UNIVERSITY OF ILLINOIS
URBANA-CHAMPAIGN

# OTTER STALKER SYSTEM

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# 1.0 INTRODUCTION

## 1.1 TITLE

Otter Stalker System

This project is in collaboration with Illinois Natural History Survey, Institute of Natural Resource Sustainability, University of Illinois Urbana Champaign in the study of the river otters.

## 1.2 HISTORY AND MOTIVATION

The main motivation of this project is to enhance the current technology available to wildlife researchers. The current otter habitat-monitoring method employs trailing cameras with limited range of sensing mechanism and fixed camera view. In other words, they are only able to detect and record the wildlife behaviors in one direction. To address the limitations of current habitat-monitoring system, the Otter Stalker System is designed to have optimal monitoring coverage to enhance wildlife study experiences.

## 1.3 OBJECTIVES

The goal of this project is to improve the sensitivity of detecting the presence of otters which is limited by the conventional habitat-monitoring methods. This system enables habitat-monitoring in all directions without compromising the effectiveness of the wildlife data obtained. Besides, it also increases the monitoring coverage of the habitat and is able to operate autonomously for up to four days.

The Otter Stalker System is capable of detecting the presence of otters in a study site. When the otters are present, the PIR sensors will detect them and send a feedback wirelessly to the microcontroller. Then, the microcontroller will interpret the feedback and decide which camera to be woken up according to the position of the otters and the coverage of the camera. Thus, the video recording starts and will be saved in a SD memory card. After the recording is done, the camera will be turned to standby mode automatically for power saving.

### *1.3.1 Benefits*

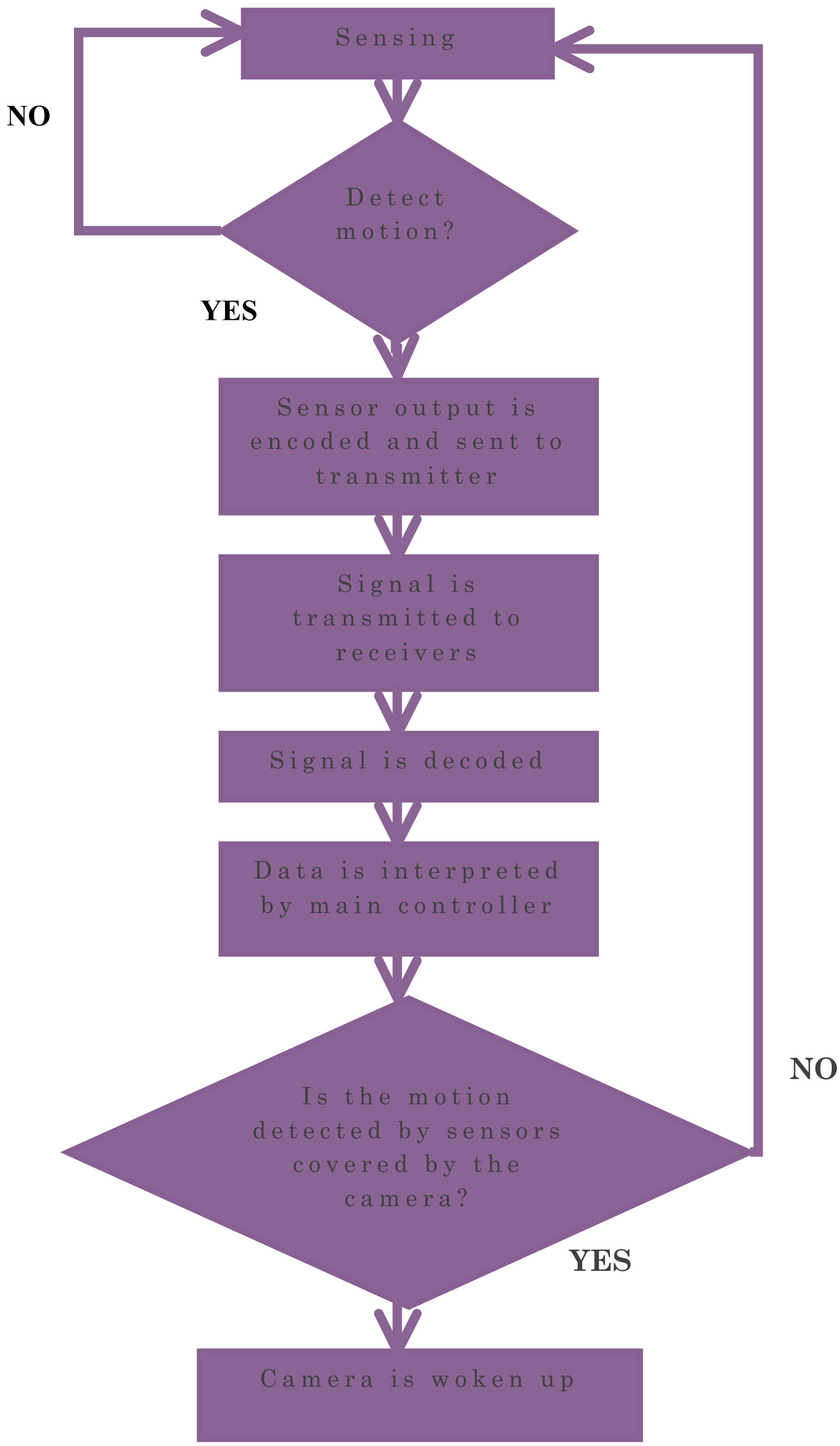
- ✓ Full monitoring coverage of 3m x 3m area of interest
- ✓ Memory-efficient since it only records while motion is detected
- ✓ Power-efficient
- ✓ Inconspicuous habitat-monitoring infrastructure
- ✓ Reduce the disturbance to the habitat by life-scientists/scholars.

### *1.3.2 Features*

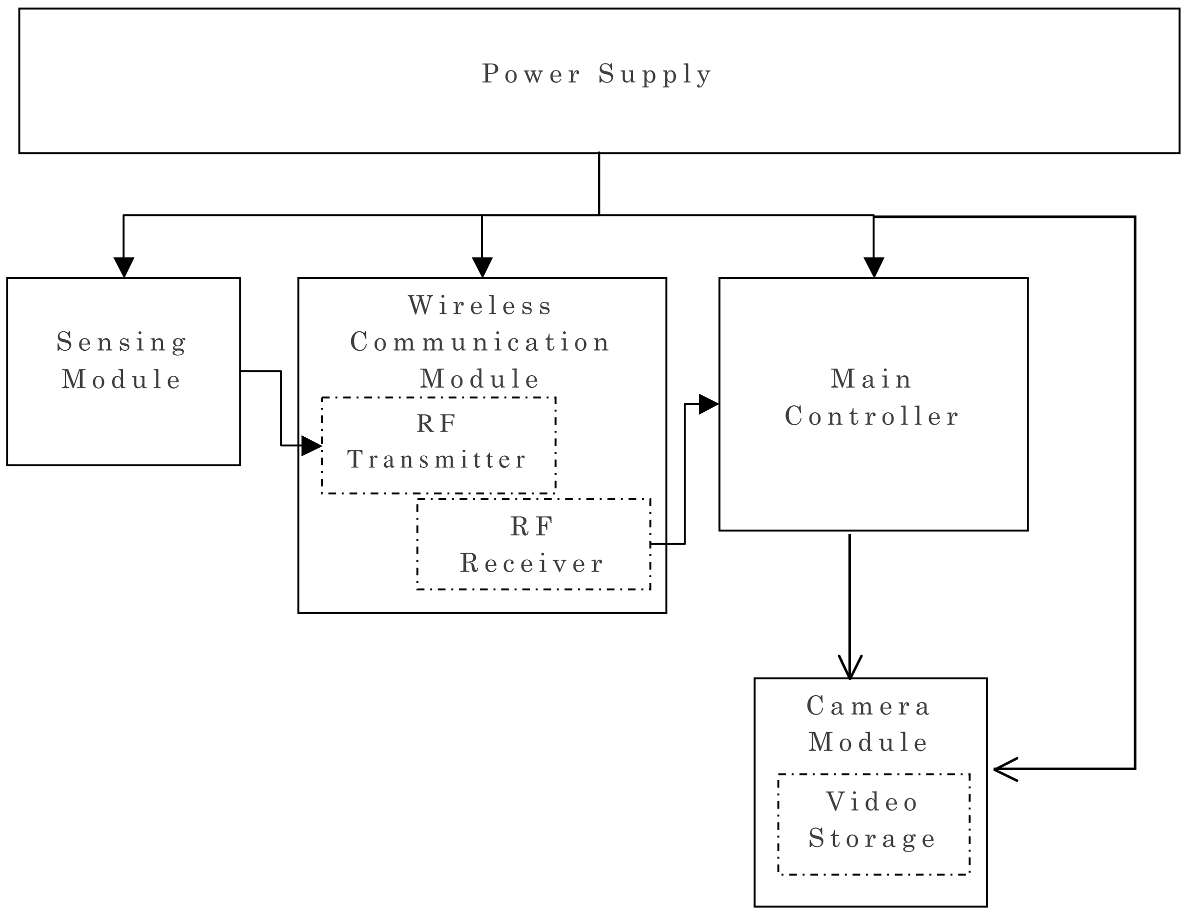
- ✓ Infrared Camera with Virtually Invisible Infrared Technology with Audio Capability
- ✓ SD Memory Card
- ✓ Weatherproof and Durable
- ✓ Color Day Video Clips and Infrared Night Video Clips

# 2.0 DESIGN

## 2.1 FLOWCHART OF OVERALL SYSTEM



## 2.2 BLOCK DIAGRAM




## 2.3 BLOCK DESCRIPTION

### *2.3.1 SENSING MODULE*

This module is made of four Panasonic NaPiOn Spot Type PIR sensors, with each of them have a sensing range of 22° and 5m long [2]. The sensors are placed as shown in the figure below to ensure full coverage of the otter study site.

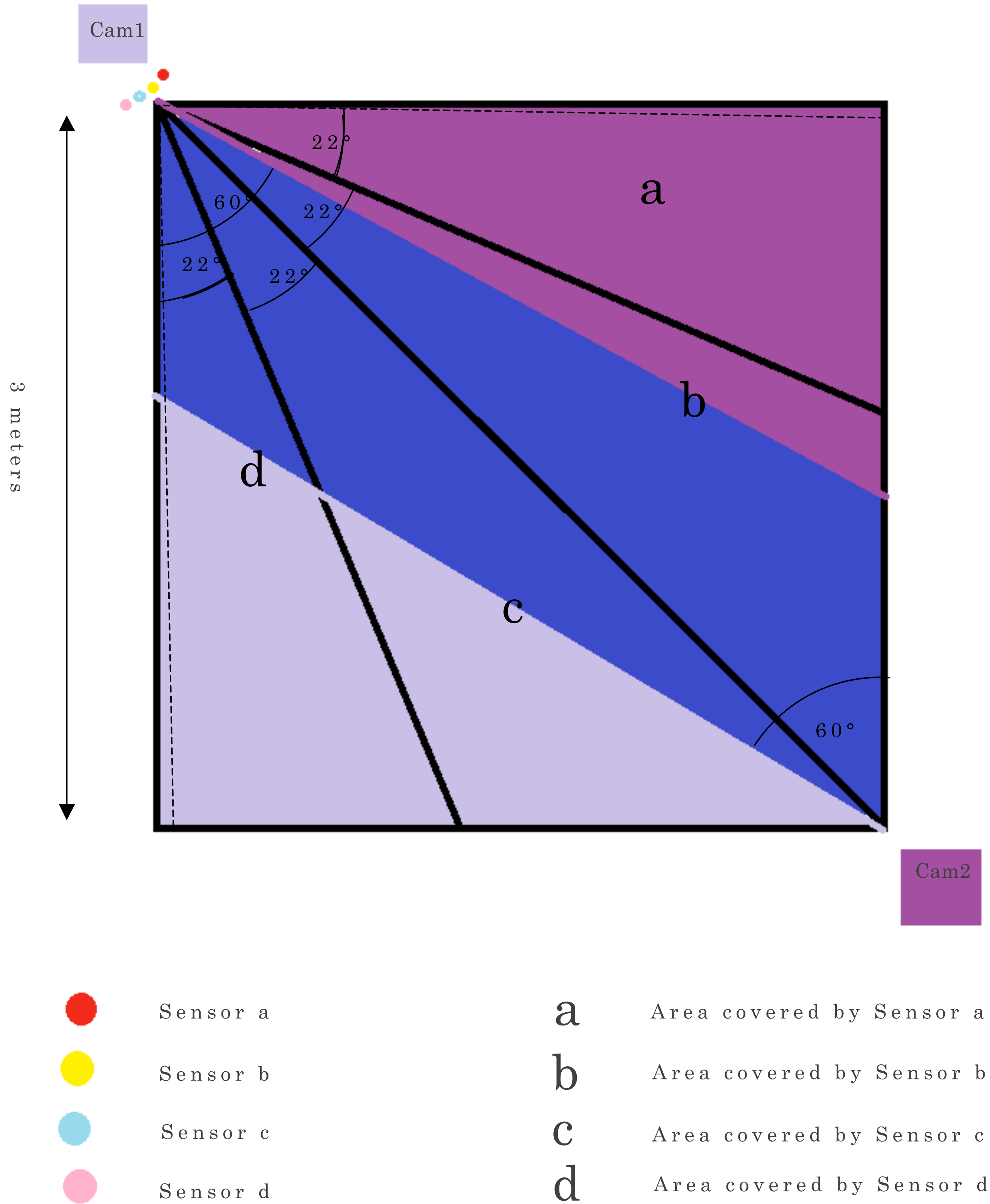



FIGURE 1: Placement and coverage of sensors and cameras

Since four sensors are used, the total angle of coverage is 88°, instead of 90° (angle of a square). Therefore, there is a 1° area not covered by the sensors on the left side and the up side of the study site. The maximum length of the area not covered by the sensors is obtained by using the arc length formula as shown below,

$$S = r\theta$$
$$= 3m \times 1° \times \frac{\pi}{180}$$
$$= 0.052m$$

where S is the arc length in meter
r is the radius in meter
θ is the angle in radian

Typically, the average body length of the otters is 0.978m to 1.129m, which is much larger than the arc length not covered by the sensors. Thus, as long as the otters occur in the study site, the detection of them is ensured.

The output of the sensor is shown in figure below:

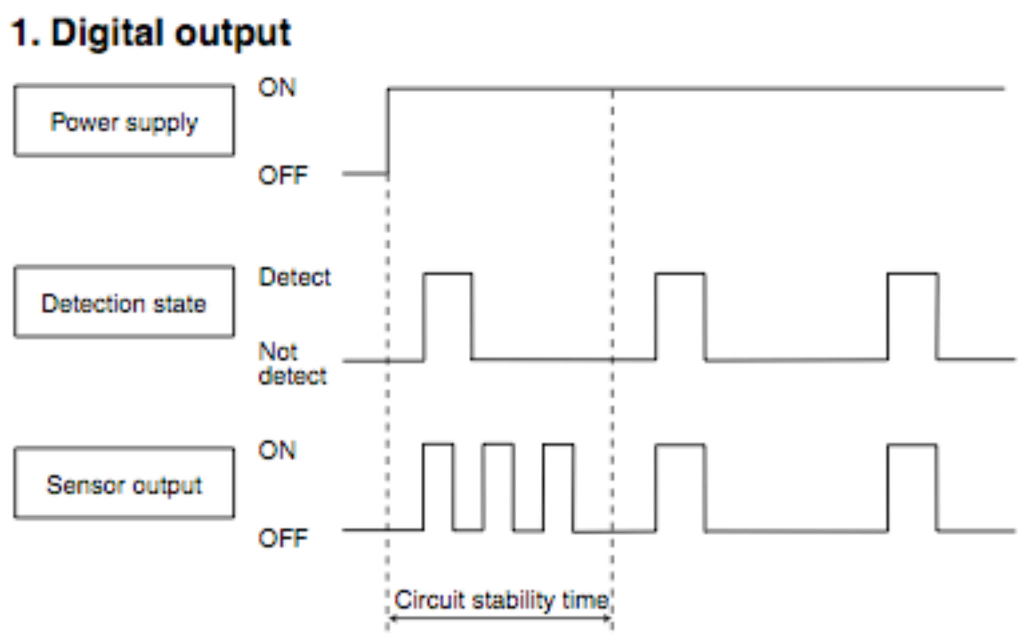



FIGURE 2: Digital output of the sensor (Graph) [2]

1) Digital output

| Items | | Symbol | Electrical characteristics *( ) is low current consumption type | Measured conditions *( ) is low current consumption type |
|---|---|---|---|---|
| Rated operating voltage | Minimum | Vdd | 3.0 V DC (2.2 V DC) | |
| | Maximum | | 6.0 V DC (3.0 V DC) | |
| Rated consumption current (Standby) Note) | Typical | Iw | 170 μA (46 μA) | Ambient temperature = 25°C 77°F<br>Operating voltage = 5V (3V)<br>Iout = 0 |
| | Maximum | | 300 μA (60 μA) | |
| Output current (when detecting) | Maximum | Iout | 100 μA | Ambient temperature = 25°C 77°F<br>Operating voltage = 5V (3V)<br>Vout ≧ Vdd–0.5 |
| Output voltage (when detecting) | Minimum | Vout | Vdd –0.5 | Ambient temperature = 25°C 77°F<br>Operating voltage = 5V (3V)<br>Open when not detecting |
| Circuit stability time | Typical | Twu | 7 s | Ambient temperature = 25°C 77°F<br>Operating voltage = 5V (3V) |
| | Maximum | | 30 s | |

Note: The current which is consumed during detection consists of the standby consumed current plus the output current.

FIGURE 3: Digital output of sensor (Table) [2]

When the sensor detects, the output voltage is $V_{dd}$ -0.5V. Since $V_{dd}$ = 5V, the output voltage will be 4.5V. When the sensor does not detect, the output voltage is 0V. The output voltage will be considered as binary logic, in which 1 = high voltage (4.5V) and 0 = low voltage (0V) when it is sent to the Wireless Communication module.

### *2.3.2 WIRELESS COMMUNICATION MODULE*

This module consists of a Linx TXM-418-LC transmitter, two Linx RXM-418-LC receivers, one 8-bits CIP-8E encoder, two 8-bits CIP-8D decoders and some logic gates. This module functions as a mean of communication between the sensors and main controllers. Each of the sensors is connected to the encoder. The encoder will encode the information from each sensor into an 8-bits binary signal as a Hamming code:

| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|---|---|---|---|---|---|---|---|
| 0 | d | c | b | $P_3$ | a | $P_2$ | $P_1$ |

where a, b, c, and d are either 0 (not detecting) or 1 (detecting) according to output voltage of sensor a, b, c, and d respectively and $P_1$, $P_2$, and $P_3$ are the parity bits.. The code is designed in this form so that errors can be detected and corrected. Since there are four sensors, there will be 16 possible scenarios. Below is a table showing the codes for 16 different situations:

| Situations | d | c | b | a | Cam1 | Cam2 |
|---|---|---|---|---|---|---|
| no sensor detects | 0 | 0 | 0 | 0 | 0 | 0 |
| a detects | 0 | 0 | 0 | 1 | 1 | 0 |
| b detects | 0 | 0 | 1 | 0 | 1 | 1 |
| a and b detect | 0 | 0 | 1 | 1 | 1 | 1 |
| c detects | 0 | 1 | 0 | 0 | 1 | 1 |
| a and c detect | 0 | 1 | 0 | 1 | 1 | 1 |
| b and c detect | 0 | 1 | 1 | 0 | 1 | 1 |
| a, b and c detect | 0 | 1 | 1 | 1 | 1 | 1 |
| d detects | 1 | 0 | 0 | 0 | 0 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| a and d detect | 1 | 0 | 0 | 1 | 1 | 1 |
| b and d detect | 1 | 0 | 1 | 0 | 1 | 1 |
| a, b and d detect | 1 | 0 | 1 | 1 | 1 | 1 |
| c and d detect | 1 | 1 | 0 | 0 | 1 | 1 |
| a, c and d detect | 1 | 1 | 0 | 1 | 1 | 1 |
| b, c and d detect | 1 | 1 | 1 | 0 | 1 | 1 |
| all detect | 1 | 1 | 1 | 1 | 1 | 1 |

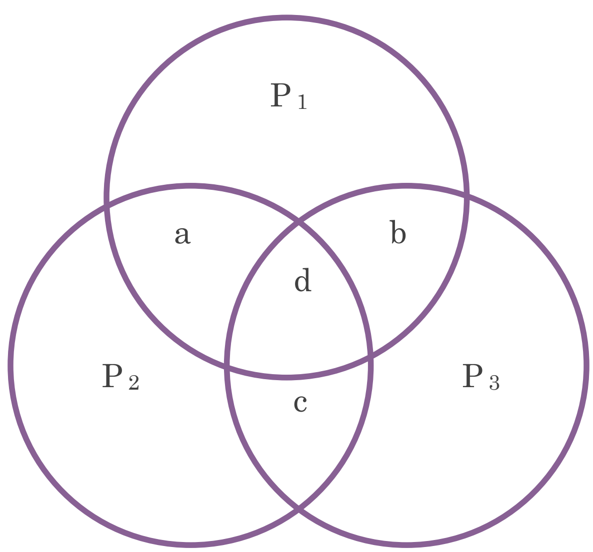
TABLE 1: Codes for 16 different situations

After the information from sensors has been encoded, the signal will be transmitted to the receivers equipped on each main controller. The decoder will decode the data received and pass it to the main controller for further analysis.

### *2.3.3 MAIN CONTROLLER*

The main controller used in this project is MSP430G2553 from Texas Instrument. Based on the feedback from the sensors, it controls the field of view of the camera by deciding which camera to be woken up.

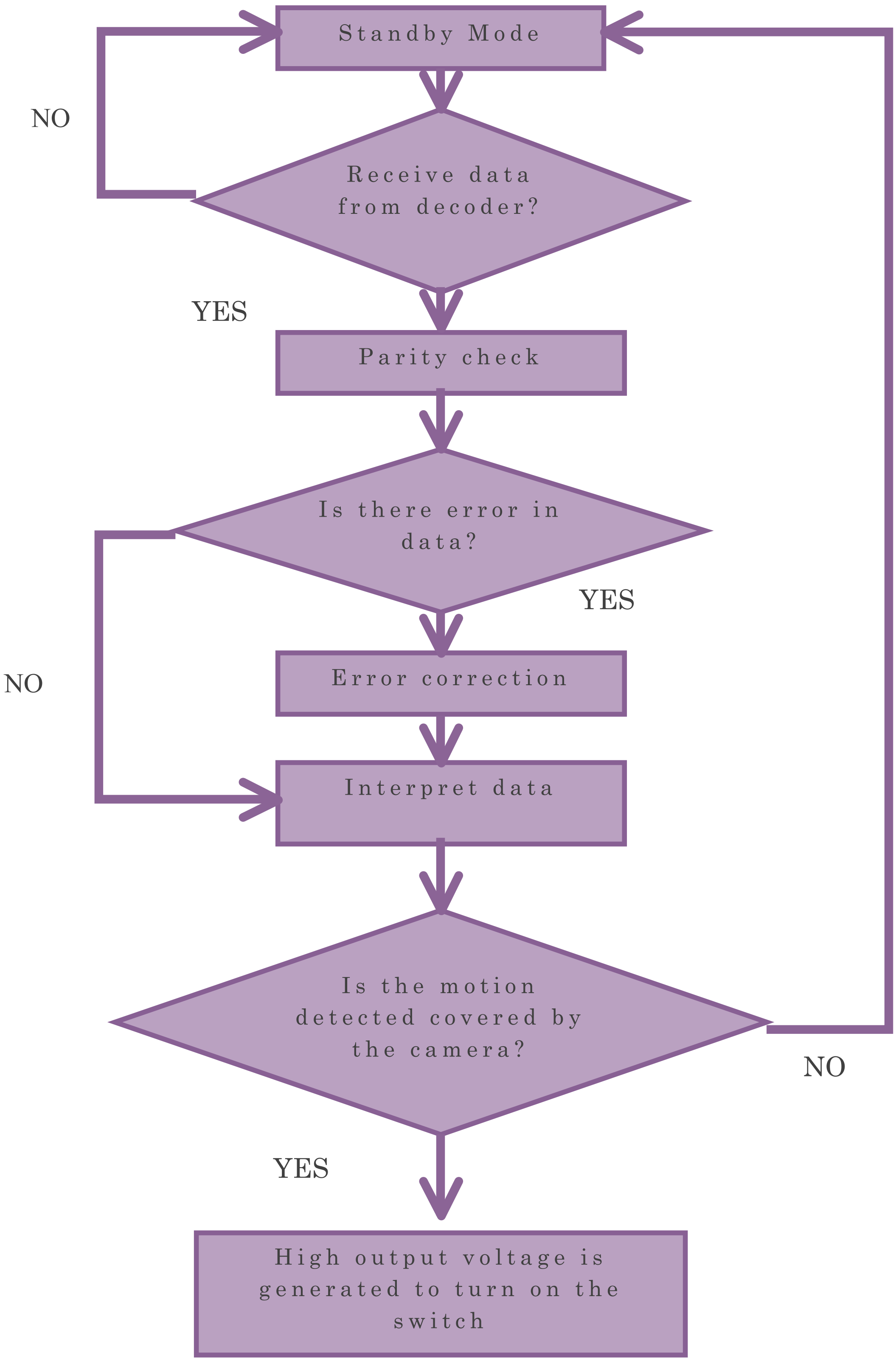
Besides controlling the camera, the microcontroller is able to detect 2-bits errors and correct 1-bit errors since the data sent from the transmitter is constructed as Hamming code:




where

$P_1$ = a XOR b XOR d
$P_2$ = a XOR c XOR d
$P_3$ = b XOR c XOR d

Below is the flowchart of microcontroller:



*2.3.4 CAMERA MODULE*

The camera module contains two Spy Point Pro X Plus Trail Cameras with audio capability and data storage. The cameras are weatherproof and have night-vision capability. They will be woken up or turned to standby mode controlled by the main controllers. The cameras will record a short-length video (10s, 30s, 60s or 90s) [1] and store it in memory storage. They are placed at specific locations as shown in the figure below to ensure the full coverage of the otter study site.

Since the camera is originally connected to a PIR sensor used to trigger the video recording, experiments have been carried out to look for a method to modify accordingly to this project, such that the video recording should be triggered by the Sensing module of this system. Two pins were found to be able to trigger the video recording function of the camera when they are shorted together. The voltage across these two pins is 3V. Thus, a digital N-type MOSFET (FDV301N) can be used as a switch to turn on the video recording function.

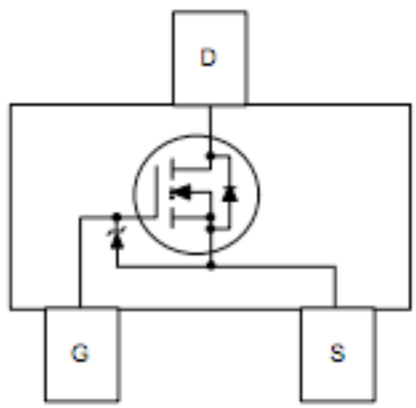



FIGURE 4: Schematic inside FDV301N [4]

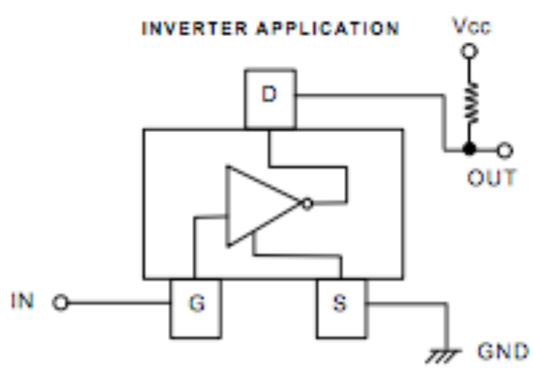



FIGURE 5: Schematic of FDV301N [4]

The pin (PIN 1) with the higher voltage will be connected to the drain of the FET while the pin (PIN 2) with the lower voltage will be connected to the source of the FET. The switch will be controlled by the output voltage of the microcontroller, which will be connected to the gate of the FET. The maximum threshold voltage of the FET is 1.06V [4]. Theoretically, when $V_{GS} > V_{th}$, the FET is turned on and the current is allowed to flow between the drain and the source. On the other hand, when $V_{GS} < V_{th}$, the FET is turned off, then there is no conduction between drain and source. Therefore, when the output voltage is larger than 1.06V, the video recording will be triggered.

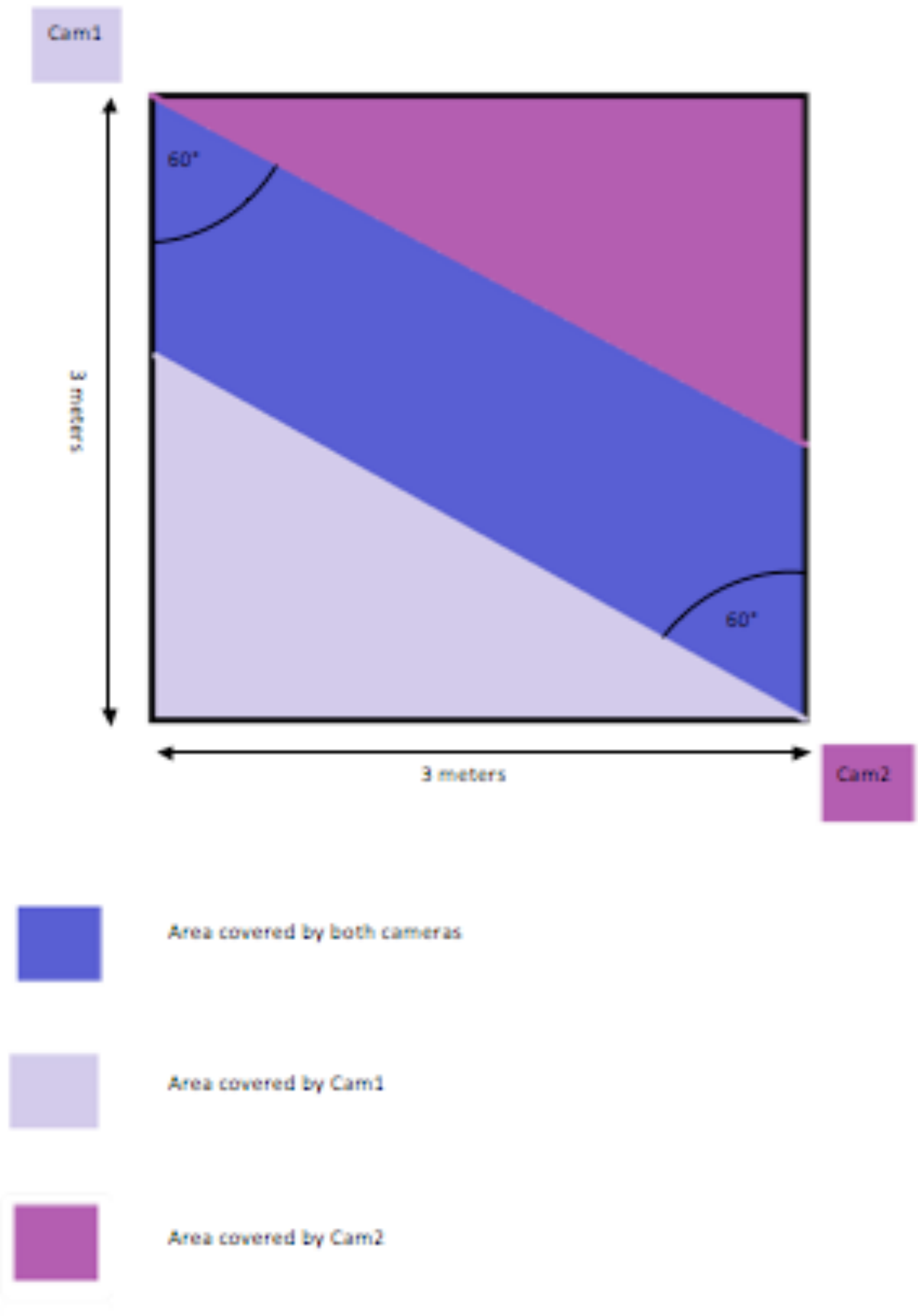



FIGURE 6: Placement and coverage of cameras

### *2.3.5 POWER SUPPLY*

The power supply module will be divided into three parts:

a) Camera module
b) Sensing module and Wireless Communication module
c) Main controller

#### 2.3.5.1 Camera module

The Spy Point Pro X Plus Trail Camera requires 12V DC[1] to operate. The camera originally comes with a 12V rechargeable lithium battery.

#### 2.3.5.2 Sensing module and Wireless Communication module

Table below shows the operating voltage for each component:

| Component | Min (VDC) | Max(VDC) |
|---|---|---|
| PIR Sensor | 3 | 6 |
| Encoder | 3 | 5.5 |
| Decoder | 3 | 5.5 |
| Transmitter | 2.7 | 5.2 |
| Receiver | 4 | 5.2 |

TABLE 2: Operating voltage for each component[2][7][8][9][10]

Therefore, four 1.5V batteries will be connected in series to provide a total of 6V voltage. Then, a 5V voltage regulator (L7805CV) will be used to regulate 6V to 5V to supply the required voltage to the components listed above.

#### 2.3.5.3 Main Controller

The microcontroller required 1.8VDC – 3.6VDC[3] to operate. Similar in the Sensing and Wireless Communication module, four 1.5V batteries (the same in the module above) will be connected in series to provide 6V of voltage. Then, a 3.3V voltage regulator (LD1117V33) will be used to regulate 6V to 3.3V to supply the required voltage to the microcontroller.

## 2.4 SCHEMATIC OF OVERALL SYSTEM

*2.4.1 TRANSMITTER PART*

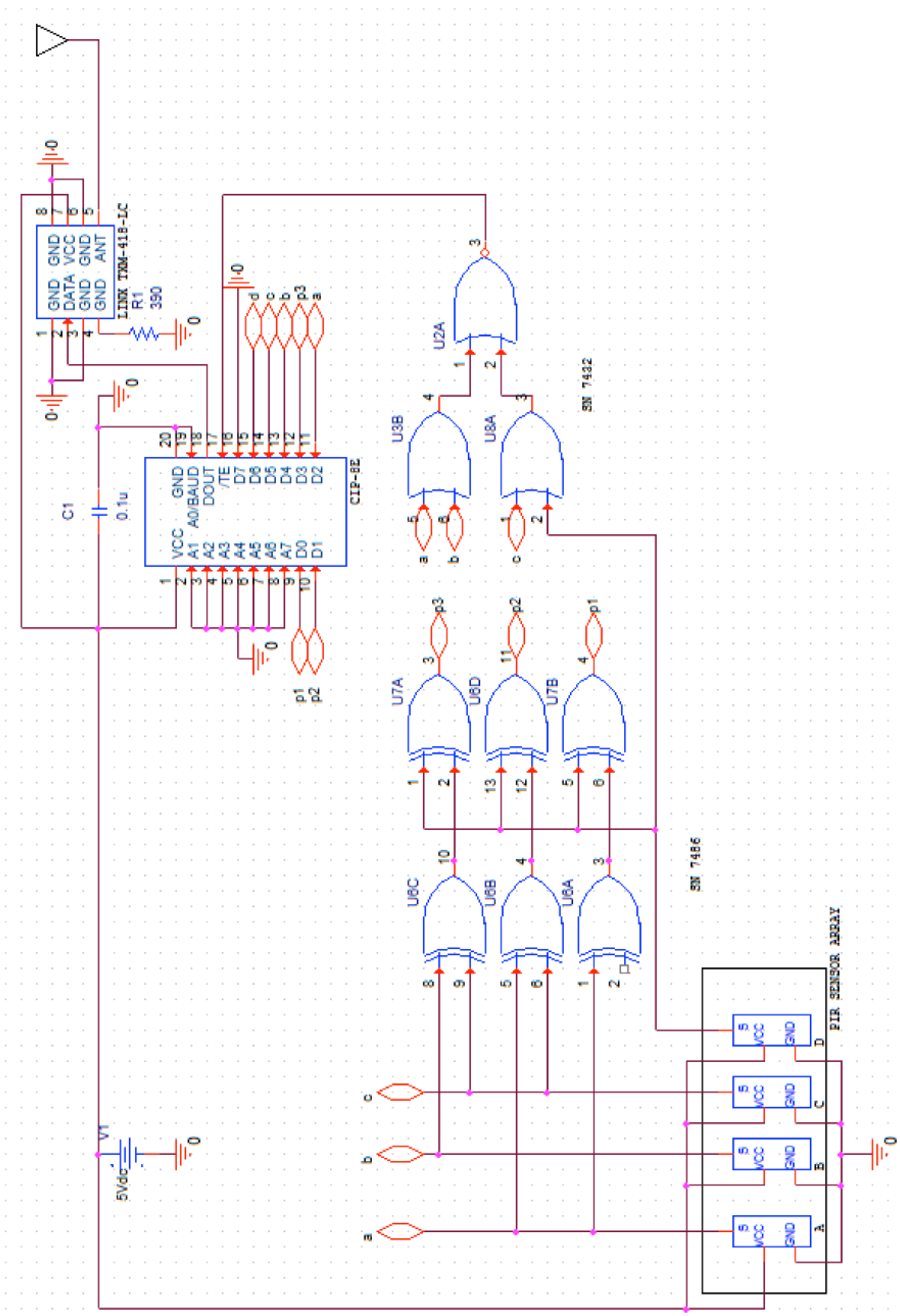


FIGURE 7: Schematic of transmitter part

*2.4.2 RECEIVER PART*

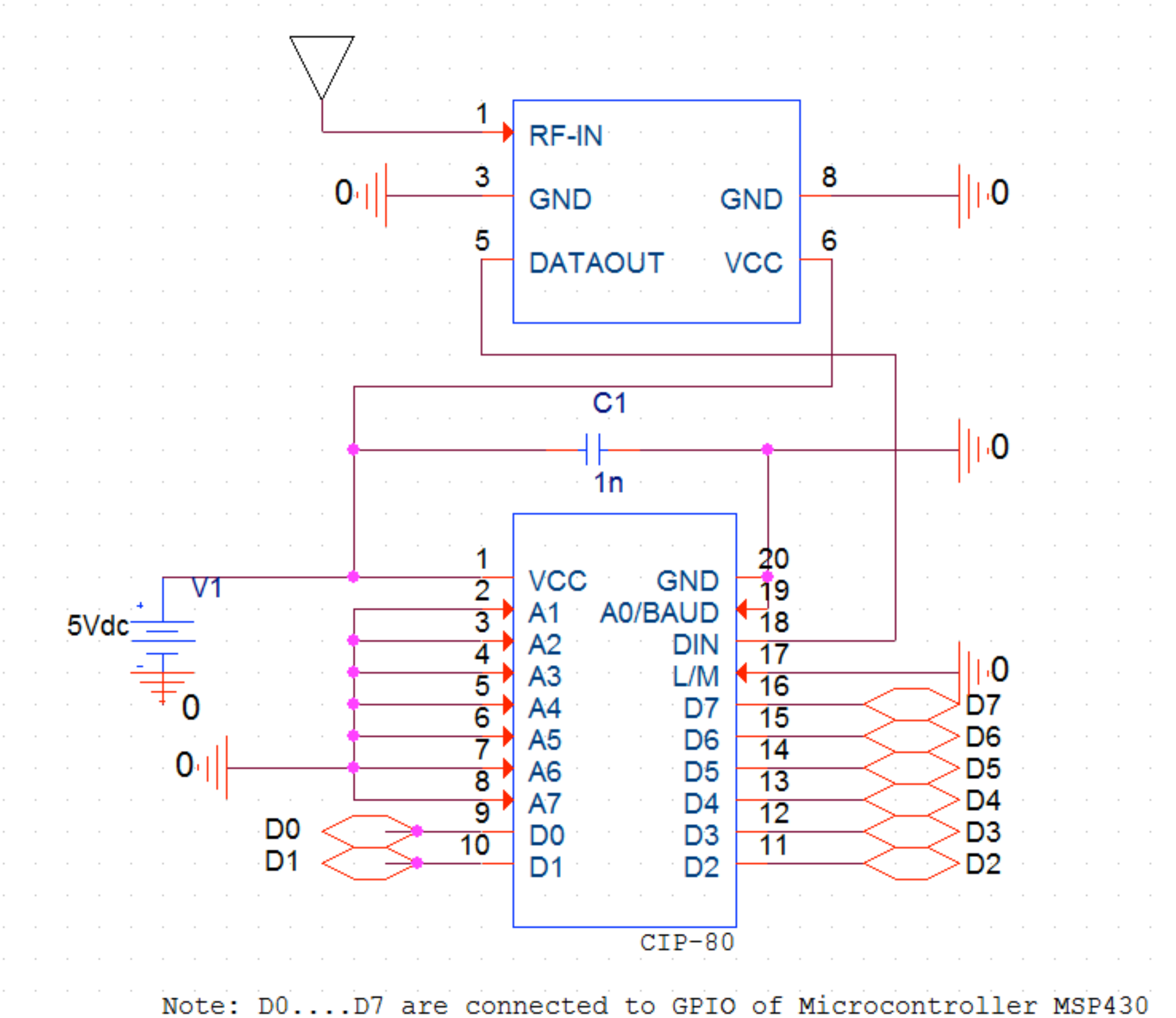



FIGURE 8: Schematic of receiver part

*2.4.3 MICROCONTROLLER*

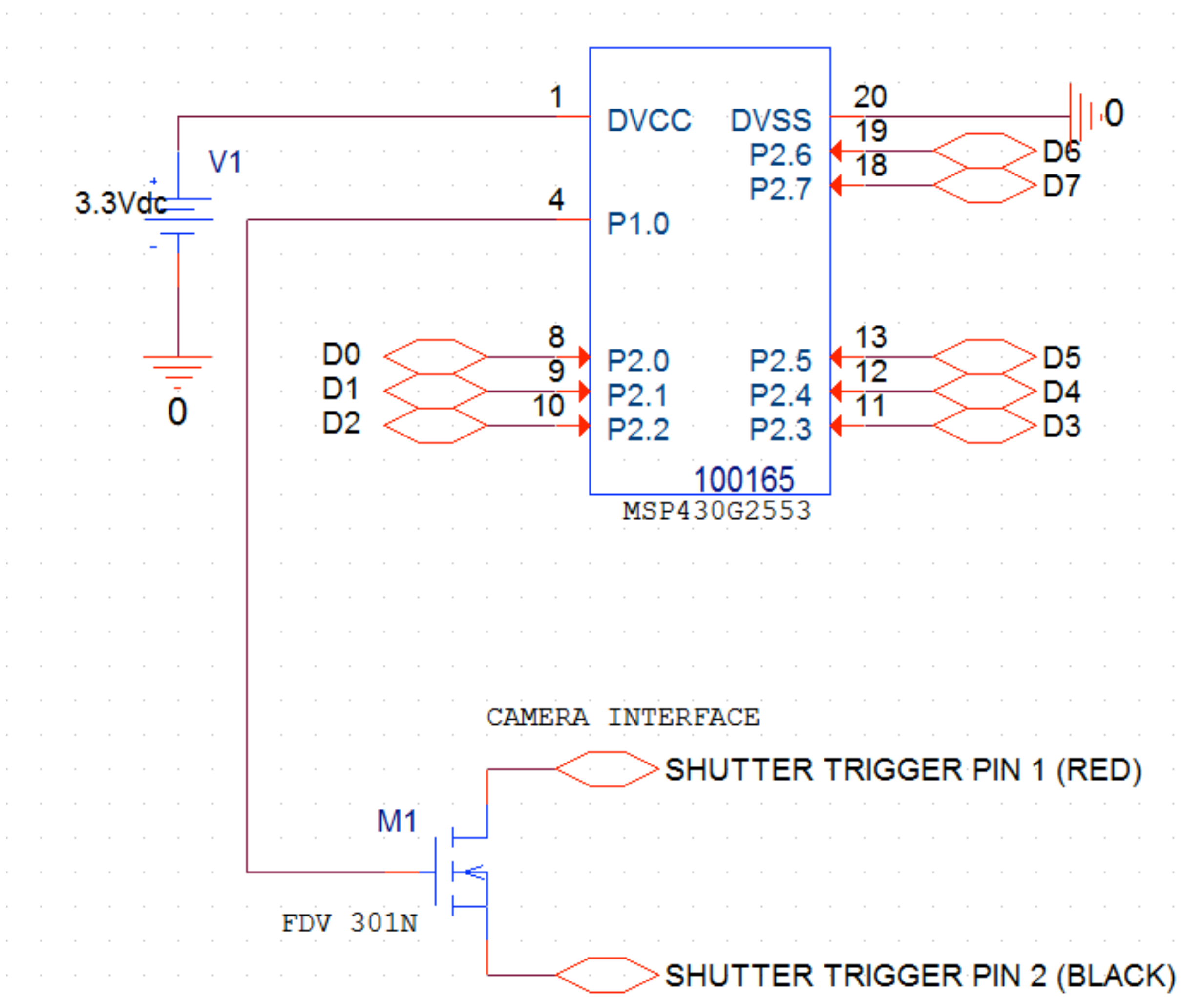



FIGURE 9: Schematic of microcontroller

*2.4.4 VOLTAGE REGULATION*

2.4.4.1 Sensing Module and Wireless Communication Module

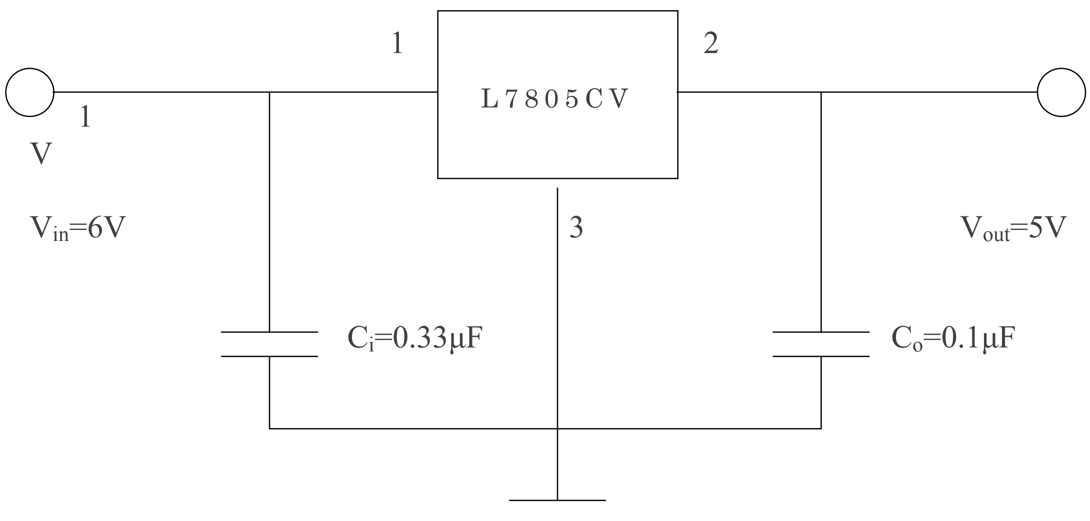



FIGURE 10: Schematic of voltage regulator for Sensing module and Wireless Communication module [5]

2.4.4.2 Main Controller

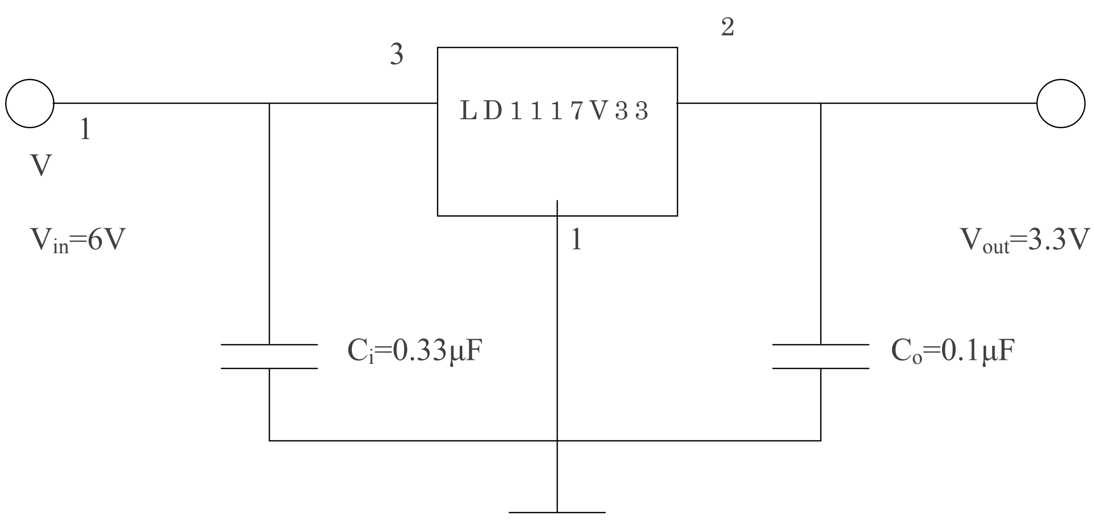



FIGURE 11: Schematic of voltage regulator for Main Controller[6]

## 2.5 PERFORMANCE REQUIREMENT

- The system should be able to sense the presence of wildlife within an area of 3m x 3m.
- The signal to noise ratio (SNR) from the transmitters to the receivers should be larger than 20dB.
- It should wake the particular cameras up according to the positions of the otters.
- It should have the capability of taking color day video clips and infrared night video clips with audio recording.
- It should be inconspicuous to the otters and does not harm the well-being or obscure the movements of the otters.
- The cameras should be turned to standby mode automatically when the video recording is done.
- Batteries that support this system must have a lifetime of at least four days, as the researchers will visit the site twice a week to collect data and change the batteries.
- It has to be weatherproof and "chew-proof".

## 2.6 DESIGN CALCULATION AND SIMULATION/INITIAL TESTING

### *2.6.1 NOISE/INTERFERENCE REDUCTION*

As the project involves PIR sensors and RF components for transmission, the quality power supply must be good as the power supply noise will affects their performances. Although voltage regulators is used, it is better to insert a capacitor across the $V_{CC/}$ and ground of sensors, transmitter and receiver to filter the noise. The capacitor also acts as decoupling or bypass capacitor on other IC components. According to datasheet, a 10Ω resistor in series with the supply followed by a 10µF tantalum capacitor from VCC to ground will help in cases where the quality of supply power is poor for transmitter and receiver. A 33µF capacitor is used for the PIR sensors. A 0.1 µF capacitor should be sufficient for microcontroller and other digital components (encoder, decoder, logic gates).

Below is small test of 5V DC power supply quality with and without 33µF capacitor:

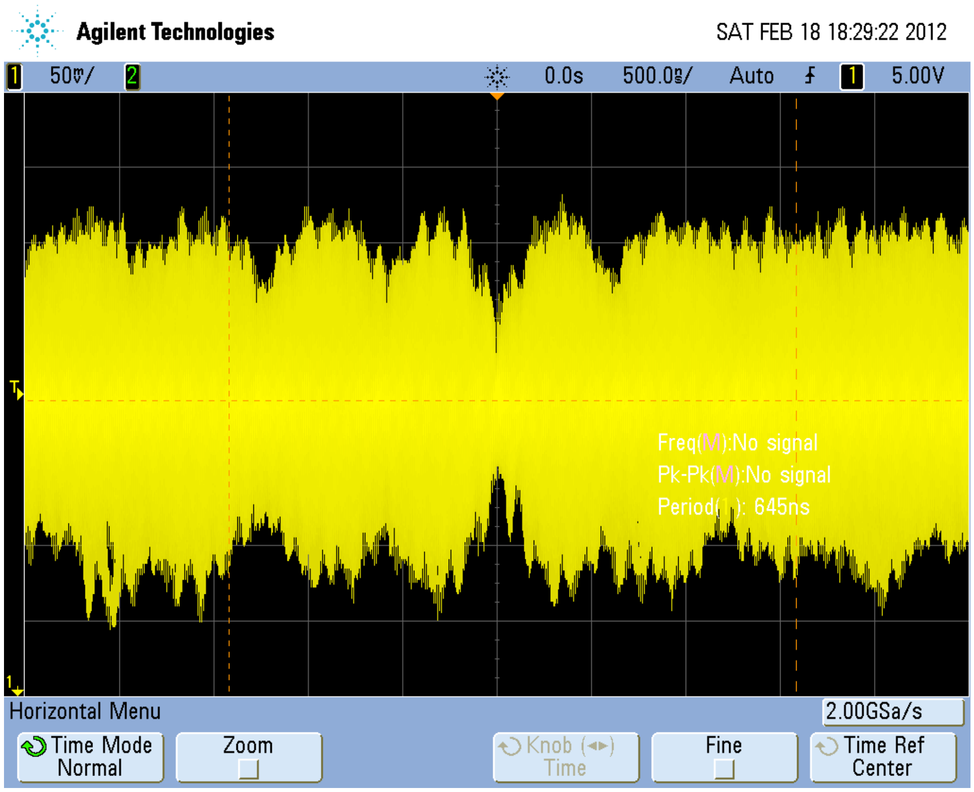



FIGURE 12 : 5V DC power supply without 33µF capacitor ($V_{p-p}$= 200mV)

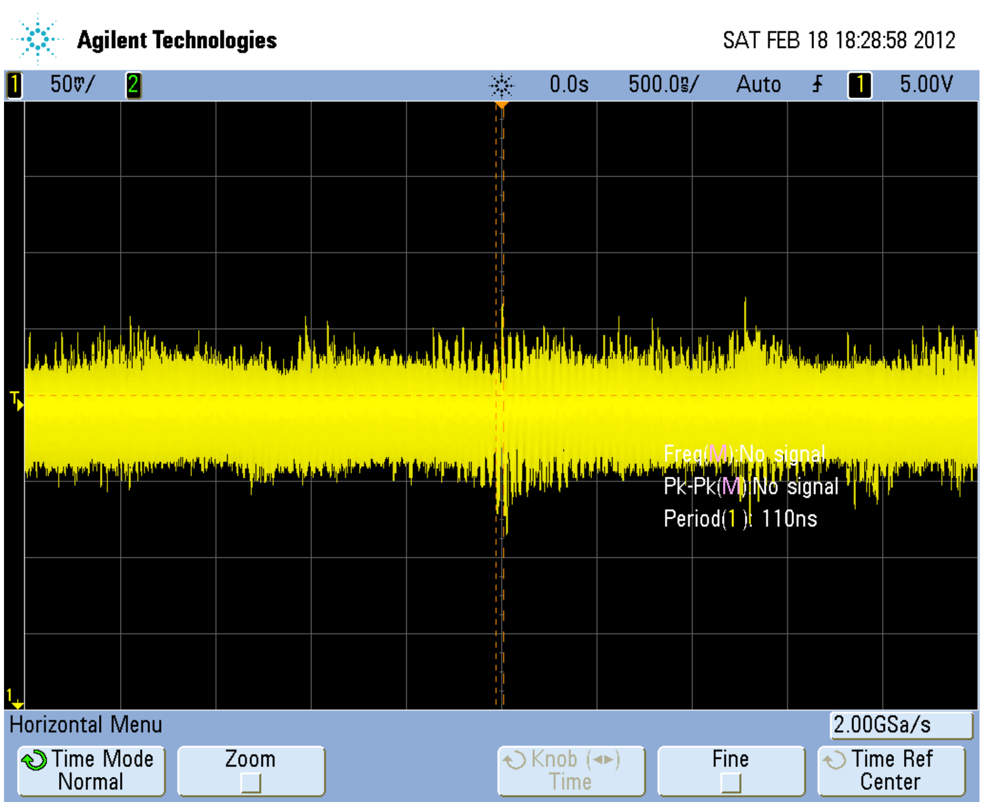



FIGURE 13: 5V DC power supply without 33µF capacitor ($V_{p-p}$= 92mV)

*2.6.2 TRANSMITTER'S ANTENNA OUTPUT POWER ADJUSTMENT*

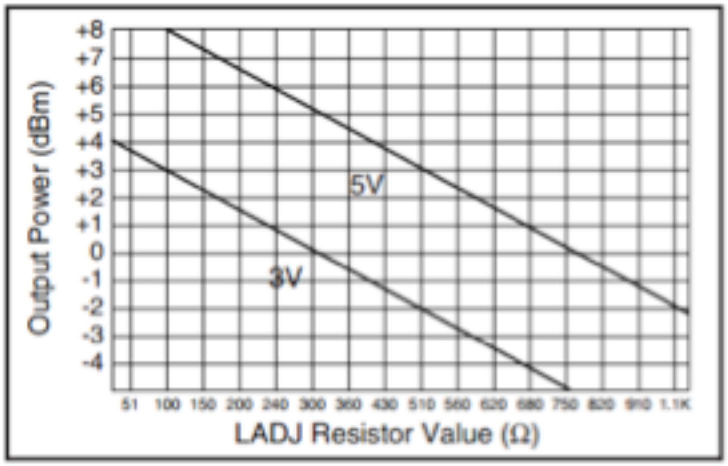



FIGURE 14: Output power vs LADJ Resistor[9]

The output power of the transmitter used is intentionally very high to compensate for losses resulting from inefficient antennas that may be used to realize cost or space savings. This is higher than the output power FCC regulations allow. To adjust the output power, a resistor may be placed between Pin 4 (LADJ) and ground of transmitter to achieve up to a 7dB reduction in output power. The resistor value can be obtained from the plot above. To comply with FCC, a 390Ω resistor is connected to pin 4 to obtain 4dBm[9] output power for 5V DC supply power. This resistance value might be adjusted to compensate losses from the transmitter module.

*2.6.3 CALCULATION OF RECEIVER'S SIGNAL TO NOISE RATIO*

For the receiver, the signal to noise ratio is calculated to estimate the receiver's performance. The sensitivity formula is given as:

$$S_i = k \times (T_A + T_{Rx}) \times BW_{3dB} \times \frac{S_o}{N_o}$$

Rearranging it, the signal to noise ratio formula is:

$$\frac{S_o}{N_o} = \frac{S_i}{k \times (T_A + T_{Rx}) \times BW_{3dB}}$$

Where $S_i$ is the sensitivity of the antenna
$k$ is the Boltzmann constant
$T_A$ is the temperature of the antenna
$T_{Rx}$ is the temperature of the receiver
$BW_{3dB}$ is the bandwidth of the signal

Assuming the receiver use single pole RC filter,

$$nBW = \frac{\pi}{2}\ BW_{3dB}$$

According to the datasheet, the noise bandwidth, $nBW$ is 280kHz[10]
Thus, the $BW_{3dB} = 178.3kHz$
According to the datasheet, sensitivity of the receiver for $10^{-5}$ BER is typically -95dBm[10].
Assuming the temperature of the antenna and receiver is at room temperature
($T_A = T_{Rx} =$ 293K), the signal to noise ratio is

$$\frac{S_o}{N_o} = 219.248 \approx 23.4\ dB$$

*2.6.4 POWER CONSUMPTION*

Since the otter stalker system will be implemented in a remote area, the operating time of the system is limited by the battery life of the system. Thus, the power consumption of the overall system is crucial. As the environmental factors such as otter's presence and appearance of other wildlife animals are unpredictable, the rough estimation of the system's power consumption is shown below.

| Components | Quantity | Total Standby Current | Total Active Current |
|---|---|---|---|
| PIR Sensors | 4 | 680µA | 680µA |
| Encoder | 1 | 0.2µA | 800µA |
| Decoder | 2 | 0.4µA | 1600µA |
| Transmitter | 1 | 1.5µA | 300µA |
| Receiver | 2 | 1400µA | 600µA |
| Microcontroller | 2 | 3µA | 840µA |
| Others (Logic ICs, Voltage Regulators, FETs) | - | 421.1µA | 561.1µA |

TABLE 3: Power consumption of each component[2][3][4][5][6][8][9][10]

For 4 days,
The total standby current usage is:
$(680 + 0.2 + 0.4 + 1.5 + 1400 + 3 + 421.1)\mu\times 24\times 4 = 240.5952\text{mAH}$

The total active current usage (assuming for 48 hours of recording in 4 days) is:
$(680 + 800 + 1600 + 300 + 600 + 840 + 561.1)\mu\times 48 = 258.29\text{mAH}$
The total current usage in 4 days is 499mAH. As normal rechargeable NiMH C batteries can hold up to at least 1100 mAh, the consumption rate is little. Thus, the internal battery life of the camera will be the deciding factor for the battery life of the overall system. Since the trail camera is powered by 12 V Lithium batteries, the camera should be capable of lasting for 4 days.

*2.6.5 INITIAL CAMERA TESTING*

Several video recording devices are considered for the Otter Stalker System. The following devices and its disadvantage of the device are shown below:

| Video Recording Device | Disadvantage |
|---|---|
| Outdoor CCTV Camera | Need a expensive portable DVR to store the video since the study site is remote |
| Wireless IP Camera | The place is remote and thus hard to find internet connection |
| Car Back-up Assist Camera | Need a expensive portable DVR to store the video since the study site is remote |
| Car Camera | Not weatherproof |

TABLE 4: Disadvantages of each video recording devide

Thus, trail camera is chosen for the Otter Stalker System as Samantha provided the camera. The trail camera is suitable for the Otter Stalker System. This is because of the following features:

- It has field of view of 60° angle of coverage
- It has day color video recording
- It has night vision capability with IR LED illumination which is inconspicuous to otters
- Video recorded is directly saved into a SD memory card
- An internal battery that last about a week

We also tested the camera's performance regarding its video quality. At day, it is able to capture video just like any good 12 megapixel camcorder. At night, the video quality is also good with its IR illumination capable of covering as far as 20m. Thus, it should be suitable for the 3m x 3m area of the otter site. With viewing angle of 60°, two cameras are suffice to cover the area.

However, a trigger mechanism is needed to activate the video recording of the trail camera. Since the trail camera has its own PIR sensor, the sensor needs to be triggered to activate the video recording. Thus, trigger test was conducted and below are the results:

| Test Methods | Results |
|---|---|
| Using a heat element place in front of PIR sensor | The camera was not triggered. It takes long time to heat up the element for low power consumption. |
| Using a IR LED and normal LED in front of PIR sensor | The camera was not triggered. This failure is maybe due to the lack of motion. |
| Using oscillating object in front of the PIR sensor | The camera was not triggered due to lack of heat |

TABLE 5: Trigger tests and results

As the entire test failed, the trail camera was opened up to inspect the components of the camera. The objective is to find for the camera trigger mechanism. The inspection starts by following the PIR sensor wiring connection as the sensor are the one triggering the video recording of the camera. The camera shutter trigger pins are found. Multimeter and oscilloscope are used to analyze the shutter trigger pins. Two of the pins trigger the video recording when they are shorted together. The potential difference of both pins is 3V. Thus, a MOSFET can be used as a switch to short both shutter trigger pins by using a microcontroller to control the gate voltage of the MOSFET. Both trigger pins are connected to the source and drain of the MOSFET respectively. Below are simulations of using NMOSFET and doing a DC Sweep on the gate voltage of the MOSFET.

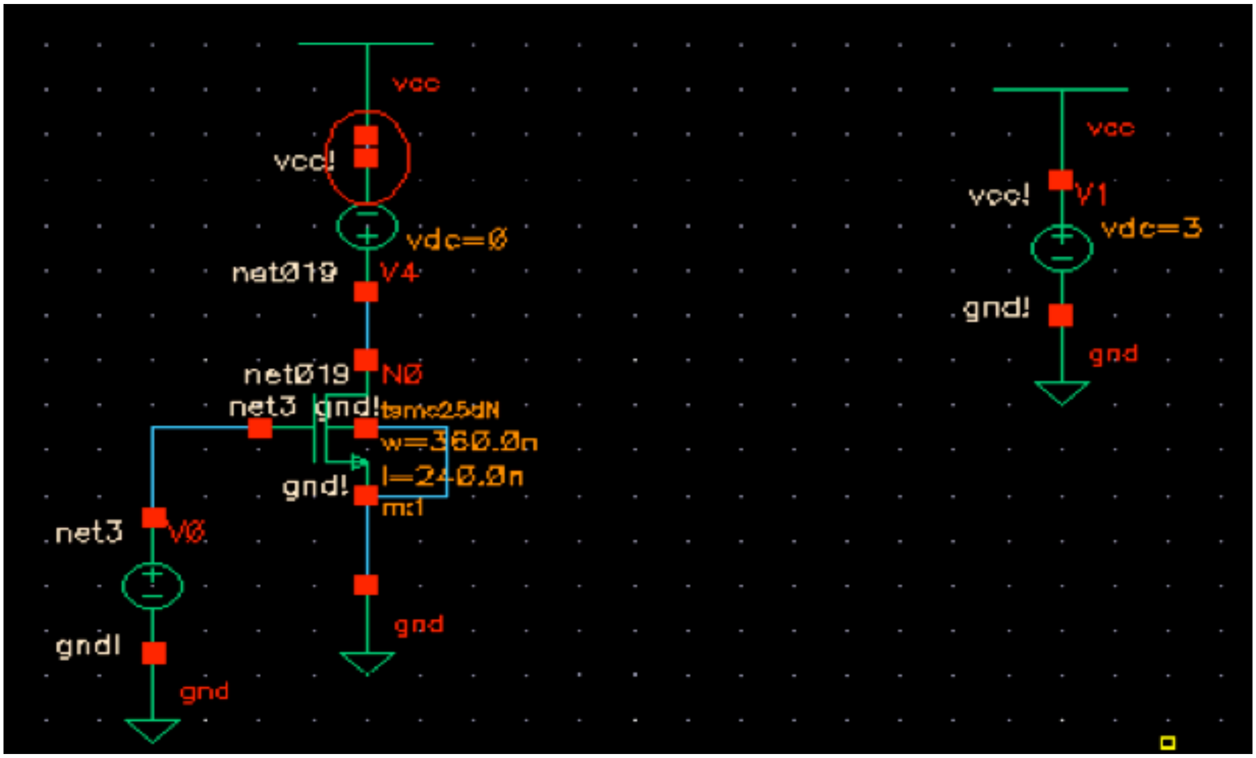


FIGURE 15: Schematic of the simulation of NMOSFET with $V_{DS}$=3V and performing a DC Sweep on $V_{G}$.

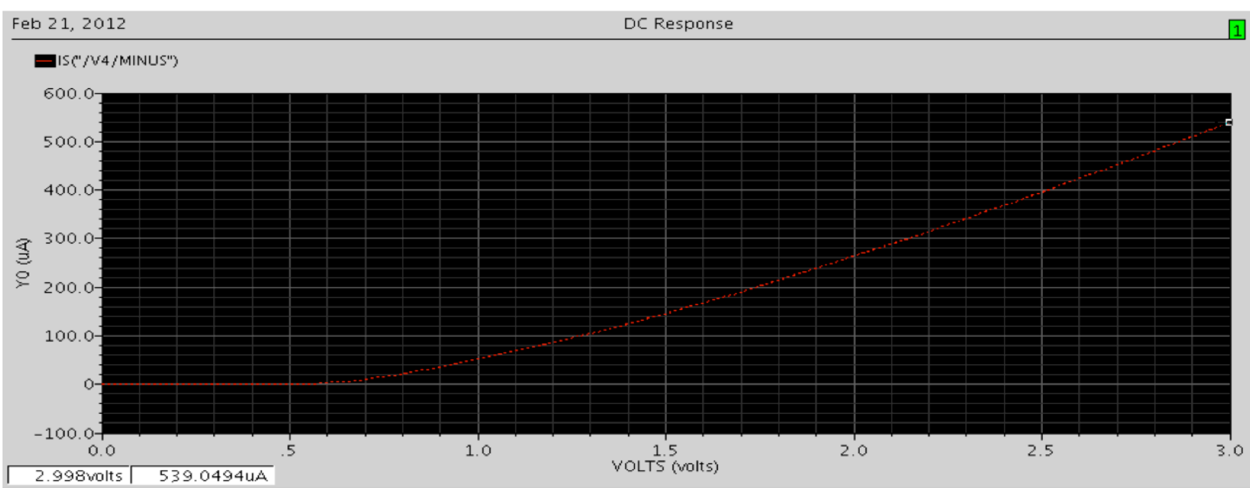


FIGURE 16: Plot of $I_D$ versus $V_{GS}$

From the simulation, there is current flowing when $V_{GS}$ is higher than the threshold voltage, $V_T$. Thus, there is a N-channel created that is connecting the drain and source of the MOSFET. Real test has to be conducted as we do not account losses in the simulation.

## 2.7 SPECIAL CIRCUIT

Special circuit not required.

# 3.0VERIFICATION

## 3.1 REQUIREMENTS, VERIFIVATION AND TESTING PROCEDURES

The testing consists of six independent modules, which are the sensing module, wireless communication module, main controller, camera module, power supply and case. The required equipments are oscilloscope, multimeter, myDAQ with LabView, lab kit box with breadboard, scissors, measurement instruments and LEDs. Most of the test will be conducted indoor. Some test requires emulation of wildlife environment and is done outdoor.

| Requirements | Verification |
|---|---|
| 1. *Sensing Module*<br>The PIR sensor output high when motion is detected within 3m x 3m outdoor area. The conditional probability of false alarm and miss of the sensors array should be within 10%<br><br>a. Within an 3m x 3m indoor area with lesser interferences, the conditional probability of false alarm and miss of the sensors array should be within 15%<br><br>b. The sensor is able to detect motion 4.5m away<br><br>c. The output voltage vs distance from the PIR sensors should be constant with tolerance +/-0.5V<br><br>d. The detection angle of the sensors is 22 degree with 10% tolerance. | A 3m x 3m test site is set up at Bardeen Quad. PIR sensors are placed according to Figure 1. NI MyDAQ is used to acquire digital output data from the sensors.<br><br>*-Preliminary Function Test*<br>Before going to the field test, a basic test is conducted to make sure that the sensor is working as expected. PIR sensor output is connected to oscilloscope with trigger voltage at about 4.3V – 4.8V. Hand is waved across the sensor and the oscilloscope waveform is observed. The waveform should indicate the sensor output 4.3V – 4.8V<br><br>*-False Alarm Test*<br>For 15 minutes, no motion or person will be inside the test site. The sensors' output must always be low. Within these 15 minutes, the output of the sensors will be sampled every 5 seconds. The false alarm probability is calculated and must be less than 10%.<br><br>*-Miss Test*<br>For another 5 minutes, a person will be moving randomly inside the test site. Within these 5 minutes, the output of the sensors will be sampled every 0.5 seconds. The miss probability is calculated and must be less than 10%.<br><br>If the tests above fail, the following steps will be performed. |

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|---|---|
| | a. Within an area of 3m x 3m in a dark room, the *False Alarm Test* and *Miss Test* are repeated.<br><br>b. A person will be crossing perpendicularly through the sensor detection beam 4.5m away. The oscilloscope waveform should indicate the sensor output at about 4.3V – 4.8V.<br><br>c. A person will be cutting through the sensor detection beam and zig-zagging away from the sensor. The zig-zag pattern is to make sure that the PIR sensors detect temperature differences within the angle of detection. The sensors output will be observed with oscilloscope. Since it is a digital PIR sensor, the output voltage should be constant.<br><br>d. Placing a PIR sensor at fixed location, a line is drawn across the sensor 7cm away. The sensor output is connected to LED with 50Ohm in between. Hand is slowly moved along the line from the side (right and left). When LED is lighted up, the hand location is marked on the line. The length between both marks (right and left) should be more than 2.7cm. |
| 2. *Wireless Communication Module*<br>A bits sequence can be transferred from transmitter to receiver.<br><br>a. The SNR (Signal to Noise Ratio) is more than 20 dB<br><br>b. The total response time of this module should be lesser than 5ms. | Precaution: While dealing with this module, ESD (Electrostatic Discharge) wrist strap must be worn all the time to avoid possible malfunction of transmitter and receiver.<br><br>A random eight bits are fed into the encoder at the transmitter end. The decoder from the receiver end should output the same eight bits. The decoder |

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|---|---|
| | outputs can be determined by eight LEDs. The transmitter and receiver should be placed 5m away. 6 tests will be conducted and all tests should pass.<br><br>a. The SNR of the receiver is measured with Vector Signal Analyzer.<br><br>b. A 20% duty cycle pulse is generated by function generator and is inputted into the encoder. The encoder pin which is fed with the signal pulse is connected to oscilloscope channel 1. Then, the output from the decoder will be connected to the oscilloscope channel 2. The time differences of both input and output signal is observed. The test is repeated with 80% duty cycle. |
| 3. *Main Controller*<br>The microcontroller will output the results as stated from the truth table above by taking in 8 bits sequence inputs. It can correct one bit error.<br><br>a. The microcontroller is able to detect two bit error.<br><br>b. The microcontroller is able to correct one bit error.<br><br>c. The $V_{OH}$ of the microcontroller should be 3.3V<br><br>d. The response time of this module should be lesser than 5ms. | The main controller GPIO pins will be fed in with eight bits sequences according to the truth table, Table 1. The output should be as stated as the truth table. The outputs can be tested with LEDs.<br><br>*Single Error Correction (SEC) Test*<br>One bit of the sequences is made intentionally wrong. The output of the microcontroller should be as stated as the truth table. Five sample tests will be conducted with difference set of bit sequences.<br><br>If the tests above fail, the following steps will be performed.<br><br>a. The microcontroller will be fed with two different four bits sequence with distance 2. One of the GPIO pin is assigned for debugging use. When error is detected, the LED lights up. Five sample tests should be performed. |

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|---|---|
| | b. The microcontroller will be fed with two different four bits sequence with distance 1. One bit of the sequences is made intentionally wrong. The output of the microcontroller is compared with its' input. They should be the same.<br><br>c. The output of the microcontroller is connected to a multimeter. The inputs of the microcontroller is fed with bits "1111" and the voltage of the output is measured. Input bits "1111" will always activate the camera.<br><br>d. A 20% duty cycle pulse is generated by function generator and is inputed into the microcontroller. The input pin which is fed with the signal pulse is connected to oscilloscope channel 1. Then, the output from the microcontroller will be connected to the oscilloscope channel 2. The time difference of both input and output signal is observed. The test is repeated with 80% duty cycle. |
| 4. *Camera Module*<br>Camera takes photos when 3.3V is supplied.<br><br>a. The voltage FET switch has a linear I-V curve if gate voltage is within threshold voltage and 3.3V.<br><br>b. When 3.3V is supplied to the FET switch, the signal input voltage of the camera should be zero. | The camera is set to *Photo* mode instead of *Video* mode. This is because the screen will flash when the photo is taken and it will be easier to be recognized. Since the delay between two photos taken is 10s, two consecutive tests should be conducted between 10s or more. 3.3V is supplied to the FET gate voltage, the camera screen should flash.<br><br>If the tests above fail, the following steps will be performed.<br><br>a. The gate voltage of the FET is connected to the batteries. The DC |

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| | input voltage is regulated so that the gate voltage applied ranges from 0 to 3.5 with 0.5V spacing. The current will be measured with multimeter. If the current is too small to be measurable, a large resistor is placed in the circuit and the voltage difference between drain and source of the FET is measured.<br><br>b. The gate voltage is applied with 3.3V using batteries with voltage regulator. The drain voltage is measured with multimeter. |
| 5. *Power Supply*<br>The power supply should be able to provide clean 5V and 3.3V.<br><br>a. The power supply noise should be within 20mV pk-pk.<br><br>b. 6VDC is provided to the voltage regulators. The output of the voltage regulator must be 3.3V and 5V respectively with tolerance 5%. | The power supply tests should be done with batteries. The output of the power supply will be observed with an oscilloscope.<br><br>If the tests above fail, the following steps will be performed.<br><br>a. A DC power supply is connected directly to the oscilloscope. The peak to peak voltage is measured.<br><br>b. The output of the voltage regulators is measured with multimeter. The desired output voltage should be obtained. |
| 6. *Case*<br>The case should cover all external module and protect the circuit from any possible hazards.<br><br>a. The case must be weatherproof<br><br>b. The case must be "chew-proof" | All wires, chips and microcontroller are kept inside the case. With a sealed case, all the components cannot be taken out.<br><br>a. The empty case will be sprayed with water from all directions. The inside of the case is examined and there should not have any trace of waterdrops.<br><br>b. The case should be able to withstand a scissor stab. This test should be conducted carefully with no one standing around the |

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| | experimenter. |

TABLE 6: Requirements and verifications

## 3.2 TOLERANCE ANALYSIS

The tolerance tests will be conducted to obtain the limit of the whole system before breaking down.

| Module | Tolerance Tests |
|---|---|
| Sensing Module | The *False Alarm Test* and *Miss Test* are conducted. The sensor array is deviated from the original position 5 degree each time. Two tests above are conducted repeatedly until the probability of miss and false alarm is above 30%. The maximum allowed angle deviation is recorded. |
| Wireless Communication Module | A range test will be conducted. To emulate the habitat environment, it will be conducted at the Bardeen Quad. The receiver is moved away, with bushes and trees in between, and the maximum range in which valid data is not received is recorded. |
| Camera Module | The camera is deviated from the original position 5 degree each time. A person will move inside the test area. The photo taken will be observed. If there is no presence of the moving person, it is counted an error. The probability of error accepted is 50%. The maximum allowed angle deviation is recorded |

TABLE 7: Tolerance Tests

## 3.3 ETHICAL ISSUES

In the process of designing the Otter Stalker System, ethical guidelines based on the IEEE Code of Ethics had always been referred and practiced.

The main objective of this project is to enhance the current technology available to the river otter researchers in habitat-monitoring. In the accordance with code 5, which states that "*to improve the understanding of technology; its appropriate application, and potential consequences*", researches had been carried out on the current available technology, otters' habitats and active hours in order to fulfill the requirements of this project.

Since Wireless Communication module is an essential part of this project, related Federal Communication Commission(FCC) regulations are complied. In the accordance with code 1, which states that "*to 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 legal considerations section in the data sheets of the products used in this project has been consulted. Since the transmitter and receivers used in this project operates at

418MHz, Part 15, Section 231 of the FCC regulations, which regulate 260-470MHz band, had been adhered.

# 4.0 COST AND SCHEDULE

## 4.1 COST ANALYSIS

### *4.1.1 LABOR*

| NAME | RATE/HR | HOURS | TOTAL (=RATE*HOURS*2.5) |
|---|---|---|---|
| **Yon Chiet** | $30.00 | 240 | $18000.00 |
| **Yong Siang** | $30.00 | 240 | $18000.00 |
| **Hui Lin** | $30.00 | 240 | $18000.00 |
| | | TOTAL | $54000.00 |

TABLE 8: Cost of labor

### *4.1.2 PARTS*

| PART | STATUS | COST | QUANTITY | TOTAL |
|---|---|---|---|---|
| **SpyPoint Pro X Plus Trail Camera** | **Received** | **$289.00** | **2** | **$578.00** |
| **PIR Sensor (Panasonic NaPiOn Spot type)** | **Received** | **$15.44** | **4** | **$61.76** |
| **Linx Transmitter (TXM-418-LC)** | **Pending** | **$6.42** | **1** | **$6.42** |
| **Linx Receiver (RXM-418-LC)** | **Pending** | **$7.77** | **2** | **$15.54** |
| **Antenna (ANT-418-PW-RA-ND)** | **Pending** | **$3.99** | **3** | **$11.97** |
| **Encoder (CIP-8E)** | **Ordered** | **$4.30** | **1** | **$4.30** |
| **Decoder (CIP-8D)** | **Ordered** | **$4.30** | **2** | **$8.60** |
| **5V Voltage Regulator (L7805CV)** | **Pending** | **$0.60** | **1** | **$0.60** |
| **3.3 Voltage Regulator (LD1117V33)** | **Pending** | **$0.68** | **1** | **$0.68** |
| **Digital FET (FDV301N)** | **Pending** | **$0.20** | **1** | **$0.20** |
| **Microcontroller (MSP430G2553)** | **Received** | **$4.30** | **2** | **$8.60** |
| **C-Cell batteries** | **Received** | **$2.50** | **8** | **$20.00** |
| **0.1uF Capacitor** | **Received** | **$0.10** | **6** | **$0.60** |
| **0.33uF Capacitor** | **Received** | **$0.10** | **6** | **$0.60** |
| **10uF Capacitor** | **Received** | **$0.10** | **2** | **$0.20** |

| | | | | |
|---|---|---|---|---|
| **PVC casing** | **Pending** | **$10.00** | **1** | **$10.00** |
| **Logic Gates** | **Received** | **$0.50** | **5** | **$2.50** |
| **Tripod** | **Pending** | **$15.00** | **2** | **$30.00** |
| | | | **TOTAL** | **$760.57** |

TABLE 9: Cost of parts

*4.1.3 GRAND TOTAL*

| SECTION | TOTAL |
|---|---|
| **Labor** | $54000.00 |
| **Parts** | $760.57 |
| **GRAND TOTAL** | **$54760.57** |

TABLE 10: Total cost

### 4.2 SCHEDULE

| DATE | TASK | MEMBER |
|---|---|---|
| **6-Feb** | Writing proposal (introduction, design) | Yon Chiet |
| | Writing proposal (verification, design) | Yong Siang |
| | Writing proposal (cost and schedule, design) | Hui Lin |
| **13-Feb** | Signing up for Design Review | Yon Chiet |
| | Researching on microcontroller | Yon Chiet |
| | Researching on transmitter and receiver | Yon Chiet |
| | Researching on camera | Yong Siang |
| | Researching power supply | Yong Siang |
| | Researching on sensor | Hui Lin |
| | Ordering parts | Hui Lin |
| **20-Feb** | Design Review | Yon Chiet, |
| | Designing wireless communication system (transmitters and receivers) | Yon Chiet |
| | Designing video capturing system | Yong Siang |
| | Designing sensing system | Hui Lin |
| **27-Feb** | Combining wireless communication system and sensing system | Yon Chiet |
| | Designing power supply and casing | Yong Siang |
| | Measuring and testing PIR sensing range and placement of sensors | Hui Lin |
| **5-Mar** | Microcontroller programming (video capturing system) | Yon Chiet |
| | Microcontroller programming (hamming code) | Yong Siang |

| | | |
|---|---|---|
| | Microcontroller programming (wireless communication and sensing system) | Hui Lin |
| **12-Mar** | Writing individual report | Yong Siang |
| | Testing and collecting data (video capturing system) | Yon Chiet |
| | Testing and collecting data (microcontroller and power supply) | Yong Siang |
| | Testing and collecting data (wireless communication and sensing system) | Hui Lin |
| **19-Mar** | SPRING BREAK | |
| **26-Mar** | Checking and helping the progress of other group members | Hui Lin |
| | Debugging (video capturing system) | Yon Chiet |
| | Signing up for Mock Presentation | Yong Siang |
| | Debugging (hamming code) | Yong Siang |
| | Debugging (wireless communication and sensing system) | Hui Lin |
| **2-Apr** | Mock Presentation | Yon Chiet |
| | Field testing and collecting data (video capturing system) | Yon Chiet |
| | Field testing and collecting data (wireless communication system) | Yong Siang |
| | Field testing and collecting data (sensing system) | Hui Lin |
| **9-Apr** | Compilation of test data and debugging (video capturing system) | Yon Chiet |
| | Compilation of test data and debugging (microcontroller and power supply) | Yong Siang |
| | Compilation of test data and debugging (wireless communication and sensing system) | Hui Lin |
| **16-Apr** | Writing final report (video capturing system) | Yon Chiet |
| | Writing final report (microcontroller and power supply) | Yong Siang |
| | Writing final report (wireless communication and sensing system) | Hui Lin |
| | Signing up for Demo and Presentation | Hui Lin |
| **23-Apr** | Demo | Yong Siang |
| | Compiling and finalizing final report | Hui Lin |
| **30-Apr** | Presentation | Yong Siang |

TABLE 11: Schedule

## 5.0 REFERENCES

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