Heart Rate Alarm System for Swimmer in Triathlon

ECE 445

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Objectives

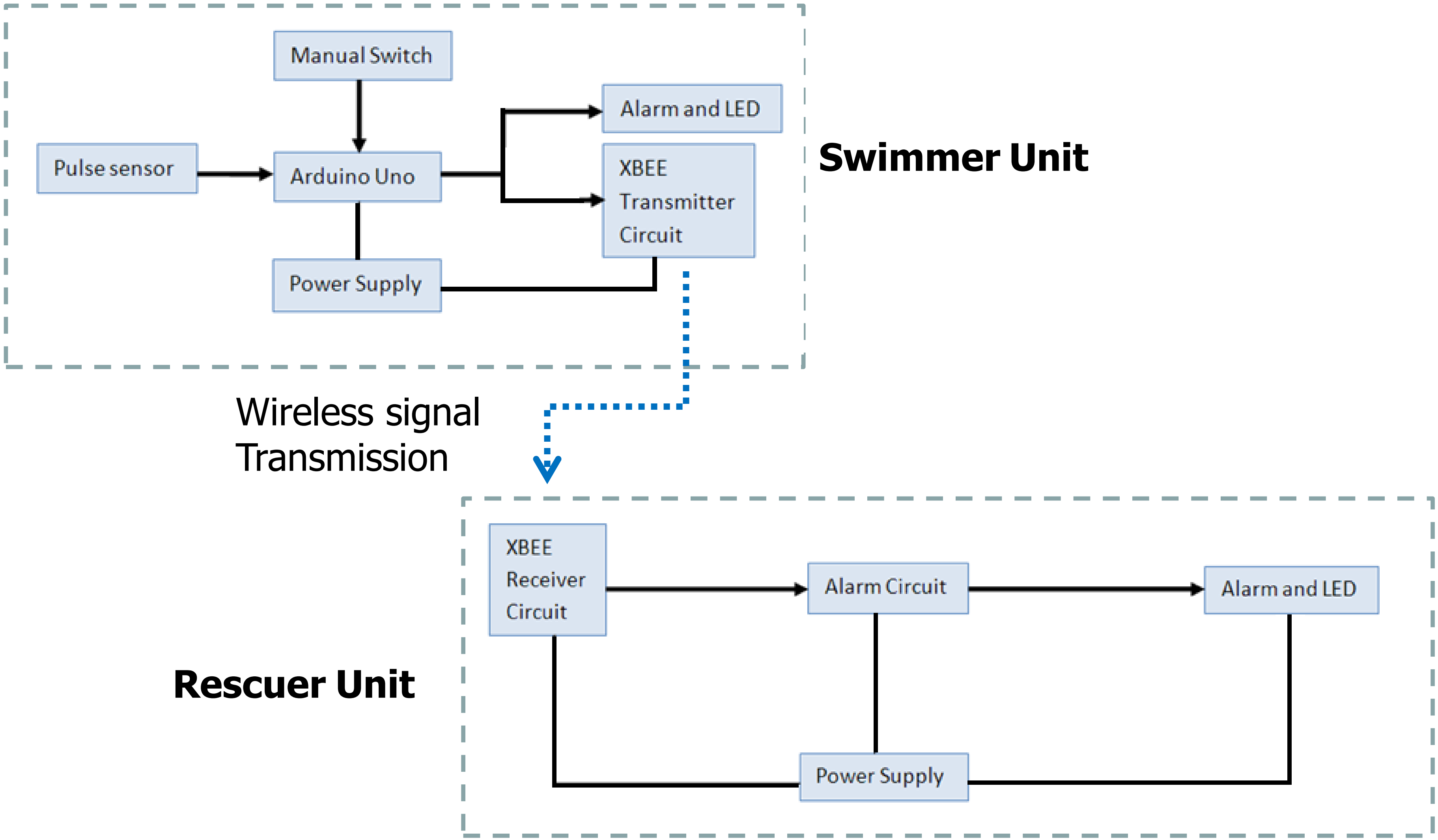
- Remote alarm system for triathlon swimmers
- Detect abnormal heart rate
- Alarm surrounding swimmers
- Notify rescuers
- Save lives

Gaynor, W. (2012). *Nottingham's outlaw triathlon 1 July 2012* [photograph], Retrieved Dec. 7th, 2012, from: http://blog.swimshop.co.uk/2012/07/nottinghams-outlaw-triathlon-1-july.html

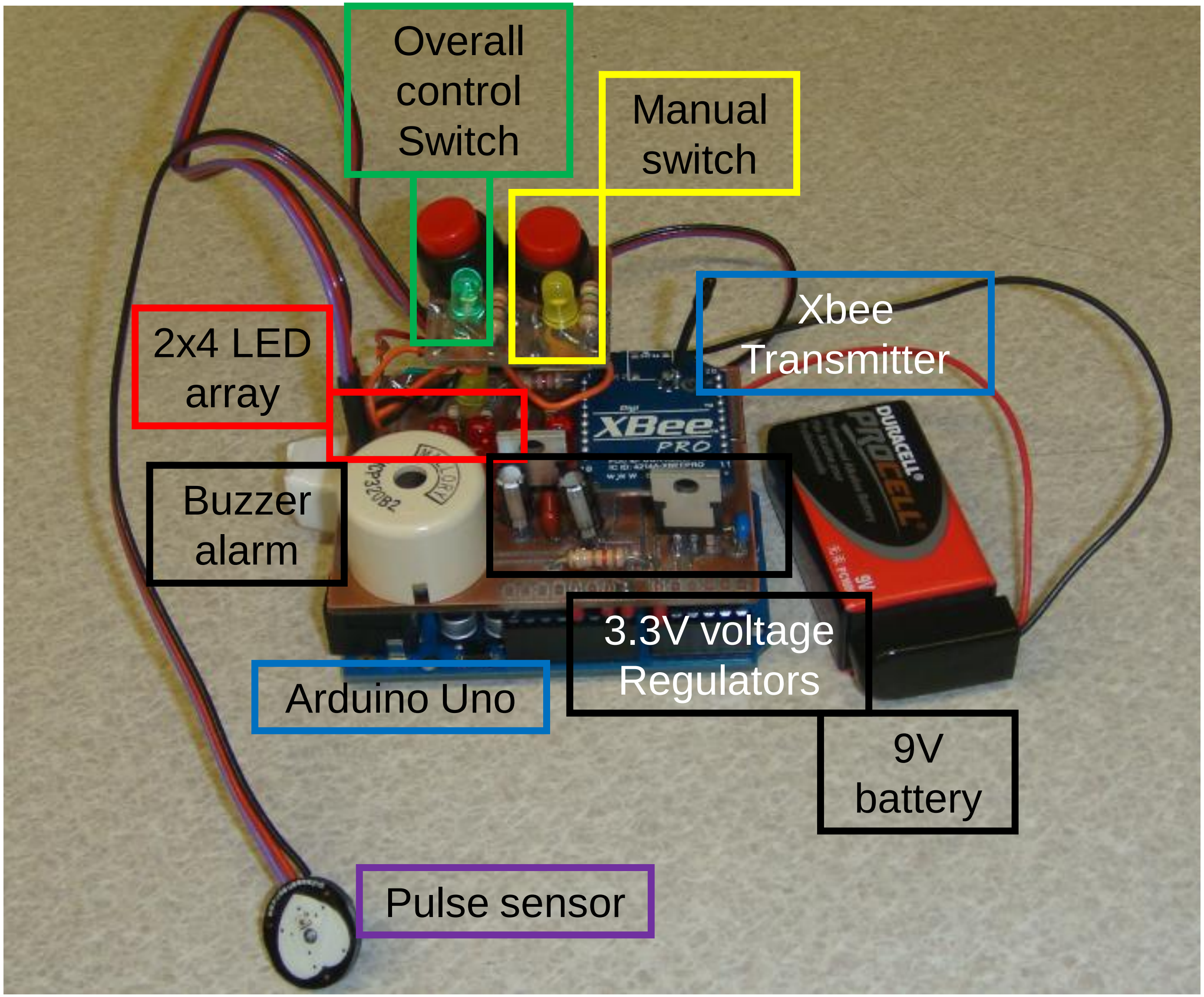
Features

- Wireless module efficient for 50m distance
- Real-time heart rate detection
- Manual switch control
- LED and buzzer alarm
- Underwater unit
- Portable size

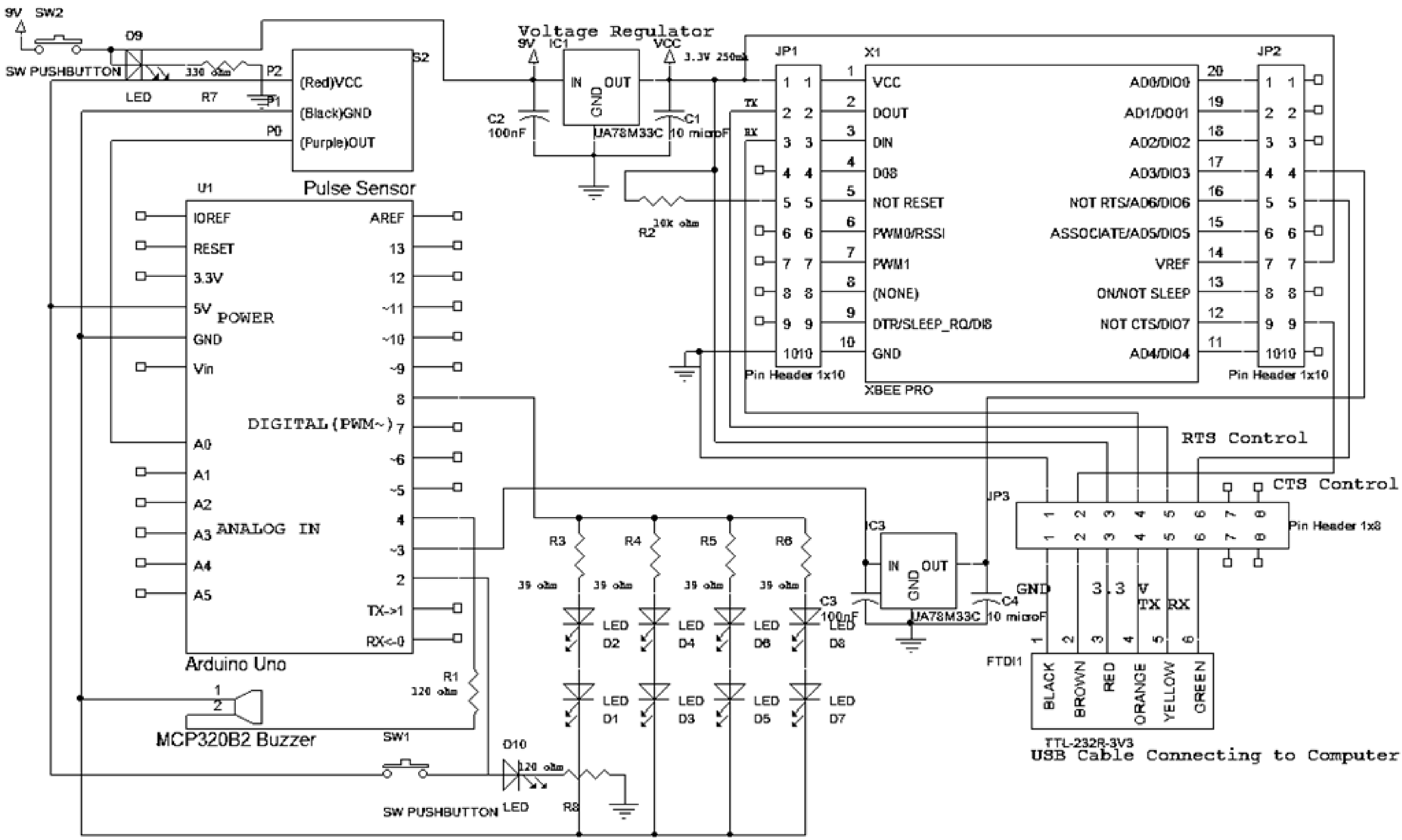
System Overview



Swimmer Unit

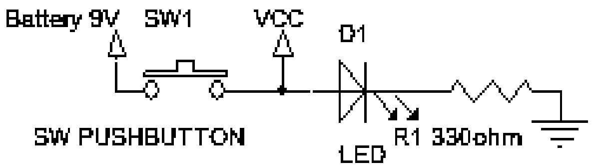


Swimmer Unit Schematic

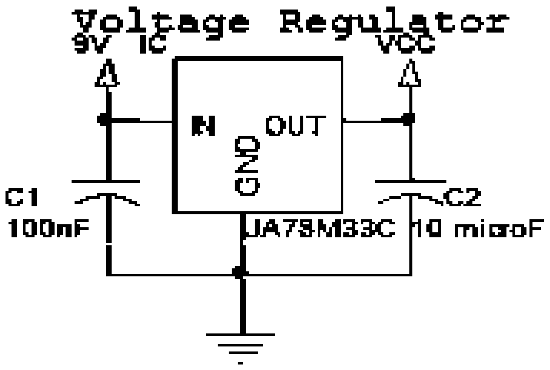


Power Supply

- Energy source : 9V battery
  - Overall Control Switch
  - Arduino Vin 6-9V



- Linear voltage regulator : UA78M33C
  - Xbee VCC: regulate 9V to 3.3V(±0.5V)
  - Xbee control input: regulate 5V(Arduino output) to 3.3V(±0.5V)



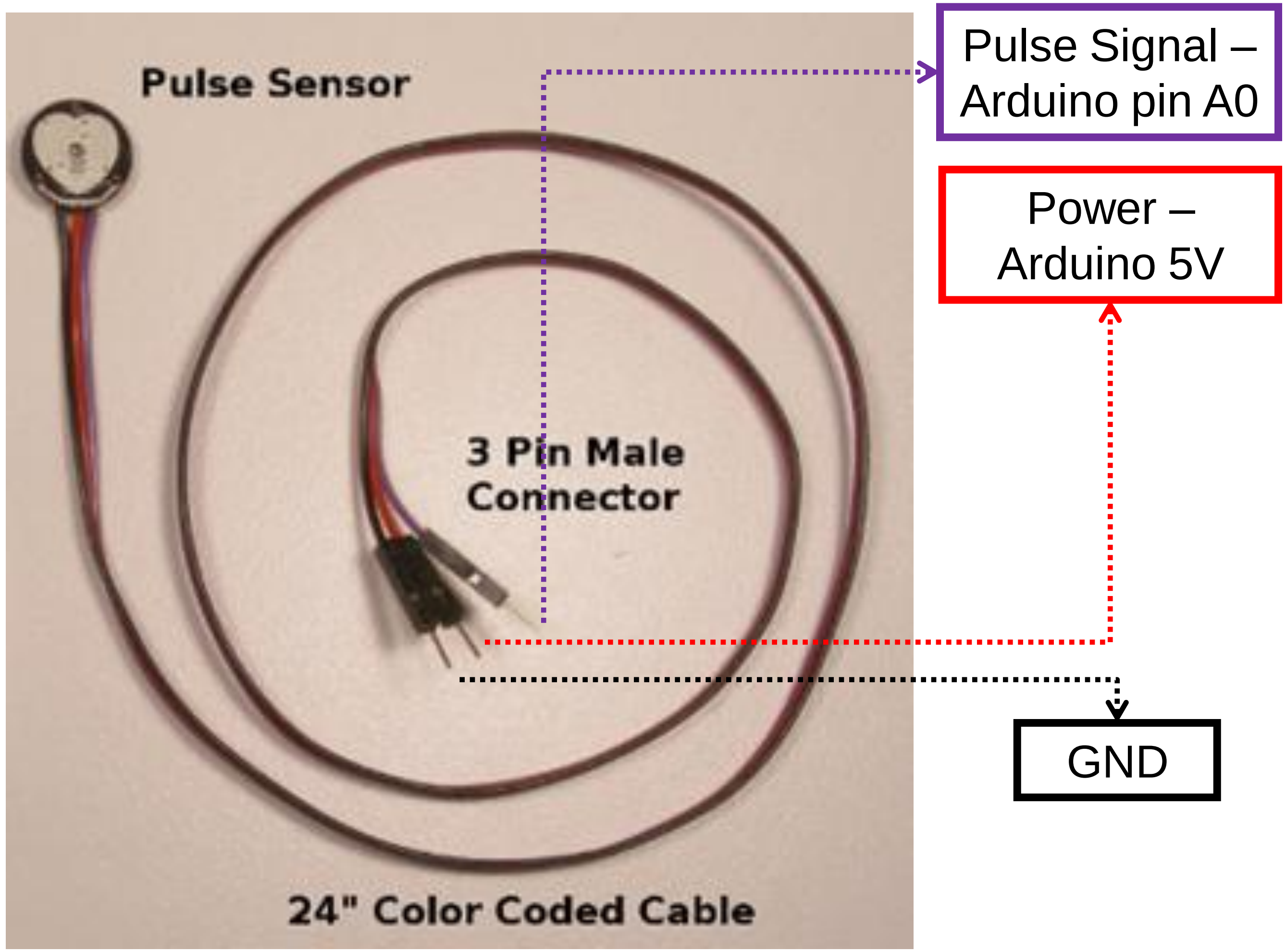
Power Supply Test

Arduino Vin (Power Supply)	Arduino Voh
6V	4.97V
7V	4.97V
9V	4.97V

UA78M33C VCC (Power Supply)	UA78M33C Vout
0V	0.0001mV
1V	0.01mV
2V	0.05mV
3V	2.42mV
4V	3.20V
5V	**3.29V**
9V	**3.29v**

Pulse Sensor

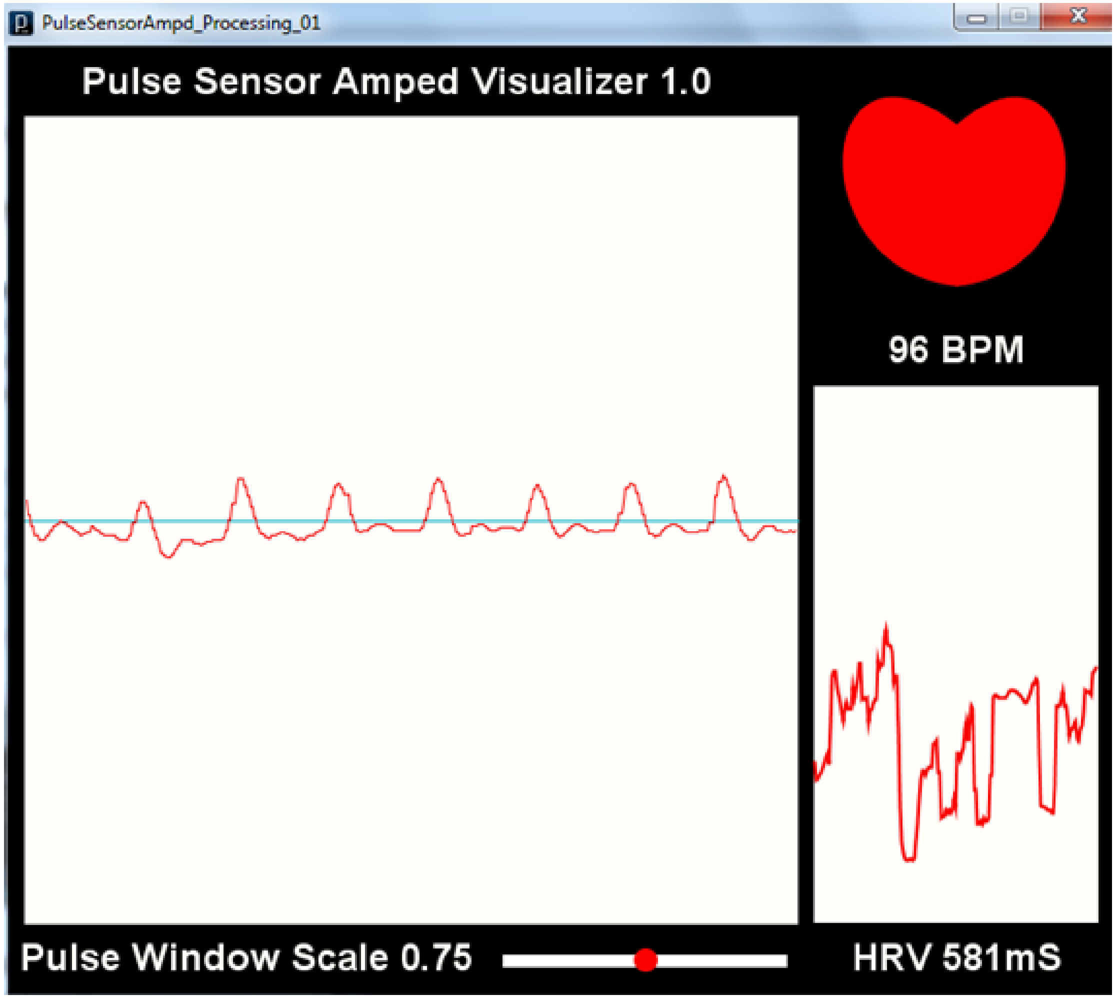
- Optical Sensor
- Clip onto fingertip or earlobe



Murphy, J., & Gitman, Y. (2012). *Pulse sensor getting started guide* [photograph], Retrieved Sept. 28th, 2012, from: https://docs.google.com/document/d/1iOZv-ubb-cbfhLEYUawFpGXLxOGqULidrHE5UD5vx9s/edit

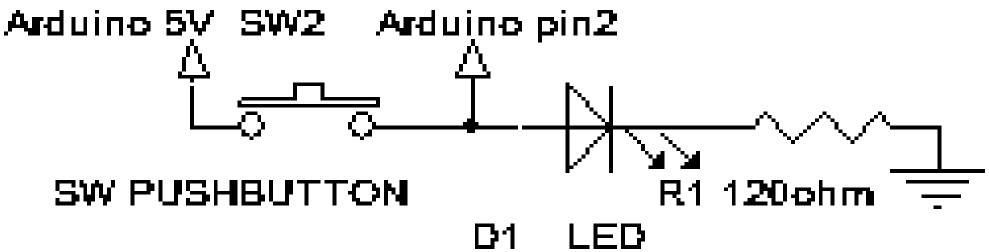
Pulse Sensor Test

- Open source test code from sensor producer
- Visualizer window
- LED on Arduino (pin13) blinks corresponding to heart beats
- Consistently updated BPM



Manual Switch

- Manually trigger alarm by controlling input at Arduino pin2
- Push-on-push-off button switch
  - Push once: yellow LED on
  - Push again: yellow LED off



Arduino Uno

- Programming highlights:
  - Revise code provided by sensor producer
    - Use interrupt() to update BPM value every 10 pulses
    - Discard first several data at initial state to avoid inaccuracy
  - Original code determining outputs to LEDs, buzzer and Xbee transmitter
    - Comparing BPM with preset thresholds
    - Manual switch logic

Arduino Uno Test

- Set difference thresholds to simulate different heart rate behaviors:
  - BPM range 0-200 : test heart rate would be normal (within the range)
  - BPM range 0-20: test heart rate would be abnormal (out of the range)

Arduino Test Results		
Heart Rate Behavior	**Manual Switch (pin2)**	**Vout at pin3,4,8**
Normal	Off	3.77mV
Normal	On	4.97V
Abnormal	Off	4.98V

LED Array

- Original Design and pre-calculation:
  - 3x3 LED array
  - Off when Arduino pin8 outputs 0V(±0.3V)
  - light up consistently when Arduino pin8 outputs 5V(±0.5V)
  - Assume voltage drop of LED is 1.2V, forward current is 0.05A, the resistors in series of each column of LEDs have resistance:

$$R = \frac{5 - 3 \times 1.2}{0.05} \approx 30\Omega$$

LED Array

- Initial Test and Failures

Vin (Power supply)	Current in each column	LEDs observation	Voltage Drop for each LED
0V < 4.6V	/	Off	/
4.6V	/	Very dim	/
5V	0.002A	Visible from above in daylight	1.66V
~5.5V	0.025A	Obvious in daylight	1.99V

- 5V Vin could not supply appropriate LED performance
- Linear voltage regulator can not amplify voltage

LED Array

- Revision and Test
  - Change design to 2x4 LED array in series of resistors with resistance:

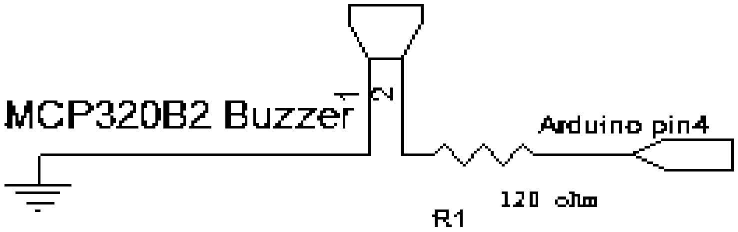
$$R = \frac{5 - 2 \times 2}{0.025} = 40\Omega$$

  - Using 39 ohm resistors due to availability

Vin (Power supply)	Current in each column	LEDs observation	Voltage Drop for each LED
5V	25.25mA	Obvious in daylight	2.0V

Buzzer Alarm

- MC320B2 Buzzer
  - Off when Arduino pin4 outputs 0V(±0.3V)
  - Alarm when Arduino pin4 outputs 5V(±0.5V)



- Test results (with 120Ω resistor in series):

Vin (Power supply)	Current	Buzzer Performance
0 < 0.7V	/	Off
0.7V	0.097mA	Audible
5V	2.098mA	Noisy

Wireless Transceiver

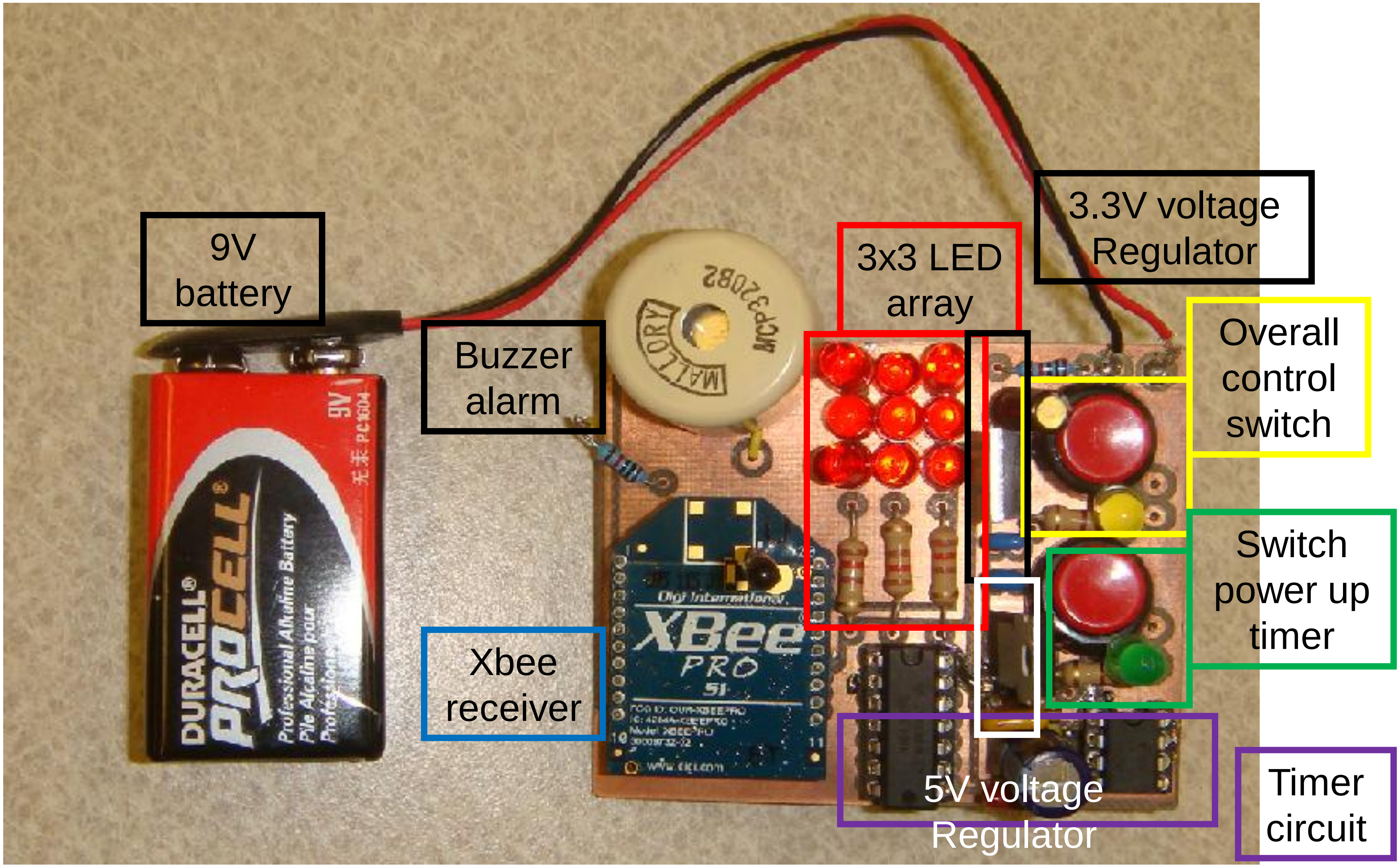
- Xbee Pro modules
- Initial configuration on computer via FTDI
  - Receiver D3 changes according to Transmitter D3

	Channel	PanID	ATMY	ATDL	ATBD	D3	IU
Xbee Transmitter	C	3137	10	11	6	DI	/
Xbee Receiver	C	3137	11	10	6	Do low	Disabled

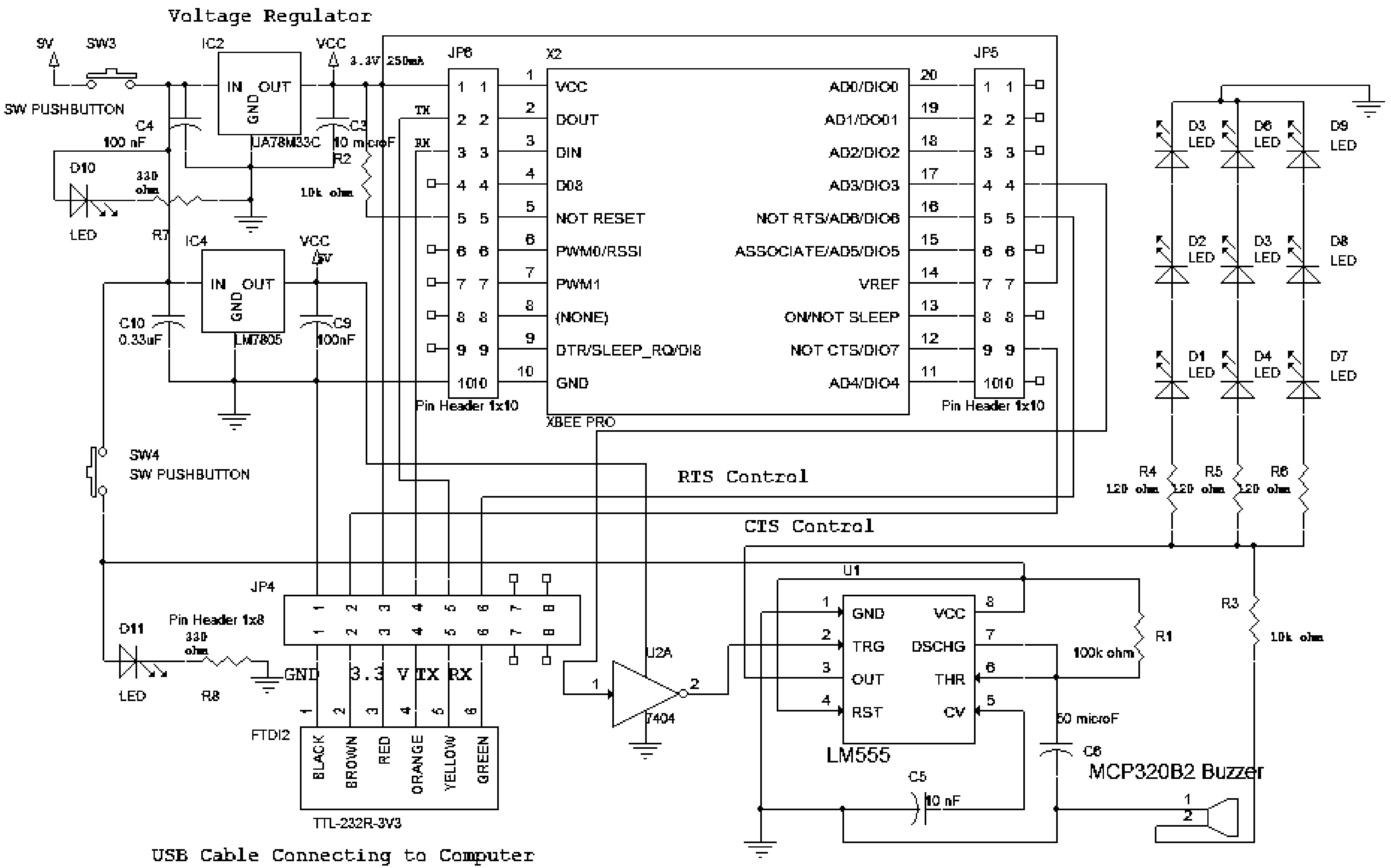
- Test results:

D3 Input of Transmitter	No transmitter	GND	0~1.7V	1.8V	VCC (3.3V)
D3 Output of Receiver	low(default)	3.72mV	LOW	High	3.28V

Rescuer Unit



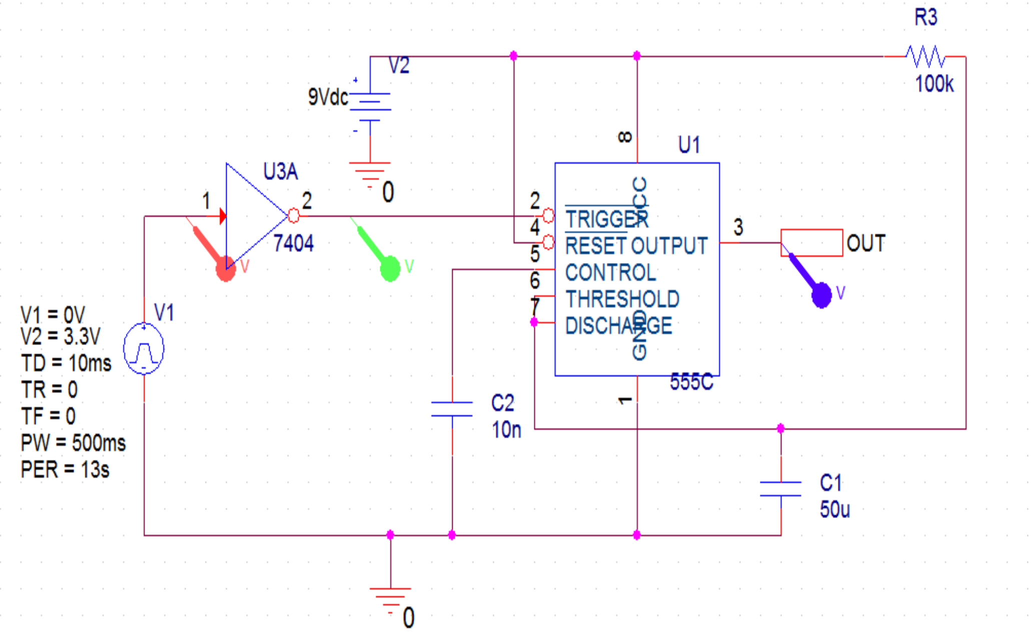
Rescuer Unit Schematic

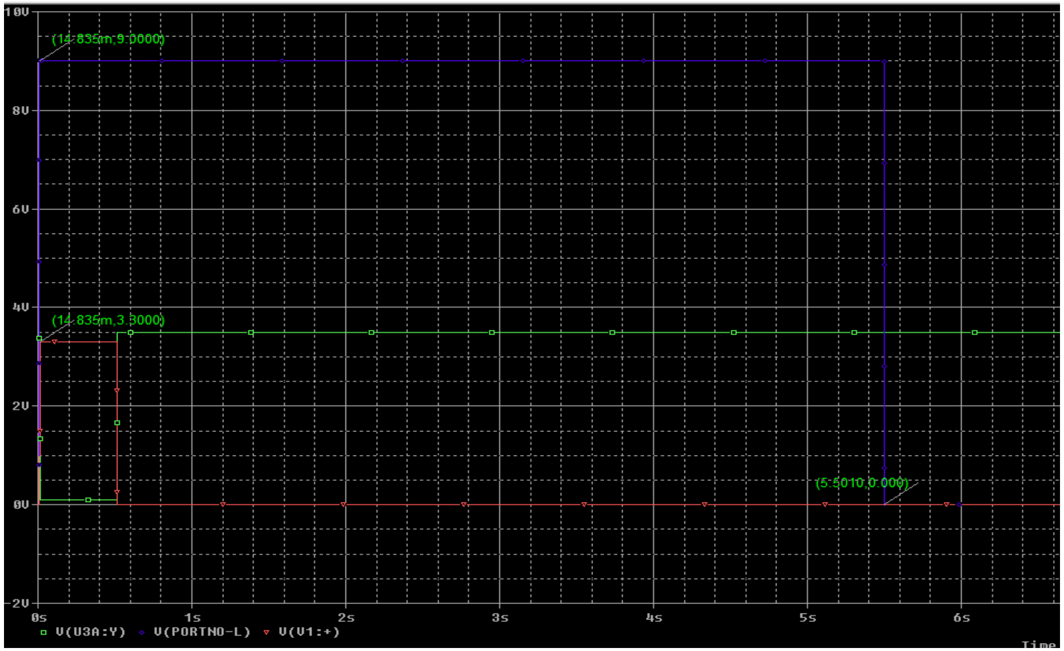


Timer Circuit

- LM555 timer
  - Extend pulse input
- Simulation and pre-calculation:

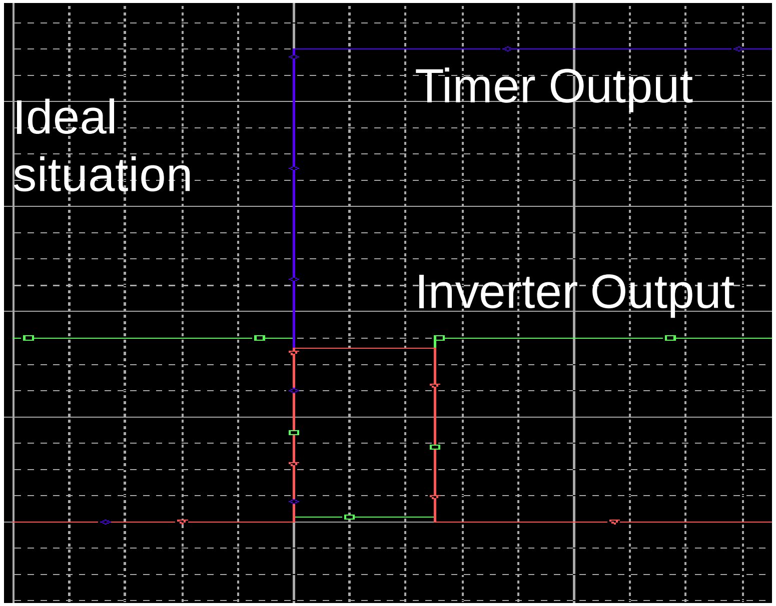
$$t = 1.1RC$$
$$= 1.1 \times 100k\Omega \times 50\mu F$$
$$= 5.5s$$

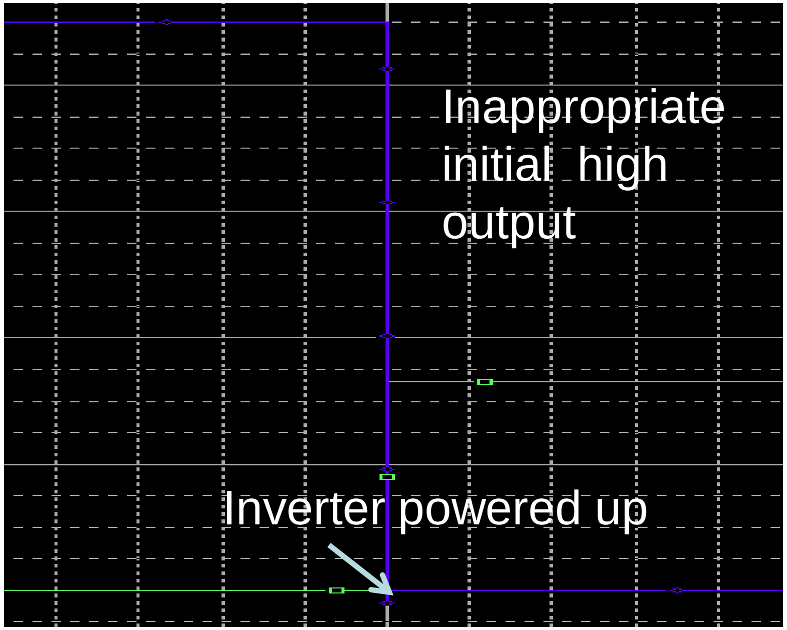




Timer Circuit

- Debugging and Revision:
  - Inappropriate initial output when inverter and timer are powered up at the same time
  - Add LM7805 voltage regulator and switches to make sure inverter is powered up(5V) before timer(9V)





LED Array

- Revised Design
  - 3x3 array
  - Assume same forward current and voltage drop as in swimmer unit
  - Resistance of resistor in series with each array is

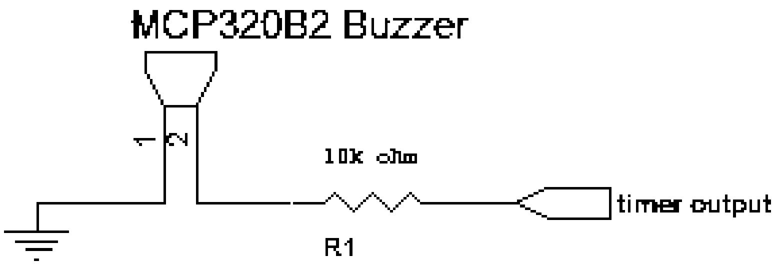
$$R = \frac{9 - 3 \times 2}{0.025} = 120\Omega$$

- Test results:

Vin (Power supply)	LEDs observation
0V < 4.7V	Off
4.7V	Very dim
~5.5V	Visible in daylight
9V	Obvious in daylight

Buzzer Alarm

- MC320B2 Buzzer
  - Off when timer output is 0V(±0.3V)
  - Alarm when timer output is 9V(±0.5V)



- Test results and revision

Vin (Power supply)	Resistor in series	Buzzer Performance
>1.0V	10kΩ	Audible
9V	20kΩ, 46kΩ, 100kΩ,	Not loud enough
9V	10kΩ	Loud (with 0.65mA)

Full System Performance

Requirements

- The system should work efficiently when swimmer unit is underwater
- The system should work efficiently when two units are 25m (±5m) away from each other.

Test Results

- When swimmer unit is in waterproof case and underwater, the system could function appropriately when rescuer unit is put 60m away.

Successes

- All 3 PCBs can perform complete functions
- PCB boards are well-designed and in small size
- Xbee transceiver can work efficiently when transmitter is underwater and receiver is 60m away

Challenges

- Implementing small size PCBs
- Debugging concrete PCBs
- Revising timer circuit
- Set up Xbee modules
- Debugging program
- Underwater test

Future Developments

- Use surface mount PCB boards
- Make suitable waterproof case for swimmer unit
- Add more functions via programming
- Add positioning device

Ethical Considerations

- IEEE Code of Ethics
  - 3. to be honest and realistic in stating claims or estimates based on available data
  - 7. to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others
  - 9. to avoid injuring others, their property, reputation, or employment by false or malicious action

Thank you!

- Professor Andy Singer
- Professor Brian Lilly
- TA Justine Fortier
- ECE part shop: Skot Wiedmann
- ECE part shop: Mark Smart