Bike Buddy

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***Abstract* — The Bike Buddy is a renewable energy project, inspired by today's increasing cost of energy. It features a bike with an electric AC generator, which will power onboard electronics through a system of lithium-ion batteries. The devices being powered by this system include a LCD monitor, GPS, USB plug in (with charging capabilities), a temperature sensor, and a microcontroller. The LCD monitor displays the following: geo-location, rider velocity, ambient temperature, time of day, power being generated by the rider pedaling the bike, and the charge state of the lithium-ion batteries. The objective of this project is to effectively charge the lithium ion batteries via the electric AC generator, while maintaining complete operation of the onboard peripheral devices.**

***Index Terms* — Renewable energy, bicycle generator,**

I. Introduction

The Bike Buddy is a self-sustained, eco-friendly system which can be implemented on almost any bicycle. With alternative energy sources quickly on the rise, we felt this would be an interesting and motivational project for efficiently creating and harnessing power. We also wanted to be able to read how much power could be created by a human pedaling a bicycle. Questions arose like how long could they sustain generating a significant amount of power? And was this enough power for modern devices used for entertainment purposes? Not only would the Bike Buddy answer these questions, it would provide information on what types of applications could arise from human generated power sources.

Renewable and alternative energy sources are becoming more important to our society and future generations. Our design group wished to build something with energy as our focus. After a little brainstorming we decided to use the idea of harnessing the energy which could be produced from putting an electric generator on a bike. This isn't an original idea and in fact bike powered projects are quite common. Our group wished to design a unique system that could be used on the open road versus a stationary mechanism.

A small "bottle" shaped electric generator designed specifically for bikes was found on the internet. It works by hugging the tire of the bike to spin the induction mechanism of the generator. Four battery types were considered for the Bike Buddy, and lithium ion was chosen as the best solution. The Li-ion's high power-to-weight ratio, cycle durability, and charge/discharge efficiency makes it the most attractive choice for our application. Two 7.4 Volt lithium ion batteries will be used in our design. One will provide power to the onboard devices, while the other is being charged by the generator. When the battery powering the Bike Buddy reaches a critical discharge level, it will switch states with the other battery going into charge mode.

Fig 1. Bicycle with

To switch the batteries, we designed a switching circuit that monitors the two batteries. There are two comparators connected to each of the batteries to monitor the voltage levels and compare them to a reference voltage of 3.5V. Once the battery supplying power to the main circuit reaches 3.5V, the comparator connected to that battery sends a signal to series of p-channel MOSFET's switching the output to the other battery. Right after the switch, the drained battery is connected to the charger until the next switch cycle. Although the switching is done very quickly, the main board may experience voltage dips occasionally. Therefore, to prevent any intermittent power loss, a capacitor is connected to the output.

A microcontroller is used to collect data from the GPS module and temperature sensor and display this information on the LCD. The GPS and LCD both communicate using asynchronous serial data, which is handled by USART on the microcontroller. These devices will need a range of 3.3 to 6 Volts to power each. An adjustable switching regulator was chosen to regulate the batteries voltage to supply power to these devices. The MAX608 had the required input and output voltage ranges for our design. Three MAX608 regulators are to be used in dividing up the power from the battery to each device.

There are many similar projects which have been built and documented on the internet. When doing research for the Bike Buddy many of these projects were studied to find the best design methods. Some were previous Electrical Engineering Senior design projects and others were independent studies. Both provided insightful information on the design process and parts that could be used.

II. System Components

The system is best presented in terms of system components; that is, the individual physical modules—whether purchased or designed—that are interfaced to create the final product. This section provides a semi-technical introduction to each of these components.

A. *Electric generator*

The 'bottle' generator chosen for the project has a marked output of 6 watts at 12 volts AC, shown in **Error! Reference source not found.**. This voltage is unregulated. It is attached to the bike frame near the rear wheel with a metal clamp. Its dimensions are 2.5" in length with a diameter of 1.25".

B. *Power supply*

The power supply takes an AC input voltage from 0V to 50V that normally comes from a small generator and converts it to DC. Since the generator can only output a minimal voltage, there is no need to use a step-down transformer in the power supply; just a simple voltage regulator will suffice. The DC conversion circuit will output a DC voltage with enough filtering to prevent transient noise. After that voltage is converted and regulated, that DC voltage is used to charge a rechargeable battery. That same voltage will also be used to power a switching circuit that'll decide which battery to use to power the system.

C. *Battery*

Two 2-cell lithium ion battery packs are used in this project. The Lithium Ion module is made of 2 pieces of high quality 18500 rechargeable cells with a 2 Amp poly switch for full protection of over-heating. The cells are wrapped in transparent PVC shrink with external 22 AWG wire. This pack is installed with an internal IC chip to prevent over and under discharge situations.

D. *Battery Switcher*

Since two Li-Ion batteries are in used, it is crucial that can switch between the two batteries when one is depleted. To achieve that feat, we use an automatic switching mechanism to monitors the battery levels and switch when necessary without halting the normal operation of the unit. Two comparators are used to keep monitor the battery levels and compare them with a minimum voltage of 3.5V. When the Li-Ion battery that powers the unit reaches 3.5V, the output of the comparator is high to turn on a transistor that controls the input power of the unit.

E. *Display*

A 160x128 pixel liquid crystal display was chosen for the project. The screen requires 6-7 V and has scalable LED backlighting. According to the datasheet, it draws approximately 220 milliamps with the backlight on. It is mounted on a daughterboard with the dimensions 4" x 5" and 0.65" deep, requiring four metal spacers to attach to the main circuit board. Connected to the screen is an intermediate 'backpack' circuit which provides serial communication and four pins: VCC, GND, Tx and Rx data lines. The Tx pin was included by the manufacturers for potential code revisions, so only the Rx pin will be used in the design. This pin is connected directly to an I/O pin on the microcontroller. The data is serial TTL at 115,200 baud (default).

F. *Microcontroller*

The heart of the project is the ATmega128L, a powerful microcontroller with a variety of I/O features. It is powered by 3.3v and draws current in the range of milliamps. It features 53 multi-purpose I/O pins, an analog-to-digital converter, and 128KB of programmable Flash memory. This microcontroller can drive a graphical display and handle multiple peripherals at once. It is a surface-mount device soldered to a daughterboard with standard 0.1 inch pitch headers intended for four 16-pin sockets (in the formation of a square). The board is 1.5 inches square, and each socket is 13/16" long with slightly more than 1/16" spacing between sockets.

G. *GPS receiver*

Bike Buddy requires a low-power GPS receiver with an embedded antenna to provide information including velocity, global position, and the time of day. The LS20031 receiver meets these needs. The daughterboard is roughly square with a dimension of 1 and 5/16 inch, and requires four metal spacers to attach to the main circuit board. Five bare pads on the underside of the chip can be soldered to (VCC, Tx, Rx, two redundant GND). The data line is serial with a default baud rate of 57,600bps. The software interface provided is in the form of an MTK packet, which encases standard NMEA sentences.

H. *Temperature sensor*

Temperature sensor is SHT75 digital humidity and temperature sensor is the high-quality version of the pin-type humidity sensor series with cutting edge accuracy. It has features such as energy consumption 80µW, RH operating range at 0 to 100%, temperature range from -40 to +125°C (-40 – +257°F) and output as digital using 2-wire interface.

I. *Universal Serial Bus port*

The Universal Serial Bus (USB) has already become a standard interface in today's consumer devices. It is very easy to plug and play, and its high data transfer rates have resulted in a wide adoption among all kind of electronics such as computer, digital camera, mp3 players and even cellophanes. It also has bidirectional communication, and it offer great power source to charge for many devices. Using USB port as a power source for battery charging or to power up devices do not show significant challenges to the design.

III. System Concept

To be understood as a complete system, a flow diagram of operation is helpful.

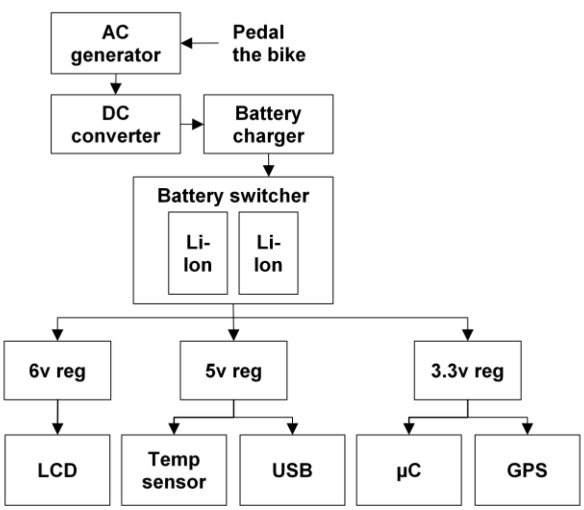

Fig 1. Complete power flow diagram.

A. *Power Supply*

To convert AC to DC efficiently, we use the DF04M one phase bridge rectifier. A 10uF capacitor is used to filter out the ripple in the output. The configuration is to be connected to a voltage regulator for more filtering.

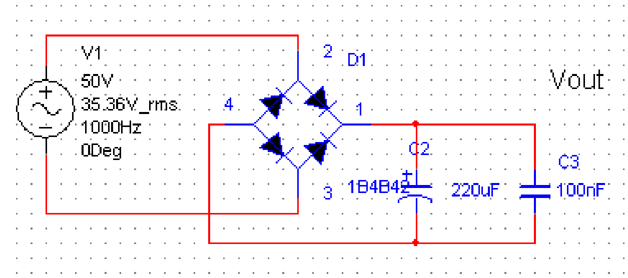

Fig 3. Schematic for the bridge rectifier circuit to convert AC to DC.

To calculate the DC voltage output at a particular AC input from the generator, we need to take into account the fact that we're using a full-bridge rectifier in the configuration.

At 12V AC from the generator: Vdc = Vpeak – Vr(p-p)/2 = 12(sqrt(2) = 16.9V

After the voltage is converted, a 10V regulator is applied to further remove the ripple and keep the output at the constant 10V for the charger and the switcher. The LM317 voltage regulator has an input to output voltage difference of 3V to 40V. So if the output is 10V, the input can be between 13V and 50V. At maximum speed, the generator's DC output fall within that range.

B. *Charger*

To charge an 8.4V Li-ion battery, we selected the MCP73842 smart charger chip. The design configurations in Figure 4 were provided by Microchip on the datasheet of the charger chip. This particular configuration below works well with a 2-cell battery like the one we using, we only need to find the external parts for our desired voltage and current.

The resistor between pins 1 and 2 is used to monitor the current level. It is calculated by dividing the voltage difference on the two input pins by the desired charge current. The voltage difference is 120mV per the datasheet, and the desire current is 2A for the 8.4V battery we are using. Therefore,

$$R_{SENSE} = 120\text{mV} / 2\text{A} = 60\text{m}\Omega$$

$$\textit{Power dissipation} = 60\text{m}\Omega \times 2\text{A}^2 = 120\text{mW}$$

The gate to source threshold voltage and the resistance from drain to source of the external P-channel mosfet must be taken into consideration. They both must be low enough as their configurations affect the performance of the charger. The maximum allowable threshold voltage and is computed below:

$$V_{GS} = V_{DRVMAX} - (V_{DDMIN} - V_{FCSMAX}) = 1.0V - (8.7V - 0.120V) = -7.58\ V$$

This is a worst-case scenario. The resistance from drain to source must be low enough to accommodate this gate voltage. All of this can be avoided by selecting the right p-channel mosfet such as the Fairchild NDS8434, which has a very low gate to drain internal resistance.

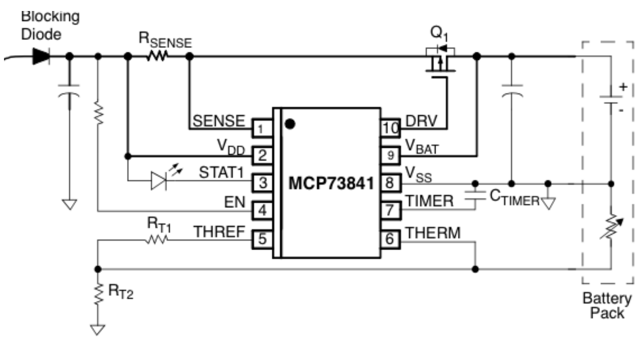

Fig 2. Schematic for the smart Li-Ion battery charger.

As soon a battery is connected, the MCP73842 will check the quality of the charge on the battery, the temperature, voltage and current for safe operation. Resistors R_{T1} and R_{T2} regulate the low and high temperature threshold levels. To find those resistor values we need to use the formulas provided in the datasheet for PTC thermistors.

$R_{T1} = 2(R_{COLD})(R_{HOT}) / (R_{HOT} - R_{COLD})$
$R_{T2} = 2(R_{COLD})(R_{HOT}) / (R_{HOT} - 3R_{COLD})$
If R_{COLD} = 33 (degrees Fahrenheit), and R_{HOT} = 100 (degrees Fahrenheit)
$R_{T1} = 98.5\Omega$
$R_{T2} = 6.6K\Omega$

The first resistor can be about 6.1k given that the input voltage is about 10V. We want to limit the current going inside the chip to between 1 and 2mA. Ctimer capacitor determines the amount of time for each of the three stages in the figure. Each of the stages occur at 1.5 hour intervals, so the capacitor simply need to find the time for the preconditioning and all of the other time threshold will be set. These configurations will be implemented in the charger's circuitry, they will be calibrated during the testing phase of the design.

Tprecon = (Ctimer)(1.0 Hour)/ 0.1uF
At Ctimer = 0.1uF , Tprecon = 60 minutes

Therefore, a battery will take 60 minutes for preconditioning, 90 minutes for fast charge, and 180 minutes for termination period. So, after 1.5 hours, the battery should be fully charged. The amount of time to charge the battery will be determined by the current and voltage level on the battery itself.

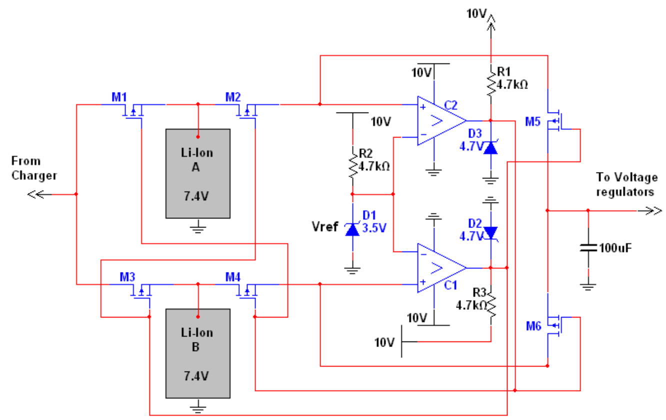

Fig 3. Schematic for the stand-alone automatic battery switcher.

For the battery switcher, the design is very comprehensive given the concept and behavior we want to achieve. In Fig 3. Schematic for the stand-alone automatic battery switcher. as battery A is being charged, battery B is sourcing the circuit. Once battery B falls below Vref at 3.5V, the output on comparator C1 is grounded thus turning off the p-channel mosfets M2, M3, and M5. M2 connects battery A to the output while M3 connects battery B to the charger. Once comparator C2 notices the higher voltage on Battery A, its output is at 4.7V biasing the p-channel mosfets M1, M4 and M6. M1 disconnects battery A from the charger, M4 disconnects battery B from the output, and M6 breaks the circuit to prevent the output from reaching comparator C1. M5 also prevents the output voltage from reaching comparator C2 while battery B is in use. The 100uF capacitor on the output prevents voltage dips while the batteries switch.

C. *Voltage regulators*

The Max 608 adjustable voltage regulator can be implemented for voltage regulation on each of our devices in the Bike Buddy. It is a BiCMOS step-up power supply controller with preset and adjustable output options. It uses the advantages of pulse-frequency modulation and pulse width modulation to give a high efficiency over a large range of current. The external sense resistor and power transistor allow for the user to change the output current for each unique application. The design requires that R2 be between 10k and 500k, and Vref=1.5 V. The following equation is used to determine R1 for a desired Vout.

R2=R1(Vout/Vref-1).
For a 6V output; R1=10k and R2=30k.

Next is the schematic for setting an output voltage of 3.3V on the same MAX608 chip. Several components are added to enhance efficiency and minimize power loss. Using the smallest capacitance values possible will ensure circuit stability; higher capacitance values may degrade line regulation. In order to achieve the highest accuracy possible in the output voltage, resistors with a 1% tolerance should be used in order to achieve a 5% deviation. Using N-FET transistors will allow for a higher efficiency as well because they don't draw any DC gate-drive current during operation.

The MAX608 chip is preset with the output of 5V, so no changes had to be made to the external circuit topology presented in the data sheet. The MAX608 also features a low input voltage start-up oscillator. This will guarantee start up under no load with voltages down to 1.8 Volts. This will ensure proper regulation should the battery drop below the minimum charging voltage.

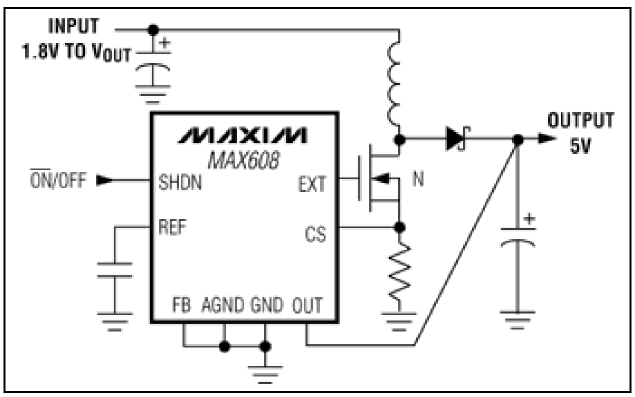

Fig 6. MAX608 - Voltage regulator with an output of 5V.

A. *Display Subsystem*

One of the roles of the ATmega128L is to organize the information obtained from the LS20031 GPS module and to display it with the Graphical LCD. Both the GPS and the LCD transmit/receive asynchronous serial data at scalable baud rates, chosen to be 57,600 bps. The ATmega128L handles this communication using both USART subsystems.

Asynchronous serial transfer in the ATmega128 is highly time sensitive. Shown the datasheet, the optimal system clock rate for using UART is a multiple of 1.8432 MHz. This multiple is given in the ATmega128L datasheet, and yields a 0.0% error rate for data transfer. A clock rate of 7.3728 MHz was chosen for the ATmega128.

The microcontroller ships with fuse settings CKSEL = "0001" and SUT = "10", leaving the default clock source the Internal RC Oscillator at 1 MHz with the longest startup time (65ms). This must be updated to connect the chosen external oscillator.

CKSEL3..0	Frequency Range (MHz)
0101	0.1 – 0.9
0110	0.9 – 3.0
0111	3.0 – 8.0
1000	8.0 – 12.0

Table 1. Fuse bits for the ATmega128 source clock.

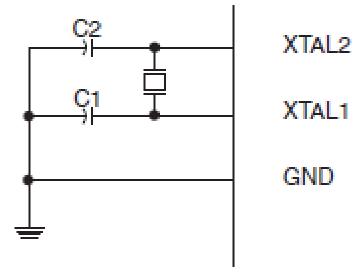

Fig 7. Schematic for the external crystal.

The analog to digital converter on the microcontroller is used to monitor the power created by the generator and the charge levels of the two batteries. To turn on that configuration in the hardware, we have to power the A/D converter by connection the AVcc pin to 3.3V, same as the Vcc. We use a 10uH inductor between the Vcc and the AVcc pins to filter out any noise that may affect each of the input pins. Since we want to use the internal 2.56V reference voltage with the AD converter, we have to ground the Aref pin using a 0.1uF.

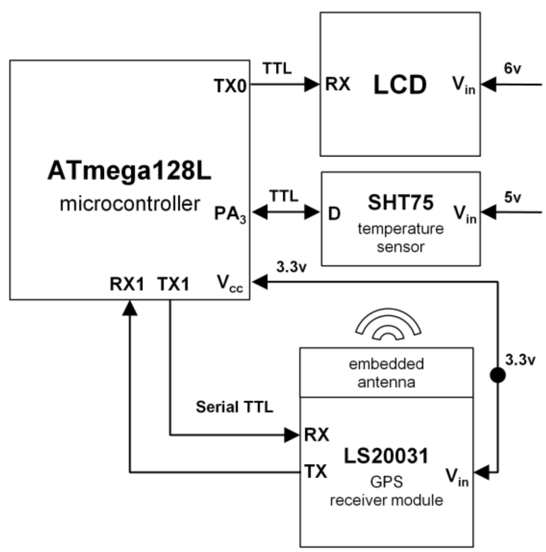

Fig 8. Hardware block diagram for the display subsystem.

Software for the ATmega128L is written in C. Libraries for the AVR microcontroller are provided with a software package included in the STK300 development board. Sensor data is read and stored more slowly than it's received, and updated roughly every 1/6 of a second to the LCD. Controlling the screen is made simple by the backpack circuit that is integrated with this LCD. The circuit features an ATmega168 controller with a basic set of commands and a built-in font for ASCII characters. Pixels are referenced to with (0, 0) being the bottom-left corner of the screen and (127, 63) being the top-right corner. Every command is preceded with the character "|" (pipe), or ASCII 0x7C. Commands for drawing to the LCD are detailed in Table .

Command	Byte	Argument
Set X Coordinate	0x18	0:127d
Set Y Coordinate	0x19	0:63d
Set/Reset Pixel	0x10	x, y, 0:1d
Draw Line	0x02	x1, y1, x2, y2, 0:1d
Draw Circle	0x07	x, y, r, 0:1d
Draw Box	0x0F	x1, y1, x2, y2, 0:1d
Erase Block	0x05	x1, y1, x2, y2

Table 2. Commands for the LCD.

The layout of the screen will be sent upon start-up, consisting of boxes and lines to distinguish the different data. Cursor positions for various text fields in the screen layout will be stored in variables.

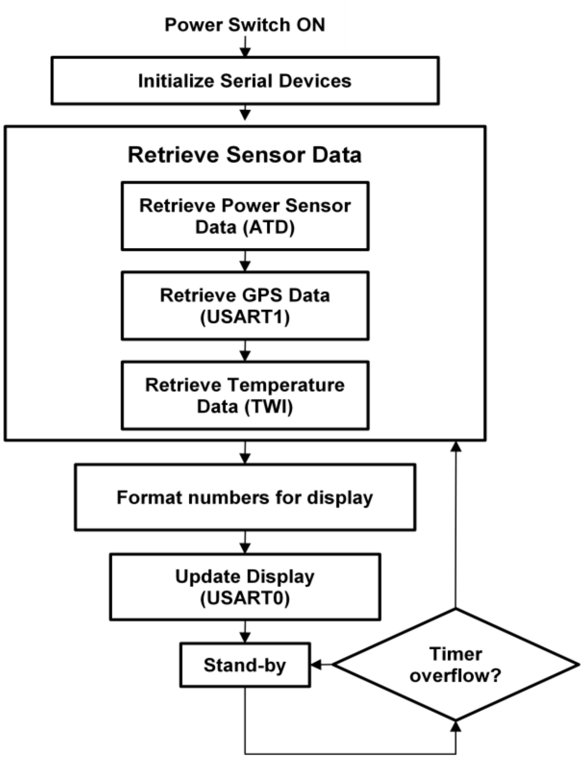

Fig 9. Software flow diagram.

A print function updates/displays a string to a particular point on the screen. This routine has two phases: (1) erasing the text by sending the Erase Block command, and (2) setting the x, y coordinates and sending the string message. The print function is called as part of the larger 'screen update' routine that is called every 1/6 second.

The GPS module sends packets in the form of NMEA sentences at a frequency of once per second (scalable up to 5 Hz). The only NMEA record used in the design is the Recommended Minimum Specific GNSS Data (RMC), which provides UTC time, date, latitude, longitude, speed over ground, and course over ground. The full record is shown with the following example:

```
 $GPRMC,053740.000,A,2503.6319,N,12136
.0099,E,2.69,79.65,100106,,,A*53
```

These packets are transmitted through USART1 and read only several times per second. When a packet read, it is stored in memory and later parsed by a function which takes only the desired values (UTC time, date, latitude, longitude, speed over ground, and course over ground) and stores them in memory. When the screen is ready to be updated, a print function is called for each datum. This function sends the "Erase Block" command with the statically defined coordinate space for each particular datum, sets the X, Y coordinates for the text generator accordingly, and sends the byte sequence to the LCD as an ASCII string.

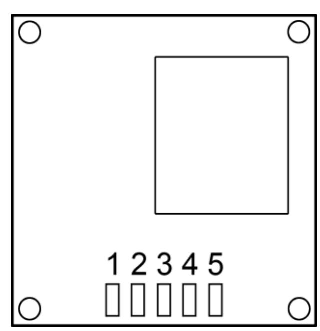

Fig 4. Underside of the GPS receiver.

The LS20031 package consists of a 32 channel GPS receiver with embedded smart antenna, and a small battery for storing system data for rapid satellite acquisition. There are five bare pads 1.2 mm apart on the underside of the LS20031 (please refer to to the figure below). Wire can be easily soldered to these pads. The Vcc pin will have 3.3v from the power supply circuit.

Both input and output data lines will connect directly to two I/O pins on Port A of the microcontroller. The unit needs to face the open sky to operate effectively. The package is 30 sq mm and 5.8 mm thick, with a 1 mm hole in each corner. This will be attached to the perforated main board with four metal spacers.

#	Pin	Peripheral	Periph. Pin
1	VCC	6v regulator	—
2	RX	ATmega128L	PD3 (28)
3	TX	ATmega128L	PD2 (27)
4	GND	—	GND
5	GND	—	GND

Table 3. Pin assignment for the GPS receiver.

D. *Temperature sensor*

Sensor works stable within recommended normal range. Long term exposures to conditions outside normal range, especially at humidity >80%RH, may temporarily offset the RH signal (+3 %RH after 60h). After return to normal range it will slowly return towards calibration state by itself. The supply voltage of SHT75 must be in the range of 2.4 and 5.5V, recommended supply voltage is 3.3V. Decoupling of VDD and GND by a 100nF capacitor is integrated on the backside of the sensor packaging.

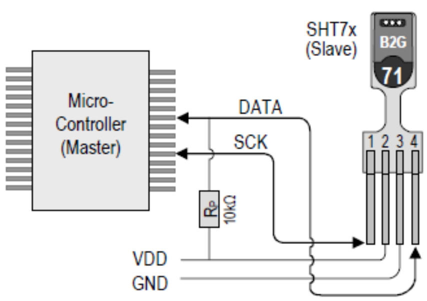

Fig 10. Typical application circuit, including pull up resistor RP

The serial interface of the SHT7x is optimized for sensor readout and effective power consumption. The sensor cannot be addressed by I2C protocol, however, the sensor can be connected to an I2C bus without interference with other devices connected to the bus. Microcontroller must witch between protocols.

Pin	Name	Comment
1	SCK	Serial Clock, input only
2	VDD	Source Voltage
3	GND	Ground
4	DATA	Serial Data, bidirectional

Table 4. SHT75 pin assignment.

E. *USB*

USB port will be installed on the side of the bike Buddy. Having a USB on the bike is very useful. USB power will allow users to use other devices such as mp3 players, light, fan or any other devices that support USB power. Simply plug the USB cord to the USB port in Bike Buddy. Also USB port will be function as charger for certain devices such as cell phones. Using the USB cable comes with most of cell phones will let you charge the battery using USB port.

Cell Type	Charge Time
700mAh NiCd	1.5h
1100mAh NiCd	2.5h
1600mAh NiMH	3.5h
2000mAh NiMH	4.5h
2500mAh NiMH	5.5h

Table 5. Table Charging Time by USB

IV. Conclusion

The idea of the Bike Buddy was a collaborative effort in designing a product that would be fun to use and a challenge to design. Alternative and renewable energy sources were at the heart of our motivation for this project. Using an electric generator to supply power to the bikes features remained a constant throughout the design process. While the methods of transferring and storing that energy were debated and redesigned numerous times.

The onboard devices the Bike Buddy would feature were also changed and reinvented throughout the course of the semester. Several items which ended up be excluded from the design were: a speaker system that would play music from an IPod or Mp3 player, a USB download function that would record paths traveled and other information which needed memory, and a heart rate sensor to measure burned calories and other dietary information. Had more time been available one of our goals was to interface the LCD with the GPS to display information such as frequent routes traveled and different distances of each.

Most projects involving pedal power generations were stationary in nature. What made our project unique is that fact that the user can bike anywhere they want and have all sorts of devices being powered as they ride.

ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance and support of Dr. Samuel Richie.

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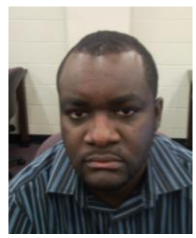
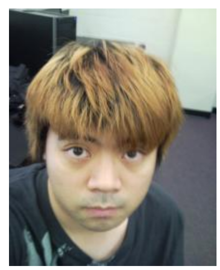
BIOGRAPHICAL INFORMATION

Nick Quinlan is currently a senior at the University of Central Florida. He plans to receive a Bachelor’s of Science degree in Electrical Engineering in May of 2010, and continue to get his masters in Business Administration. Current interests are digital communications and sound engineering.



Ari Nacius is currently a senior at the University of Central Florida. He plans to receive a Bachelor of Science degree in Electrical Engineering in Aug of 2010. After graduating from UCF, he plans to further his studies in the field of wireless communications and renewable energy.



Nowook Park is a senior student of electrical engineering department at University of Central Florida, Going to purse a working carrier in Electrical engineer. Interests are computer hardware and robotics. Park hopes to pursue a career in the specialized area of hardware engineering and/or electric circuit design. Research and design is a concentration that keeps him very focused and interested.

Ethan Pemble is a 23-year-old graduating Computer Engineering student seeking employment with a large software company such as Microsoft. He is interested in developing future technologies that aid in the betterment of mankind.