Emergency Vehicle Alert Device (E.V.A.D.E.)

Josh Guinn, Charles Logan, Derrick J. Nelson, and Stephen Watson

School of Electrical Engineering and Computer Science, University of Central Florida, Orlando, Florida, 32816-2450

***Abstract* — Emergency vehicles rely on lights and sounds in order to attract the attention of those in the area. Modern automobile design and manufacturing processes, however, continue to insulate the interior spaces of passenger vehicles from outside "noise". As sound isolation improves, the effectiveness of the emergency vehicle alert systems is diminished. This reduced sensitivity to emergency vehicles increases emergency response time and creates driving hazards as some drivers may not immediately respond to the presence of an emergency vehicle. This paper describes a new system that would augment an emergency vehicle's alert systems, overcoming the problem of acoustic isolation.**

***Index Terms* — Amplitude shift keying, automotive electronics, digital signal processing, hall effect, global positioning systems, radio transceivers, vehicle safety.**

I. Introduction

Emergency services (police, fire, ambulatory, etc.) rely on lights and sirens to alert people to the presence of emergency vehicles. Sirens are omnidirectional and can attract a driver's attention regardless of that driver's visual focus, therefore, sirens are typically the first warning motorists receive. However, as sound isolation within the cabins of modern vehicles improves, the effectiveness of emergency vehicle sirens is diminished. As drivers take longer to notice emergency vehicles, the time for those emergency vehicles to respond to a scene is increased. Also, when only some drivers respond to an approaching emergency vehicle, the unaware drivers may not anticipate seemingly erratic changes in the surrounding traffic, which increases the chances for collisions.

The E.V.A.D.E. system is an augmentation to the emergency alert systems (lights and sirens) currently employed by emergency vehicles. The system solves the problem of sound isolation by generating audio and visual warnings within the cabins of properly equipped vehicles. The system is composed of two modules, the Emergency Alert Transmitter (EAT) and the Emergency Alert Receiver (EAR). When the warning lights on an emergency vehicle are activated, the emergency alert transmitter broadcasts a signal which is picked up by the emergency alert receiver. The EAR processes the signal, extracting pertinent data, and generates a warning message customized to each vehicle in which the system is installed. The audible warning message is sent through the vehicle's pre-existing speakers while a visual warning is sent to the external display installed in the dashboard.

The E.V.A.D.E. system features a compass and GPS chip in order to determine the position of a transmitting emergency vehicle relative to that of the receiving vehicle. The system is small enough to be installed behind a vehicle's dashboard and inexpensive enough to be offered as an after-market add-on or as a factory-installed option. The already low cost ownership for the E.V.A.D.E. system could be reduced or eliminated through discounts in auto insurance or tax incentives.

II. Design Requirements

The E.V.A.D.E. system is designed to be seamlessly incorporated into current standard vehicle platforms. The devices may be factory installed or sold as aftermarket additions. The transmitter requires pre-programming to indicate the type of emergency vehicle in which it is being installed. The design requirements of the E.V.A.D.E. system are as follows:

- Operates on standard 12V vehicle power, filtered against alternator "noise"
- Determines vehicle position (latitude and longitude) and heading (N, S, E, W, NE, SE, NW, SW)
- Operates correctly regardless of motion of the vehicle
- Transmits up to 1500 ft.
- Stores and plays pre-recorded alert messages in English and in Spanish
- Displays a text message (in English or Spanish) to alert the driver
- Indicates relative position of emergency vehicle via LED display
- Does not interfere with operation of stereo system
- Bypasses stereo operation when necessary
- Broadcasts within the Emergency Services Pool, as defined by the FCC [1]

III. Overview of Operation

The E.V.A.D.E. system is divided into two separate devices, the Emergency Alert Transmitter (EAT) and the Emergency Alert Receiver (EAR). They work in tandem to alert motorists to the presence of emergency vehicles.

A. Emergency Alert Transmitter

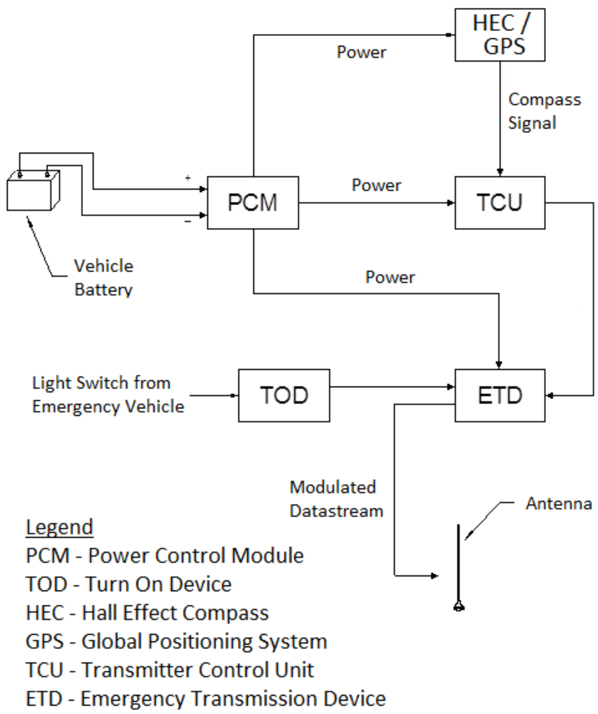

Fig. 1. Emergency Alert Transmitter Block Diagram

The block diagram for the Emergency Alert Transmitter (EAT) is shown in Fig. 1. The EAT is installed in emergency vehicles. It operates on vehicle power, but remains in standby mode when not needed. When the vehicle's emergency lights are activated, the EAT begins transmitting. It broadcasts a signal containing several pieces of information; such as the type of emergency vehicle, its position, and its heading.

B. Emergency Alert Receiver

The block diagram for the Emergency Alert Receiver (EAR) is shown in Fig. 2. The EAR is installed in non-emergency vehicles, such as passenger vehicles. It operates on vehicle power, but remains in a low-power state until it receives the signal from the transmitter. The EAR extracts the information about the emergency vehicle at the same time that it gathers information on its own position and heading. The EAR compares the two sets of information in order to determine the position of the emergency vehicle relative to its own position. Based on this calculation, it determines the appropriate alert message and sends that message to the vehicle's speakers and to the visual display mounted in the dashboard. The alert message may be played in English or in Spanish and continues until the alert is no longer required.

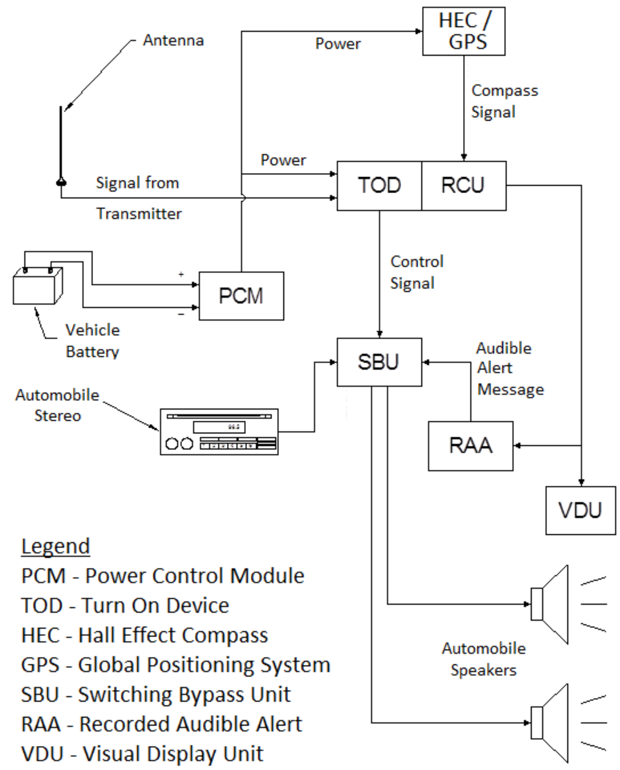

Fig. 2. Emergency Alert Transmitter Block Diagram

IV. System Components

Many of the components are common between the Emergency Alert Transmitter and the Emergency Alert Receiver. In order to minimize redundancy, descriptions are focused on individual components, rather than on the devices in which they reside.

A. Turn-On Devices

The Emergency Alert Transmitter (EAT) will transmit only when the vehicle's emergency lights are active. Therefore, the Turn-On Device for the EAT consists of a simple switch. It will be incorporated into the pre-existing light switches in the emergency vehicle, and will interface with the transmitter. Most of the rest of the EAT will be powered whenever the emergency vehicle is running. This is done in order for the GPS chip to maintain connection with the positioning satellite.

The Turn-On Device for the Emergency Alert Receiver is incorporated into the Receiver Control Unit (RCU) and is realized using software programming. The RCU and GPS will be powered whenever the vehicle is in operation.

Most of the other components will be in stand-by mode, if available. Once the RCU generates an alert signal, it will send a control signal to the other components to activate them.

B. Power Control Modules

The power control modules operate on standard 12V vehicle power. The inputs are filtered against alternator "noise" and the outputs to the E.V.A.D.E. components are also filtered to maintain stable voltage levels. Fig. 3 shows the PCM for the transmitter, which provides the EAT with 3.3V.

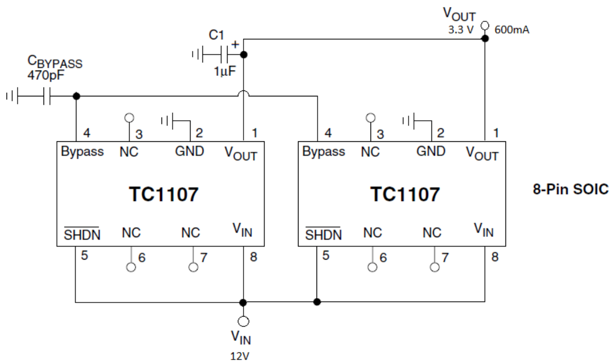

Fig. 3. Power Control Module (EAT)

Fig. 4 shows the PCM for the receiver, which provides the EAR with 3.3V and 5V.

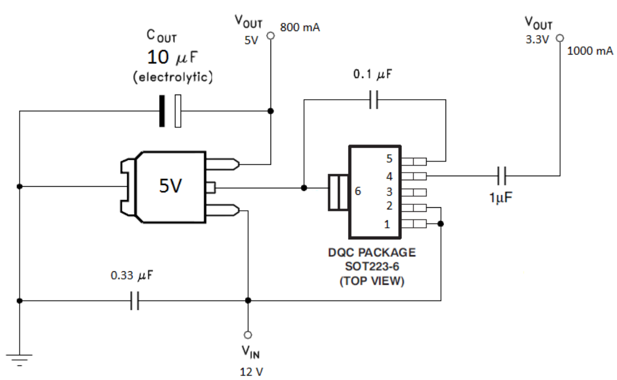

Fig. 4. Power Control Module (EAR)

Various linear voltage regulators were used in the PCMs. Linear regulators are less efficient, but provide much cleaner outputs (low noise) than switching regulators. Switching regulators were not used because of the tendency to introduce radio frequency interference into the system, which could adversely affect the transmitter and receiver.

C. Hall-Effect Compass

The Hall-Effect Compass (HEC) Modules for both the EAT and the EAR are identical in construction and operation. The Dismore Digital Sensor No. 1490 is the specific compass used in this application. The Hall-Effect Compass is capable of outputting eight different directional readings (N, E, S, W, NE, SE, SW, NW). The outputs are open collector NPN transistors which sink 25 mA at 12 V. However, for our application, the HEC will be operated at a lower voltage level, and will therefore sink a smaller output current. The HEC utilizes pull-down resistors on each output to maintain a steady output value. Table I shows the output states of the HEC pins for the eight possible vehicle headings.

Table I
HEC Pin Outputs

Direction	N Pin	S Pin	E Pin	W Pin
N	1	0	0	0
S	0	1	0	0
E	0	0	1	0
W	0	0	0	1
NE	1	0	1	0
NW	1	0	0	1
SE	0	1	1	0
SW	0	1	0	1

In order to reduce the length and complexity of the transmitted signal, the 4-bit signal was reduced to 3 bits using Boolean algebra. This reduced bit code is shown in Table II.

Table II
TCU/RCU Directional Outputs

Direction	3-Bit Code
N	000
S	001
E	011
W	010
NE	110
NW	111
SE	101
SW	100

The logic statements that are used to determine the pin outputs are

$$P_1 = (S+W)(N'+E') \quad (1)$$

$$P_2 = (S+E)(N'+W') \quad (2)$$

$$P_3 = (E+W)(N'+S'). \quad (3)$$

In the equations above, (1) is the most significant bit, (2) is the middle bit, and (3) is the least significant bit.

D. Global Positioning System (GPS)

The GPS Modules for both the EAT and the EAR are identical in construction and operation. The GPS chip, the Antenova M10214-A1, used in this design requires very few external components. It will remain powered at all times that the vehicle is in operation. This allows the GPS chip to maintain connection with the GPS satellites, minimizing the time required to obtain the vehicle's position. The GPS chip will operate at a baud rate of 9600 bps and will communicate with the TCU/RCU via UART interface.

Table III
GLL Message Format

Name	Section from Example	Description
Message ID	$GPGLL	Standard GLL protocol heading
Latitude	ddmm.mmmm	Latitude Coordinates
N/S Indicator	X	N=North, S=South
Longitude	dddmm.mmmm	Longitude Coordinates
E/W Indicator	Y	E=East, W=West
UTC Time	hhmmss.sss	Coordinated Universal Time
Status	A	A=data valid, V=data not valid
Checksum	*41	Error checking count
<CR><LF>	<CR><LF>	End of message termination

The GPS chip will output its data in GLL (geographic position latitude and longitude) message format. This format consists of a string of ASCII characters, such as "$GPGLL,ddmm.mmmm,X,dddmm.mmmm,Y,hhmmss.sss,A,*41,<CR><LF>". Table III gives the message breakdown. This data will be sent to the microcontroller, which will extract and save only the information that it needs.

E. Transmitter Control Unit

The Transmitter Control Unit receives data from the compass and GPS, concatenates the needed information, and sends the bit stream to the transmitter for broadcasting. The composition of the bit stream is shown in Table IV.

Table IV
TCU Bit Stream

MSB	Type of Vehicle	2 bits
	Compass Heading	3 bits
	Latitude	72 bits
LSB	Longitude	80 bits

The Microchip Technology PIC32 microcontroller serves as the TCU. It has separate code and data space, with a program counter mapped to the data space. It has a high execution speed enabling the control unit to quickly process the signals with little or no noticeable delays. The PIC32 also features 512 KB of FLASH memory. The most important feature for the E.V.A.D.E. device is the inclusion of full JTAG and wire programming, which was very important for the necessary serial interfaces to the other components.

F. Emergency Transmission Device

The Emergency Transmission Device is composed of the Micrel MICRF113 transmitter. When the TOD activates the ETD, the transmitter receives the emergency signal from the TCU, modulates and internally amplifies the signal, and broadcasts the signal to be picked up by EAR-equipped vehicles in the vicinity. The transmitter transmits out to 1500 ft. The transmitter circuit is shown in Fig. 5.

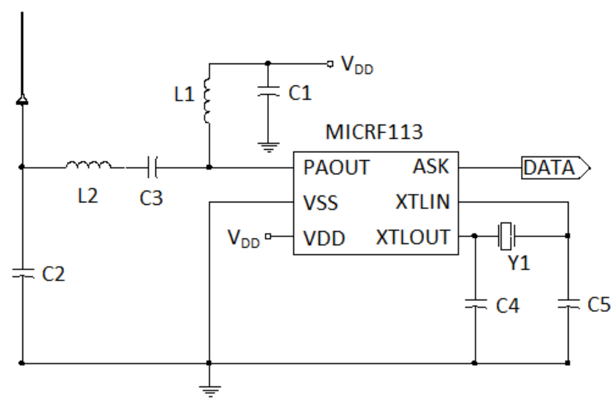

Fig. 5. Emergency Transmission Device (ETD)

The crystal oscillator, Y1, is a reference oscillator with an ESR of 20Ω and is used to tune the transmitter to the desired frequency. The capacitance values of C_4 and C_5 are 18 pF, and the crystal oscillator frequency will be 9.84357 MHz. The function of the PLL × 32 is to provide a stable carrier frequency for transmission. It is a divide by 32 phase locked loop oscillator.

The power amplifier severs two purposes: to buffer the VCO from the external elements and to amplify the signal to the desired level. The series resistor and inductor limiting the power level are omitted in order to obtain maximum power amplification.

The output power of the power amplifier is enabled by supplying the ASK signal with VDD applied continuously. This arrangement uses more power than an alternate arrangement, but since the device is running on vehicle power, this won't be a problem. The enable control gates the ASK data output. It will only allow transmission when the oscillator is phase loop locked and amplitude and under voltage detection conditions are valid. The under voltage detection will block the operating voltage if the operating voltage falls below 1.6 V.

The ETD will transmit at 315 MHz, which is within the Public Safety Pool defined by the FCC [1]. As the name implies, this bandwidth is reserved for public safety uses, for which the E.V.A.D.E. system should qualify. This reduces the possibility of harmful interference compromising the integrity of the transmitted emergency signal.

G. Receiver

The receiver in the EAR is the Micrel MICRF022YM-FS48. When the EAR receives the emergency alert signal, the receiver demodulates the signal and sends it to the RCU. The receiver circuit is shown in Fig. 6.

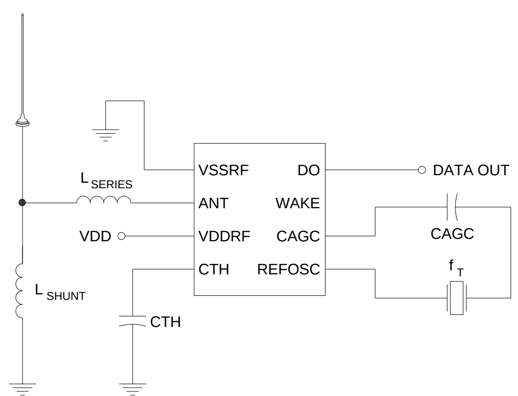

Fig. 6. Receiver

In order for the receiver to properly demodulate the incoming signal, the frequency must be correctly set via the reference oscillator. The following equations were used to determine the reference oscillator frequency.

$$f_{LO} = f_{TX} + (0.86 / 315 \times f_{TX}) \quad (4)$$

$$f_T = f_{LO} / 64.5. \quad (5)$$

In the above equations, f_{LO} is the internal oscillator frequency, f_{TX} is the modulation frequency of the transmitted signal, and f_T is the reference oscillator frequency. The transmitted signal is modulated at 315 MHz, so from (1) and (2), f_T was found to be 4.897 MHz.

In order to determine the value of the C_{TH} capacitor, the data-slicing-level time constant needs to be selected. This selection is strongly dependent on system issues including system decoding response time and data code structure. According to the datasheet, the typical value range for the data-slicing-level time constant is 5 ms to 50 ms. From this range, the datasheet offers an equation to solve for the effective resistance, R_{SC} and C_{TH} at the operating frequency of 315 MHz:

$$R_{SC} = 145\Omega (4.8970 / f_T) \quad (6)$$

$$C_{TH} = 1.05946 \times 10^{-10} / R_{SC.} \quad (7)$$

The appropriate value for C_{TH} for this system was determined to be 0.047 µF.

H. Receiver Control Unit

The Receiver Control Unit receives data from the compass and GPS as well as the bit stream from the receiver. It compares the information to determine the relative position of the emergency vehicle with respect to its own position and sends that information to the RAA and VDU.

Considering the receiving vehicle to be at the origin of a standard Cartesian coordinate system, taking the difference of coordinates should give the location of the emergency vehicle relative to the receiving vehicle in four quadrants. The difference of the receiving vehicle's coordinates minus the emergency vehicles coordinates creates four possible quadrants as shown in Fig. 7. Once the quadrant has been determined, the directional headings of both compasses must be considered in order to determine if it is appropriate to alert the driver.

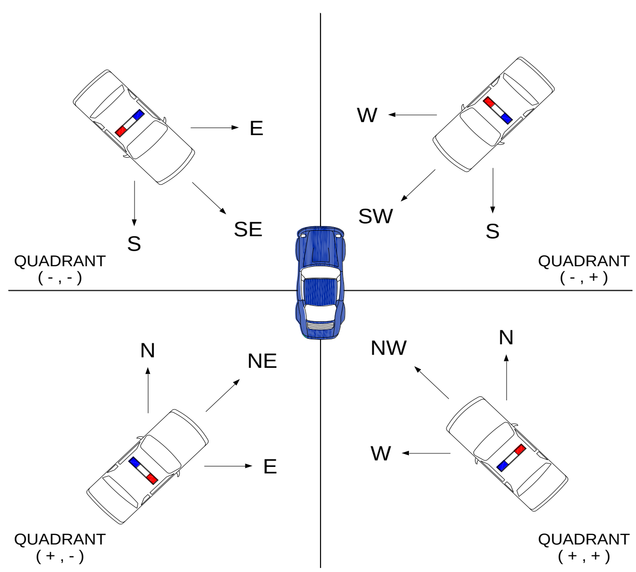

Fig. 7. Calculating Relative Position

The RCU uses the same microcontroller as the TCU. For additional information, see above.

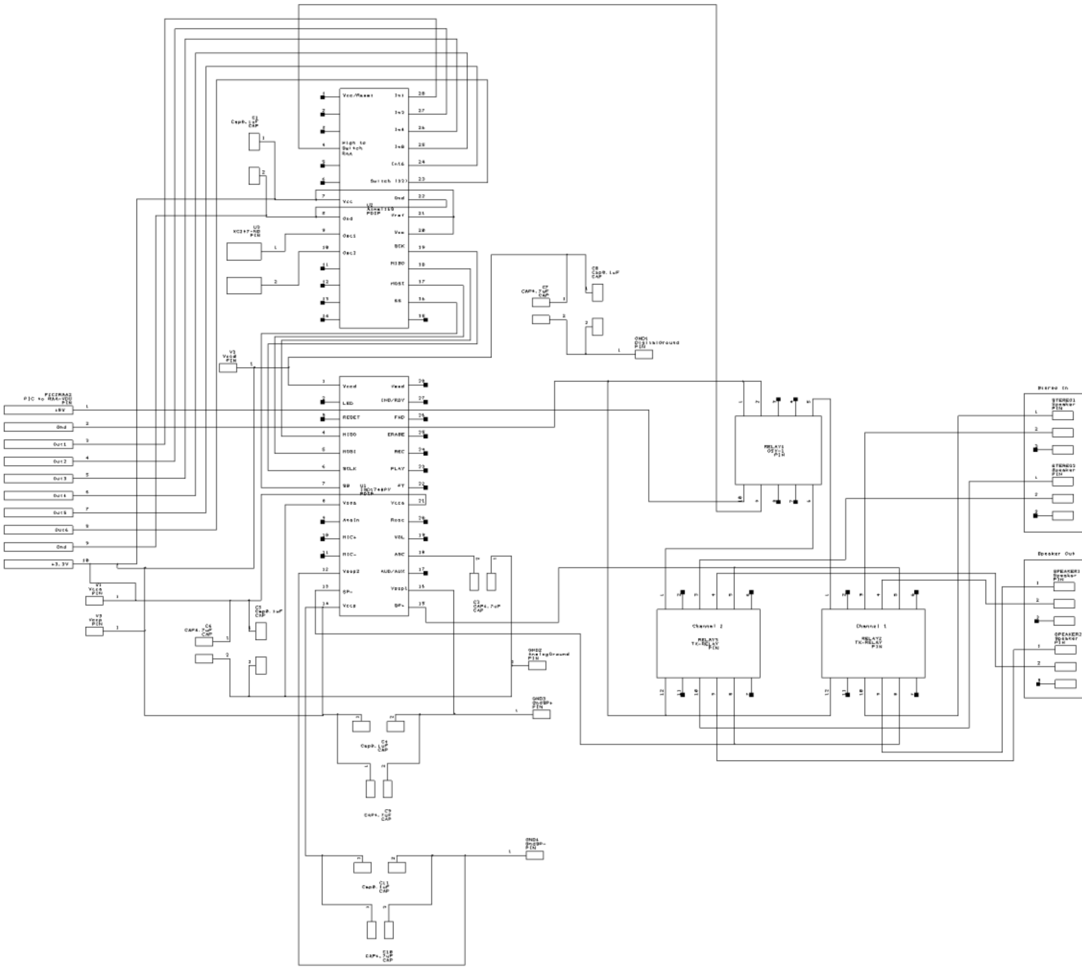

Fig. 8. RAA Schematic

I. Recorded Audible Alert

The Recorded Audible Alert (RAA) module is composed of the Nuvoton ISD1760 ChipCorder and the ATMEL ATmega328 microcontroller. All of the possible alert messages are stored on the ChipCorder in on-chip flash memory. The RAA microcontroller receives the alert information from the RCU and sends a control signal to the ChipCorder, instructing it to play the appropriate audible alert message. That message is sent to the vehicle's speakers via the SBU.

Each message was made in .wav files, including English and Spanish versions. Audio editing software was used to sample a given audio file and produce a binary file of the sampled audio (a type .raw). Once the .raw file of the sampled audio message was created, the file was converted into a text (or .txt) file containing the binary code for the message. All of these files were then saved to the memory of the receiver control unit.

The command allocations in the memory stored the respective message in the memory mapped to each alert direction. After the files were saved in memory and the memory location was correctly mapped as discussed in the design of the receiver control unit, the RCU must simply select the correct message corresponding to the particular emergency situation. The RAA outputs an audio signal that is capable of being played through the vehicle's audio speakers.

J. Switching Bypass Unit

The Switching Bypass Unit is composed of several relays. When no alert message is required, the relays pass the stereo signal (if present) to the vehicle's speakers. When an alert message is required, the relays bypass the stereo signal and allow the alert message to be passed to the vehicle's speakers.

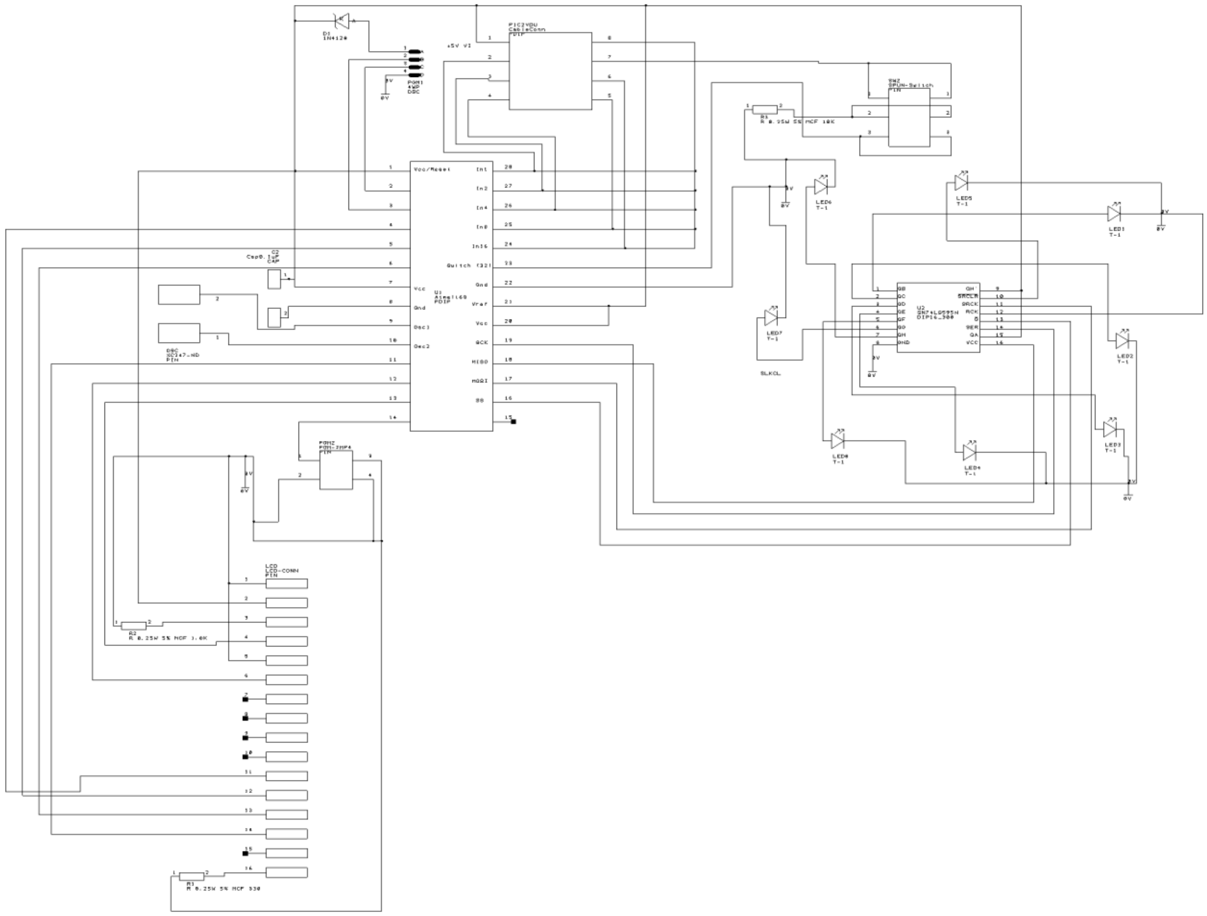

Fig. 9. VDU Schematic

Each speaker requires a dedicated relay. In its current configuration, the E.V.A.D.E. system accommodates only the front two speakers. A production model would require additional relays to bypass the rear speakers. The automotive grade relays chosen for this system require 5V at the relay input in order to activate. However, the PIC microcontroller is only able to supply 3.3V. So the SBU utilizes an additional, control relay. It engages at 3.3V, passing a 5V DC signal to the bypass relays, engaging them and allowing the alert message to pass to the speakers.

K. Visual Display Unit

The Visual Display Unit, shown schematically in Fig. 9, alerts the driver that an emergency vehicle is approaching in two ways. First, an LCD screen will display a preprogrammed message. This message will show "Emergency Vehicle Approaching" and add a fourth line "from front", "from rear", "from left", or "from right". This allows a hearing impaired driver to realize an emergency vehicle is approaching, and from which direction the emergency is coming. Second, a flashing LED around the bezel of the LCD screen will draw attention to the message appearing on the screen, as well as show the direction of the emergency vehicle. The LEDs are arranged to refer to the eight possible directions transmitted by the hall-effect compass (N, S, E, W, NE, NW, SE, SW). Under normal (non-emergency) operation, the display will show the current heading of the vehicle. The VDU bezel with screen is shown in Fig. 10.

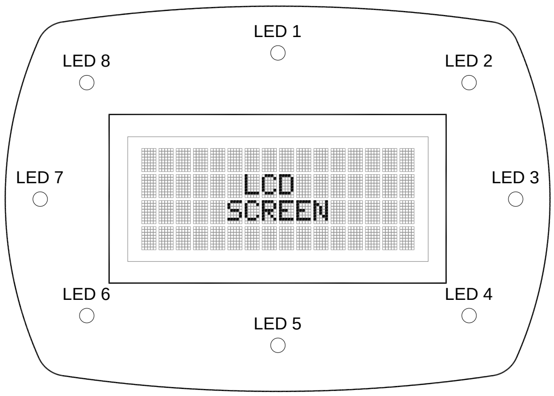

Fig. 10. VDU Screen and Bezel

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BIOGRAPHIES

Joshua Guinn, is studying electrical engineering and will be graduating in Dec 2010. He is planning on pursuing a working career in the electrical engineer profession while continuing his studies toward a master's degree in business administration.

Charles H. Logan, Jr. has worked with AutoCAD at a Mechanical, Electrical, Plumbing and Fire Protection firm for the past 11 years. He has worked through CADD design to CADD Department manager, and is currently doing electrical building design, maintains CADD department manager status, and fulfills 50% of the I.T. responsibilities. Also, he has an extensive knowledge of AutoLISP programming, which enables him to program routines that make the entire staff more productive. He has also taken courses in Basic, VB, VB.net, Java, C, C++, and assembly for both Motorola and Intel. Although he is an Electrical Engineering major, he still enjoys doing some of the coding to create the final outcome for all projects. His history in architecture and drafting also allows him to be a great asset in the physical design aspects of all projects.

Derrick J. Nelson is Marine Corps veteran studying electrical engineering, and will graduate in May 2011 with his Baccalaureate degree. His professional interests lie primarily in the field of power generation and distribution, though he also has interests in alternative energy and the semiconductor industry.

Stephen Watson is a 21 year-old electrical engineering major. He is greatly interested in power systems and will be working on gas turbine control systems for Siemens Energy in Orlando.

REFERENCES

[1] National Archives and Records Administration. "E-code of Federal Regulations". April 29, 2010. May 1, 2010. http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?&c=ecfr&tpl=/ecfrbrowse/Title47/47tab_02.tpl.

[2] Lathi, B.P. and Zhi Ding. *Modern Digital and Analog Communication Systems*, Fourth Edition. New York: Oxford University Press, 2009. Print.

[3] Neamen, Donald. *Microelectronics: Circuit Analysis and Design*, Third Edition. New York: McGraw-Hill, 2007. Print.

[4] KNJN LLC. "LED Displays" & "RS-232". July 8, 2009. May1 2010. http://www.fpga4fun.com/SiteInformation.html

[5] Atmel. "AT40K05AL", "ATK10AL", "AT40K20AL", "AT40K40AL". Copyright 2010. May 1, 2010. http://www.atmel.com/dyn/products/devices.asp?family_id=623

[6] Rensselaer Polytechnic Institute. "Rage Against the AVR -> (Stereo PWM Audio)" Dane Kouttron. May 1, 2010 http://www.rpi.edu/~kouttd/03/Rage_against_the_arduino.html

[7] Micrel. "MICRF112 Data Sheet", "MICRF113 Data Sheet", "MICRF405 Data Sheet". Copyright 2010. May 1, 2010. http://www.micrel.com/page.do?page=product-info/qwikradio.shtml

[8] LUMEX. "LCM-X01604DXX Data Sheet". October 9, 1998. May 1, 2010. http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail&name=67-1761-ND

[9] The Robson Company, Inc. "Dinsmore Sensing Systems General Information" May 1, 2010. http://www.robsonco.com/Dinsmore/Untitled_4.html

[10] Antenova. "GPS Radionova M10214 RF Antenna Module" Copyright 2008. May 1, 2010. http://www.antenova.com/?id=1036

[11] Microchip. "PIC32 Overview Brochure" November 17, 2009 "PIC32MX3XX/4XX Family Data Sheet". April 19, 2010. http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=2591