VEHICLE MONITORING SYSTEM

Design Review

Chris Blount & Michael Jermann

TA: Justine Fortier

Team #35

Introduction

Our project, "Vehicle Monitoring System," is an addition to traditional car alarms that will increase users' situational awareness of vehicle security threats via the real-time transmission of on-site images. We believe that many consumers would prefer to visually judge their vehicle's safety during times of crisis rather than rely purely upon traditional alarms or the alerts of next-generation systems. Our system provides users with this ability and represents the next stage in evolution of automobile security systems. Additionally, we feel that this product has the potential to quickly gain a niche market share in the vehicle security space.

Existing Technology

Traditional car alarm systems are ineffective and inefficient due to the frequency with which they sound, providing little protection or security to vehicle owners. This has resulted in the proliferation of "next-generation" car alarm systems. State-of-the-art vehicle security systems, such as the Viper 3303 or Python 991, offer real-time threat alerts and two-way communication. Threat alerts are transmitted to a remote or a smartphone and displayed via a "car security dashboard". These alerts consist of a combination of text and audio and provide detailed information regarding the security incursion. Additionally, we found one product capable of transmitting a low-resolution image of the vehicle to the user (ScyTek's Vision Guard 8000, which is no longer supported by the company); however, this system is range-limited and of questionable quality. The two-way communication that many of these devices support permits the user to remotely start the engine, disarm the system, and turn on the lights. Other recent car alarm innovations include cabin strobe lights, local video recording, and synthetic graphical car representations.

Objectives

Our primary goal is to improve user situational awareness during vehicle security threats. A cabin-mounted camera will be triggered to capture images when a threat is detected (via the existing car alarm system). These images will be processed by the microcontroller and sent to the user's smartphone via GSM/GPRS networks. The user will be able to visually judge the situation and take action. Another goal of ours is to permit the user to remotely control the system using SMS. After a security alert, the user will be able to send commands to the microcontroller to deactivating the car alarm or capture additional images. Additionally, we would like to permit the user to capture images even when a security threat has not been detected. We believe that these systems are most valuable when the user is far away from his/her vehicle; therefore, we will implement long-range wireless transmission/alert access.

Benefits

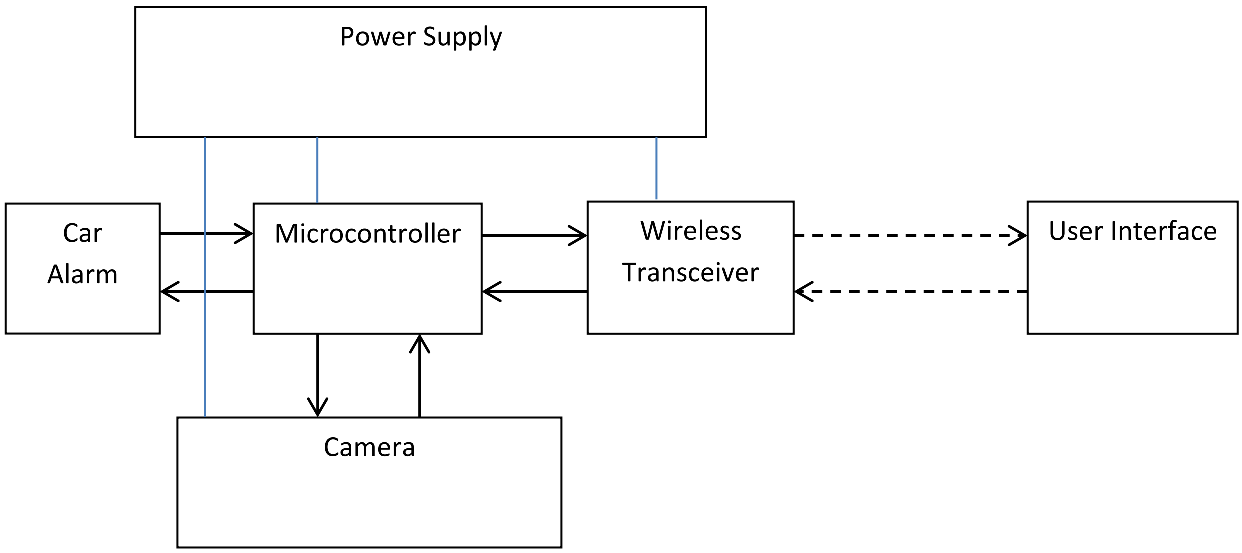
- Increased vehicle situational awareness during automobile security threats
- Improved wireless transmission to user device – no remote required and have cell sized range
- Supports both on-command and automated image capture abilities

Features

- Access to GSM/GPRS wireless networks
- Real-time wireless transmission of images to users
- System control using SMS commands
- Mountable low-resolution CMOS camera for customized vehicle image

Design

Block Diagram



Block Descriptions

Car Alarm

Car Alarms typically have a wide array of sensors such as microphones, pressure sensors, mercury tilt/shock sensors, and door sensors that keep track of the environment in and around the car to detect intrusion. When the sensor detect something happening they send that signal to a microcontroller that determines whether or not a threshold has been surpassed and then the controller will send a 12V signal to the car alarm siren in order to activate it.

We will control the activation of this siren by placing a DK2A-12V relay between the car alarm controller and siren. The microcontroller will detect when the 12V signal is activated, prompting image acquisition to occur. The microcontroller output will be connected directly to the relay and will activate the alarm if prompted to from an SMS message from the user.

Camera

A cabin-mounted CMOS camera (the C238R) will be used for image capture. It will provide 640x480 resolution and will implement JPEG compression, allowing us to take RGB images. It will controlled by the microcontroller via a serial port (15200 8-N-1). Additionally, it will transfer data to the microcontroller after image acquisition and compression is completed.

Microcontroller

We will be using the Arduino Mega 2560 microcontroller for this design. We need a microcontroller that has two serial interfaces for interfacing with both the CMOS camera and GSM/GPRS module. The memory demands are driven by the CMOS camera; we require at least 200 kB of flash memory in order to store JPEG images. This device will also respond to user SMS commands.

Wireless Transceiver

This will provide our system with the ability to send images to the user and respond to SMS commands. In order to achieve MMS capability, we will be using an Arduino shield (the SLD33149P sold by Seeed Studio) that uses the SIM900 GSM/GPRS module. This will interface with the microcontroller over a serial interface (15200 8-N-1). This will provide us with nearly universal coverage and allow us to easily control the system via SMS messages. A prepaid SIM card will be required for this module as well.\

Power Supply

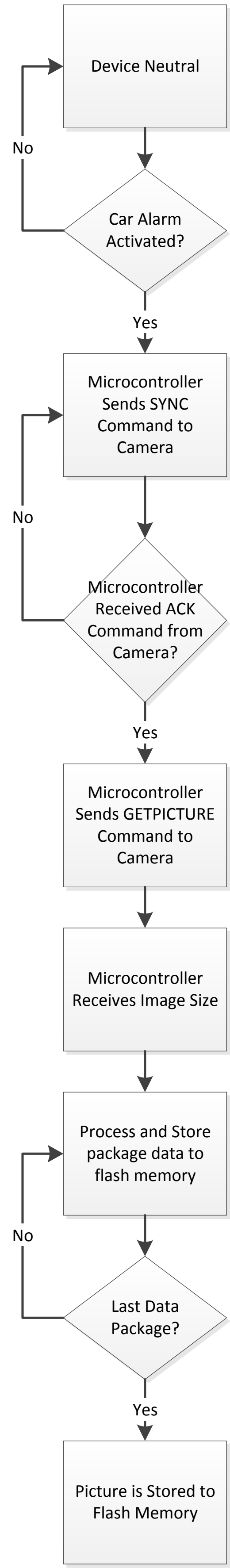
For our power conversion we decided to go with a buck converter because of the high efficiency that could be achieved. We need high efficiency in our power electronics because we have a limited power supply from the battery of the car. The chip we chose is the Texas Instruments TPS54383 the lower frequency model therefore higher efficiency. This chip is a dual non-synchronous buck converter. It has an input range of 4.5-24V and an output of 3 amps maximum. This chip was chosen for our design because we need a chip that could handle a current of over 2 amps as well as handle two outputs, one for the C328R camera and one for the SIM900 wireless card.

Performance Requirements

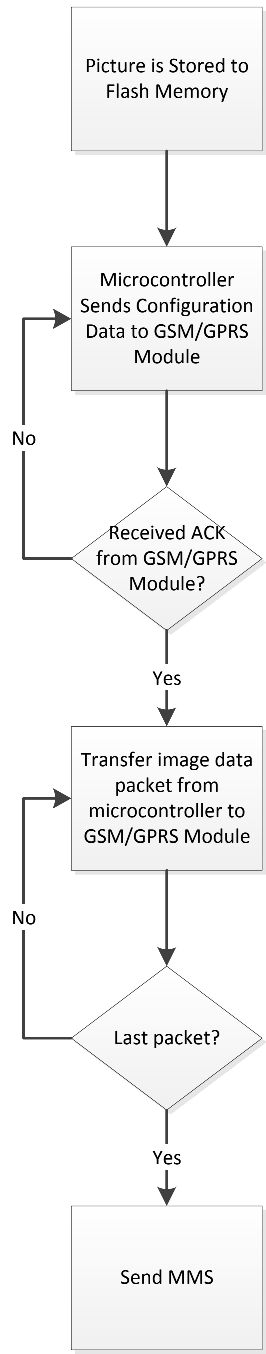
- Transmit photo of at least 200 kB to user's smartphone and be able to receive SMS commands back from the user.
- Have user receive alert within 5 minutes of security incursion (based upon the bottleneck of sending and receiving data over cellular networks).
- Make the system affordable by being under $300.
- Make the system user-friendly and easy-to-install by using less than 10 inputs and outputs.

Software Flowchart

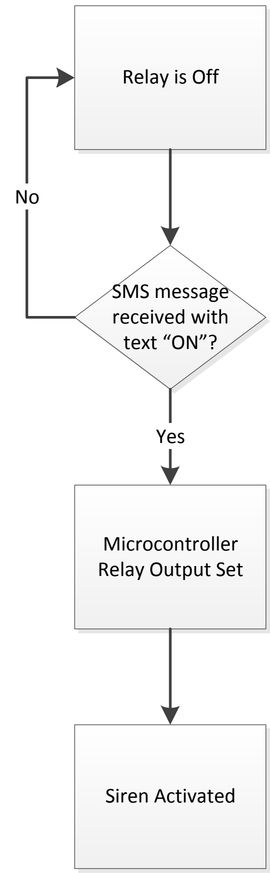
Image Acquisition Process:



Sending MMS Messages:

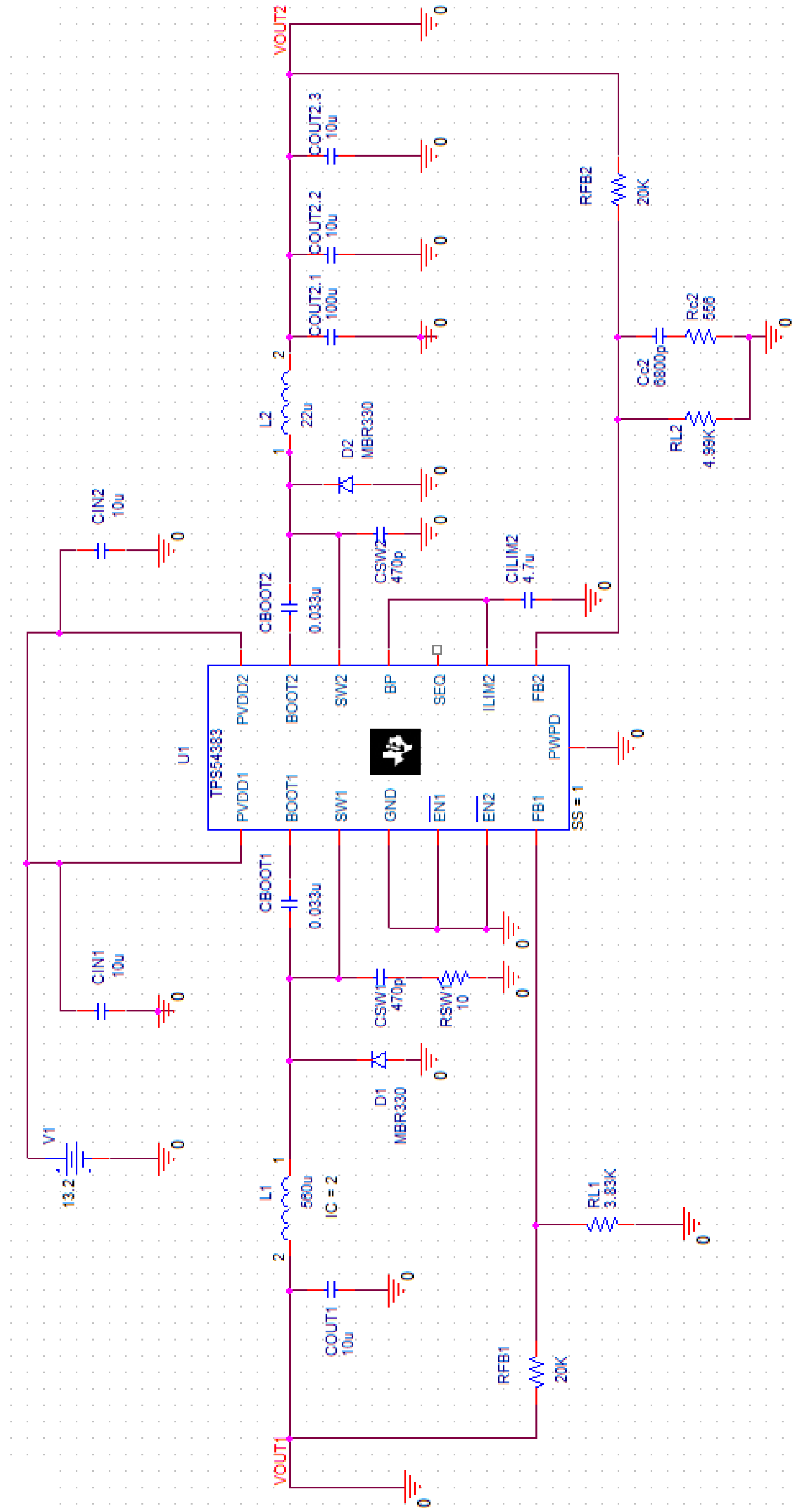


Receiving SMS Messages:

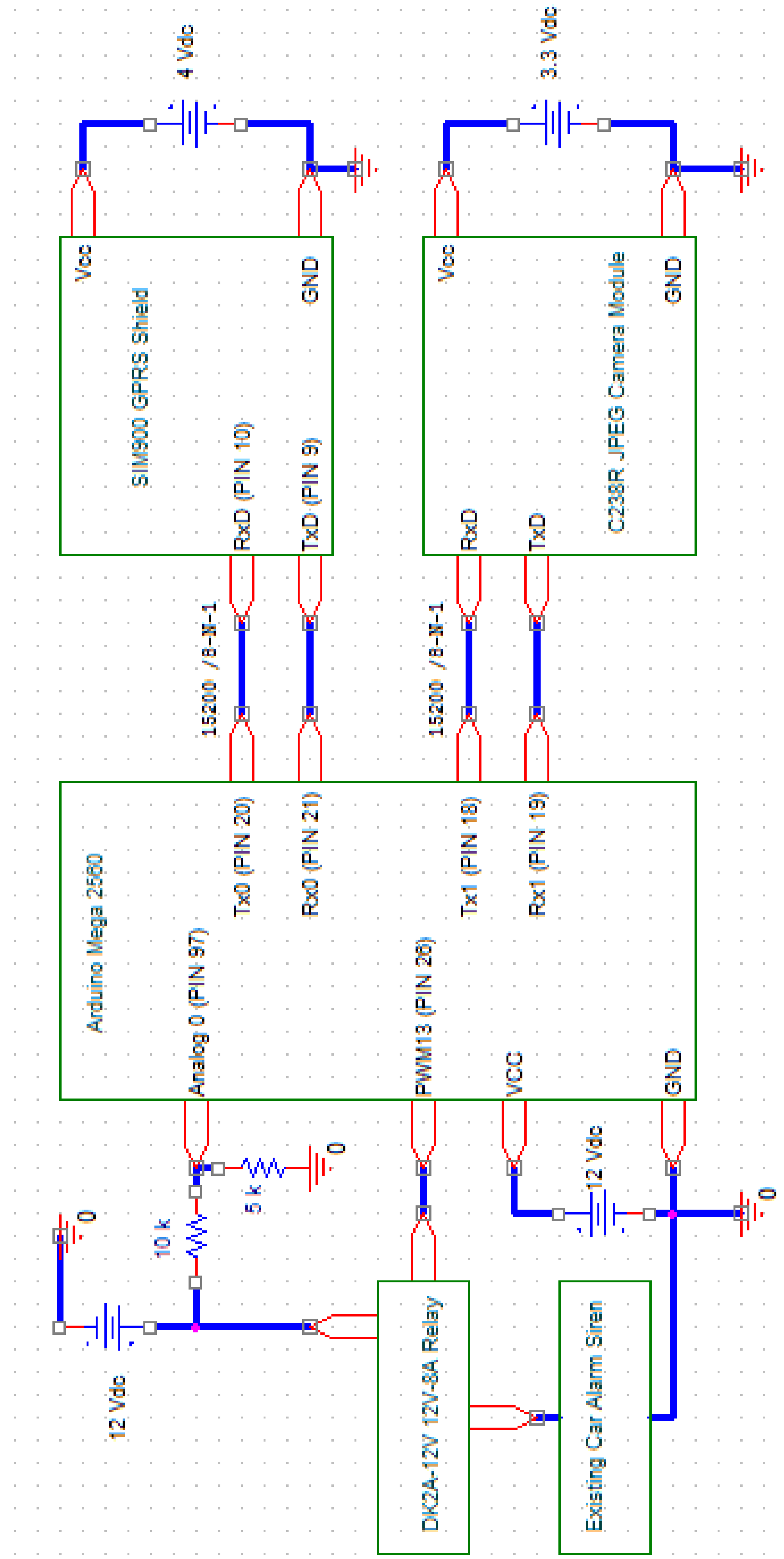


Schematics

Power Supply Schematic:



Microprocessor Schematic:



Calculations:

Power Supply:

We followed the datasheet 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 gave us these equations:

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

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

$$D_{MAX1} \approx \frac{3.3 + .5}{9.6 + .5} = 37.6\% \qquad D_{MIN1} \approx \frac{3.3 + .5}{13.2 + .5} = 27.7\%$$

$$D_{MAX2} \approx \frac{4.0 + .5}{9.6 + .5} = 44.6\% \qquad D_{MIN2} \approx \frac{4.0 + .5}{13.2 + .5} = 32.8\%$$

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.

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

These were put into the given equations to find the minimum value of the inductor:

$$L_{MIN} = \frac{V_{IN(\mathrm{MAX})} - V_{OUT}}{I_{IRIP(MAX)}} \; x \; D_{MIN} \; x \; \frac{1}{f_{SW}}$$

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

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

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:

$$V_{BR(MIN)} \geq 1.2 \; x \; V_{IN(MAX)} = 1.2 \; x \; 13.2 = 15.84 \; V$$

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:

$$I_{D(AVG)} \approx I_{OUT(MAX)} \; x \; (1 - D_{MIN})$$

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

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

Now we estimate max power through the diode:

$$P_{D(MAX)} = I_{D(AVG)} \; x \; V_{FM}$$

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

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

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

Output Capacitor:

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

$$C_{OUT} = \frac{1}{4 \; x \; \pi^2 x \; (f_{res})^2 \; x \; L}$$

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

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

To pick the correct capacitor we need calculate the maximum ESR they can have:

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

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

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

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

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 is used:

$$R_L = \frac{V_{FB} x\ R_{FB}}{V_{OUT} + V_{FB}}$$

$$R_{L1} = \frac{.8\ x\ 20x10^3}{3.3 - .8} = 6.4\ k\Omega$$

$$R_{L2} = \frac{.8\ x\ 20x10^3}{4.0 - .8} = 5\ k\Omega$$

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.

$$f_{ESR(ZERO)} = \frac{1}{2\ x\ \pi\ x\ ESR\ x\ C}$$

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

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

For the second circuit we need compensation in the form of an R-C circuit:

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

A standard value of 590 Ω is selected.

$$R_{EQ} = R_C + (R_{FB}||R_{L2}) = 590 + 4000 = 4.59 \; k\Omega$$

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

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

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.

Verification

Our design consists of five relatively modular components – the power supply, microprocessor, GPRS module, CMOS camera, and car-alarm relay. At the highest level, we can verify the working status of all five components by setting the 12 V car alarm input, receiving an MMS containing a picture of the vehicle, and subsequently sending an SMS message to the system to halt car alarm operation. By measuring the voltage of the relay output, along with the received MMS message, we can confirm that the system is accomplishing its basic function.

Requirement	**Verification**
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 "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 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.
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 analog input should now be between 3-5 V. If not, the test has failed.
5. Standby power consumption of the system is less than 100 mA 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.	5. The car alarm input will be set to zero. We will then measure the current 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.

Tolerance Analysis

The system needs to be able to work with low power consumption while providing high reliability and fast response time. The microcontroller must manage efficiently the turning on and off of the wireless communication when not needed to save power. All components must have a total standby power of less than 100 mA to not drain the car battery. We will test this to ensure the user does not lose too much charge to the battery when left overnight and not be able to start their car in the morning.

Cost and Schedule

Cost Analysis

Cost of labor

40 $/hr x 20 hrs/week x (2.5) x 13 weeks = $26,000 per person

$26,000/person x 2 people = $52,000 labor cost

Cost of components

Part	**#**	**Cost per part**	**Total**
ArduinoMega	1	$60	$60
Camera C328R	1	$60	$60
GSM/GPRS Module	1	$60	$60
Prepaid SIM Card (2MB)	3	$12	$36
TI TPS54383 Buck Converter	1	$6.40	$6.40
Coilcraft MSS1278-564KLB	1	$1.00	$1.00
Coilcraft MSS1278-153ML	1	$1.00	$1.00
ON SEMI MBRS330T3	2	$.50	$1.00
Panasonic EEE FC1A101P	1	$.83	$.83
TDK C2012X5R0J106M	3	$.10	$.30
Misc. Capacitors	5	$.10	$.50
Resistors	7	$.05	$.35
Back up battery	1	$5	$5
PCB board	1	$5	$5
Box for project	1	$10	$10
DK2A-12V Relay	1	$13	$13

Grand total for components = $237.38

Total cost

$52,000 labor + $237.38 parts = $52,237.38

Schedule

Week #	Dates	Chris Blount	Mike Jermann
1	2/6	Research for proposal	Research for proposal
2	2/13	Research and design camera interface with microcontroller. Design power supply.	Research and design wireless interface with microcontroller. Design alarm system interface
3	2/20	Complete design review and order parts for camera and power supply.	Complete design review and order parts for wireless interface and alarm interface.
4	2/27	Build the circuit for the camera and begin power supply as parts arrive.	Build the circuit for the wireless interface and put together alarm interface.

5	3/5	Build the circuit for the camera, finish power supply, and debug. Work on C328R code.	Build the circuit for the wireless interface, finish alarm interface, and debug. Work on SIM900 code.
6	3/12	Begin testing of picture storage in the microcontroller.	Begin testing of MMS sending and SMS receiving in the microcontroller.
7	3/19	(Spring break) Put project pieces together.	(Spring break) Put project pieces together.
8	3/26	Test full project functionality and do mock demo. Go through C328R verification tests.	Test full project functionality and do mock demo. Go through SIM900 verification tests.
9	4/2	Debug full project together and continue testing.	Debug full project together and continue testing.
10	4/9	Continue full project debug and testing. Show concept functionality in demo car.	Continue full project debug and testing. Show concept functionality in demo car.
11	4/16	Start making the slides for the presentation. Check project for full functionality.	Start writing the final paper. Check project for full functionality.
12	4/23	Demo the project. Finish final presentation. Edit paper.	Demo the project and continue the writing process. Practice final presentation.
13	4/30	Do final presentation and turn in final paper.	Do final presentation and turn in final paper.

Ethical Considerations:

A potential ethical conflict with regards to this system could be using it to spy on the owner of a vehicle. This is due to the remote-monitoring capabilities inherent to this system. However, this system involves a rather intricate infrastructure and cannot be installed without access to the interior cabin and car battery. Therefore, the only individuals who will have their image taken by this system set off the car alarm. Regardless of their intentions, we believe that it is the right of the car owner to be aware of who was in the vicinity of the vehicle. We believe this system has minimal potential to falsely incriminate an individual of a crime such as car vandalism due to its real-time nature and therefore believe it is an ethically sound product.