Appendix A Requirement and Verification Table

This section contains our verification requirements, along with the status of each sub-requirement.

Table A.1 System Requirements and Verifications

Requirement	Verification	Status
1. Relay is controlled by SMS messages sent to GSM/GPRS module a. The relay is in the "OFF" state by default b. SMS messages are received and properly processed by microcontroller c. Relay is controlled by PWM output from microcontroller d. Output from relay is able to act as the input to the car-alarm siren	1. The 12V car alarm input will be switched on manually. An SMS message containing the text "ON" will then be sent to the phone number assigned to the system SIM card. If successful, the load connected to the output of the relay will be at 12 V shortly thereafter. Additionally, if the system passes this test the following verification steps (a-d) may be skipped. If not, they must be undertaken sequentially. a. Prior to sending the SMS message the voltage across the relay output load will be measured. If this voltage is zero, the relay is in the "OFF" state and the system is operating correctly. b. If within 5 minutes of the SMS message being sent (based on sample texts sent and received) there is current at the output of the relay, the microcontroller has responded to the SMS input. We will also send an SMS message with an input other than "ON." If there is current at the output of the relay within 5 minutes of this message being sent, this functionality is not working correctly. c. We will measure the current at the PWM output. If at least 13.3 mA of current is output following the SMS message, this is working correctly. If not, this output is not providing sufficient current to switch	1. Verified (as per full-system functionality test) a. Relay output measured at 0.01 V before SMS message sent b. Relay output was activated within 20 seconds of SMS message being sent c. Arduino digital pin current output sufficient to activate relay d. Relay measured at 11.69 V after relay activated

	"ON" the relay. d. Upon the relay being switched on, the voltage drop across the load 12 V ± 10%. If it is outside this range, the output signal is not capable of powering the alarm siren.	
2. Microcontroller is able to control and receive JPEG images from the CMOS camera a. Microcontroller is able to sync with camera b. Camera takes picture when commanded to by microcontroller c. Image data is transferred from camera to microcontroller flash memory	2. We will connect the microcontroller to a computer via a serial-to-USB connection and undertake the procedure to command the camera to take a picture. After approximately 1 minute (necessary for data transfer and JPEG compression) we will transfer the data from the flash memory to the computer. If this data contains a valid JPEG image, the test has succeeded. a. After sending the SYNC message for 62 seconds the microcontroller should have received an ACK message from the camera. If it has not, the test has failed. b. After sending the GETPICTURE command to the camera, the microcontroller should receive a message containing an image size less than 200 kB within 30 seconds as specified. If it does not receive this message, no picture was taken and the test has failed. Additionally, if the image size is more than 200 kB our microprocessor may not be able to process the image and the test has failed. c. We will transfer the image data from the flash memory of the microcontroller to the computer. The data must be in JPEG format or else the test has failed. The image must also be less than 200 kB or else the test has failed. Finally, the image must be in color or else the test	2. Verified as per full-system functionality test a. Sync was successful within 10 seconds b. Image of approximately 4 kB written to microprocessor EEPROM within 60 seconds c. Picture was sent in valid JPEG format and successfully reconstructed

	has failed.	
3. System is able to send MMS messages to the user within 5 minutes. a. Microcontroller is able to sync the GSP/GPRS module b. MMS is successfully received by user	3. We will connect the microcontroller to a computer via a serial-to-USB connection and undertake the procedure (as listed in the flow chart) to send an MMS message. We will manually load the microcontroller flash memory with a JPEG of approximately 200 kB. We will then undergo the procedure to send the MMS message to a user. If the user receives the MMS message containing the correct image within 5 minutes, the test was successful. If the MMS is not received, the transmission takes more than 5 minutes, or the image data is incorrect, then the test has failed. a. After sending the SYNC message the microcontroller should receive a "CONNECT" message within 60 seconds. If it does not, the test has failed. b. Within 5 minutes of sending the MMS ("AT+CMMSDOWN" command) the pre-programmed phone number should have received the MMS message. If the user has an active data connection and has not received the message in this time frame, try again at a different time (to account for carrier difficulties). If it still does not work, then test has failed.	3. Verified as per full-system functionality test a. Sync was successful within 10 seconds b. MMS was message received by user within 120 seconds
4. System is able to detect when the car alarm goes off	4. We will monitor the voltage of the microprocessor analog input connected to the car alarm signal through resistors. We will measure at this node using a voltmeter first with the car alarm signal off. This voltage should measure zero. We will then turn the 12V car alarm signal on. The voltage at the digital input should now be between 3-5 V. If not, the test has failed.	4. Verified as per full-system functionality test When car alarm signal was not activated, the input of the corresponding pin of the microcontroller was measured at 0 V. When activated, the voltage of the pin was measured to be 4.11 V.
5. Standby current draw of the system is less than 100 mA	5. The car alarm input will be set to zero. We will then measure the current	5. Not verified – See Table D.1

in order to not drain the car battery. a. Test the power consumption of the microcontroller. b. Test the power consumption of the wireless card. c. Test the power consumption of the camera.	entering the circuit using a multimeter. If the current is more than 100 mA the test has failed; if not, the test was successful. a. We will test the current in the microcontroller's power supply section of the circuit. If it is less than ~30 mA then the test passes. b. We will test the current in the wireless card's power supply section of the circuit. If it is less than ~30 mA then the test passes. c. We will test the current in the camera's power supply section of the circuit. If it is less than ~30 mA then the test passes.	
6. Power supply functions for input range of 13.2 to 9.6 V	6. The DC signal will be swept slowly from 13.2 to 9.6 V. If the power supply is still outputting the correct voltages on the outputs then the test is successful if not the test has failed and the components need to be checked for accurate placement and connection.	6. Verified – See Figures D.1 – D.4

Appendix B Block Diagrams and Flow Charts

The figures below contain diagrams that describe the high-level interfaces and software for the various subcomponents of the system.

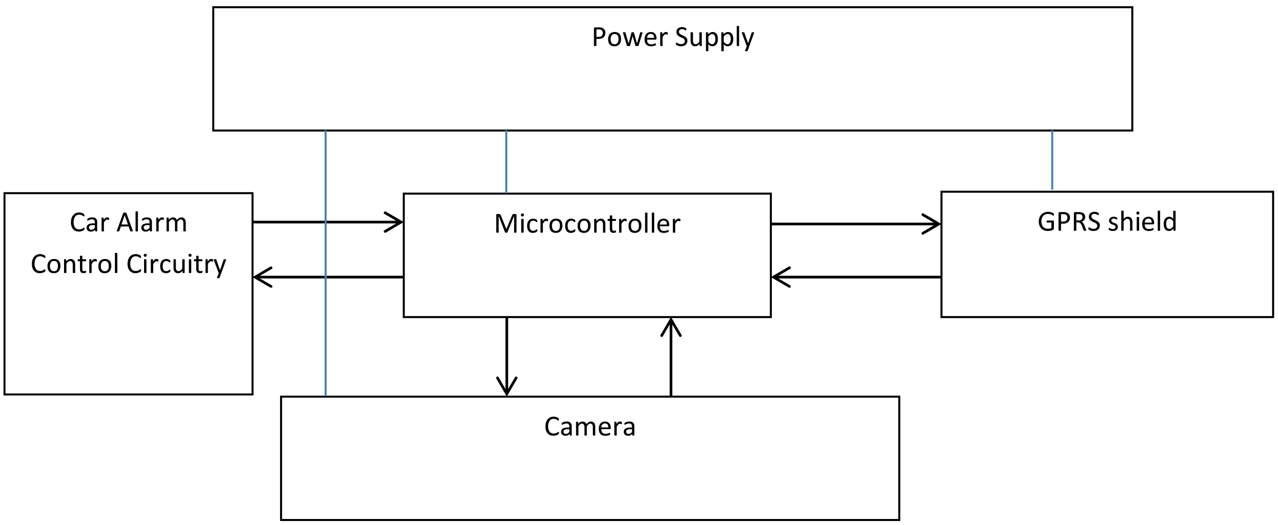


Figure B.1: High-level system block diagram

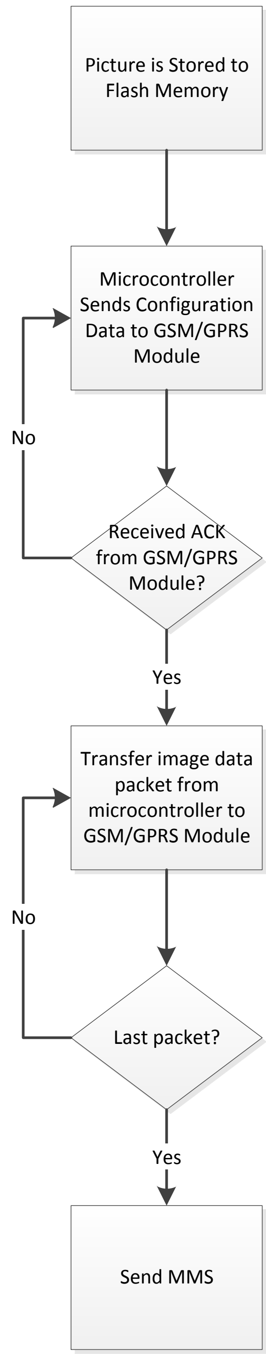


Figure B.2: MMS Software Flowchart

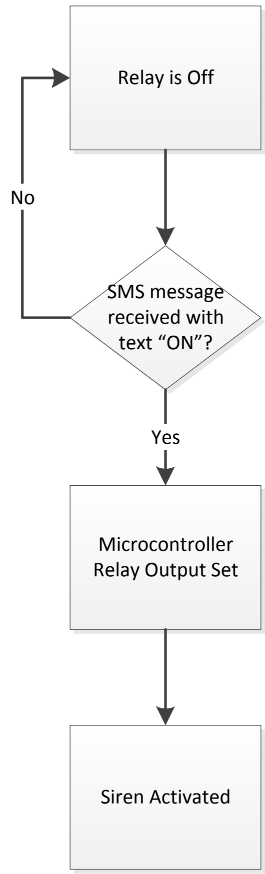


Figure B.3: SMS Software Flowchart

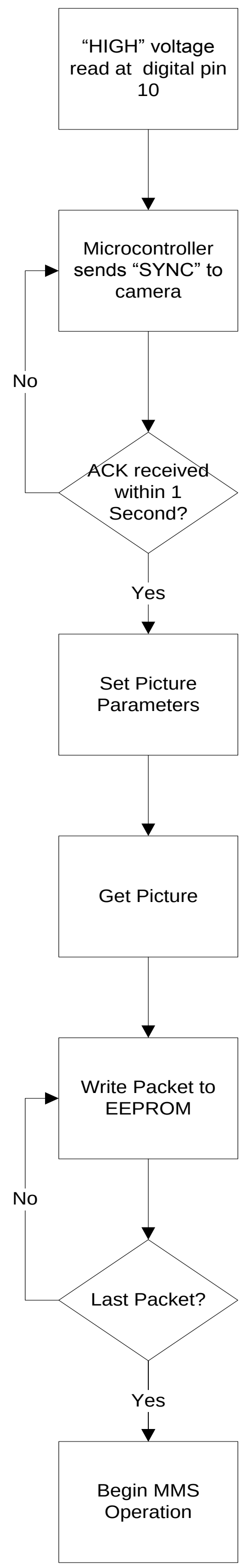


Figure B.4: Camera Software Flowchart

Appendix C Schematics and Pin-Outs

This section contains the schematics and pin-outs for various system components.

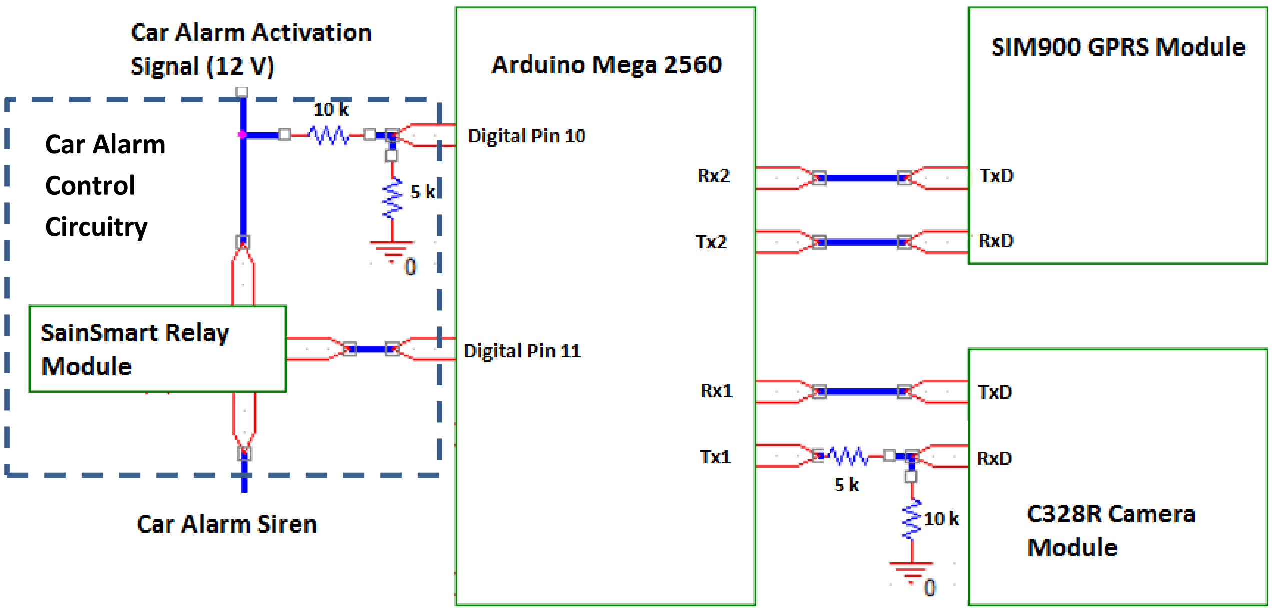


Figure C.1: System Schematic

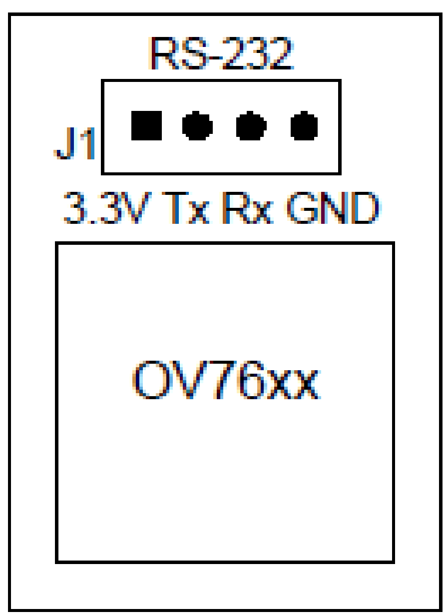


Figure C.2: Camera Schematic

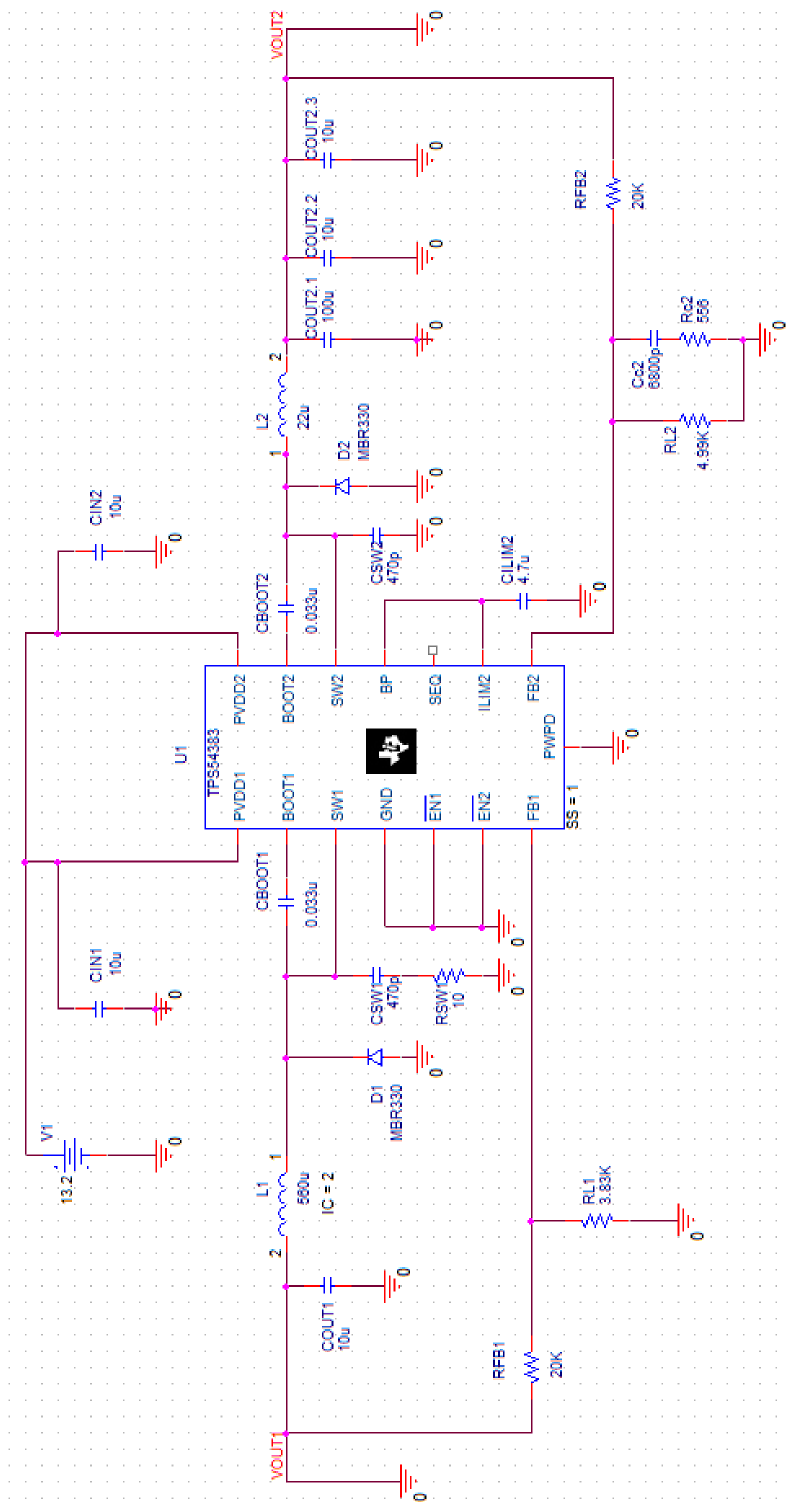


Figure C.3: Initial Power supply schematic

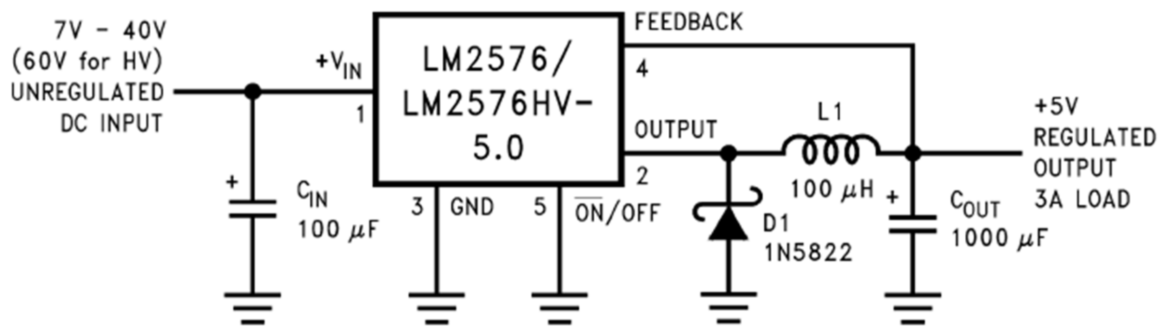


Figure C.4: TI LM2576 5V Buck Converter Schematic[2]

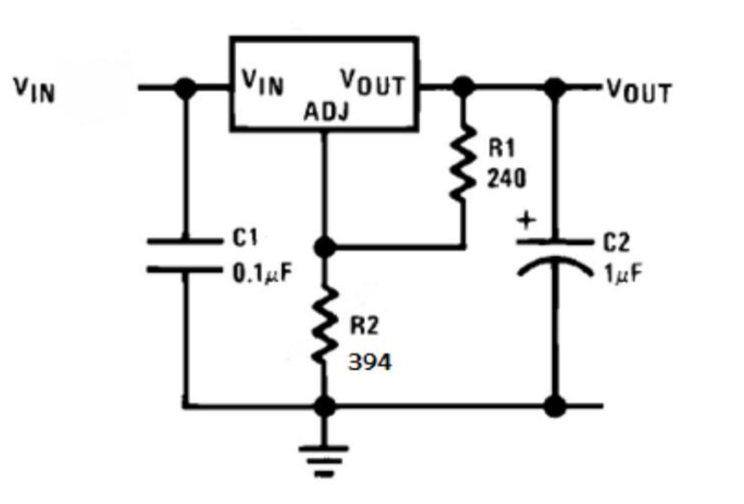


Figure C.5: TI LM317T 3.3V Linear Regulator Schematic [3]

Appendix D Test Data

This section contains graphs, screenshots, and tables resulting from verification testing.

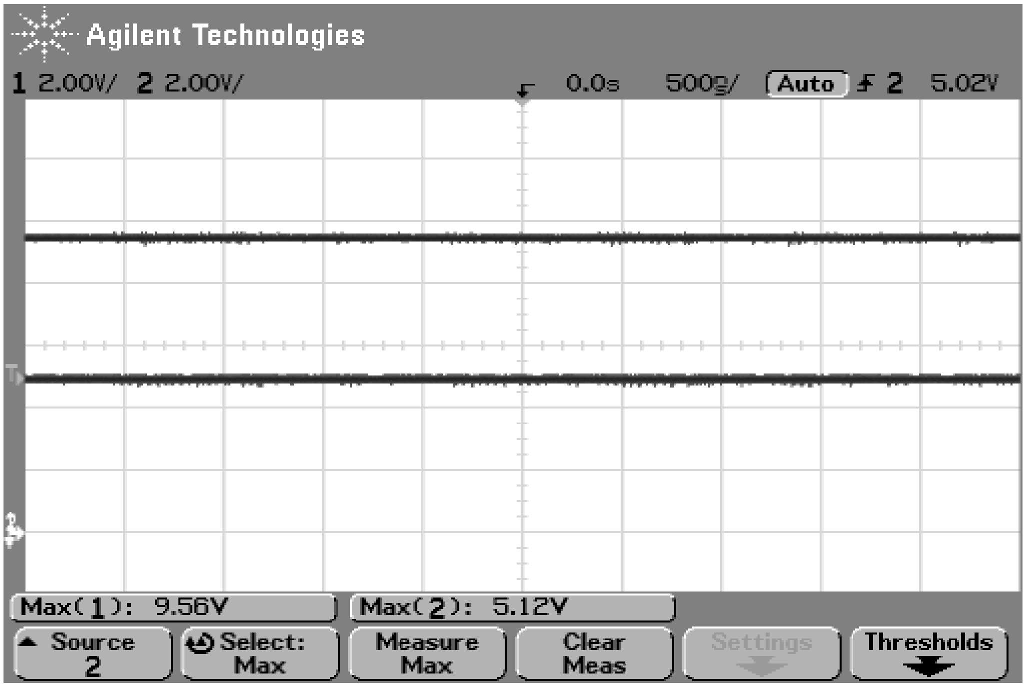


Figure D.1 Channel 1 9.6V input, Channel 2 5V expected output

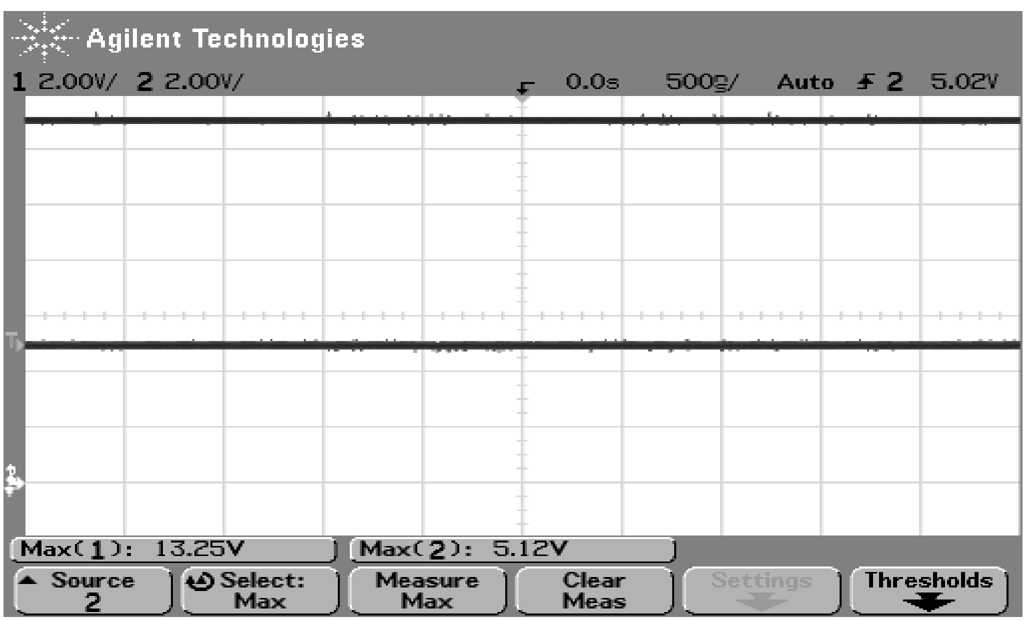


Figure D.2 Channel 1 13.2V input, Channel 2 5V expected output

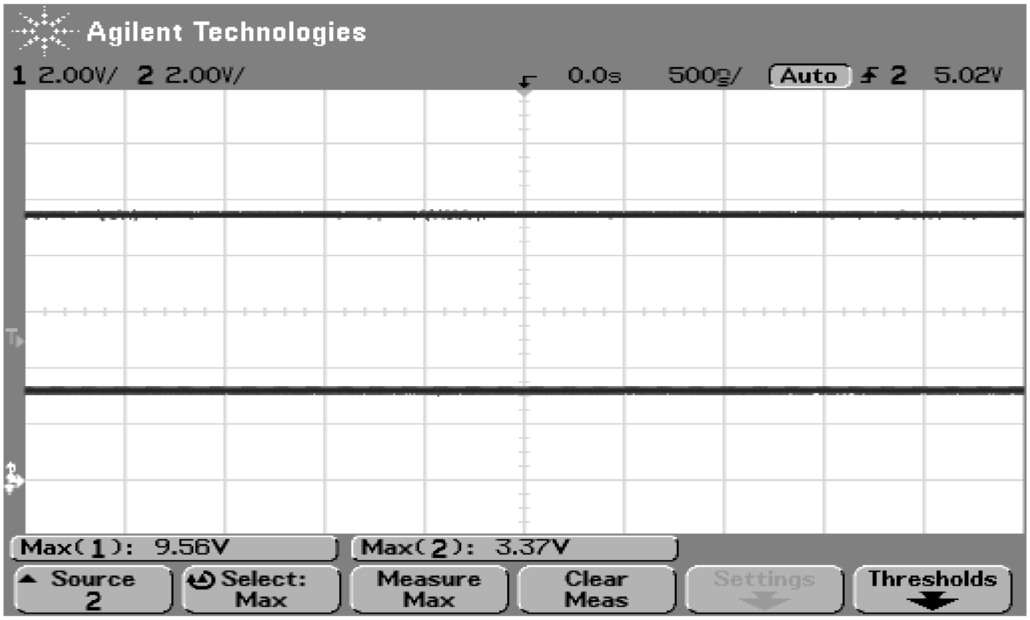


Figure D.3 Channel 1 9.6V input, Channel 2 3.3V expected output

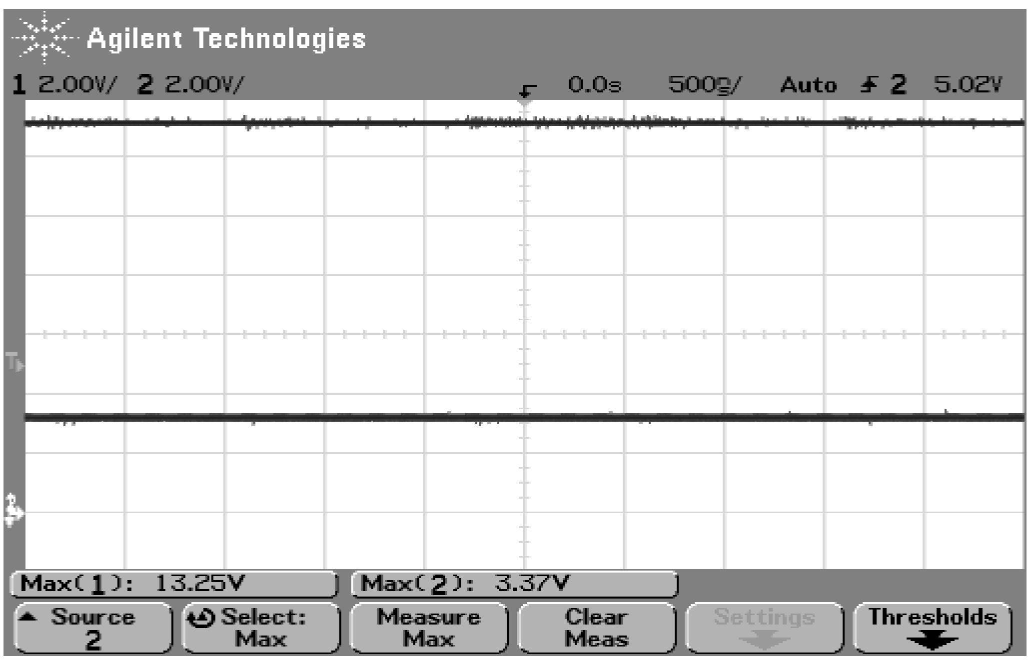


Figure D.4 Channel 1 13.2V input, Channel 2 3.3V expected output

Table D.1 Current and Power draw of components

Components	Current Draw	Power
Full System w/o GPRS on	169 mA	2.03 W
Full System w/ GPRS on	184 mA	2.21 W
Arduino	77.7 mA	932 mW
Camera	.67 mA	2.2 mW
GPRS	17.9 mA	89.5 mW
Relay	137.8 mA	689 mW

Table D.2 Efficiency of Power supply

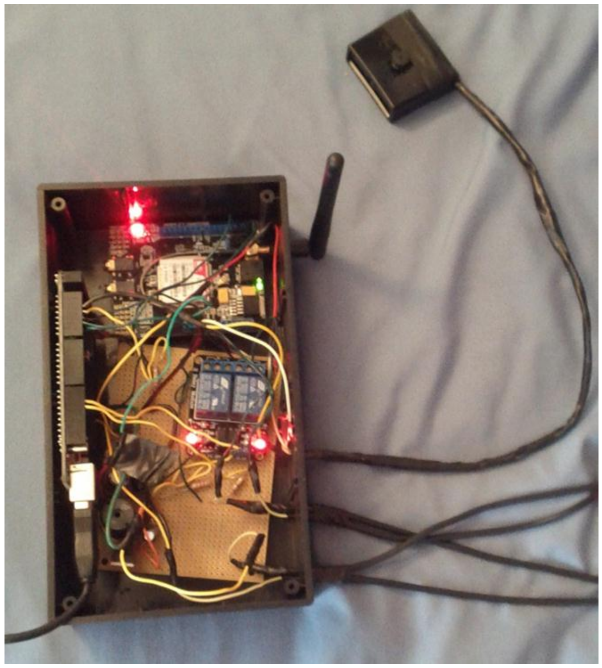
Input Power	192 mW
Output Power	76.96 mW
Efficiency	40%

Appendix E Pictures

This section contains sample pictures and pictures of the project.

Figure E.1: Actual Image Taken By System

Figure E.2: Picture of Final Product



Picture E.3: Picture of Internal Circuitry

Appendix F Reference Calculations

This section contains lengthy calculations that we performed when designing system components.

Calculation F.1 TI TPS54383 Dual Output Buck Converter

We followed the datasheet [11] specifications for the design and below are the calculations performed for the external circuitry.

(Subscript 1 is for the camera side and subscript 2 is for the wireless card side)

Predetermined constants for this chip:

- Switching frequency: $f_{SW} = 310kHz$
- Internal voltage reference: $V_{FB} = .8V$

Our Circuit parameters:

- $V_{IN} = 9.6 - 13.2V$
- $V_{OUT1} = 3.3V$
- $V_{OUT1(MIN)} = 3.2V$
- $V_{OUT1(MAX)} = 3.4V$
- $V_{OUT2} = 4.0V$
- $V_{OUT2(MIN)} = 3.1V$
- $V_{OUT2(MAX)} = 4.8V$
- $I_{OUT1} = .06\ A$
- $I_{OUT2} = 2.5\ A$

Duty Cycle:

To estimate the duty cycle the datasheet[1] gave us equations F.1.1 and F.1.2:

$$D_{MAX} \approx \frac{V_{OUT} + V_{FD}}{V_{IN(\mathrm{MIN})} + V_{FD}} \qquad \text{(F.1.1)}$$

$$D_{MIN} \approx \frac{V_{OUT} + V_{FD}}{V_{IN(\mathrm{MAX})} + V_{FD}} \qquad \text{(F.1.2)}$$

(The value V_{FD} is equal to the estimated forward drop of a Schottky rectifier diode of .5V)

$$D_{MAX1} \approx \frac{3.3 + .5}{9.6 + .5} = 37.6\% \qquad D_{MAX2} \approx \frac{4.0 + .5}{9.6 + .5} = 44.6\% \qquad \text{(F.1.1)}$$

$$D_{MIN1} \approx \frac{3.3 + .5}{13.2 + .5} = 27.7\% \qquad D_{MIN2} \approx \frac{4.0 + .5}{13.2 + .5} = 32.8\% \tag{F.1.2}$$

Inductor:

To select an inductor first we need to calculate $I_{LRIP(MAX)}$ the peak to peak ripple current which is 30% of the maximum output current Equation F.1.3.

$$I_{IRIP1(MAX)} = .06\ x\ .3 = 18\ mA \qquad I_{IRIP2(MAX)} = 2.5\ x\ .3 = 750\ mA \tag{F.1.3}$$

These were put into the given Equation F.1.4 to find the minimum value of the inductor:

$$L_{MIN} = \frac{V_{IN(\text{MAX})} - V_{OUT}}{I_{IRIP(MAX)}}\ x\ D_{MIN}\ x\ \frac{1}{f_{SW}} \tag{F.1.4}$$

$$L_{MIN1} = \frac{13.2 - 3.3}{.018}\ x\ .277\ x\ \frac{1}{310x10^3} = 491x10^{-6}H \tag{F.1.4}$$

$$L_{MIN2} = \frac{13.2 - 4.0}{.7}\ x\ .328\ x\ \frac{1}{310x10^3} = 13x10^{-6}H \tag{F.1.4}$$

The next higher standard inductor value of 560 µH is best for the first circuit. We chose the coilcraft MSS1278-564KLB as our inductor.

The next higher standard inductor value of 22 µH is best for the second circuit. We chose the coilcraft MSS1278-153ML as our inductor as recommended by the manufacturer.

Rectifier Diode:

First we need to calculate the minimum breakdown voltage of the Schottky diode in Equation F.1.5:

$$V_{BR(MIN)} \geq 1.2\ x\ V_{IN(MAX)} = 1.2\ x\ 13.2 = 15.84\ V \tag{F.1.5}$$

The diode chosen for the circuit is the ON SEMI MBRS330T3 because of its reverse breakdown voltage characteristics as recommended.

Now we must estimate the average current in the diode given by the Equation F.1.6:

$$I_{D(AVG)} \approx I_{OUT(MAX)}\ x\ (1 - D_{MIN}) \tag{F.1.6}$$

$$I_{D(AVG)1} \approx .06\ x\ (1 - .277) = .043\ A \tag{F.1.6}$$

$$I_{D(AVG)2} \approx 2.5\ x\ (1 - .328) = 1.68\ A \tag{F.1.6}$$

Now we estimate max power through the diode with Equation F.1.7:

$$P_{D(MAX)} = I_{D(AVG)}\ x\ V_{FM} \tag{F.1.7}$$

The forward voltage drop at the selected current is V_{FM1} = .03V and V_{FM2} = .04V.

$$P_{D(MAX)1} = .043\ x\ .03 = 1.29\ mW \tag{F.1.7}$$

$$P_{D(MAX)2} = 1.68\ x.04 = 670\ mW \tag{F.1.7}$$

Output Capacitor:

The converter's internal compensation creates a f_{res} at 3kHz. The Equation F.1.8 given for output capacitance is as follows:

$$C_{OUT} = \frac{1}{4\ x\ \pi^2 x\ (f_{res})^2\ x\ L} \tag{F.1.8}$$

$$C_{OUT1} = \frac{1}{4\ x\ \pi^2 x\ (3x10^3)^2\ x\ 560x10^{-6}} = 5.03\ \mu F \tag{F.1.8}$$

$$C_{OUT2} = \frac{1}{4\ x\ \pi^2 x\ (3x10^3)^2\ x\ 22x10^{-6}} = 128\ \mu F \tag{F.1.8}$$

To pick the correct capacitor we need calculate the maximum ESR they can have with Equation F.1.9:

$$ESR_{MAX} = \frac{V_{RIP}}{I_{RIP}} - \frac{D}{f_{SW}\ x\ C_{OUT}} \tag{F.1.9}$$

The manufacturer rounds the duty cycle to 50% and gives the ripple voltage as 50 mV[1].

$$ESR_{MAX1} = \frac{.05}{.018} - \frac{.5}{310x10^3\ x\ 5.03x10^{-6}} = 2.46\ \Omega \tag{F.1.9}$$

$$ESR_{MAX} = \frac{.05}{.75} - \frac{.5}{310x10^3\ x\ 128x10^{-6}} = 54\ m\Omega \tag{F.1.9}$$

For the first circuit we chose the next highest capacitance of 10 µF and a ceramic TDK C2012X5R0J106M is chosen. This easily fits the ESR requirements with only an impedance of 2.5 mΩ.

For the second circuit we chose an electrolytic 100 µF Panasonic EEE FC1A101P with 400 mΩ ESR and two ceramic 10 µF TDK C2012X5R0J106M capacitors with 2.5 mΩ ESR. These capacitors are put in parallel to provide a combined ESR of 28 mΩ at 300 kHz.

Voltage setting resistors:

The primary feedback resistor between the VOUT and FB pins is recommended to be set at 20 kΩ. To calculate the lower resistors this Equation F.1.10 is used:

$$R_L = \frac{V_{FB} x\, R_{FB}}{V_{OUT} + V_{FB}} \qquad \text{(F.1.10)}$$

$$R_{L1} = \frac{.8\ x\ 20x10^3}{3.3\ -\ .8} = 6.4\ k\Omega \qquad \text{(F.1.10)}$$

$$R_{L2} = \frac{.8\ x\ 20x10^3}{4.0\ -\ .8} = 5\ k\Omega \qquad \text{(F.1.10)}$$

Standard 0603 1/16 watt resistors are chosen at the values of 6.34 and 4.99 kΩ respectively.

Compensation Capacitors:

We need to check the ESR zero of the main output capacitor and if it is less than 20 kHz then and R-C filter is needed in parallel with R_L.

$$f_{ESR(ZERO)} = \frac{1}{2\ x\ \pi\ x\ ESR\ x\ C} \qquad \text{(F.1.10)}$$

$$f_{ESR(ZERO)1} = \frac{1}{2\ x\ \pi\ x\ .0025\ x\ 10x10^{-6}} = 6.3x10^6\ Hz \qquad \text{(F.1.10)}$$

$$f_{ESR(ZERO)2} = \frac{1}{2\ x\ \pi\ x\ .4\ x\ 100x10^{-6}} = 3980\ Hz \qquad \text{(F.1.10)}$$

For the second circuit we need compensation in the form of an R-C circuit shown in Equations F.1.11-13:

$$R_C = \frac{R_{L2}}{(\frac{f_{ESR(DESIRED)}}{f_{ESR(ZERO)2}} - 1)} = \frac{5x10^3}{(\frac{40x10^3}{3980} - 1)} = 556\ \Omega \qquad \text{(F.1.11)}$$

A standard value of 590 Ω is selected.

$$R_{EQ} = R_C + (R_{FB}||R_{L2}) = 590 + 4000 = 4.59\ k\Omega \tag{F.1.12}$$

$$C_C = \frac{1}{2\ x\ \pi\ x\ R_{EQ}\ x\ f_{ESR(ZERO)}} = \frac{1}{2\ x\ \pi\ x\ 4590\ x\ 3980} = 8.71\ \text{nF} \tag{F.1.13}$$

The TDK C1005X7R1E682MT is chosen at 6800 pF for the closest equivalent as suggested by the datasheet[1].

Input Capacitor:

A minimum 10 μF ceramic input capacitor on each PVDD pin so these are added as C_{IN}.

Boot Strap Capacitor:

The manufacturer requires a 33 nF capacitor across the BOOT pin and the SW pin. Also required off of these pins is a 470 pF capacitor in series with a 10 Ω resistor tied to ground[1].