3,U12,U13,U14	4	SPV1040	DigiKey	NA		$0.00
U4,U5	2	LTC6800	DigiKey	LTC6800HMS8#PBF-N	$3.12	$6.24
U6	1	ADS1015	DigiKey	296-25227-1-ND	$3.42	$3.42
U7,U8	2	bq2057CTS	DigiKey	296-25916-1-ND	$1.91	$3.82
B1,B2	2	Li-ion(2Cell)	NA	NA		$0.00
TH1,TH2	2	NTC	DigiKey	BC2384-ND	$1.54	$3.08
U10	1	LMR61428	DigiKey	LMR61428XMM/NOPB	$1.87	$1.87
U9	1	SM72238	DigiKey	296-39811-5-ND	$1.67	$1.67
U11	1	FT230X	DigiKey	768-1135-1-ND	$2.04	$2.04
J2	1	USB	NA	NA		$0.00
J3	1	Barrel	NA	NA		$0.00
U15	1	LM75BDP	DigiKey	568-4768-1-ND	$0.62	$0.62
U16	1	HIH6130	DigiKey	480-3651-1-ND	$13.75	$13.75
					TOTAL	$84.53

Page 2

Figure 26

Appendix C: Mechanical Drawings

Appendix D: Calculations

Appendix E: Data Sheet Snippets

This appendix contains the 1st sheet of the data sheets for the parts used in this project.

TEXAS INSTRUMENTS

ADS1013
ADS1014
ADS1015

www.ti.com

SBAS473C – MAY 2009 – REVISED OCTOBER 2009

Ultra-Small, Low-Power, 12-Bit Analog-to-Digital Converter with Internal Reference

Check for Samples: ADS1013 ADS1014 ADS1015

FEATURES

- **ULTRA-SMALL QFN PACKAGE: 2mm × 1,5mm × 0,4mm**
- **WIDE SUPPLY RANGE: 2.0V to 5.5V**
- **LOW CURRENT CONSUMPTION: Continuous Mode: Only 150µA Single-Shot Mode: Auto Shut-Down**
- **PROGRAMMABLE DATA RATE: 128SPS to 3.3kSPS**
- **INTERNAL LOW-DRIFT VOLTAGE REFERENCE**
- **INTERNAL OSCILLATOR**
- **INTERNAL PGA**
- **I²C™ INTERFACE: Pin-Selectable Addresses**
- **FOUR SINGLE-ENDED OR TWO DIFFERENTIAL INPUTS (ADS1015)**
- **PROGRAMMABLE COMPARATOR (ADS1014 and ADS1015)**

APPLICATIONS

- **PORTABLE INSTRUMENTATION**
- **CONSUMER GOODS**
- **BATTERY MONITORING**
- **TEMPERATURE MEASUREMENT**
- **FACTORY AUTOMATION AND PROCESS CONTROLS**

DESCRIPTION

The ADS1013, ADS1014, and ADS1015 are precision analog-to-digital converters (ADCs) with 12 bits of resolution offered in an ultra-small, leadless QFN-10 package or an MSOP-10 package. The ADS1013/4/5 are designed with precision, power, and ease of implementation in mind. The ADS1013/4/5 feature an onboard reference and oscillator. Data are transferred via an I²C-compatible serial interface; four I²C slave addresses can be selected. The ADS1013/4/5 operate from a single power supply ranging from 2.0V to 5.5V.

The ADS1013/4/5 can perform conversions at rates up to 3300 samples per second (SPS). An onboard PGA is available on the ADS1014 and ADS1015 that offers input ranges from the supply to as low as ±256mV, allowing both large and small signals to be measured with high resolution. The ADS1015 also features an input multiplexer (MUX) that provides two differential or four single-ended inputs.

The ADS1013/4/5 operate either in continuous conversion mode or a single-shot mode that automatically powers down after a conversion and greatly reduces current consumption during idle periods. The ADS1013/4/5 are specified from –40°C to +125°C.

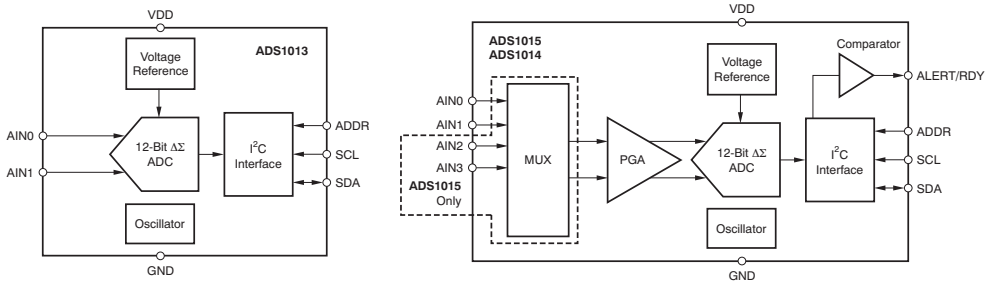

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Figure 27: 1st Page of ADS1013 Datasheet

Features

- High Performance, Low Power AVR® 8-Bit Microcontroller
- Advanced RISC Architecture
  - 131 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 20 MIPS Throughput at 20 MHz
  - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
  - 4/8/16/32K Bytes of In-System Self-Programmable Flash progam memory (ATmega48PA/88PA/168PA/328P)
  - 256/512/512/1K Bytes EEPROM (ATmega48PA/88PA/168PA/328P)
  - 512/1K/1K/2K Bytes Internal SRAM (ATmega48PA/88PA/168PA/328P)
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C(1)
  - Optional Boot Code Section with Independent Lock Bits
    - In-System Programming by On-chip Boot Program
    - True Read-While-Write Operation
  - Programming Lock for Software Security
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Six PWM Channels
  - 8-channel 10-bit ADC in TQFP and QFN/MLF package
    - Temperature Measurement
  - 6-channel 10-bit ADC in PDIP Package
    - Temperature Measurement
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Byte-oriented 2-wire Serial Interface (Philips I^2C compatible)
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
  - Interrupt and Wake-up on Pin Change
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated Oscillator
  - External and Internal Interrupt Sources
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby
- I/O and Packages
  - 23 Programmable I/O Lines
  - 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF
- Operating Voltage:
  - 1.8 - 5.5V for ATmega48PA/88PA/168PA/328P
- Temperature Range:
  - -40°C to 85°C
- Speed Grade:
  - 0 - 20 MHz @ 1.8 - 5.5V
- Low Power Consumption at 1 MHz, 1.8V, 25°C for ATmega48PA/88PA/168PA/328P:
  - Active Mode: 0.2 mA
  - Power-down Mode: 0.1 A
  - Power-save Mode: 0.75 A (Including 32 kHz RTC)

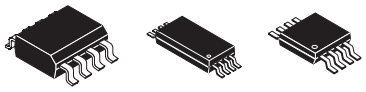
8-bit AVR® Microcontroller with 4/8/16/32K Bytes In-System Programmable Flash

ATmega48PA
ATmega88PA
ATmega168PA
ATmega328P

Rev. 8161D–AVR–10/09

Figure 28: 1st Page of ATmega328P Datasheet

TEXAS INSTRUMENTS



bq2057, bq2057C
bq2057T, bq2057W

SLUS025F – MAY 2001 – REVISED JULY 2002

ADVANCED LINEAR CHARGE MANAGEMENT IC FOR SINGLE- AND TWO-CELL LITHIUM-ION AND LITHIUM-POLYMER

FEATURES

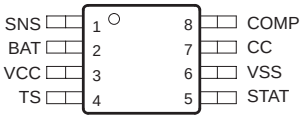
- **Ideal for Single (4.1 V or 4.2 V) and Dual-Cell (8.2 V or 8.4 V) Li-Ion or Li-Pol Packs**
- **Requires Small Number of External Components**
- **0.3 V Dropout Voltage for Minimizing Heat Dissipation**
- **Better Than ±1% Voltage Regulation Accuracy With Preset Voltages**
- **AutoComp™ Dynamic Compensation of Battery Pack's Internal Impedance to Reduce Charge Time**
- **Optional Cell-Temperature Monitoring Before and During Charge**
- **Integrated Voltage and Current Regulation With Programmable Charge-Current and High- or Low-Side Current Sensing**
- **Integrated Cell Conditioning for Reviving Deeply Discharged Cells and Minimizing Heat Dissipation During Initial Stage Of Charge**
- **Charge Status Output for Single or Dual Led or Host Processor Interface**
- **Automatic Battery-Recharge Feature**
- **Charge Termination by Minimum Current**
- **Automatic Low-Power Sleep Mode When V_{CC} Is Removed**
- **EVMs Available for Quick Evaluation**
- **Packaging: 8-Pin SOIC, 8-Pin TSSOP, 8-Pin MSOP**

DESCRIPTION

The BENCHMARQ bq2057 series advanced Lithium-Ion (Li-Ion) and Lithium-Polymer (Li-Pol) linear charge-management ICs are designed for cost-sensitive and compact portable electronics. They combine high-accuracy current and voltage regulation, battery conditioning, temperature monitoring, charge termination, charge-status indication, and AutoComp charge-rate compensation in a single 8-pin IC. MSOP, TSSOP, and SOIC package options are offered to fit a wide range of end applications.

The bq2057 continuously measures battery temperature using an external thermistor. For safety, the bq2057 inhibits charge until the battery temperature is within user-defined thresholds. The bq2057 then charges the battery in three phases: conditioning, constant current, and constant voltage. If the battery voltage is below the low-voltage threshold, $V_{(min)}$, the bq2057 precharges using a low current to condition the battery. The conditioning charge rate is approximately 10% of the regulation current. The conditioning current also minimizes heat dissipation in the external pass-element during the initial stage of the charge. After conditioning, the bq2057 applies a constant current to the battery. An external sense-resistor sets the current. The sense-resistor can be on either the high or low side of the battery without additional components. The constant-current phase continues until the battery reaches the charge-regulation voltage.

bq2057xSN or bq2057xTS
SOIC (SN) or TSSOP (TS) PACKAGE
(TOP VIEW)



bq2057xDGK
MSOP (DGK) PACKAGE
(TOP VIEW)

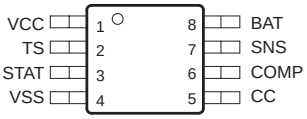


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Figure 29: 1st Page of bq2057 Datasheet

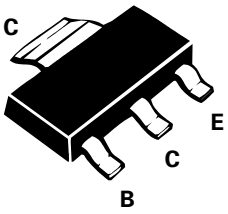
SOT223 PNP SILICON PLANAR MEDIUM POWER HIGH GAIN TRANSISTOR

FZT788B

ISSUE 3 - OCTOBER 1995

FEATURES

* Low equivalent on-resistance; **$R_{CE(sat)}$ 93mΩ at 3A**
* Gain of 300 at I_C=2 Amps and Very low saturation voltage



APPLICATIONS

* Battery powered circuits

COMPLEMENTAY TYPE – FZT688B

PARTMARKING DETAIL – FZT788B

ABSOLUTE MAXIMUM RATINGS.

PARAMETER	SYMBOL	VALUE	UNIT
Collector-Base Voltage	V_{CBO}	-15	V
Collector-Emitter Voltage	V_{CEO}	-15	V
Emitter-Base Voltage	V_{EBO}	-5	V
Peak Pulse Current	I_{CM}	-8	A
Continuous Collector Current	I_C	-3	A
Power Dissipation at T_{amb}=25°C	P_{tot}	2	W
Operating and Storage Temperature Range	T_j:T_{stg}	-55 to +150	°C

ELECTRICAL CHARACTERISTICS (at T_{amb} = 25°C)

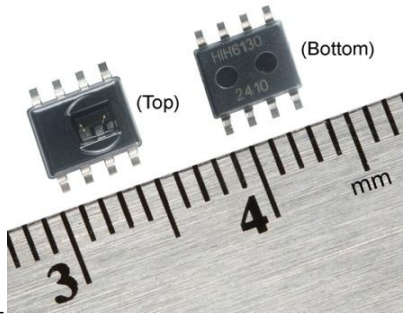
PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNIT	CONDITIONS.
Collector-Base Breakdown Voltage	$V_{(BR)CBO}$	-15			V	I_C=-100μA
Collector-Emitter Breakdown Voltage	$V_{(BR)CEO}$	-15			V	I_C=-10mA*
Emitter-Base Breakdown Voltage	$V_{(BR)EBO}$	-5			V	I_E=-100μA
Collector Cut-Off Current	I_{CBO}			-0.1	μA	V_{CB}=-10V
Emitter Cut-Off Current	I_{EBO}			-0.1	μA	V_{EB}=-4V
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			-0.15 -0.25 -0.45 -0.5	V V V	I_C=-0.5A, I_B=-2.5mA* I_C=-1A, I_B=-5mA* I_C=-2A, I_B=-10mA* I_C=-3A, I_B=-50mA*
Base-Emitter Saturation Voltage	$V_{BE(sat)}$			-0.9	V	I_C=-1A, I_B=-5mA*
Base-Emitter Turn-On Voltage	$V_{BE(on)}$		-0.75		V	I_C=-1A, V_{CE}=-2V*
Static Forward Current Transfer Ratio	h_{FE}	500 400 300 150		1500		I_C=-10mA, V_{CE}=-2V* I_C=-1A, V_{CE}=-2V* I_C=-2A, V_{CE}=-2V* I_C=-6A, V_{CE}=-2V*
Transition Frequency	f_T	100			MHz	I_C=-50mA, V_{CE}=-5V f=50MHz
Input Capacitance	C_{ibo}		225		pF	V_{EB}=-0.5V, f=1MHz
Output Capacitance	C_{obo}		25		pF	V_{CB}=-10V, f=1MHz
Switching Times	t_{on} t_{off}		35 400		ns ns	I_C=-500mA, I_{B1}=-50mA I_{B2}=-50mA, V_{CC}=-10V

*Measured under pulsed conditions. Pulse width=300μs. Duty cycle ≤2%
Spice parameter data is available upon request for this device

Figure 30: 1st Page of FZT788B Datasheet

Honeywell

Honeywell HumidIcon™ Digital Humidity/Temperature Sensors: HIH-6130/6131 Series



DESCRIPTION (★ = *competitive differentiator)*
Honeywell HumidIcon™ Digital Humidity/Temperature Sensors: HIH-6130/6131 Series, is a digital output-type relative humidity (RH) and temperature sensor combined in the same package. These devices offer several competitive advantages, including:

- Industry-leading Total Error Band
- Industry-leading stability
- Industry-leading reliability
- Lowest total cost solution
- True temperature-compensated digital I^2C output
- Energy efficiency
- Ultra-small package

★ **Industry-leading Total Error Band (TEB) (±5 %RH):** Honeywell specifies Total Error Band—the most comprehensive, clear, and meaningful measurement –that provides the sensor's true accuracy of ±5 %RH over a compensated range of 5 °C to 50 °C [41 °F to 122 °F] and 10 %RH to 90 %RH. TEB includes all errors due to:

- Humidity non-linearity
- Humidity hysteresis
- Humidity non-repeatability
- Thermal effect on zero
- Thermal effect on span
- Thermal hysteresis

Total Error Band should not be confused with "Accuracy", which is actually a component of Total Error Band. Many competitors simply specify the accuracy of their device; however, the specification may exclude hysteresis and temperature effects, and may be calculated over a very narrow range, at only one point in the range, or at their absolute best accuracy level. It is then up to the customer to calibrate the device to make sure it has the accuracy needed for the life of the application.

Honeywell's industry-leading Total Error Band provides the following benefits to the customer:

- Eliminates individually testing and calibrating every sensor, which can increase their manufacturing time and process
- Supports system accuracy and warranty requirements
- Helps to optimize system uptime
- Provides excellent sensor interchangeability—the customer can remove one sensor from the tape, remove the next sensor from the tape, and there is no part-to-part variation in accuracy

For more information about Total Error Band, please see the related Technical Note "Explanation of the Total Error Band Specification for Honeywell's Digital Humidity/Temperature Sensors."

★ **Industry-leading long term stability (1.2 %RH over five years):** Competitive humidity sensors need to go through a 12 hour at 75 %RH rehydration process (which requires special equipment chambers) to correct reflow temperature offset. Honeywell's sensor also experiences an offset after reflow; however, it only requires a five hour rehydration under ambient conditions (>50 %RH). Honeywell's industry-leading long term stability provides the following benefits to the customer:

- Minimizes system performance issues
- Helps support system uptime by eliminating the need to service or replace the sensor during its application life
- Eliminates the need to regularly recalibrate the sensor in their application, which can be inconvenient and costly

★ **Industry-leading reliability:** Honeywell's new HIH-6130/6131 Series sensors use a laser trimmed, thermoset polymer capacitive sensing element. The element's multilayer construction provides resistance to most application hazards such as condensation, dust, dirt, oils, and common environmental chemicals which help provide industry-leading stability and reliability.

Figure 31: 1st Page of HIH6130 Datasheet

湖南桑顿新能源有限公司
Hunan Sounddon New Energy Co.,Ltd

Specification No. APL-2013517
Edition No. 1.0

Cylindrical Li－ion Battery Pack

Product Specification

Model：18650 3.7v 4400mAh

Hunan Sounddon New Energy Co., Ltd

Address:No.98, Fuzhou Road,Jinhua Demonstration Area,Xiangtan City,Hunan Province,China.

http://www.soundnewenergy.com

Tel: (86) 731 - 5856 7126

Fax: (86) 731 - 5823 6346

E-mail:linda.ding@soundnewenergy.com

Prepared by：Liu Li

Checked by：Zhu Qiang

Approve by: Xiao Linping

All 10 Sheets

Figure 32: 1st Page of Li-Ion Battery Pack Datasheet

LM75B

Digital temperature sensor and thermal watchdog

Rev. 6.1 — 6 February 2015 Product data sheet

1. General description

The LM75B is a temperature-to-digital converter using an on-chip band gap temperature sensor and Sigma-Delta A-to-D conversion technique with an overtemperature detection output. The LM75B contains a number of data registers: Configuration register (Conf) to store the device settings such as device operation mode, OS operation mode, OS polarity and OS fault queue as described in Section 7 “Functional description”; temperature register (Temp) to store the digital temp reading, and set-point registers (Tos and Thyst) to store programmable overtemperature shutdown and hysteresis limits, that can be communicated by a controller via the 2-wire serial I^2C-bus interface. The device also includes an open-drain output (OS) which becomes active when the temperature exceeds the programmed limits. There are three selectable logic address pins so that eight devices can be connected on the same bus without address conflict.

The LM75B can be configured for different operation conditions. It can be set in normal mode to periodically monitor the ambient temperature, or in shutdown mode to minimize power consumption. The OS output operates in either of two selectable modes: OS comparator mode or OS interrupt mode. Its active state can be selected as either HIGH or LOW. The fault queue that defines the number of consecutive faults in order to activate the OS output is programmable as well as the set-point limits.

The temperature register always stores an 11-bit two’s complement data giving a temperature resolution of 0.125 °C. This high temperature resolution is particularly useful in applications of measuring precisely the thermal drift or runaway. When the LM75B is accessed the conversion in process is not interrupted (that is, the I^2C-bus section is totally independent of the Sigma-Delta converter section) and accessing the LM75B continuously without waiting at least one conversion time between communications will not prevent the device from updating the Temp register with a new conversion result. The new conversion result will be available immediately after the Temp register is updated.

The LM75B powers up in the normal operation mode with the OS in comparator mode, temperature threshold of 80 °C and hysteresis of 75 °C, so that it can be used as a stand-alone thermostat with those pre-defined temperature set points.

2. Features and benefits

- Pin-for-pin replacement for industry standard LM75 and LM75A and offers improved temperature resolution of 0.125 °C and specification of a single part over power supply range from 2.8 V to 5.5 V
- I^2C-bus interface with up to 8 devices on the same bus
- Power supply range from 2.8 V to 5.5 V
- Temperatures range from −55 °C to +125 °C

Figure 33: 1st Page of LM75B Datasheet

LMR61428 SIMPLE SWITCHER® 14Vout, 2.85A Step-Up Voltage Regulator in VSSOP

Check for Samples: LMR61428

FEATURES

- **1.2V to 14V Input Voltage**
- **Adjustable Output Voltage up to 14V**
- **Switch Current up to 2.85A**
- **Up to 2 MHz Switching Frequency**
- **Low Shutdown Iq, <1µA**
- **Cycle-by-Cycle Current Limiting**
- **VSSOP Packaging (3.0 x 5.0 x 1.09mm)**
- **WEBENCH® Enabled**

PERFORMANCE BENEFITS

- **Extremely Easy to Use**
- **Tiny Overall Solution Reduces System Cost**

APPLICATIONS

- **Boost/SEPIC Conversions from 3.3V, 5V, and 12V**
- **Space Constrained Applications**
- **LCD Displays**
- **LED Applications**

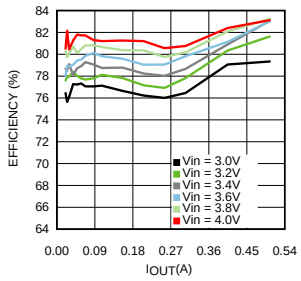
DESCRIPTION

The LMR61428 is a step-up DC-DC switching regulator for battery-powered and low input voltage systems that can achieve efficiencies up to 90%. It has a wide input voltage range from 1.2V to 14V and a possible regulated output voltage range of 1.24V to 14V. It has an internal 0.17Ω N-Channel MOSFET power switch.

The high switching frequency of up to 2MHz of the LMR61428 allows for tiny surface mount inductors and capacitors. Because of the unique constant-duty-cycle gated oscillator topology very high efficiencies are realized over a wide load range. The supply current is reduced to 80µA because of the BiCMOS process technology. In the shutdown mode, the supply current is less than 2.5µA. The LMR61428 is available in a VSSOP-8 package.

System Performance

Efficiency vs Load Current, V_{OUT} = 5V



Efficiency vs Load Current, V_{OUT} = 3.3V

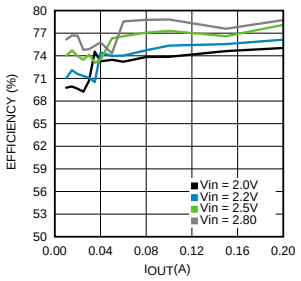


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Figure 34: 1st Page of LMR61428 Datasheet

LTC4412

Low Loss PowerPath™ Controller in ThinSOT

FEATURES

- **Very Low Loss Replacement for Power Supply OR'ing Diodes**
- **Minimal External Components**
- **Automatic Switching Between DC Sources**
- **Simplifies Load Sharing with Multiple Batteries**
- **Low Quiescent Current: 11µA**
- 3V to 28V AC/DC Adapter Voltage Range
- 2.5V to 28V Battery Voltage Range
- Reverse Battery Protection
- Drives Almost Any Size MOSFET for Wide Range of Current Requirements
- MOSFET Gate Protection Clamp
- Manual Control Input
- Low Profile (1mm) ThinSOT™ Package

APPLICATIONS

- Cellular Phones
- Notebook and Handheld Computers
- Digital Cameras
- USB-Powered Peripherals
- Uninterruptible Power Supplies
- Logic Controlled Power Switch

LT, LTC, LTM, Linear Technology and the Linear logo are registered trademarks and PowerPath and ThinSOT are trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners.

DESCRIPTION

The LTC®4412 controls an external P-channel MOSFET to create a near ideal diode function for power switchover or load sharing. This permits highly efficient OR'ing of multiple power sources for extended battery life and low self-heating. When conducting, the voltage drop across the MOSFET is typically 20mV. For applications with a wall adapter or other auxiliary power source, the load is automatically disconnected from the battery when the auxiliary source is connected. Two or more LTC4412s may be interconnected to allow load sharing between multiple batteries or charging of multiple batteries from a single charger.

The wide supply operating range supports operation from one to six Li-Ion cells in series. The low quiescent current (11µA typical) is independent of the load current. The gate driver includes an internal voltage clamp for MOSFET protection.

The STAT pin can be used to enable an auxiliary P-channel MOSFET power switch when an auxiliary supply is detected. This pin may also be used to indicate to a microcontroller that an auxiliary supply is connected. The control (CTL) input enables the user to force the primary MOSFET off and the STAT pin low.

The LTC4412 is available in a low profile (1mm) ThinSOT package.

TYPICAL APPLICATION

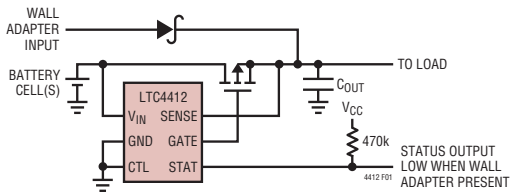

Figure 1. Automatic Switchover of Load Between a Battery and a Wall Adapter

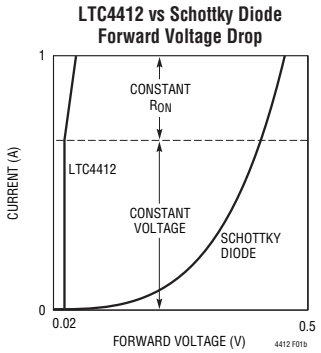

Figure 35: 1st Page of LTC4412 Datasheet

LTC6800

Rail-to-Rail, Input and Output, Instrumentation Amplifier

FEATURES

- **116dB CMRR Independent of Gain**
- **Maximum Offset Voltage: 100µV**
- **Maximum Offset Voltage Drift: 250nV/°C**
- **–40°C to 125°C Operation**
- Rail-to-Rail Input Range
- Rail-to-Rail Output Swing
- Supply Operation: 2.7V to 5.5V
- Available in MS8 and 3mm × 3mm × 0.8mm DFN Packages

APPLICATIONS

- Thermocouple Amplifiers
- Electronic Scales
- Medical Instrumentation
- Strain Gauge Amplifiers
- High Resolution Data Acquisition

DESCRIPTION

The LTC®6800 is a precision instrumentation amplifier. The CMRR is typically 116dB with a single 5V supply and is independent of gain. The input offset voltage is guaranteed below 100µV with a temperature drift of less than 250nV/°C. The LTC6800 is easy to use; the gain is adjustable with two external resistors, like a traditional op amp.

The LTC6800 uses charge balanced sampled data techniques to convert a differential input voltage into a single ended signal that is in turn amplified by a zero-drift operational amplifier.

The differential inputs operate from rail-to-rail and the single ended output swings from rail-to-rail. The LTC6800 is available in an MS8 surface mount package. For space limited applications, the LTC6800 is available in a 3mm × 3mm × 0.8mm dual fine pitch leadless package (DFN).

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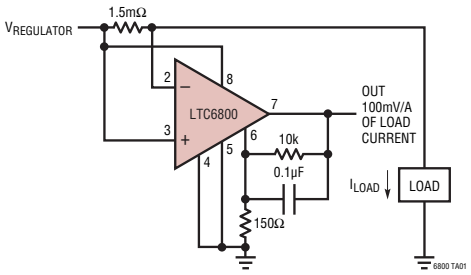
TYPICAL APPLICATION

High Side Power Supply Current Sense



Typical Input Referred Offset vs Input Common Mode Voltage (V_S = 3V)

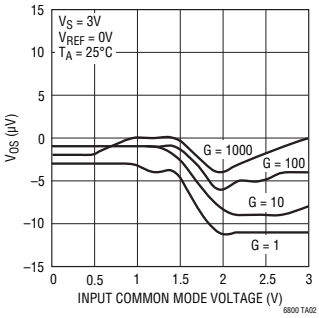


Figure 36: 1st Page of LTC6800 Datasheet

Micropower Voltage Regulator

Check for Samples: SM72238

FEATURES

- **Renewable Energy Grade**
- **High-Accuracy Output Voltage**
- **Ensured 100mA Output Current**
- **Extremely Low Quiescent Current**
- **Low Dropout Voltage**
- **Extremely Tight Load and Line Regulation**
- **Very Low Temperature Coefficient**
- **Use as Regulator or Reference**
- **Needs Minimum Capacitance for Stability**
- **Current and Thermal Limiting**
- **Stable With Low-ESR Output Capacitors (10mΩ to 6Ω)**

DESCRIPTION

The SM72238 is a micropower voltage regulator with very low quiescent current (75µA typ.) and very low dropout voltage (typ. 40mV at light loads and 380mV at 100mA). It is ideally suited for use in battery-powered systems. Furthermore, the quiescent current of the SM72238 increases only slightly in dropout, prolonging battery life.

The SM72238 is available in the surface-mount D-Pak package.

Careful design of the SM72238 has minimized all contributions to the error budget. This includes a tight initial tolerance (.5% typ.), extremely good load and line regulation (.05% typ.) and a very low output voltage temperature coefficient, making the part useful as a low-power voltage reference.

Block Diagram and Typical Applications

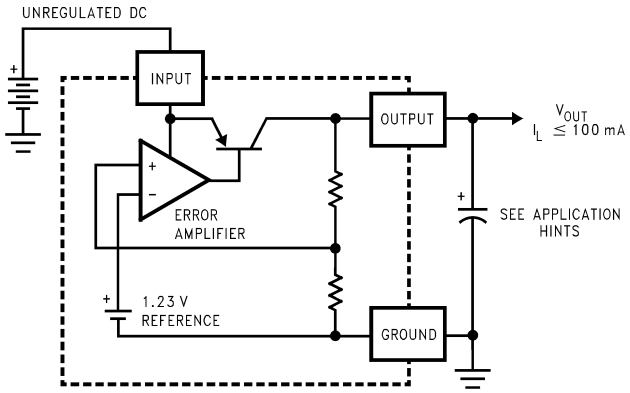


Figure 1. SM72238

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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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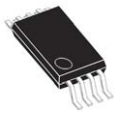
Figure 37: 1st Page of SM72238 Datasheet

life.augmented

SPV1040

High efficiency solar battery charger with embedded MPPT

Datasheet - production data



TSSOP8

Features

- 0.3 V to 5.5 V operating input voltage
- 140 mΩ internal synchronous rectifier
- 120 mΩ internal power active switch
- 100 kHz fixed PWM frequency
- Duty cycle controlled by MPPT algorithm
- Output voltage regulation, overcurrent and overtemperature protection
- Input source reverse polarity protection
- Built-in soft-start
- Up to 95% efficiency
- 3 mm x 4.4 mm TSSOP8 package

Applications

- Smart phones and GPS systems
- Wireless headsets
- Small appliances, sensors
- Portable media players
- Digital still cameras
- Toys and portable healthcare

Description

The SPV1040 device is a low power, low voltage, monolithic step-up converter with an input voltage range from 0.3 V to 5.5 V, and is capable of maximizing the energy generated by even a single solar cell (or fuel cell), where low input voltage handling capability is extremely important.

Thanks to the embedded MPPT algorithm, even under varying environmental conditions (such as irradiation, dirt, temperature) the SPV1040 offers maximum efficiency in terms of power harvested from the cells and transferred to the output.

The device employs an input voltage regulation loop, which fixes the charging battery voltage via a resistor divider. The maximum output current is set with a current sense resistor according to charging current requirements.

The SPV1040 protects itself and other application devices by stopping the PWM switching if either the maximum current threshold (up to 1.8 A) is reached or the maximum temperature limit (up to 155 °C) is exceeded.

An additional built-in feature of the SPV1040 is the input source reverse polarity protection, which prevents damage in case of reverse connection of the solar panel at the input.

Table 1. Device summary

Order code	Package	Packaging
SPV1040T	TSSOP8	Tube
SPV1040TTR		Tape and reel

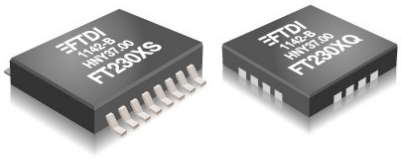
This is information on a product in full production. www.st.com

Figure 38: 1st Page of SPV1040 Datasheet

Future Technology Devices International Ltd.

FT230X

(USB to BASIC UART IC)



The FT230X is a USB to serial UART interface with optimised pin count for smaller PCB designs and the following advanced features:

- Single chip USB to asynchronous serial data transfer interface.
- Entire USB protocol handled on the chip. No USB specific firmware programming required.
- Fully integrated 2048 byte multi-time-programmable (MTP) memory, storing device descriptors and CBUS I/O configuration.
- Fully integrated clock generation with no external crystal required plus optional clock output selection enabling a glue-less interface to external MCU or FPGA.
- Data transfer rates from 300 baud to 3 Mbaud (RS422, RS485, and RS232) at TTL levels.
- 512 byte receive buffer and 512 byte transmit buffer utilising buffer smoothing technology to allow for high data throughput.
- FTDI's royalty-free Virtual Com Port (VCP) and Direct (D2XX) drivers eliminate the requirement for USB driver development in most cases.
- Configurable CBUS I/O pins.
- Transmit and receive LED drive signals.
- UART interface support for 7 or 8 data bits, 1 or 2 stop bits and odd / even / mark / space / no parity
- Synchronous and asynchronous bit bang interface options with RD# and WR# strobes.
- USB Battery Charger Detection. Allows for USB peripheral devices to detect the presence of a higher power source to enable improved charging.
- Device supplied pre-programmed with unique USB serial number.
- USB Power Configurations; supports bus- powered, self-powered and bus-powered with power switching
- Integrated +3.3V level converter for USB I/O.
- True 3.3V CMOS drive output and TTL input; operates down to 1V8 with external pull ups. Tolerant of 5V input
- Configurable I/O pin output drive strength; 4 mA (min) and 16 mA (max).
- Integrated power-on-reset circuit.
- Fully integrated AVCC supply filtering - no external filtering required.
- UART signal inversion option.
- + 5V Single Supply Operation.
- Internal 3V3/1V8 LDO regulators
- Low operating and USB suspend current; 8mA (active-typ) and 70uA (suspend-typ).
- UHCI/OHCI/EHCI host controller compatible.
- USB 2.0 Full Speed compatible.
- Extended operating temperature range; -40 to 85ºC.
- Available in compact Pb-free 16 pin SSOP and 16 pin QFN packages (both RoHS compliant).

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Figure 39: 1st Page of FTDI Datasheet

Appendix F: Source Code