OTTER PRINT SHOOTER

Design Review

ECE 445 Senior Design
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I. Introduction

1. Title

Otter Print Shooter

This project is chosen to create a footprint capturing device, known as the Otter Print Shooter, to assist the research on the Illinois otters by the Illinois Natural History Survey. The device will offer a new solution for capturing high-detail images of the otter footprints which is difficult to achieve using existing methods such as the clay board method and the print stamping method.

2. Objectives

The purpose of this project is to implement an automated footprint capturing device, called the Otter Print Shooter, for the study of wildlife. This project is conducted in collaboration with the Illinois Natural History Survey to capture the footprints of the otters that roam in a specific site on land. The collaborating partner is currently conducting a research on the North American river otters that inhibit in Illinois and wants to identify and count individual otters through their footprints. Before this project, there is no electronic device for capturing the footprints of wild animals. At present, the researchers from the Illinois Natural History Survey are trying to obtain the otter footprints using a clay board. However, this method yields poor results as the otter footprints are unclear or overlapped with the prints of other wild animals. Hence, the Otter Print Shooter will be designed to fit the purpose of capturing high-detail images of the otter footprints whenever the otters walk over it. The images will be collected and sent to the Indiana Police Forensics Lab for identification and maintaining a database of the otter footprints. Concisely, this project aims to create a novel device that aids the wildlife study and preservation.

Figure 1: The otter footprints obtained using the clay board method.

The figure on the left shows a print that is identifiable and good in terms of the current clay board method. Meanwhile, the figure on the right shows a print that is smeared by the claws of other wild animals, presumably the coyotes.

3. Functions

The Otter Print Shooter is a device with a rectangular water-proof enclosure with a transparent window on the top. The device will be buried underground and its transparent window will be at ground level. Inside the enclosure, there are sensors to detect the presence of the otters and a camera to capture the images of the otter footprints. When the sensors detect the presence of an otter as it moves and steps on the transparent window, a camera beneath the transparent window will capture an image of the otter footprint and save it in its memory card. This device can operate without human supervision and lasts up to four days.

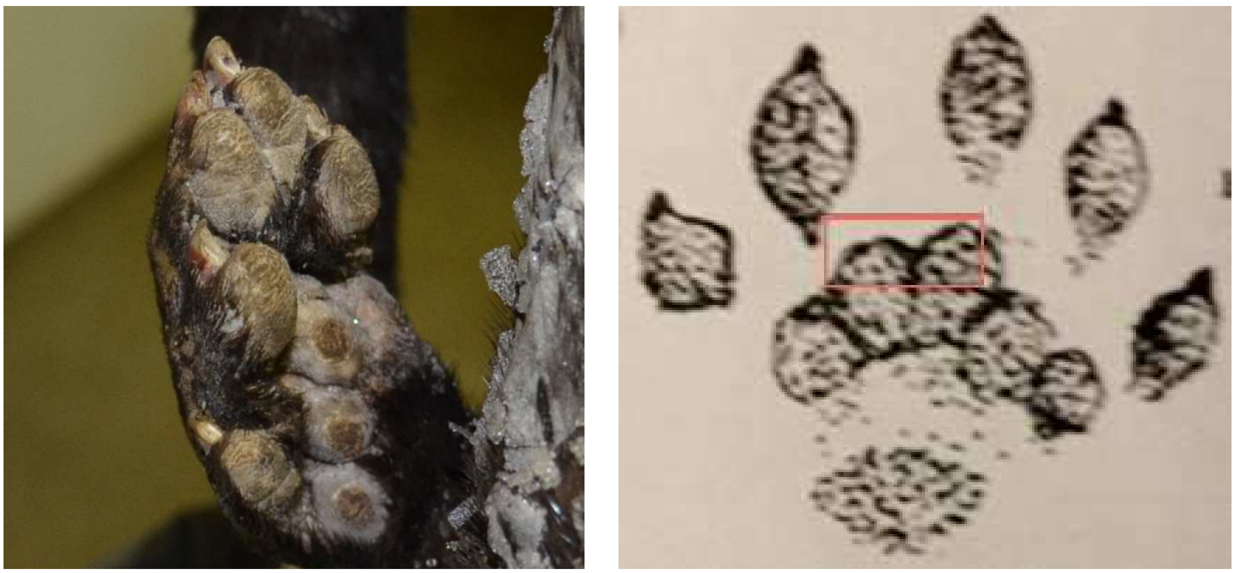


Figure 2: On the left is the paw of a dead otter and on the right is the otter footprint obtained using the print stamping method.

The red box in figure 2 outlines the part on the metacarpal pad of the river otter which will be magnified for obtaining the dot patterns used to distinguish individual otters.

4. Benefits

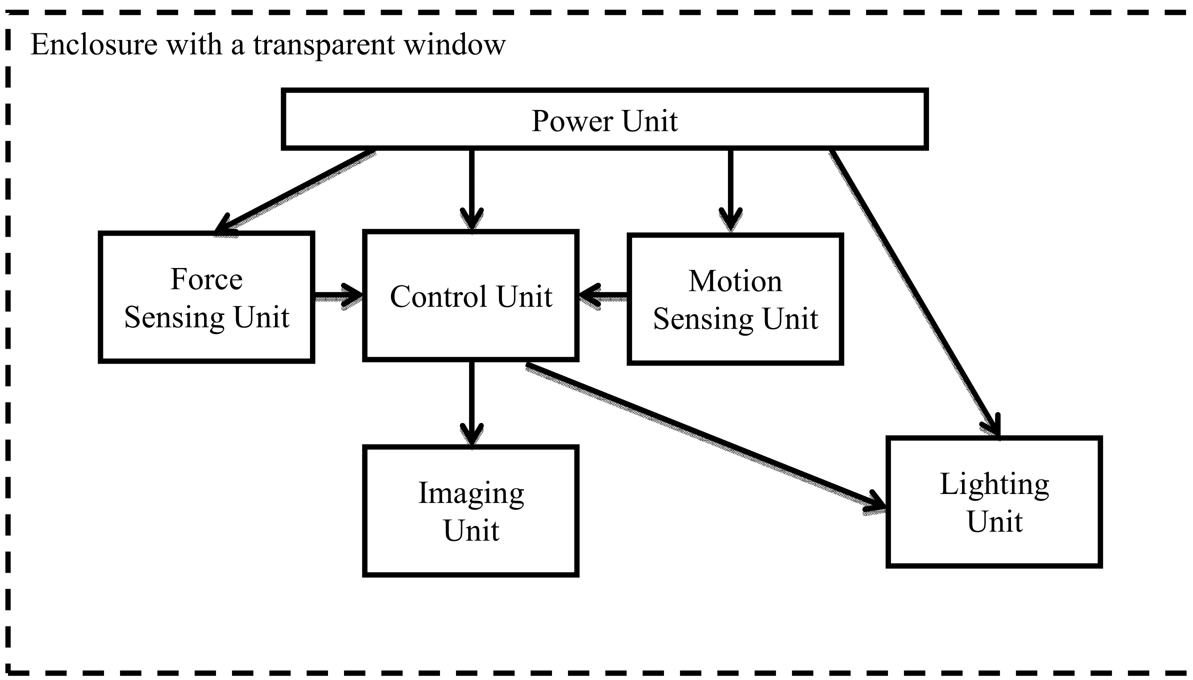
1. Provides high-detail images of the otter footprints
2. Yields consistent results in all weathers and seasons
3. Operates independently without human intervention
4. Lasts up to four days

5. Features

1. High resolution camera (>12 megapixel) with high quality optic
2. 18” x 12” ground-level acrylic capturing surface that is easy to clean and durable
3. Automatically detect otters using motion and pressure sensor and take images of their footprints
4. Low power consumption with 1mA standby current
5. High quality plastic enclosure with an inch thick acrylic sheet as the transparent window
6. Easily replaceable camera, batteries and memory card

II. Design

1. Block Diagram



2. Block Description

Power Unit

The power unit provides power to the control unit, the sensing units, and the lighting unit. It uses four Philips NiMH rechargeable batteries (2000mAh) in series to give 4.8V VDD voltage source. These batteries have low self-discharge rate and can recharge up to 1000 times. Moreover, they can be easily swapped with their spares since are small, light-weight and cheap.

The VDD source is used to power the lighting unit, the force sensing unit and the motion sensing unit. The power unit also uses the MICREL MIC5219 3.6V output LDO regulator to produce 3.6V VCC voltage source.[1] A 470pF capacitor is connected to the input of the voltage regulator to improve transient response and stabilize the VCC voltage. The VDD source is used to power the control unit.

Control Unit

The control unit of the Otter Print Shooter is the Texas Instrument MSP430G2553 mixed signal microprocessor.[2] This microprocessor has low supply voltage (1.8V to 3.6V), low power consumption in standby mode (0.5μA) and fast wake-up time (<1μs). These features are crucial to enhance the battery life while remain highly responsive.

The microcontroller will use 3.6V VCC as its supply voltage. It will also input the four FSR_SIGs (input signals from the force sensing unit) and the PIR_SIGs (input signal from the motion sensing unit) as its inputs and output the LED_SIG (output signal to the lighting unit) and the CAM_SIG (output signal to the imaging unit).

In the context of operation, the microprocessor will remain in standby mode until the PIR_SIG switches from LOW to HIGH. After it wakes up from this interrupt signal, the microprocessor will begin to generate PWM (Pulse Width Modulation) signal to the lighting unit as the LED_SIG. Then, it will gradually increase the duty cycle of the LED_SIG for five seconds while waiting for at least one of the FSR_SIGs to switch from LOW to HIGH. If all the FSR_SIGs do not change within 5 seconds, the microprocessor will return to standby mode. On the other hand, if at least one of the FSR_SIGs changes, it will turn the CAM_SIG HIGH for 0.5 second while generating the LED_SIG with 100% duty cycle. It will repeat this process for three times with two seconds intervals if at least one of the FSR_SIGs is HIGH. Finally, the microprocessor will wait for ten seconds and then return to standby mode for next cycle after it has switched the CAM_SIG HIGH for three times or all the FSR_SIGs become LOW.

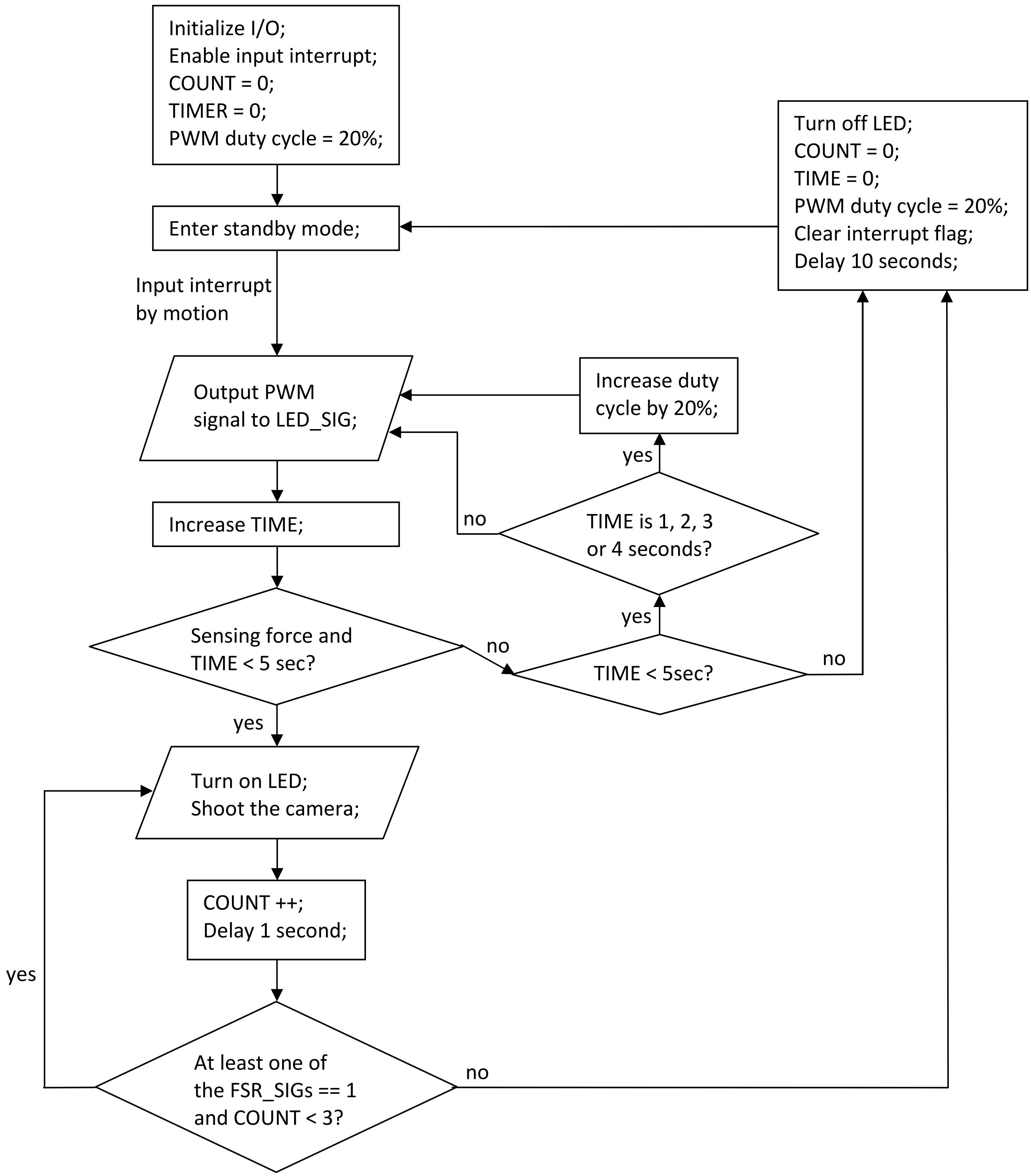


Figure 3: The flow chart of the microprocessor.

Motion Sensing Unit

The motion sensing unit is the Panasonic NaPiOn Motion Sensor (AMN41121). This sensor has a horizontal detection range of 100° and a vertical detection range of 80°. It also can detect motion up to 16ft. Besides that, the PIR sensor is powered by the power unit with 3.6V VCC and has an output to the microcontroller (PIR_SIG). Any movements within the detection zone of the sensor will trigger the sensor to output short digital pulses of HIGH signals from the sensor to the control unit through PIR_SIG.

The Panasonic motion sensor is composed of a quad-type pyroelectric element that is highly sensitive to infrared radiation. Hence, this sensor is capable of detecting the motion of any warm body, which includes the otter, because warm bodies always radiates infrared waves to its surrounding.

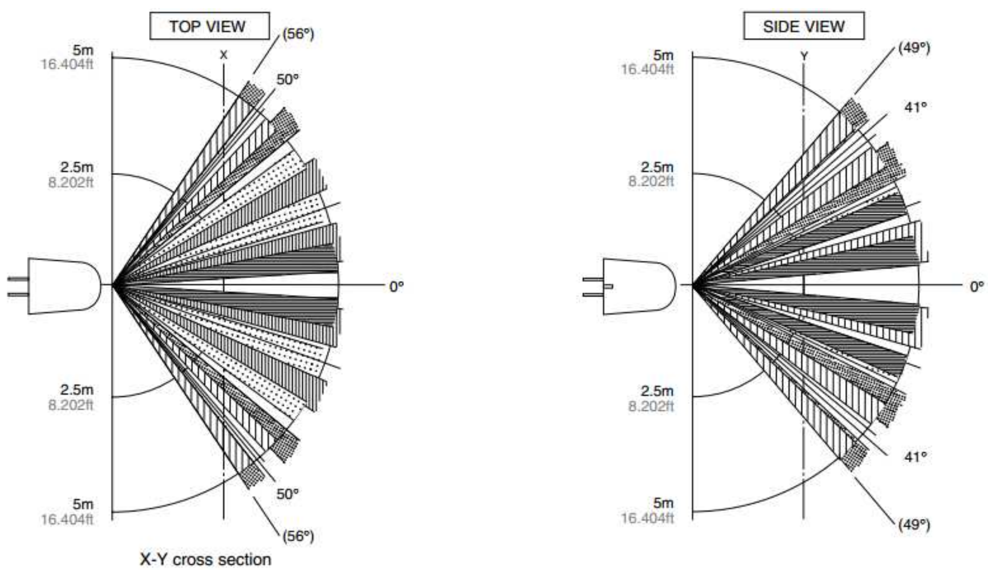


Figure 4: The detection zones of the motion sensor. [1]

Horizontal: $\tan 50° = \frac{x}{18''}$

$x = 21.45''$

$2x = 42.90''$

Vertical: $\tan 41° = \frac{x}{18''}$

$x = 15.65''$

$2x = 31.29''$

The above calculations show that the PIR sensor can detect any motion above the whole capturing window of 18”×12”.

Force Sensing Unit

The force sensing unit consists of four force sensitive resistors (FSR) and eight normal resistors to form four voltage dividers. The FSRs are the Interlink Electronic FSR402FRSs which have the force sensitivity range between 0.1N and 10N.[4] These sensors function like variable resistors where their resistances changes with the force applied on them. When there is no force, the resistances of the FSRs are very high, 10MΩ. As the force increases, the resistances of the FSRs go down until they reach the minimum resistance of 0.25kΩ. These FSRs are not very accurate and their resistances may vary up to 10%. However, this would not affect the operation of the force sensing unit because the FSRs will be used to generate digital signals to the microcontroller.

The minimum turn-on force of the force sensing unit is 10N which is the upper limit of the sensitivity range of the FSRs. This level of force is used so that the resistances of the FSRs only vary slightly when the applied force is beyond the 10N threshold.

For the voltage dividers to work as digital switches, the values of normal resistors must be chosen carefully. With a 10N applied force, the resistances of the FSRs are approximately 1kΩ. On the other hand, the microcontroller will register an input as HIGH when the input voltage is 0.6VCC and above.

$$V_{ON} = 0.6 \times 3.6V = 2.16V$$

Furthermore, a 10kΩ current-limiting resistor needs to be connected in series to each FSR to prevent a current greater than 1mA that will permanently damage the FSR. Then each of the voltage divider is powered by the power unit with 3.6V VCC. Finally, the values of series resistors can be calculated using the above conditions.

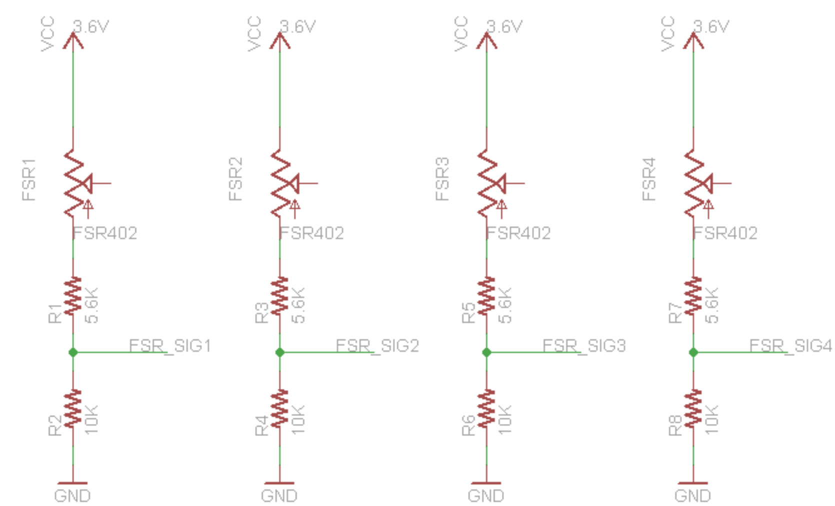


Figure 5: The voltage dividers in the force sensing unit.

Using the voltage divider rule,

$$Vo = Vcc \times (\frac{10k}{FSR + R + 10k})$$

$$Vo = 2.16V; \quad FSR = 1k\Omega; \quad Vcc = 3.6V;$$

$$10k = \frac{2.16}{3.6}(1k + R + 10k)$$

$$R = 5.67k\Omega$$

So, the resistors with the nearest value of 5.6kΩ are used in the voltage dividers.

Imaging Unit

The function of the imaging unit is to capture and store the images of the otter footprints after prompted by the shutter control unit. The imaging unit for the Otter Print Shooter is a DSLR (Digital Single-Lens Reflex). The Nikon D5100 is chosen as the reference camera due to its availability as it is currently owned by one of the group members. It is important to note that the Nikon D5100 is just one of the compatible DSLR cameras[1] for the imaging unit. In fact, the Nikon D3100 and the Canon Rebel T3 are more recommended than the Nikon D5100 because they offer very similar image quality[2] at a lower price[3]. In general, all the compatible cameras are highly responsive with startup time less than a second and zero shutter lag. Each of them also features a 3:2 aspect ratio CMOS sensor with effective resolution greater than 12 megapixels for capturing highly detailed images of the otter footprints. Additionally, the camera can be easily replaced or upgraded by user without making any change to the Otter Print Shooter.

In the aspect of the optics for these cameras, all the supported cameras will be equipped with their own compatible 18-55mm lenses. For the Nikon cameras, the Nikon AF-S DX Nikkor 18-55mm f/3.5-5.6G VR lens will be used and it has the maximum angle of view of 76°. On the other hand, for the Canon cameras, the Canon EF-S 18-55mm 1:3.5-5.6 IS II lens will be used. This Canon lens has the same focal length and aperture size as the Nikon lens but its maximum angle of view is 74°. These Nikon and Canon lenses are chosen because they are sharp, wide angle and cost efficient. Furthermore, the DSLR cameras have interchangeable lens system and are ready for any future optical upgrade.

Regarding the image storage, the imaging unit will compress and store the captured images in JPEG format because this format is widely supported and retains high image quality after compression. Besides that, the imaging unit uses an 8GB SDHC (Secure Digital High Capacity) memory card as its data storage. This 8GB memory card can store up to 1600 images[4] and can be easily swapped with a new memory card because it is inexpensive and physically small.

The imaging unit, which is one of the supported DSLR cameras, is powered by the battery dedicated to the camera itself. The battery lives of these cameras range from 550 shots[5] to 1050 shots[6] and these cameras can last for several weeks in idle. For the reference camera, the Nikon D5100 is capable of taking 660 pictures with a fully-charged battery.

[1] Refer to the appendix for the complete list of supported cameras

[2] All of these cameras were using their own compatible 18-55mm lens in the image quality comparison.

[3] The refurbished Nikon D3100 and Canon T3 are $450 while the refurbished Nikon D5100 is $600. (lens included)

[4] The average file size of the compressed JPEG images is 5MB.

[5] The battery life of 550 shots is for the Nikon D3100 and the Canon Rebel T3i using CIPA (Camera & Imaging Products Association) testing standard.

[6] The battery life of 1050 shots is for the Nikon D7000 using CIPA testing standard.

The imaging unit is positioned at the bottom center of the enclosure with its lens facing upward. This allows it to capture the otter footprints whenever the otters step on the transparent window. Finally, the imaging unit will operate using the following settings to acquire fine-detail images.

Parameter	Value	Description
Focal Length	18mm	Short focal length maximizes the angle of view and minimizes the depth of enclosure
Focus	Manual	The focus point is fixed on the transparent window
Shutter Speed	1/60 sec	Fast shutter speed helps to reduce motion blur
Aperture	F 3.5	The smallest F-number (largest aperture) allows more light to enter the camera for better low light performance
ISO Sensitivity	Auto	The camera determines the appropriate sensor sensitivity for correct exposure level
Max. ISO Level	800	The image will become too grainy if the ISO sensitivity is beyond 800
Release Mode	Continuous	This enables continuous rapid shooting
Image Size	Large	The image will have the maximum resolution

Shutter Control Unit

The purpose of the shutter release unit is to electronically control the shutter of the imaging unit using the control signal generated by the microcontroller. This can be accomplished because all the supported DSLR cameras for the Otter Print Shooter have a built-in remote shutter release feature. The shutters of these cameras can be remotely controlled by three I/O signals – SHUTTER, FOCUS and GROUND – which are accessed from the cameras via manufacturer specified ports. Regarding these ports, the Nikon cameras use its own 8-pins connector whereas the Canon cameras use a 2.5mm TRS (tip, ring, and sleeve) plug[7]. Despite of having different connectors, the operation principle for the remote shutter release is the same for the cameras by both manufacturers. More to the point, these cameras will autofocus when the FOCUS is connected to the GROUND and will release their shutters when both the FOCUS and the SHUTTER are connected to the GROUND.

Instead of a mechanical button, the shutter control unit uses the Fairchild FDV301N N-channel FET as a digital switch. This NMOS has low gate threshold voltage (<1.06V) which allows direct drive with the 3.6V output of the microcontroller at the GATE of the NMOS.[5] Since the imaging unit does not require auto-focus, the FOCUS and the SHUTTER (2.7V) are connected together to the DRAIN of the NMOS. Then, the GROUND (0V) is connected to the SOURCE of the NMOS. Using these connections, both the FOCUS and the SHUTTER will only connect to the GROUND when the gate voltage of the NMOS is HIGH. Thus, the shutter control unit will act as a switch that triggers the imaging unit whenever it receives a HIGH signal from the microcontroller.

[7] More commonly known as a stereo plug

Lighting Unit

The lighting unit consists of 12 surface mounted LEDs which will be mounted on the side of the acrylic sheet which is the material for the capturing surface. These LEDs will be responsible for providing adequate lighting when the camera is capturing images. The part number for the chosen LEDs is the 61-238/QK2C-B28322FAGB2/ET from the Everlight Electronics. Each of these LEDs has three LED dies to produce more concentrated light.

The LEDs chosen have following attributes: [6]

Illumination Color	White
Forward Voltage	3.2 V (when three LED dies are operated simultaneously)
Forward Current	20mA (for each LED die)
Viewing angle	120°
Luminous Intensity	5900 mcd

The LEDs will be powered by the power unit with 4.8V VDD. A 10uF capacitor is added as a smoothing capacitor to prevent flicking in LEDs. Since the forward voltage for each LED is 3.2V and the forward current for each LED is 3 dies x 20mA = 60mA:

$R = (V_{DD} – V_f)/ I_d$

$R = (4.8\ V – 3.2\ V)/ 0.06\ A$

$R = 26.67\Omega$

Thus, a 30Ω resistor is added before each LED. The power across this resistor, $P = I^2R = 0.06^2(30) = 0.108W$. This value is less than standard power rating of 0.25W.

The LEDs only light up when it receives a HIGH LED_SIG from the microcontroller. A surface mount NPN transistor (part number: 2DD2652 from Diodes Incorporated) acts as a switch which turns on the lighting circuit. [7] As the LED_SIG is driven directly from the microcontroller output which is 3.6V, the transistor should operate in saturation region for the switch to be on (voltage at base, V_b = 0.7V, and taking base current, I_b = 2 mA)

$R = (V_{CC} – V_b)/I_b$

$R = (3.6\ V – 0.7\ V) / 0.002\ A$

$R = 1450\Omega$

Thus, a 1500Ω resistor is added between the transistor's base and the LED signal output from the microcontroller.

The lights from the LEDs will be shined into the sides of the acrylic sheet. These lights will be trapped inside the sheet due to total internal reflection. When an otter steps on the acrylic surface, the lights inside the sheet will leak out and shine on its paws, causing its footprint to stand out.

Container and Lid

The container is a rectangular box of 20” (length) x 14” (width) x 18” (depth). The container is designed around certain restrictions. It must not be too large as the cost increases rapidly when the container is larger than 24” in any dimension. Nevertheless, it should be tall enough to provide a good distance for the camera to capture a large area of view. The dimensions of the container are determined based on the available model Nikon D5100 DSLR with its lens at 18mm focal length.

A small experiment was conducted to determine the maximum image size that gives sufficient clarity. At a distance of 18 inches (including the camera body length of 5.5 inches), the image size obtained is roughly 16.44 inches x 11.08 inches, which gives an aspect ratio of 3:2. Thus, the dimension of the capturing surface is determined to be 18 inches x 12 inches to accommodate this aspect ratio. Meanwhile, the rectangular frame surrounding the glass surface on top of the device should be approximately 1 inch on each side. This gives a total dimension of 20 inches (length) x 14 inches (width) for the lid and a depth of 18 inches for the container. There will be rubber seals in between the closure of the lid and the container to ensure that the enclosure is waterproof.

The transparent window is made of an inch-thick clear acrylic sheet that can support the weight of an adult. The minimum thickness of the supporting frame is estimated to be 1.5 inch. There is a 5mm horizontal gap in between the glass and the frame for the LEDs. This gap will be sealed with silicon sealant to keep the enclosure waterproof. Meanwhile, there is a 1mm vertical gap in between the acrylic sheet and the supporting frame for the force sensors. The silicon sealant is elastic enough for slight shear forces so that the pressure from the weight of an otter can be registered by the force sensors.

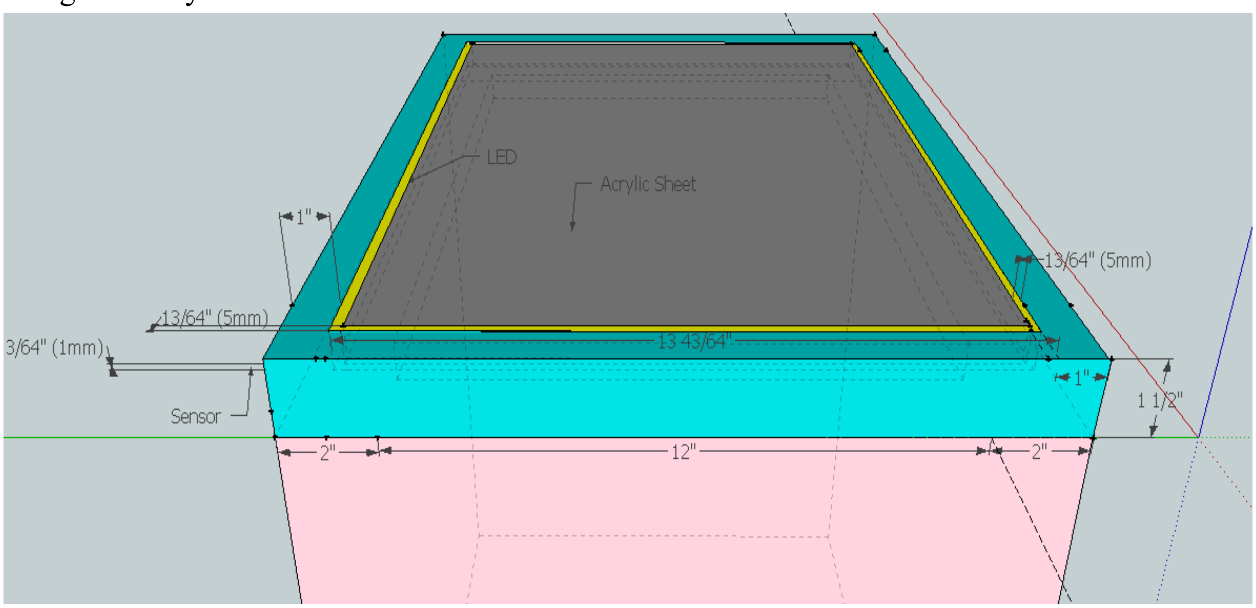


Figure 6: The cut-through view of the container with its lid.

3. Schematic

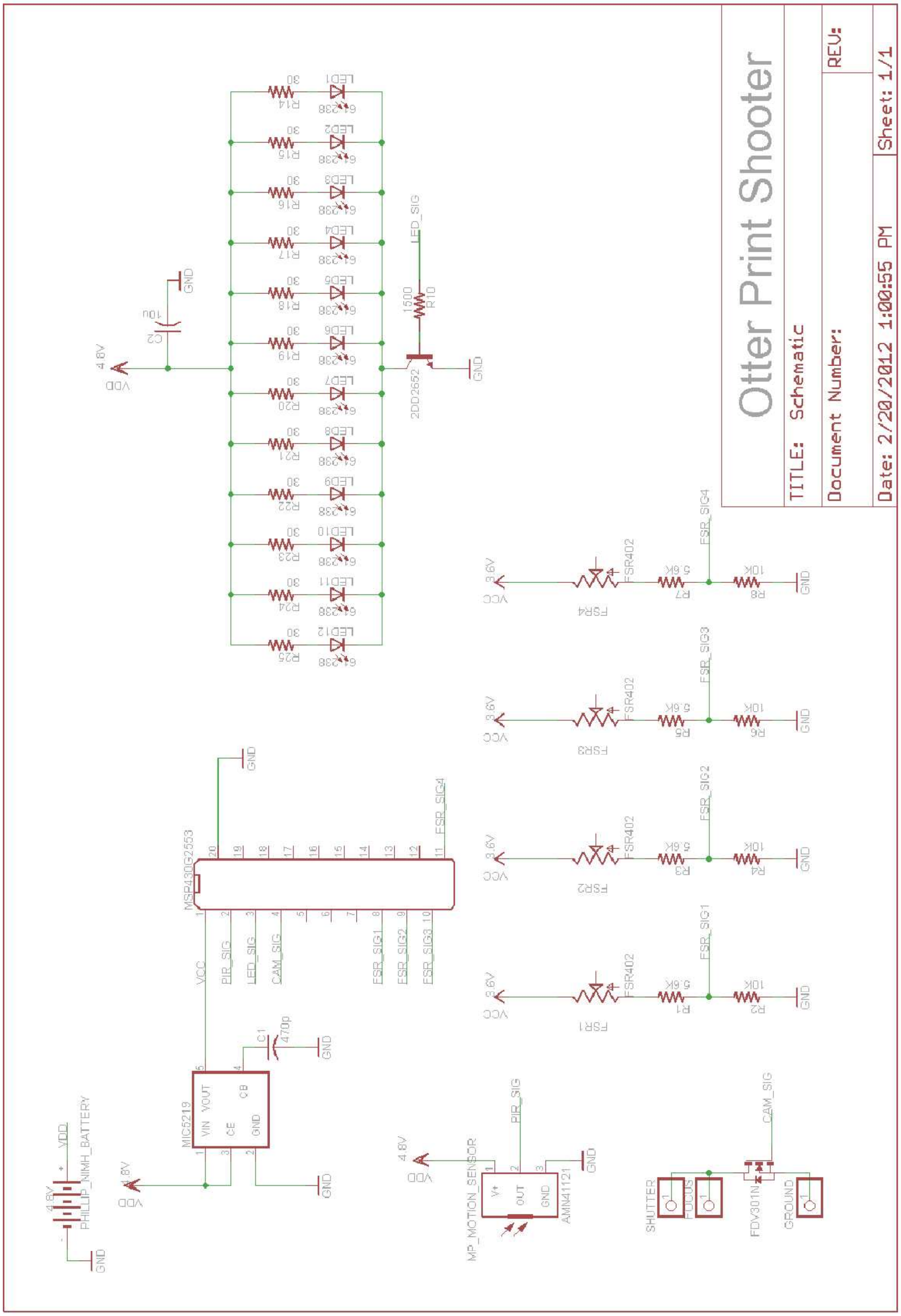


Figure 7: The complete schematic of the Otter Print Shooter.

4.Testings and Calculations

Total Internal Reflection

An experiment was conducted to verify that the acrylic sheet can be used as a waveguide. Theoretically, when a light source is shined on the sides of an acrylic sheet at an angle within the acceptance angle of the acrylic sheet, total internal reflection will occur inside the acrylic sheet. The acceptance angle of the acrylic sheet can be calculated as follow given that the refractive index of the acrylic sheet is 1.491.

$$Acceptance\ angle, \theta_A \leq 2\sin^{-1}\sqrt{{n_{acrylic}}^2 - {n_{air}}^2} = 2\sin^{-1}\sqrt{1.491^2 - 1^2}$$

$$\theta_A \leq 180°$$

This implies that the acrylic sheet can act as a waveguide when light is shined on its sides at any angle.

Figure 8: Total internal reflections in an acrylic sheet using a laser light source.

On the left of figure 8, the laser source was held upward at approximately 45° angle but the laser beam that came out from the acrylic sheet was directed downwards. On the right of figure 8, two red dots were observed within the acrylic sheet when the total internal reflection occurred and the laser beam was reflected within the acrylic sheet. This preliminary test shows that an acrylic sheet permits the occurrence of total internal reflection when light is shined on its sides. Unlike the laser, the lights coming out from the LEDs are incoherent and they propagate at various angles (viewing angle = 120° from the LED data sheet). Thus, some amounts of dispersion of light rays are expected. Nonetheless, total internal reflection would occur if there is sufficient amount of lights being captured by the acrylic sheet.

Frustrated Total Internal Reflection

A test was performed to show that the light trapped in an acrylic sheet will brighten the part of object that is in contact with the acrylic surface. Theoretically, this phenomenon, also known as frustrated total internal reflection, happens because the trapped light leaks out as the requirement for total internal reflection is no longer satisfied at the contact place. For this experiment, a LED torch light is used as light source whereas a small 3/4" acrylic sheet is used as the waveguide. While shining the light into the acrylic sheet from the side, the acrylic surface is touched with fingers to observed frustrated total internal reflection.

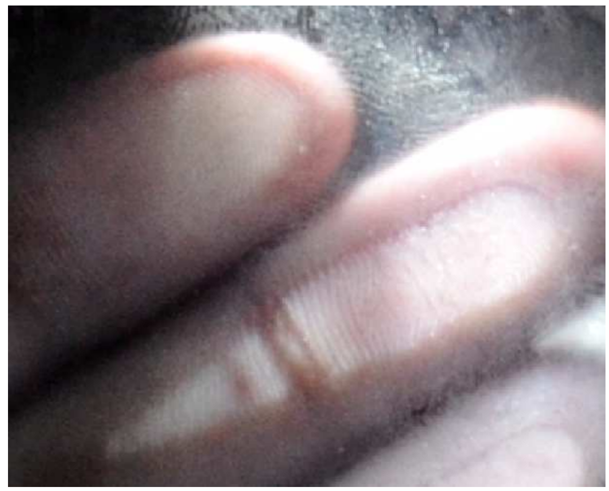


Figure 9: Frustrated total internal reflection when fingers are in contact with the acrylic sheet.

Figure 9 shows that the fingerprints taken in a dark environment are clear due to the frustrated total internal reflection. This experiment managed to prove the feasibility of capturing high-detail images of the otter footprints using a more uniform edge-illumination by the lighting unit.

Imaging Device

In order to determine the most suitable imaging device for the Otter Print Shooter, an imaging test on human fingerprints was conducted using a wide range of imaging devices as shown in the table below.

Imaging Device	Type	Pixels	Focus	SRP
Logitech Webcam Pro 9000	High-end webcam	2M	Auto/Manual	$64.99
Iphone 4S rear camera	Best phone camera	8M	Auto	$30.99
Sony DSC-W310	Budget compact camera	12M	Auto	$44.95
Panasonic DMC-LX5	High-end compact camera	10M	Auto/Manual	$499.99
Nikon D3000 w/ lens kit	Entry-level DSLR camera	10M	Auto/Manual	$499.95
Nikon D5100 w/ lens kit	Mid-level DSLR camera	16M	Auto/Manual	$849.95

The fingerprints were taken at different distances (5cm, 10cm, 15cm, 20cm, 25cm, 30cm, 35cm, 40cm and 45cm) with each device. Using this method, the maximum distance for capturing clear images of fingerprints was determined for each device. This maximum distance is crucial because a larger capturing area on the Otter Print Shooter can be obtained with a longer maximum distance.

Imaging Device	Result Description
Logitech Webcam Pro 9000	Clear images of fingerprints were obtained for distance less than 10cm using manual software focus.
Iphone 4S rear camera	Clear images of fingerprints were obtained for distance up to 15cm. The autofocus was hard to lock on the fingerprints.
Sony DSC-W310	The autofocus was impossible to lock on the fingerprints. No clear image was obtained.
Panasonic DMC-LX5	Clear images of fingerprints were obtained for distance up to 30cm using autofocus.
Nikon D3000 w/ lens kit	Clear images of fingerprints were obtained for the maximum test distance of 45cm.
Nikon D5100 w/ lens kit	Clear images of fingerprints were obtained for the maximum test distance of 45cm.

Refer to the appendix for the test images.

The result of the experiment shows that the camera optic is the limiting factor of image sharpness since both the Nikon D3000 and the Nikon D5100 produced very identical images when using the same lens. Thus, a camera with a sensor greater than 10 megapixels and a good lens is suitable for the Otter Print Shooter. This makes the DSLR cameras the best option.

In contrast, webcams and phone cameras are not suitable for this application because they use electronic shutters that lead to slow operation and high power consumption. Moreover, their cost for capturing a large area using array will be higher than the cost of one DSLR camera because there are no built-in image processor and storage system for webcams and phone cameras.

Power Consumption

Units	Standby Current	Active Current
Power Unit	130μA	170μA
Control Unit	0.7μA	420μA
Motion Sensing Unit	0.17mA	0.17mA
Force Sensing Unit	0.72mA	1mA
Lighting Unit	0.1μA	0.72A
Shutter Control Unit	0.1μA	0.1μA
Total	1.021mA	0.722A

Assume the active time for the power unit, the control unit and the force sensing unit is 15s per shot whereas the active time for the lighting unit is 5s.

Standby current usage for 4 days is $(130\mu + 0.7\mu + 0.17m + 0.72m + 0.1\mu + 0.1\mu) \times 96 = 98mAH$

Active current usage for 660 shots is $[(170\mu + 420\mu + 0.17m + 1m + 0.1\mu)15 + 0.72(5)] \times \frac{660}{3600} = 665mAH$

The total current usage for 4 days is 763mAH which is less than half of the 2000mAH of the batteries. This means that the operating time of the Otter Print Shooter is limited by the battery life of the camera. It is also important to note that the total power consumption calculated is just a rough approximation because the environmental factors such as the appearance of otters and other wild animals are unpredictable.

III. Requirements and Verifications

1. Requirements, Verifications and Testing Procedures

Requirements	Verifications
Power Unit The power must provide stable 4.8V VDD from the batteries and stable 3.6 VCC from voltage regulator. 1. The batteries must provide 4.8V when 1mA current is drawn. 2. The batteries must also supply at least 4.6V when 1A current is drawn. 3. The voltage regulator must provide 3.6V when 1mA current is drawn. 4. The voltage regulator must provide 3.6V when its input voltage is between 4.2V and 5.0V.	The voltages across the batteries and the voltage regulator are measured using a DMM. 1. Test the batteries by connecting a 4.7kΩ resistor to the batteries to simulate 1mA current drain and measure its voltage. 2. Repeat the above test with 4.7Ω resistor to simulate 1A current drain. 3. Test the voltage regular by connecting a 4.7kΩ resistor to the voltage regulator to simulate 1mA current drain and measure its voltage. 4. Supply the voltage regulator with 4.2V, 4.4V, 4.6V and 5.0V using tunable power supply and measure its output voltage.
Control Unit The microcontroller must be able to interpret HIGH signals from its inputs and generate HIGH signals to its outputs within 0.1s from its standby. In addition, it must be able to generate PWM signal of various duty cycles to its output. 1. For the input, the threshold voltage of HIGH signal must have 0.7 VCC or above. 2. For the output, the voltage of HIGH signal must have 0.9 VCC or above when 2mA current is drawn. 3. The PWM signal must have the options of 20%, 40%, 60%, 80% and 100% duty cycles and its duty cycle can increase from 0% to 100% over 5s.	The input of the microcontroller will be tested by connecting the input to a function generator. Then, the output of the microcontroller will be tested by monitoring the output using an oscilloscope. 1. Connect a 100Hz square wave signal to the input of the microcontroller and gradually increase its peak voltage until the microcontroller interprets it as a HIGH signal. 2. a. Connect a 1.8kΩ resistor to the output of the microcontroller to simulate the 2mA drain to the lighting unit b. Program the microcontroller to output HIGH signal and monitor the output voltage. 3. a. Program the microcontroller to output a PWM signal at 20%, 40%, 60%, 80% and 100% duty cycles and monitor the output waveform. b. Program the microcontroller to output a PWM signal that increases its duty cycle from 0% to 100% over 5s and

	monitor the output waveform.
<u>Motion Sensing Unit</u> The motion sensor must detect motion generate a 3.6V HIGH output. 1. It must detect motion within 40° from its center point. 2. It must detect motion within 1m away.	The output of the motion sensor will be examined using an oscilloscope. 1. a. Wave hand at the center point of the sensor (0°) while observing the output on the oscilloscope. b. Then, move to the side 20° and 40° away from the center point while observing the output on the oscilloscope. 2. a. Wave hand right in front of the sensor while observing the output on the oscilloscope. b. Then, move 0.5m, 1m and 1.5m away from the sensor while observing the output on the oscilloscope.
<u>Force Sensing Unit</u> 1. The output voltage of the force sensing unit must be 2.16V or higher when 1kg weight is applied. 2. Resistance of the force sensor must have 1kΩ or less when 1kg weight is applied. 3. Resistance of the force sensor must have at least 1MΩ when no weight is applied.	1. The force sensing unit will be tested using 0.5kg, 1kg, 3kg, and 5kg weights and its output voltage will be measured using a DMM. a. Connect 5.6kΩ and 10kΩ resistors in series with a FSR. b. Place the FSR on a flat surface. c. Place a large acrylic sheet on top of the sensor. d. Measure the voltage across the 10kΩ resistor using a DMM. e. Place different weights on top of the sheet at various spots while measuring the voltage across the 10kΩ resistor using a DMM. 2. The force sensor will be tested using 0.5kg, 1kg, 3kg, and 5kg weights and its resistance will be measured using a DMM. a. Place the force sensor on a flat surface. b. Place a large acrylic sheet on top of the sensor. c. Place different weights on top of the sheet at various spots while measuring the resistance of the sensor using a

	DMM. 3. The force sensor will be tested using no weight and its resistance will be measured using a DMM. a. Place the force sensor on a flat surface. b. Place a large acrylic sheet on top of the sensor. c. Measure the resistance of the sensor using a DMM.
<u>Imaging Unit</u> The camera must capture high-detail image of moving target within 0.5s after triggered by the shutter control unit. 1. The image taken 18" away must be able to resolve 0.5mm lines and spaces. 2. The image taken 18" away must remain its quality when the target is moving at 5cm/s or less.	The image quality will be tested by taking the images of the ISO 12233 test chart at 18" away using the camera settings listed in the block description. [8] 1. Take an image of the test chart in a well-lit room and zoom in to inspect whether the lines and spaces for the scale of 10 on the ISO 12233 test chart are distinguishable. 2. Take an image of the test chart that is being dragged along a flat surface at 5cm/s and perform the same inspection.
<u>Shutter Control Unit</u> The NMOS in the shutter control unit must trigger the shutter of the camera to take a single image after receives a 0.5s pulse from the microcontroller.	Test the operation of the shutter control unit using a function generator. a. Connect the shutter control signals from the camera between the DRAIN and the SOURCE of the NMOS. b. Generate a 0.5s 3.6V pulse using function generator to the GATE of the NMOS. c. Check whether the camera was triggered.
<u>Lighting Unit</u> The lighting unit must have adequate and controllable brightness. 1. The lighting unit must generate sufficient lights for the camera to take high-detail images at the ISO 800. 2. The brightness of the lightning unit must change according to the duty cycles of its input, LED_SIG.	1. The lighting unit will be tested at maximum brightness with its lights shined into the sides of an acrylic sheet. a. Place the ISO 12233 test chart under the acrylic sheet. b. Turn off other light sources and take an image of the test chart using the camera settings listed in the block description section. c. Zoom in to inspect whether the lines and spaces for the scale of 10 on the ISO 12233 test chart are distinguishable.

	2. The brightness of the lighting unit will be observed in a dark room with its input (LED_SIG) connected to a function generator. a. Generate a 1kHz 3.6V square wave with duty cycle of 20% to the input of the lighting unit. b. Observe the brightness of the lighting unit. c. Repeat the observation using square wave with duty cycles of 40%, 60%, 80% and 100%.
<u>Container and Lid</u> The enclosure must be water-proof.	a. Spray water on the sealed enclosure at various angles and sides. b. Open the enclosure and look for water droplet.

After fulfilling all these requirements, the Otter Print Shooter will perform a test on the otter site. Since the environment condition of the otter site is different, so some adjustments and optimizations will be made to the Otter Print Shooter based on the result of this test.

The power unit is required to last for four days. Thus, on-site testing will be needed to verify the battery life of the device as there are many unknown variables (appearance frequency of wild animals) that would affect the overall power consumption.

2. Tolerance Analysis

The most important component of the project is to be able to capture high-detail images of the otter footprints for the identification of individual otters. This means that there must be a tight tolerance on the image quality. The target detail level for an image taken 18” away is the scale of 10 (0.5mm lines and spaces) and above in the ISO 12233 test chart. In addition, the image must maintain the same level of detail when the test chart is moved at 5cm/s. An image that has the detail level at the scale of 9 when capturing a moving target is acceptable.

The test for detail level will be conducted using the following procedures.

a. Tape the ISO 12233 test chart onto a large acrylic sheet so that the test chart is on visible through the acrylic sheet.
b. Place the acrylic sheet on a flat surface.
c. Turn on the lighting unit at its maximum brightness and turn off other light sources.
d. Setup the camera using the settings described in the block description section.
e. Take an image of the test chart at 18” directly above of the test chart.
f. Upload the image to computer and zoom in to inspect whether the lines and spaces for the scale of 10 are distinguishable on the image of test chart.
g. Repeat step e while moving the acrylic sheet at 5cm/s.
h. Repeat step f.

Please refer to the appendix for examples of acceptable and unacceptable images.

IV. Cost and Schedule

1. Cost Analysis

i. Labor:

Name	(Rate/hour)×(2.5)×(Total hours)	Total Price
Hoong Chin Ng	($30/hour)×(2.5)×(150 hours)	$11,250
Sabrina Cheng	($30/hour)×(2.5)×(150 hours)	$11,250
Sze Yin Foo	($30/hour)×(2.5)×(150 hours)	$11,250
Labor Total :		**$33,750**

ii. Parts:

Part Name	Status	Quantity	Price/Unit	Total Price
TI Launchpad MSP430G2553	Received	1	$4.30	$4.30
RES Metal Film 5.1K Ohm 1/4W 1% Resistors (ERO-S2PHF5101)	Pending	4	$0.15	$0.60
RES Metal Film 10K Ohm 1/4W 1% Resistors (MFR-25FBF-10K0)	Pending	4	$0.13	$0.52
RES Metal Film 30 Ohm 1/4W 1% Resistors (ERO-S2PHF30R0)	Pending	12	$0.15	$1.80
RES Metal Film 1.5K Ohm 1/4W 1% Resistors (MFR-25FBF-1K50)	Pending	1	$0.13	$0.13
CAP ALUM 10UF 10V 20% RADIAL capacitor (SN100M010ST)	Pending	1	$0.14	$0.14
CAP 470PF 100V CERAMIC DISC Y5P capacitor (D471K20Y5PH63L6R)	Pending	1	$0.33	$0.33
Voltage Regulator 500mA 3.6V (MIC5219-3.6YM5 TR)	Pending	1	$1.43	$1.43
MOSFET N-Channel (FDV301N)	Pending	1	$0.61	$0.61
NPN Surface Mount Transistor (2DD2652)	Pending	1	$0.42	$0.42
Nikon D5100 Camera & lens	Received	1	$600.00	$600.00
3/4” Acrylic Sheet (2ft×2ft)	Pending	1	$51.35	$51.35
Container (20”×14”×18”)	Pending	1	$70.00	$70.00
Interlink Electronics Force Resistor Sensor (402)	Ordered	4	$7.00	$28.00
Panasonic NaPiOn Motion Sensor (AMN41121)	Pending	1	$15.44	$15.44
Everlight SMD Low Power LED (61-238/QK2C-B28322FAGB2/ET)	Ordered	12	$0.82	$9.84
4Philips NiMH Rechargeable Batteries 1.2V (2000 mAh) and Charger	Ordered	1	$9.00	$9.00
Parts Total :				**$793.91**

iii. **Grand Total** = Labor + Parts = $33,750 + $793.91
= **$34,543.91**

2. Schedule

Week	Date	Tasks	Team Member
1	2/6	Compilation and submission of proposal	Hoong Chin Ng
		Introduction and design proposal	Sabrina Cheng
		Verification testing, cost and schedule of proposal	Sze Yin Foo
2	2/13	Sign-up for Design Review and research on camera	Hoong Chin Ng
		Research on microcontroller and power supply	Sabrina Cheng
		Research on force sensors and motion sensors	Sze Yin Foo
3	2/20	Finalize and present the Design Review	Hoong Chin Ng
		Progress discussion with Samantha about the design	Sabrina Cheng
		Order parts	Sze Yin Foo
4	2/27	Write code for camera	Hoong Chin Ng
		Design and test the lighting unit	Sabrina Cheng
		Implement and test the force sensors	Sze Yin Foo
5	3/5	Write code for sensing unit and lighting unit	Hoong Chin Ng
		Design the power supply unit	Sabrina Cheng
		Implement and test the motion sensor	Sze Yin Foo
6	3/12	Combine all parts of the design	Hoong Chin Ng
		Testing of the power supply unit	Sabrina Cheng
		Design the plastic surface and container	Sze Yin Foo
7	3/19	SPRING BREAK	
8	3/26	Mock-up Demos	Hoong Chin Ng
		Sign-up for Mock-up Presentation	Sabrina Cheng
		Prepare for Mock-up Presentation	Sze Yin Foo
9	4/2	Assemble the real model on site	Hoong Chin Ng
		Testing model on site	Sabrina Cheng
		Compilation and analysis of data	Sze Yin Foo
10	4/9	Testing and debugging of the model	Hoong Chin Ng
		Discussion with Samantha about the results	Sabrina Cheng
		Compile information for Final Report	Sze Yin Foo
11	4/16	Sign-up for Demo	Hoong Chin Ng
		Sign-up for Presentation	Sabrina Cheng
		Prepare for Demo	Sze Yin Foo
12	4/23	Prepare for Presentation	Hoong Chin Ng
		Finalize and lead the Demo	Sabrina Cheng
		Finish first draft of Final Report	Sze Yin Foo
13	4/30	Finalize and lead the Presentation	Hoong Chin Ng

		Finish the Final Report and schedule appointment with the Writers Workshop	Sabrina Cheng
		Finalize and submit the Final Report	Sze Yin Foo

V. Ethical Considerations

In the process of obtaining background information and assembling the Otter Print Shooter for this project, ethical guidelines based on the IEEE Code of Ethics should be adhered to at all times.

The device for this project will be placed at certain sites susceptible to humans and endangered animals. Thus, pertaining to #1 code which clearly says that "t*o accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment*", the device is designed to fit public safety standards. An inch-thick acrylic sheet capable of supporting the weight of an adult human is used in the device capturing surface.

As the device is a new technology never used in the field of animal-tracking before, the project is stepping on unknown grounds. Thus, pertaining to #5 code which clearly says that "*to improve the understanding of technology, its appropriate application, and potential consequences*", research on otter behavior is done thoroughly regarding their weight, biometrics (footprints data), and active hours (night time) before designing the device that fits all the requirements exactly. Lighting unit is added as otters usually frequent the site at night. Besides, the lighting is dimmed for fear of alarming the otters.

VI. References

[1] Micrel. “MIC 5219.” Internet: http://www.micrel.com/_PDF/mic5219.pdf. [Feb.20, 2012]

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[3] Panasonic. “MP Motion Sensor ‘NaPiOn’ Datasheet.” Internet: http://pewa.panasonic.com/assets/pcsd/catalog/napion-catalog.pdf. [Feb. 20, 2012]

[4] Interlink Electronics. “FSR 402 Data Sheet.” Internet: http://www.interlinkelectronics.com/sites/default/files/2010-10-26-DataSheet-FSR402-Layout2.pdf. [Feb. 20, 2012]

[5] Fairchild Semiconductor. “FDV301N Digital FET, N-Channel.” Internet: http://www.fairchildsemi.com/ds/FD%2FFDV301N.pdf. [Feb. 20, 2012]

[6] Everlight Electronics. “Technical Data Sheet.” Internet: http://www.everlight.com/datasheets/61-238-XK2C-BXXXXXXXXXX-ET_datasheet_new_template_V2.pdf. [Feb. 20, 2012]

[7] Diodes Incorporated. “2DD2652 NPN Surface Mount Transistor.” Internet: http://www.diodes.com/datasheets/ds31633.pdf. [Feb. 20, 2012]

[8] Westin, S. H. “ISO 12233 Test Image.” Internet: http://www.graphics.cornell.edu/~westin/misc/res-chart.html. [Feb. 20, 2012]