Appendix A Requirement and Verification Table

Table A.1 System Requirements and Verifications

Requirement	Verification	Verification Status
1. The power unit must provide stable 4.8 V VDD from the batteries and stable 3.0 V VCC from voltage regulator. a. The batteries must provide at least 4.8 V when 1 mA current is drawn and at least 4.6 V when 1 A current is drawn. b. The voltage regulator must provide 3.0 V when 1 mA current is drawn. c. The voltage regulator must provide 3.0 V when its input voltage is between 4.6 V and 5.8 V.	1. The voltages across the batteries and the voltage regulator are measured using a DMM. a. Test the batteries using different resistors. i. Connect a 4.7 kΩ resistor to the batteries simulate 1mA current drain and measure its voltage. ii. Repeat the above test with 4.7 Ω resistor to simulate 1 A current drain. b. Connect a 3 kΩ resistor to the voltage regulator to simulate 1mA current drain and measure its voltage. c. Supply the voltage regulator with 4.6 V, 5.0 V, 5.2 V, 5.4 V, 5.6 V and 5.8 V using tunable power supply and measure its output voltage.	Yes
2. The control unit must be able to receive signals from the motion sensing module and the force sensing module, output signals to the imaging module and the lighting module and operate according to the Section 2.2. a. The microcontroller must be able to interpret a signal with 0.6 VCC (1.8 V) or higher as high. b. The high signal generated by the microcontroller must have 0.9 VCC (2.7 V) or higher when 2 mA current is drawn. c. The microcontroller must be able to generate a 0.1 s 3.0 V square pulse. d. The microcontroller must be able to generate a 100 Hz 3.0 V PWM signal that increases its duty cycle from 0% to 80% over 4 s with 5% increment every 0.25 s.	2. Connect the inputs of microcontroller 3.0 V switches and connect the outputs to LEDs. Turn on and off the switches to simulate input signals from the sensing modules and monitor the LEDs to verify whether its operation is similar to Section 2.2. a. Connect a 10 Hz square wave signal from a function generator to the input of the microcontroller and gradually increase its peak voltage. Record the first voltage that the microcontroller interprets as a high signal. b. Connect a 1.8 kΩ resistor to the output of the microcontroller to simulate the 2 mA drain to the lighting unit. Program the microcontroller to output high signal and verify the output voltage on a DMM.	Yes

	c. Program the microcontroller to output a 0.1 s 3.0 V square pulse and verify the output waveform on an oscilloscope. d. Program the microcontroller to output a 100 Hz 3.0 V PWM signal that increases its duty cycle from 0% to 80% over 4 s with 5% increment every 0.25 s and verify the output waveform on an oscilloscope.	
3. The camera must be able to capture images with the level of detail at least the scale of 10 on the ISO 12233 test chart at 18 inches away.	3. Take an image of the ISO 12233 test chart at 18 inches away in a well-lit room using the camera settings listed in Table 2.2. Zoom in the image to inspect whether the lines and spaces for the scale of 10 on the ISO 12233 test chart are distinguishable.	Yes
4. The shutter controller must be able to trigger the camera to take an image when it reaches a high signal.	4. Connect the input of the imaging module to a 3.0 V switch and use the switch to trigger the camera. Turn on the switch and verify whether an image was taken by the camera.	Yes
5. The force sensing unit must generate high signal to the control unit when 3kg or more is applied. a. The output voltage of the force sensing unit must be 1.8 V or higher when 3 kg weight is applied. b. Resistance of the force sensor must have 6 kΩ or less when 3 kg weight is applied and have at least 100 kΩ when no weight is applied.	5. a. The force sensing unit will be tested using no weight, 1 kg and 3 kg weights and its output voltage will be measured using a DMM. i. Connect 30 Ω and 10 kΩ resistors in series with a FSR. ii. Place the FSR on a flat surface. iii. Place a large acrylic sheet on top of the sensor. iv. Measure the voltage across the 10 kΩ resistor using a DMM. v. Place different weights of 1 kg and 3 kg on top of the sheet at various spots while measuring the voltage across the 10 kΩ resistor using a DMM. vi. Determined if the microcontroller interprets the signal as HIGH or LOW based on the programmed configuration. b. The force sensor will be tested using no weight, 1 kg and 3 kg	Yes

	weights and its resistance will be measured using a DMM. i. Place the FSR on a flat surface. ii. Place a large acrylic sheet on top of the sensor. iii. Measure the voltage across the 10 kΩ resistor using a DMM. iv. Place different weights of 1 kg and 3 kg on top of the sheet at various spots while measuring the resistance of the sensor using a DMM.	
6. The motion sensor must detect motion generate a 3.0V HIGH output. a. It must detect motion within 45° from its center point. b. It must detect motion within 1m away.	6. The output of the motion sensor will be examined using an oscilloscope. a. i. Wave hand at the center point of the sensor (90° from the surface of the acrylic sheet) while observing the output on the oscilloscope. ii. Then, move to the side 20° (70° from the surface of the acrylic sheet) and 45° away from the center point while observing the output on the oscilloscope. b. i. Wave hand right in front of the sensor while observing the output on the oscilloscope. ii. Then, move 0.5 m, 1 m and 1.5 m away from the sensor while observing the output on the oscilloscope.	Yes
7. The lighting unit must have adequate and controllable brightness. a. The lighting unit must generate sufficient lights for the camera to take high-detail images at the ISO 800. b. The brightness of the lighting unit must change according to the duty cycles of its input, LED_SIG.	7. a. The lighting unit will be tested at maximum brightness with its lights shone into the sides of an acrylic sheet. iii. Place the ISO 12233 (Figure F.1) test chart under the acrylic sheet. iv. Turn off other light sources and take an image of the test chart using the camera settings listed in Table 2.2.	Yes

	v. Zoom in to inspect whether the lines and spaces for the scale of 10 on the ISO 12233 test chart are distinguishable. b. The brightness of the lighting unit will be observed in a dark room with its input (LED_SIG) connected to a function generator. i. Generate a 100 Hz 3.0 V square wave with duty cycle of 20% to the input of the lighting unit. ii. Observe the brightness of the lighting unit. iii. Repeat the observation using square waves with duty cycles of 40%, 60%, 80% and 100%.	
8. The enclosure must be water-proof.	8. i. Spray water on the sealed enclosure at various angles and sides. ii. Open the enclosure and look for water droplet.	Yes

Appendix B Test Data and Measurements

Table B.1 Result of the Imaging Test on Various Imaging Devices

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.

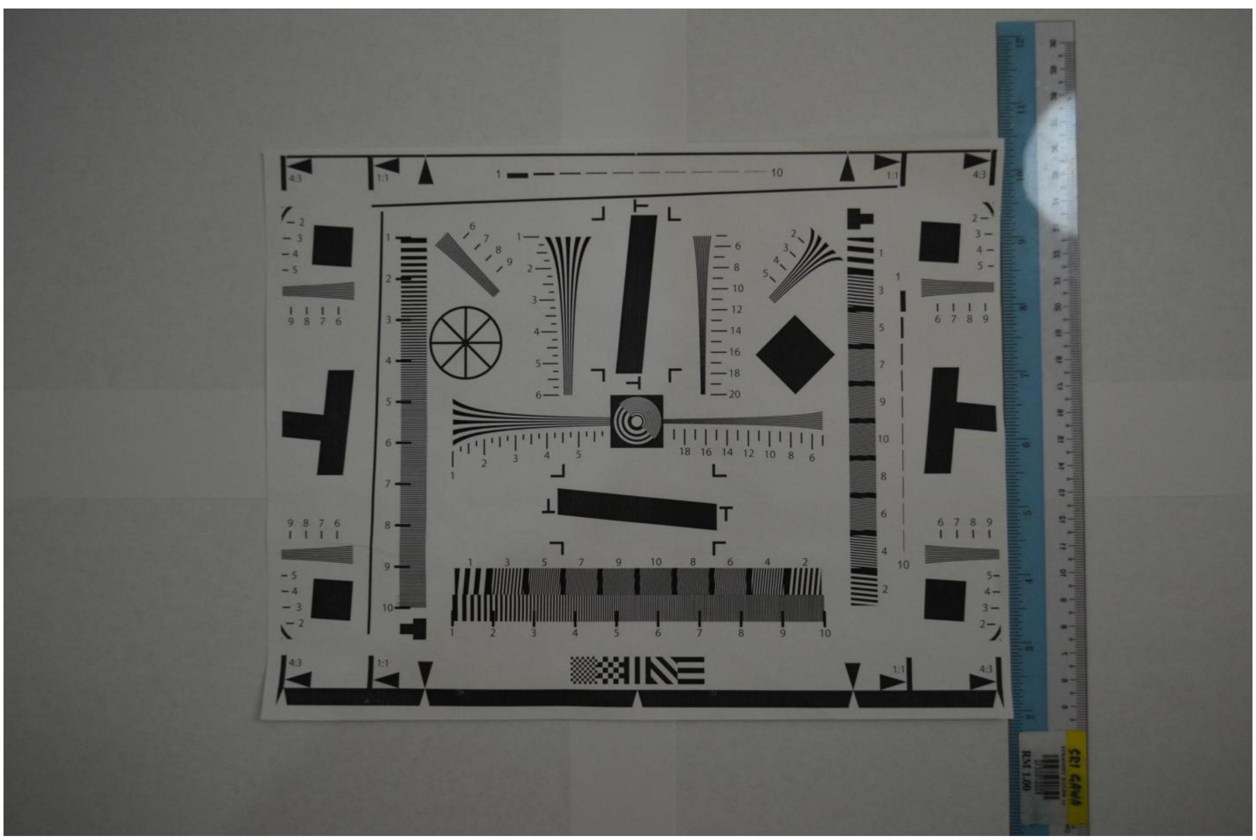

Figure B.1. Image of the ISO 12233 test chart taken 18 inches away

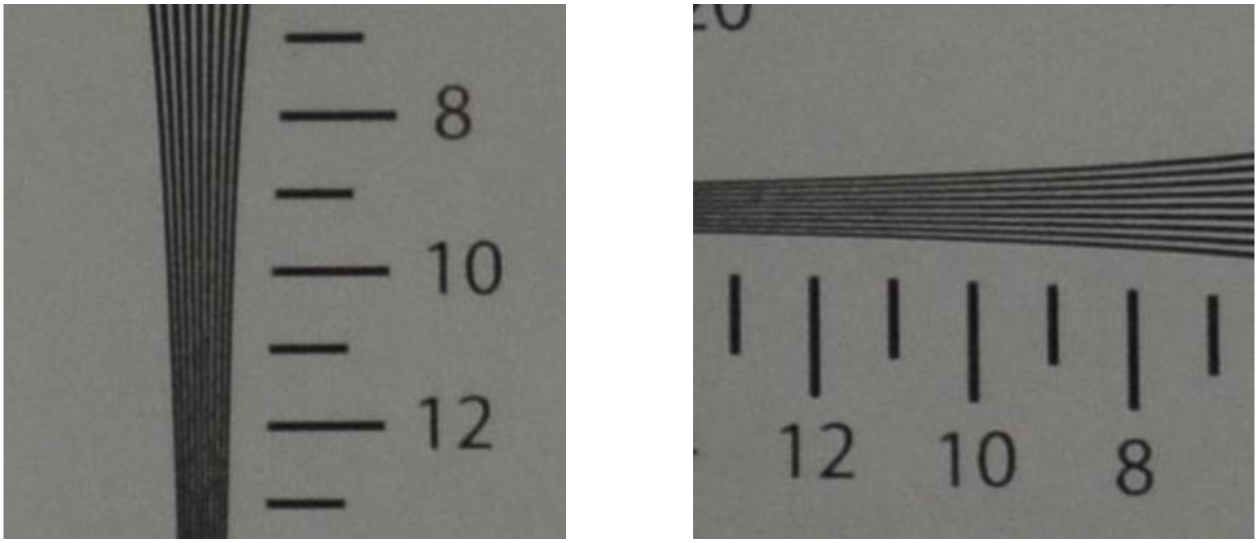

Figure B.2. Enlarged images of Figure C3 to show the lines and spaces at the scale of 10 on the ISO 12233 test chart

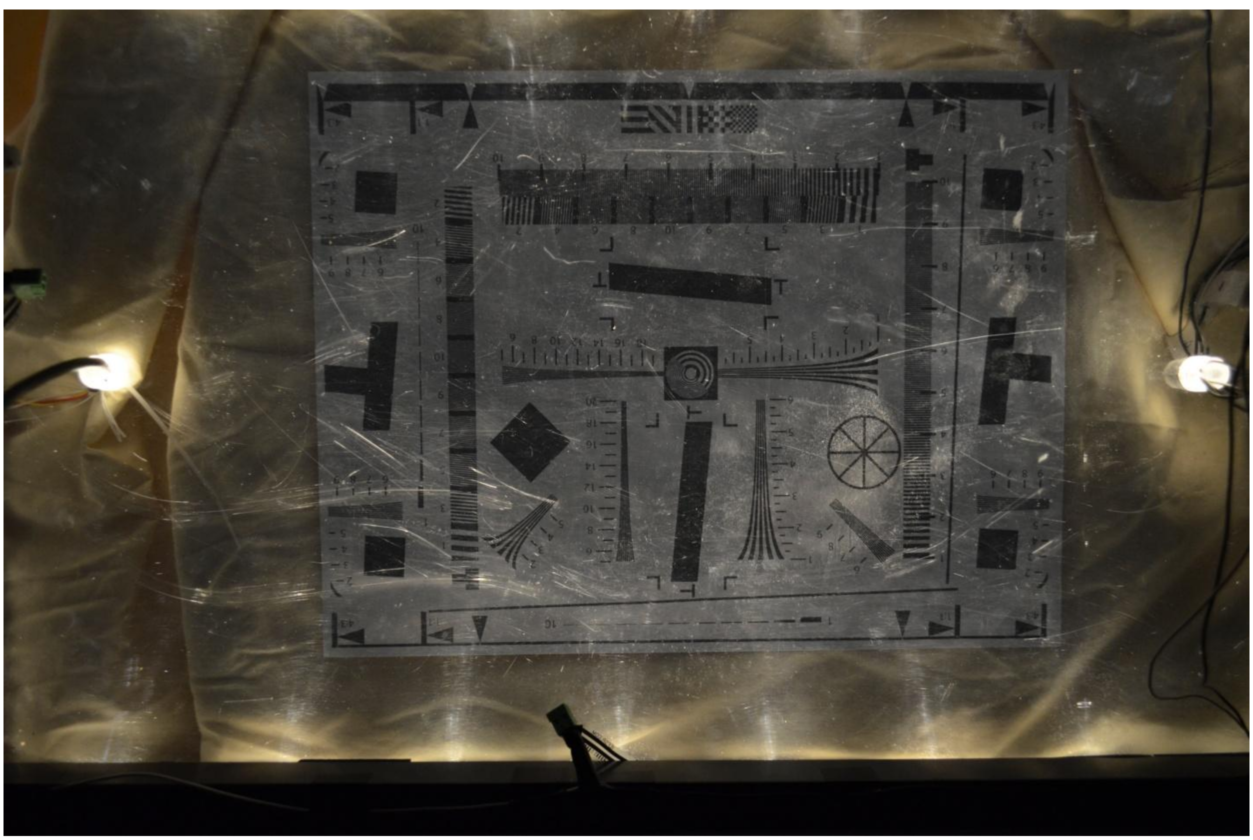

Figure B.3. Image of ISO 12233 test chart taken with only LED lights as lighting source

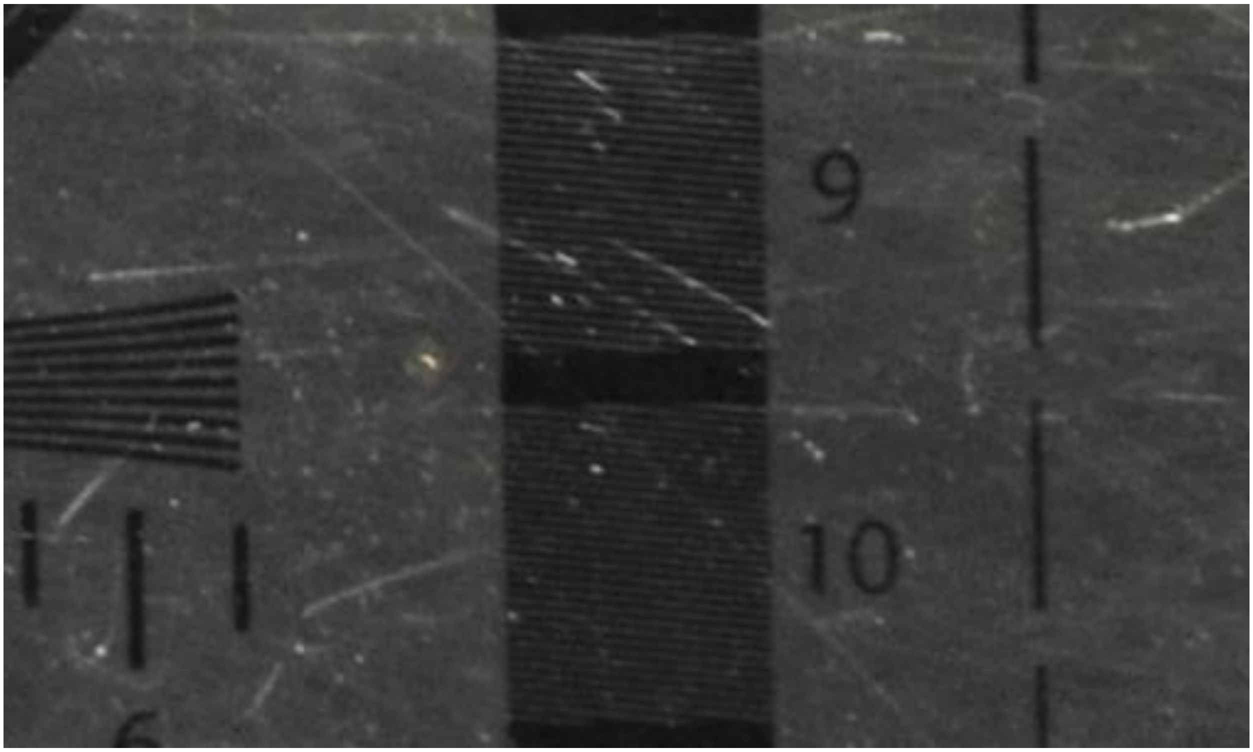

Figure B.4. Enlarged view of Figure K1 with lines and spaces of scale 9 and 10

Appendix C Flow Chart

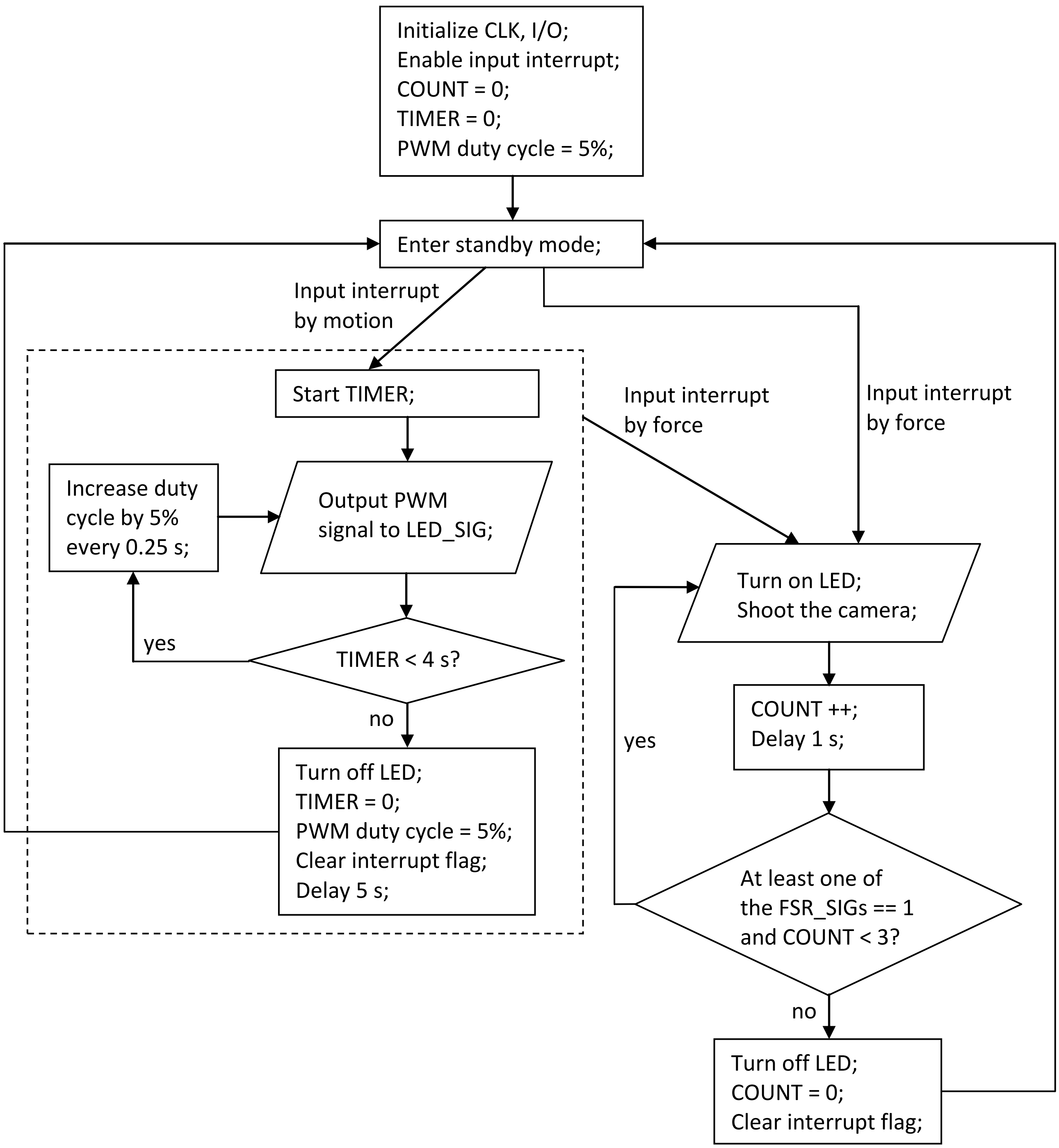

Figure C.1. Flow chart of the operation of the microcontroller

Appendix D Parts Cost

Table D.1 Parts Cost for Control Unit

Part Name	Quantity	Price/Unit ($)	Total Price ($)
4 Sanyo Eneloop AA NiMH Rechargeable Batteries and Charger	1	16.00	16.00
Battery Holder 4AA-Cells	1	1.33	1.33
Voltage Regulator 250mA 3V (MCP1700)	1	0.39	0.39
Switch Slide DPDT 6A (S202131MS02Q)	1	2.64	2.64
Parts Total			**20.36**

Table D.2 Parts Cost for Control Unit

Part Name	Quantity	Price/Unit ($)	Total Price ($)
Texas Instrument Launchpad MSP430G2553	1	4.30	4.30
Ceramic 1nF 100V Capicator (MCRR25102COGJ0100)	1	0.18	0.18
IC Socket 20 Pos Dip Tin	1	0.83	0.83
47K Ohm 1/2w 5% Carbon Film Resistor (Pk/5 2160242)	1	1.00	1.00
Aluminum 10UF 10V 20% RADIAL Capacitor (SN100m010ST)	2	0.14	0.28
Tantinum 0.1uF 50V 26Ohm Radial Capacitor (TAP104K050SCS)	1	0.40	0.40
MOSFET N-Channel (FDV301N)	1	0.61	0.61
Parts Total			**7.60**

Table D.3 Parts Cost for Imaging Module

Part Name	Quantity	Price/Unit ($)	Total Price ($)
Canon EOS REBEL T3 with 18-55mm lens	1	494.00	494.00
Optocoupler Phottrans 200% 4SMD (SFH6186-2)	1	1.01	1.01
Nikon MC-DC2 Shutter Release Interface Cable	1	16.00	16.00
Canon SMDV Shutter Release Interface Cable	1	12.00	12.00
Metal Film 2.1k Ohm 1/4W 1% Resistors (42R2101)	1	1.00	1.00
Parts Total			**524.01**

Table D.4 Parts Cost for Force Sensing Module

Part Name	Quantity	Price/Unit ($)	Total Price ($)
Interlink Electronics Force Resistor Sensor (402)	4	7.48	29.92
Flat Metal Washer	4	0.10	0.40
RES Metal Film 10K Ohm ¼W 1% Resistors (MFR-25FBF-10K0)	4	0.13	0.52
RES Metal Film 30 Ohm 2W 5% Resistor (PR02000203009JR500)	4	0.54	2.16
Tantinum 0.1uF 50V 26Ohm Radial Capacitor (TAP104K050SCS)	4	0.40	1.60
Parts Total			**34.60**

Table D.5 Parts Cost for Motion Sensing Module

Part Name	Quantity	Price/Unit ($)	Total Price ($)
Panasonic NaPiOn Motion Sensor (AMN42122)	2	15.44	30.88
Tantinum 0.1uF 50V 26Ohm Radial Capacitor (TAP104K050SCS)	2	0.40	0.80
Parts Total			**31.68**

Table D.6 Parts Cost for Lighting Module

Part Name	Quantity	Price/Unit ($)	Total Price ($)
Everlight SMD Low Power LED (61-238/Qk2C-B28322FaGB2/ET)	14	0.92	11.04
3M Copper Strips	1	16.43	16.43
100 feet Wire 22 Gauge	1	8.00	8.00
Parts Total			**35.47**

Table D.7 Parts Cost for Container and Lid

Part Name	Quantity	Price/Unit ($)	Total Price ($)
Gasket and screws	1	40.43	40.43
¾" Acrylic sheet (22"×15")	1	102.69	102.69
Silicon sealant	1	4.99	4.99
2" Foam Tape 30 ft	1	6.00	6.00
Custom made enclosure	1	400.00	400.00
Parts Total			**554.11**

Appendix E Container and Lid

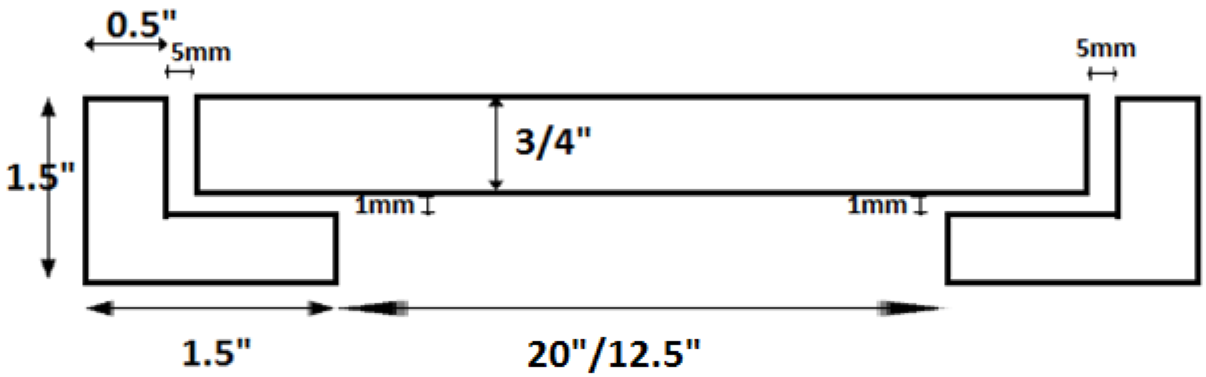

Figure E.1. Side views of the lid

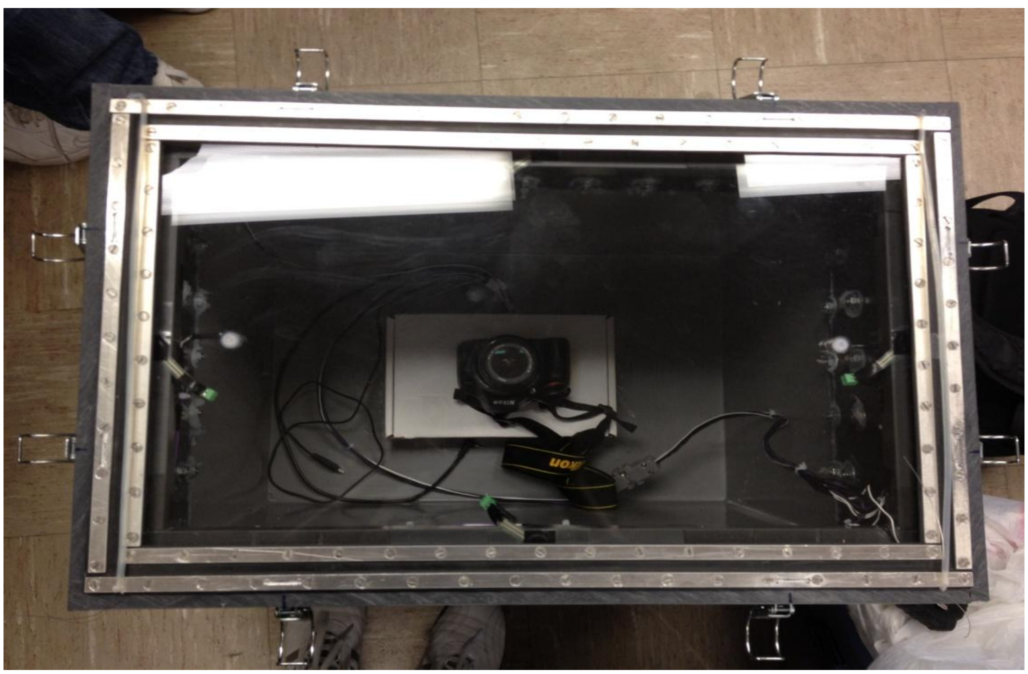

Figure E.2. Top view of the lid

Figure E.3. Wiring of FSR, PIR and LED under the lid

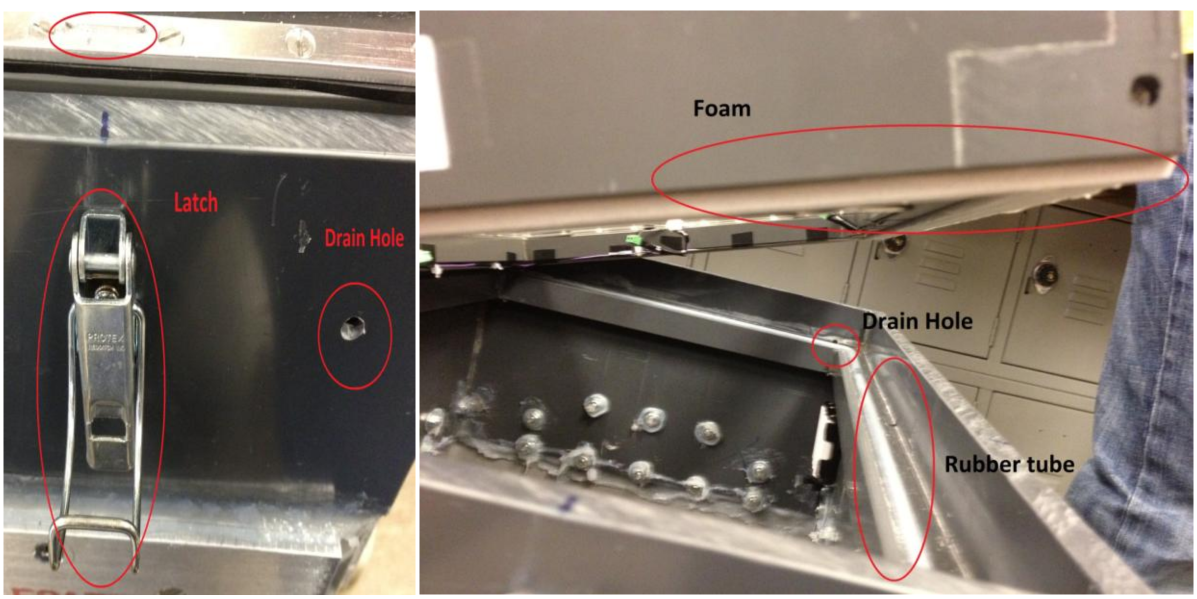

Figure E.4. Latch, rubber tube, drain hole and extra foam under the lid to enable the container to be water proof.

Appendix F ISO 12233 Test Chart

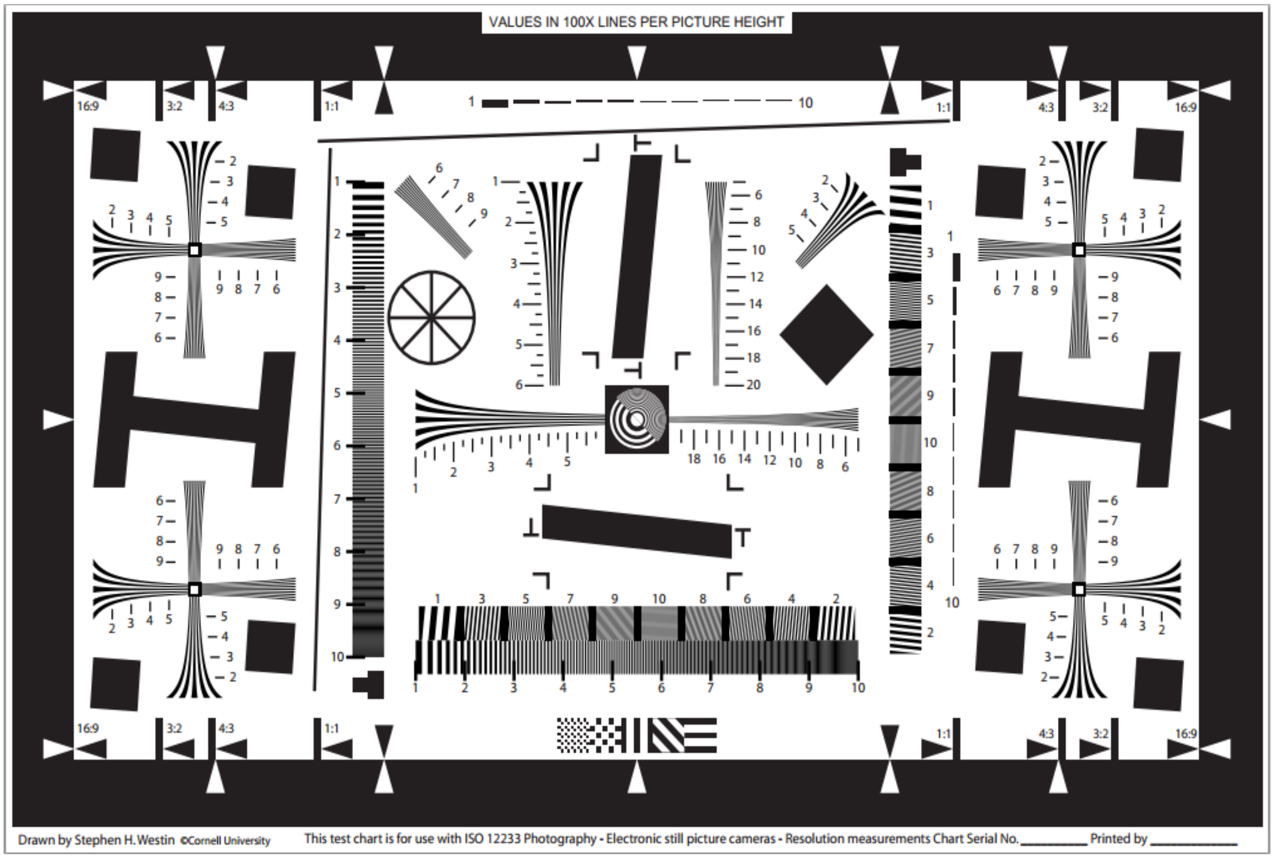

Figure F.1. ISO 12233 test chart [12]

Appendix G Table of Compatible Cameras

Table G.1 Compatible Cameras for the Otter Print Shooter

Brand	Model	Effective Resolution (M)	Suggested Retail Price ($)
Canon	EOS Rebel T2i w/ lens kit	18.0	699.99
Canon	EOS Rebel T3 w/ lens kit	12.2	549.99
Canon	EOS Rebel T3i w/ lens kit	18.0	849.99
Canon	EOS 60D	18.0	999.99
Nikon	D3100 w/ lens kit	14.2	649.95
Nikon	D5000 w/ lens kit	12.3	629.95
Nikon	D5100 w/ lens kit	16.2	849.95
Nikon	D7000	12.3	1199.95
Nikon	D90	16.2	899.95
Nikon	D800	36.3	2999.95
Nikon	D4	16.2	5999.95

Appendix H Source Code for Microprocessor

```
/*
 * Source code for the Otter Print Shooter
 * By Hoong Chin Ng
 */
#include  <msp430g2553.h>

short int i, num, count_time, PIR_SIG;
short int clock_tick (void);

void main(void)
{
// configure clock
        DCOCTL = CALDCO_1MHZ; // 1MHz DCO
        BCSCTL1 = CALBC1_1MHZ; // MCLK
        BCSCTL2 |= 0x00;
        BCSCTL3 |= 0x24; // 12kHz VLO aka ACLK
        IFG1 = 0x00; // IFG1 &= ~OFIFG;
        IE1 = 0x00;

        WDTCTL = WDTPW + WDTHOLD;          // Stop watchdog timer

// configure Port1
        P1DIR = 0x0F;   // P1.4,5,6,7 input, else output
        P1OUT = 0x00;
        P1SEL = 0x00;
        P1SEL2 = 0x00;
        P1REN = 0x00;
        P1IE |= 0xF0;   // P1.3,4,5,6,7 interrupt enable
        P1IES = 0x00;   // positive trigger
        P1IFG = 0x00;   // IFG cleared

// configure Port2
        P2DIR = ~BIT0 & ~BIT5; // P2.0 & P2.5 input, else output
        P2OUT = 0x00;
        P2SEL = BIT1;   // P2.1 PWM output
        P2SEL2 = 0x00;
        P2REN |= BIT0 + BIT5;   // enable pull up/down resistors
        P2IE |= BIT0 + BIT5;    // P2.0 & P2.5 interrupt enable
        P2IES = ~BIT0 & ~BIT5;  // positive trigger
```

```
            P2IFG = 0x00;

// configure timer0
            TA0CTL = 0x0100;
            TA0CCTL0 |= CCIE;
            TA0CCR0 = 2999;           // 0.25s interval

// configure timer1
            TA1CTL = 0x0200;
            TA1CCTL1 |= OUTMOD_7;
            TA1CCR0 = 9999;           // 10ms period
            TA1CCR1 = 500; // 5% duty cycle

            num = 0;
            count_time = 0;
            PIR_SIG = 0;

            while(1)
            {
                        if (PIR_SIG == 1)
                        {
                                    P2IE &= ~BIT0 & ~BIT5; // temporary disable port 2 interrupt
                                    PIR_SIG = 0;

                                    TA0CTL |= MC_1; // start timer0
                                    TA1CTL |= MC_1; // start timer1
                                    P2SEL |= BIT1;

                                    while (count_time < 16 && num == 0) // count until 4 sec
                                    {
                                                while (clock_tick () != 1) {}
                                                            TA1CCR1 += 500; // increase duty cycle by 5%
                                    }

                                    P2SEL &= ~BIT1;
                                    TA0CTL &= ~(MC1 + MC0); // stop timer0
                                    TA1CTL &= ~(MC1 + MC0); // stop timer1
                                    TA1CCR1 = 500;// reset duty cycle to 5%
                                    num = 0;
                                    count_time = 0;
// wait for 5 sec before next motion detection
                                    for (i = 0 ; i < 20000 ; i++)
```

```
                    _delay_cycles(50);
                for (i = 0 ; i < 20000 ; i++)
                    _delay_cycles(50);
                for (i = 0 ; i < 20000 ; i++)
                    _delay_cycles(50);
                for (i = 0 ; i < 20000 ; i++)
                    _delay_cycles(50);

                P2IE |= BIT0 + BIT5;       // enable back port 2 interrupt
            }

            _BIS_SR(LPM3_bits + GIE);         // Enter LPM3 with interrupt enabled
        }
}

// port 1 interrupt
#pragma vector = PORT1_VECTOR
__interrupt void FSR (void)
{
        num = 0;
        P2SEL &= ~BIT1;
        P2OUT |= BIT1;
// capture max of 3 images when hold down
        while ( ((P1IN & 0xF0)!=0x00) && (num < 3) )
        {

            P1OUT |= BIT0; // camera on
            _delay_cycles(100000); // Delay 0.1s

            P1OUT &= ~BIT0; // camera off
            _delay_cycles(900000); // Delay 0.9s
            num ++;
        }

        P2OUT &= ~BIT1;
        P1IFG = 0x00;

        _BIC_SR_IRQ(LPM3_bits);          // Clear LPM3 bits from SR
}

// port2 interrupt
#pragma vector = PORT2_VECTOR
```

```
__interrupt void PIR (void)
{
	PIR_SIG = 1;
	P2IFG = 0x00;
	_BIC_SR_IRQ(LPM3_bits);		// Clear LPM3 bits from SR
}

short int clock_tick (void)
{
	short int temp;
	temp = count_time;
	while (temp == count_time){}

	return 1;
}

// 0.25s count
#pragma vector = TIMER0_A0_VECTOR
__interrupt void Timer0_A (void)
{
	count_time ++;
}
```

Appendix I PCB Layout

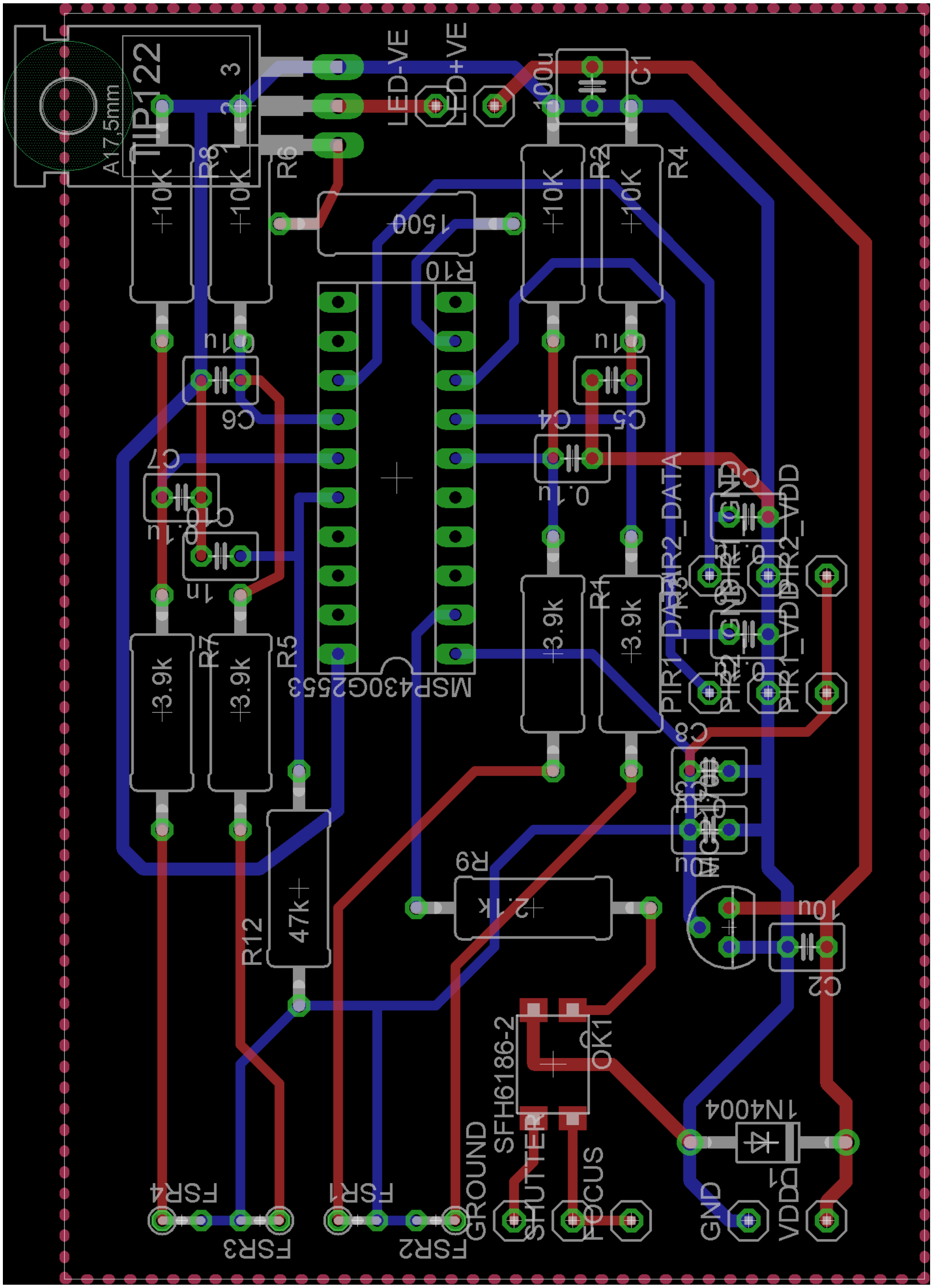

Figure I.1 PCB layout