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"No Strain, No Gain"

Power Measurement of Performance Bicycles

IPRO 324 - Project Plan

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IPRO 324 Spring 2011

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Table of Contents

Abstract

During the 2011 Spring Semester, IPRO 324 aimed to further develop a power meter that can be applied to any crank set and will accurately collect and transmit data to current cycling computers as well as cost significantly less than comparable systems. The need and development of such a system is in response to the increasing number of competitive cyclists around the world that are using technology to monitor training data in order to improve their training methods. Power measurements are important to such training, however existing power meters are expensive and require the cyclist to replace existing crank sets.

Thus, this semester built upon the work of previous semesters in order to bring this system closer to completion. The work done during the Spring 2011 semester focused on establishing the communication between the circuit used for power measurements and the cycling computer via the integration of a microprocessor. In addition, an improved design for the casing that would house such a system on the crank was developed.

Purpose and Objectives

The overall objective of this IPRO is to create are power meter that is less expensive and which can be applied to any crank set that cyclists may own. The problem with the current power meter market is that the cyclists must spend a $1000 or more in order to integrate the system into their training. Also, the cyclist is forced to replace the current crank they have when purchasing one of these meters.

The main purpose of 2011 Spring IPRO 324 team is to build upon work completed during previous semesters in order to bring this design closer to production. Work by the Spring 2011 semester was geared toward making communication between the circuit that collects the power data and the cycling computer via ANT+ wireless technology. The ANT+ wireless communication will transmit power data gathered via the circuit on board to the cycling computer that is also ANT+ compatible. In addition to establishing communication, this semester aimed to develop a high level interface for the current program that is used in establishing communication between the microprocessor and the ANT+ chip. This would allow future semesters to focus less on the initial program of the system and more toward the programming needed to establish communication between the ANT+ chip and the cycling computer. Also, the idea for integrating a port into the system that can be used for future firmware or software updates could be easily performed on the system was proposed. Lastly, this semester focused on improving the design of the casing for this power meter such that it will allow for more room to house the circuit as well as become more applicable to a wide range of crank sets.

Team Organization and Approach

When initially determining what the focus of this semesters work should be we considered the disciplines and strengths of the respective members of our group. Since there were only three different disciplines represented, it made sense to divide our team into sub-teams based on those disciplines. The sub-teams formed consisted of computer science, electrical engineering, and mechanical engineering. Since the majority of the group consisted of backgrounds in electrical engineering and computer science, it was clear that focus should be placed on the aspects of the project covered by those disciplines.

Thus, it was decided that the main goal of this semester was to establish communication with the Garmin unit for this was the major component of the power meter system that had not be successfully completed in previous semesters. However, this was something that was going to require building and testing several circuit configurations in addition to rewriting the majority of previous coding. The electrical engineering and computer science teams worked closely together to test and debug the communication between the microprocessor and ANT chip, which is the initial step in creating communication between the circuit and the cycling computer. At the end of the semester communication was established between the microprocessor and ANT chip. However, the teams did not achieve their goal of communicating with the Garmin cycling computer, but the work they did will make it significantly easier for future IPRO 324's to establish communication with the Garmin unit.

A secondary goal determined by the this team was to create a more versatile housing unit that would better house the current system as well as cover a wider range of performance bicycles. This task was focused on by the mechanical engineering team. The team spent much of the semester learning the appropriate modeling software to create the housing design. A new more versatile design was achieved by the mechanical engineering team with help from Kai Hansen in the machine shop in the Engineering 1 building.

Analysis

Electrical Team

During the first weeks of the semester the electrical engineering team started to review the previous semester's results, most importantly the circuit design. However, the team encountered numerous hurdles in that documentation on the circuit was minimal, and the design was very complicated. The team then decided to bring in outside help in the form of a previous member of which he was able to run through the circuit with the team and explain exactly how it operated. After obtaining a deeper understand of the past design, we were able to continue forward in the work that was projected for this semester.

We determined that the next step in obtaining the ultimate result of communication between the bicycle's circuit and the Garmin unit, would be to establish communication between the current microprocessor and ANT+ chip. The first move was to research these two technologies. The team had no prior experience with working with either so extensive research had to be done in order to achieve the byte synchronous communication needed to transmit data.

After sufficiently researching both the microprocessor and the ANT chip, the electrical engineering team then began to work in the circuit to achieve this communication. This involved many different iterations of the circuit diagram. Documentation on exactly which diagrams to use that were provided by previous semesters as well as from the ANT+ was very poor and difficult to understand. A considerable amount of time was spent testing these different configurations, recording the results, and trying to figure out exactly how to establish communication between the system and the Garmin unit. The team contacted outside help from the ANT forums and tech support from Nordic Semiconductor.

Ultimately, after many different versions of the diagrams, the electrical engineering team in conjuncture with the computer science team was able to achieve communication between the micro controller and the ANT+ chip. The correct diagrams are now listed in the appendices and should be referenced by future IPRO 324 in order to continue work on achieving communication between the circuit and the cycling computer.

Mechanical Team

Throughout the semester, the mechanical team worked to update the existing housing design to ensure that it is more versatile as well as house the circuit for the system. Due to the fact the end goal for the housing requires use on as many crank sets as possible, the initial design must be as versatile as possible.

The mechanical team spent the first couple weeks of the semester learning the old design as well as obtaining the correct software to update the design. The correct modeling software that the original design was created in was originally not available for the mechanical team. Obtaining this software proved to be an initial starting block because it was harder to obtain that expected. Additionally, without the software, the mechanical team could not review the previous design in order to see what needed to be updated.

Once all the software was obtained and the original design learned, the mechanical team made a few additions to the design. Such additions included adding bolt holes to the housing so that it can be secured onto the crank. Also, since the processes of properly installing the strain gauges in the housing had never been documented, the mechanical team made sure to do so in order for future teams to understand and learn the correct process. Finally, the team worked with Kai Hansen in the machine shop at IIT to obtain a prototype of the design which may be retrofitted into the test bicycle.

Computer Science Team

In collaboration with the electrical engineering team, our group chose to try and create a viable solution for the end stages of this product. This involved placing a MCU or micro controller onto the circuit board along with an ANT+ device to transmit the incoming power data over a radio frequency (RF). The final product requires such a setup on the bicycle in order to ensure the space requirement are met along with the ability to record the power data while the bike is in use.

To start off, the computer science team, having little background on the relevant subjects already, spent the first few weeks conducting research on the various settings of the microprocessor, protocols for communication between the MCU and an ANT chip, and also the communication protocols between the ANT chip and an ANT+ device such as a Garmin unit. While most of this would appear to be straightforward, much of the provided documentation on these subjects was either vague or inaccurate. In order to ensure we had the correct settings for the MCU and communication, the computer science team had to work closely with the electrical engineering team to produce multiple iterative designs. With each new update to the circuit, the computer science team had to go through and check each possible combination of the settings for the MCU in order try and successfully communicate with the ANT chip. Unfortunately, due to the number of sections in the documentation which were too vague to be sure about, we were required to go through a large number of permutations of the code.

However, even though the number of tries completed were numerous, working with the electrical engineering team very closely, the computer science team did manage to obtain communication between the MCU and the ANT chip. This is the very first step in obtaining communication between the circuit board and the Garmin device and now will enable future computer science teams to focus more on the ANT+ protocols and the SPI protocol for communication between the two processors. Additionally, in order to aid these future team members, the computer science team has produced a high level interface in the code in order to reduce the amount of background information required to work with the code and to move the focus toward ANT+ communication and not the MCU's settings.

Conclusion

Although we did not achieve communication between the ANT+ chip and the Garmin unit, this semester was successful. We conquered the very difficult task of getting the microprocessor and ANT+ chip to communicate with one another. The next step will be establishing communication with the Garmin unit. This should be significantly easier for future IPRO 324's because the communication from the ANT+ chip to the Garmin unit is well documented and follows strict protocols.

At the beginning of the semester the documentation from previous semesters was minimal at best. Our group had to spend a significant amount of time researching work that had previously been done. The future IPRO 324's should have a much easier time starting the project because of the improvements that our group has made in the project's documentation. We hope that these improvements will accelerate the future teams progress by clarifying the methods used and the work done.

It is also strongly suggested that future IPRO 324 team members have prior experience in the areas of 3-dimensional modeling and embedded systems. There was a large portion of our teams time spent learning key concepts that could have been eliminated if our members had more prior experience.

After the establishment of communication between the ANT+ chip and the Garmin unit is achieved, future members should focus on creating a printed circuit board that will fit within the housing. With both of these tasks accomplished the product will likely be ready to go to market. At this point, IPRO 324 could easily become an EnPRO.

Appendix

[Contact Information]

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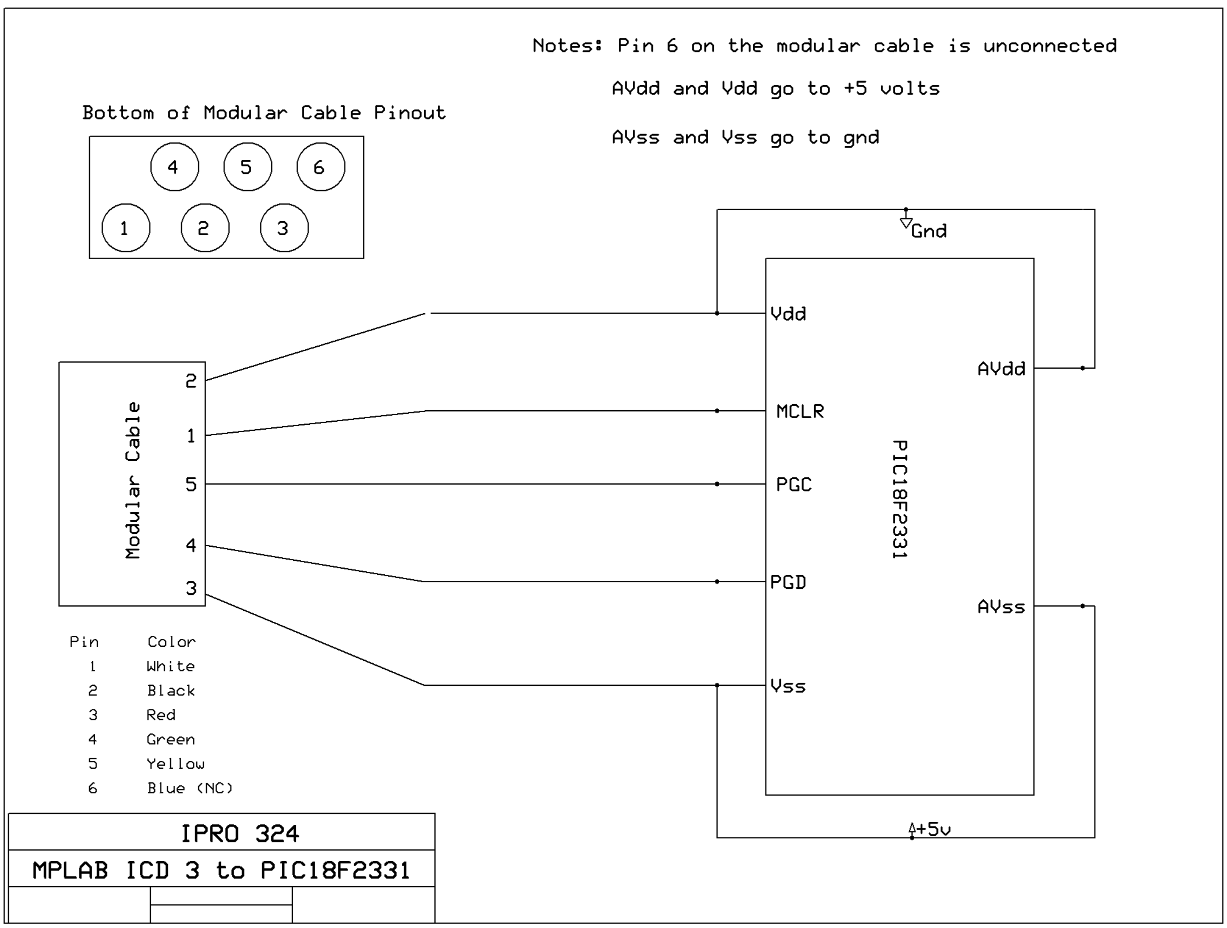
[Budget]

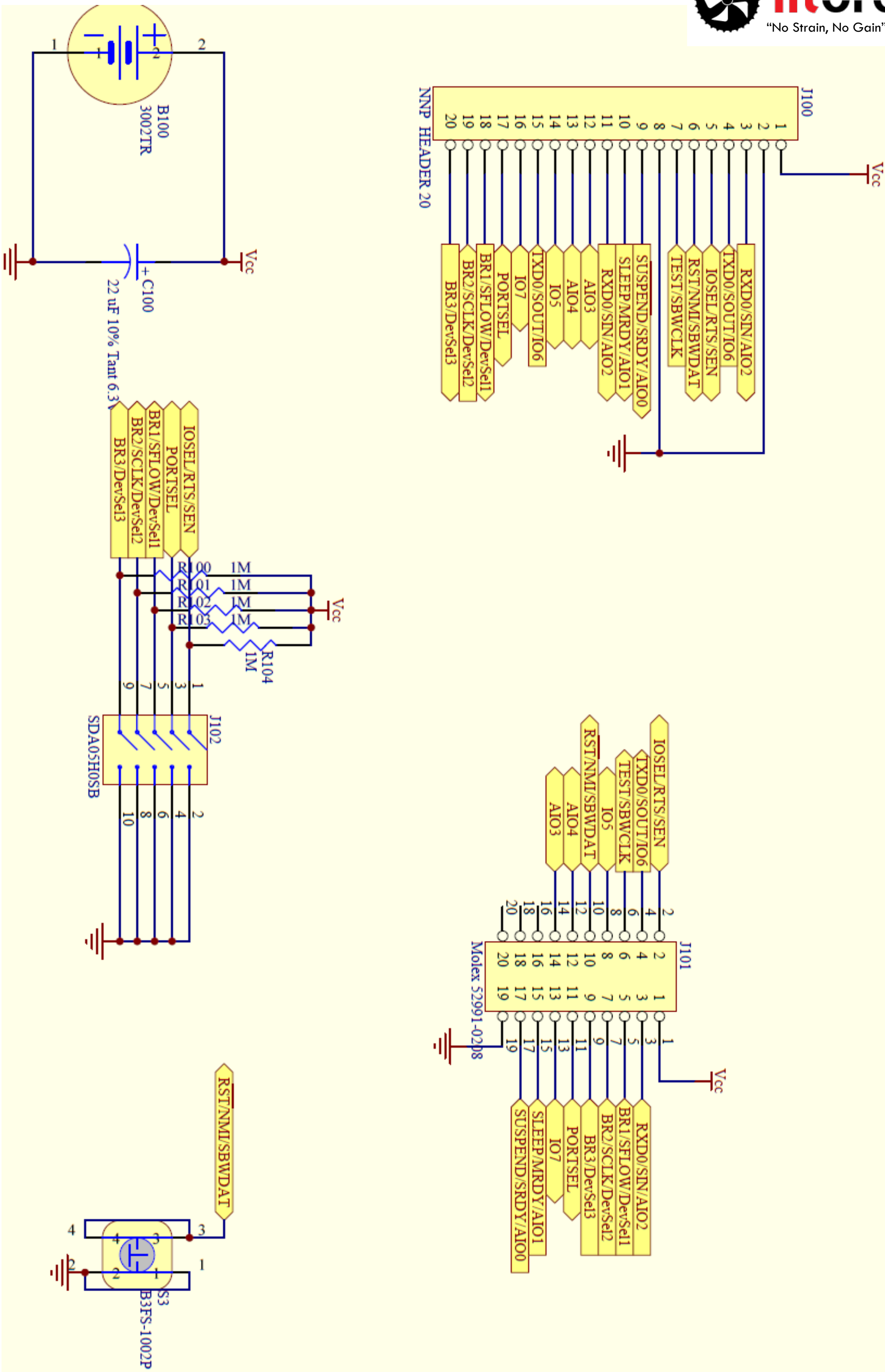
Item	*Cost*	*Description*
Prototyping	$50	Prototype of improved design was made
Electrical devices/parts	$100	Various electrical components needed for the circuit
ANT+ development kit	$700	Contains ANT+ chip to establish communication between the circuit and Garmin unit
Total Cost:	$850	

All of the following images and reference pdf files are uploaded to igroups for future groups to use and utilize. The first diagram is the connection from the MPLAB's "In circuit debugger" (ICD) 3 to the micro controller. This connection serves two purposes. First, it allows the microprocessor to be programmed. Second, it allows the microprocessor's registers and variables to be looked at before and after operation allowing for easier debugging. (Reference: MPLAD_ICD3_manual.pfd)

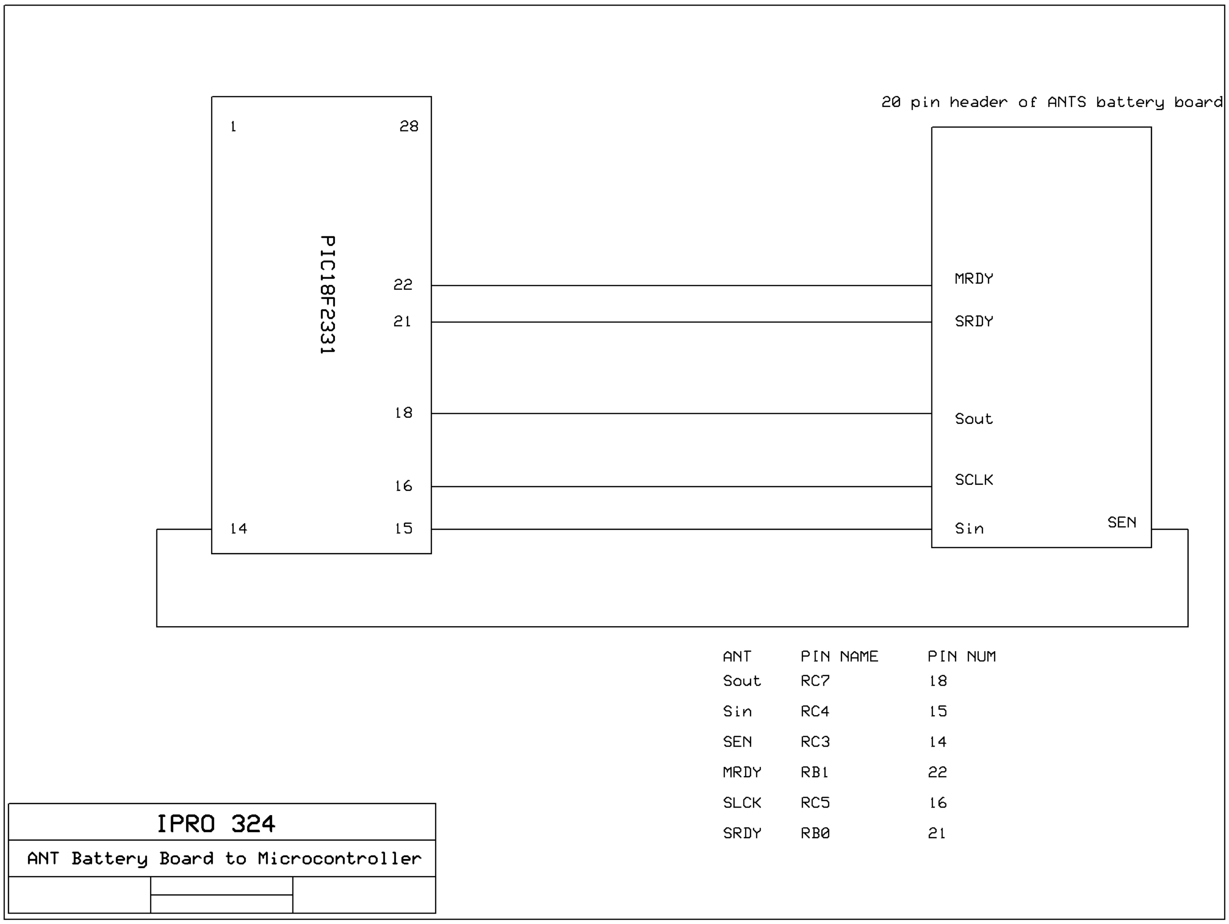


The next diagram is the diagram depicting the pinout and pin assignments of ANT's 20 pin header battery board. Its important to note that pins 1 are connected to Vcc in the battery board, pins 2 and 8 are also connected to ground through the battery board. No external work has to be done with any of those pins. Also the pull up resistors in the dip switches are already included in the battery board.

Also, pins 17 – 20 are set according to the dip switches on the back of the battery board. This can be seen by the SDA05H0SB component in the diagram. These pins should be set depending on what kind of communication the user wishes to use. In the case of this IPRO which we are trying to achieve byte synchronous communication, pins SFLOW and BR3/DevSel3 are set to ground and everything else is set to Vcc. (Reference: Battery Board.pdf, Ant_Devolopment_Kit_User_Maunal.pdf, ANTchip_AP281M5IB.pdf)


B100
3002TR
C100
22 uF 10% Tant 6.3V
Vcc
J100
NNP HEADER 20
RXD0/SIN/AIO2
TXD0/SOUT/IO6
IOSEL/RTS/SEN
RST/NMI/SBWDAT
TEST/SBWCLK
SUSPEND/SRDY/AIO0
SLEEP/MRDY/AIO1
RXD0/SIN/AIO2
AIO3
AIO4
IO5
TXD0/SOUT/IO6
IO7
PORTSEL
BR1/SFLOW/DevSel1
BR2/SCLK/DevSel2
BR3/DevSel3
R100 1M
R101 1M
R102 1M
R103 1M
R104 1M
J102
SDA05H0SB
J101
Molex 52991-0208
S3
B3FS-1002P

The last diagram is how the battery board and the microprocessor come together. In combination with this diagram and the MPLAB ICD3 diagram, the user can program and debug the circuit at the same time. (Reference: pic18f2331 microcontroller datasheet.pdf, BatteryBoard.pdf, Ant_Devolopment_Kit_User_Maunal.pdf, ANTchip_AP281M5IB.pdf).



ANT	PIN NAME	PIN NUM
Sout	RC7	18
Sin	RC4	15
SEN	RC3	14
MRDY	RB1	22
SLCK	RC5	16
SRDY	RB0	21