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Automotive OBDII Simulator

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Automotive OBD-II Simulator

A Major Qualifying Project Report

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Executive Summary

As automobiles have become more complicated, they have included more complicated computer systems to help manage a growing list of functions. Part of that computer system is the diagnostic subsystem that is responsible for monitoring the status of the vehicle's various systems and providing automotive professionals with the information they need to deal with these complex systems. Without a complex diagnostic system, professionals would likely find themselves ill equipped to deal with the growing list of components in the automobile and the ever growing demands of Government regulators to monitor those components. Automotive professionals are thus in need of both the tools to make full use of the diagnostic system and the tools and materials to teach newcomers to the field how to use the diagnostic system.

One set of tools professionals can use are diagnostic scanning and monitoring devices that provide them with human readable translations of the complex codes the system outputs, allowing them to quickly and efficiently diagnose and repair problems. Another set of tools are those that allow those professionals to take on the roll of the engine itself, to simulate scenarios and problems so they can be ready to handle them. The goal of, and any continuation of, this project is to construct such a simulator. Individual goals for the simulator include being cost competitive with other products that provide similar functionality, user friendliness, completeness with regard to the implementation of applicable standards, and simplicity.

The simulator being constructed in this project revolves around an Atmel ATmega168 AVR microcontroller. This microcontroller is an 8bit general purpose microcontroller with 16kB of code memory, three 8-bit general purpose data I/O ports, a 10bit resolution analog to digital converter (ADC), an industry standard serial peripheral interface (SPI), and a 14MHz clock speed. The ATmega168 was chosen for its ease of use, low cost, robust community, and the availability of chips preprogrammed with a bootloader which eliminates the need for an expensive hardware programmer during development. The simulator is rounded out by a Hitachi HD44780U based LCD and a Grayhill 4x4 matrix keypad. The LCD and keypad provide the simple, friendly user interface for the project while the microcontroller handles “everything under the hood.”

This project was successful in meeting a number of the goals set forth including building a simulator device and a simple user-friendly interface. Unfortunately, working with actual automotive systems turned out to be too ambitious for a one student project and the CAN interface was unable to be completed. Furthermore, the availability of information regarding the industry OBD-II diagnostic standard turned out to be very limited, at least in terms of freely available information, which hampered the meeting of some of the project goals. Ultimately, a great deal of work with both the hardware and software of such a simulator was successfully accomplished in what has resulted in an excellent learning opportunity, with many new skills learned and many old ones sharpened.

Abstract

This project aims to create a user-modifiable simulator of the OBD-II diagnostic system of a modern automobile. Such a simulator is designed to help automobile professionals train new employees and to test and calibrate their equipment. The diagnostic system is implemented with the help of an ATmega168 AVR microcontroller. The device includes an LCD screen and input keypad for the end user to modify and verify changes to the diagnostic information.

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1.0 Introduction

As automobiles have become increasingly sophisticated in the past few decades, they have included computer control systems of ever increasing complexity. Almost all modern vehicles contain an on-board computer called the Engine Control Unit (ECU). This computer is paired with an array of subsystems and sensors to allow it to adjust and control a variety of performance parameters, including the amount of fuel to use and ignition timing. The rising complexity of the automobile and the inclusion of complicated embedded computing systems poses further challenges for mechanics and technicians tasked with vehicle repair and maintenance. To aid people who service modern automobiles, the on-board computing and sensing resources were made available to the user via a system called On-Board Diagnostics (OBD).

The current system of On-Board Diagnostics is called OBD-II. OBD-II gives the user access to a variety of sensor values, stored data, and threshold statuses that the ECU keeps track of. The user interfaces with the OBD-II system by using either a stand-alone or PC-integrated diagnostic scanning device, colloquially known as a scan tool. The scan tool helps to simplify basic interaction with an automobile's computer system, but still presents a need for significant training and experience to be an effective aid. The process of training users for all sorts of situations involving on-board computer systems would be unwieldy if actual vehicles that had experienced the desired situation were needed for each such situation. To provide a robust training capability, an additional device, one that can simulate different situations from the perspective of a vehicles on-board computer systems, becomes necessary. The goal of this project is to build a single protocol (CAN Bus) OBD-II simulator that potentially supports all available generic PIDs.

Background information and market analysis of competing products can be found in section 2. High level design, including a block diagram, can be found in section 3. Specific component selections can be found in section 4. Hardware construction and assembly can be found in section 5. Software implementation can be found in section 6. Project results can be found in section 7. Cost analysis can be found in section 8. Recommendations can be found in section 9. The conclusion can be found in section 10. Datasheets, code and other technical details can be found in the bibliography and appendices following the conclusion.

1.1 Objectives

The objectives of this project are to create a microcontroller driven OBD-II simulator device that allows a user to simulate working on an automobile from the perspective of an electronic diagnostic scanner; to provide a visual programming interface that works completely without the aid of a personal computer; to support the full range of OBD-II generic Parameter IDs (PIDs); and to be easy enough to use and affordable enough to be competitive or to at least provide the building blocks to reach that goal if the project continued beyond its known scope.

2.0 Background

OBD-II is the second generation of on board diagnostic systems for use in automobiles. It is an improvement in both its capability and degree of standardization over the previous OBD-I specification. The OBD-II specification defines the connector used for connecting devices to the diagnostic system, the pin functions of that connector, the electrical signaling protocols that can be used, the format of messages sent and received, and a list of generic parameters that a vehicle might monitor.

OBD-II includes five different signaling protocols. SAE J1850 PWM is a pulse-width modulation protocol used primarily in vehicles manufactured by the Ford Motor Company. SAE J1850 VPW is a variable pulse width protocol used primarily by General Motors. ISO 9141-2 is a serial protocol similar to RS-232 that is used primarily in Chrysler, European, and Asian vehicles. ISO 14230 KWP2000 is another serial signaling protocol but is not commonly used. Finally, ISO 15765 CAN is a popular protocol used outside of the United States. All vehicles manufactured in the United States after 2008 are required to support the CAN protocol, effectively reducing the five competing protocols to a single dominant one.

The message format used in OBD-II is based on Parameter IDs (PIDs). A PID identifies a quantifiable property that can be measured and monitored in an automobile and defines how that information is requested and provided. A table of PIDs is shown in Appendix C.

2.1 Market Analysis

Before launching into any venture, an entrepreneur must take a survey of the market landscape in order to determine if and how his services will be of use. The successful entrepreneur is someone who both correctly identifies gaps in a market, where the more urgent needs of consumers are not being satisfied, and makes the correct decisions in order to satisfy those needs. Entrepreneurs that succeed are rewarded with profit and opportunity. Engineers must also look at the status of the market to determine what efforts are worthwhile in undertaking and are not wasteful duplications of what has already been achieved. The engineer also must understand what has come before their efforts, so that they can strive to achieve something novel and useful.

This project strives to construct an easy to use and affordable stand-alone OBD-II simulator. Potential competitive products include other OBD-II simulator class devices, but are not limited only to stand-alone or affordable models. Three different competing products that are representative of potential competition with the objective of this project have been chosen for comparison. They include a feature rich, expensive stand-alone device with the ECUsim 5100 Multiprotocol OBD-II ECU Simulator; a feature light, low cost stand-alone device with the CAN Bus ECU Simulator; and a PC tethered device that is limited only by its software in the Xtreme OBD 2.

2.1.1 ECUsim 5100 Multiprotocol OBD-II ECU Simulator

The ECUsim 5100 is a high end OBD-II simulator that retails for $850 for the base configuration. It supports all five of the OBD-II signaling protocols and can interface with up to three of them at a time using Plug In Modules (PIMs). The unit comes with a single PIM and can be upgraded to two or three PIMs for $150 per additional PIM. The total cost for this product thus ranges from $850 for the base setup to $1,150 for all the bells and whistles. The ECUsim 5100 supports all OBD-II modes except for oxygen sensor monitoring, and supports all fixed and user adjustable Parameter IDs (PIDs). The ECUsim represents the all inclusive, high end product in the OBD-II simulator market.

Figure 1: ECUsim 5100

2.1.2 CAN Bus ECU Simulator

The CAN Bus ECU Simulator is the CAN Bus protocol version of a set of simulators, each tailored specifically for one of the OBD-II signaling protocols. This product retails for $250. The CAN Bus ECU Simulator and all of its corresponding products only support and target a single OBD-II protocol. Use with multiple protocols would require purchasing multiple devices. The CAN Bus ECU simulator supports a small subset of the available modes and PIDs that the OBD-II specification defines. The modes and PIDs supported represent the most commonly used ones, including thirty-nine fixed-value PIDs and five user adjustable ones. The CAN Bus ECU Simulator represents the low cost, limited capability product in the OBD-II simulator market.

Figure 2: CAN Bus ECU Simulator

2.1.3 Xtreme OBD 2

The Xtreme OBD 2 was a software based OBD-II simulator that required a direct connection to a PC to be used. It retailed for $169 at the time this market research was conducted. This product is no longer available. This product was potentially removed from the market for legal reasons, as it was capable of easily simulating proprietary automotive technology. This product will no longer be regarded as a competitor, but will remain in the report as lessons can still be drawn from it.

The goal of this project is to build a single protocol (CAN Bus) OBD-II simulator that potentially supports all available generic PIDs. Based on that goal, this project is similar to the CAN Bus ECU simulator in protocol limitations, but aims to exceed it in functionality and ease of use. Compared to the ECUsim 5100, this project aims to provide a reduced level of functionality in all areas, but combined with an easier to use interface. Based on the current market for OBD-II simulators, it is reasonable to place a product based on the goals of this project somewhere above the $250 price range of the CAN Bus ECU Simulator, but below the $850 price range of the ECUsim 5100. Something in the $400-500 may be appropriate for a finished and marketable product.

3.0 High Level Design

Recall from the objectives that the aim of this project is to create a microcontroller driven OBD-II simulator that interfaces with a diagnostic tool and provides a stand-alone user interface. Based on these objectives, the general criteria for the hardware of this project and the definition of functional blocks can be made. This project must include three major component blocks: input, output, and processing. The input block must include sub-blocks for an LCD display, keypad, and power. The output block must include a CAN bus system. The processing block must include a microcontroller. Figure 3 shows the block diagram for this project.

3.1 Block Diagram

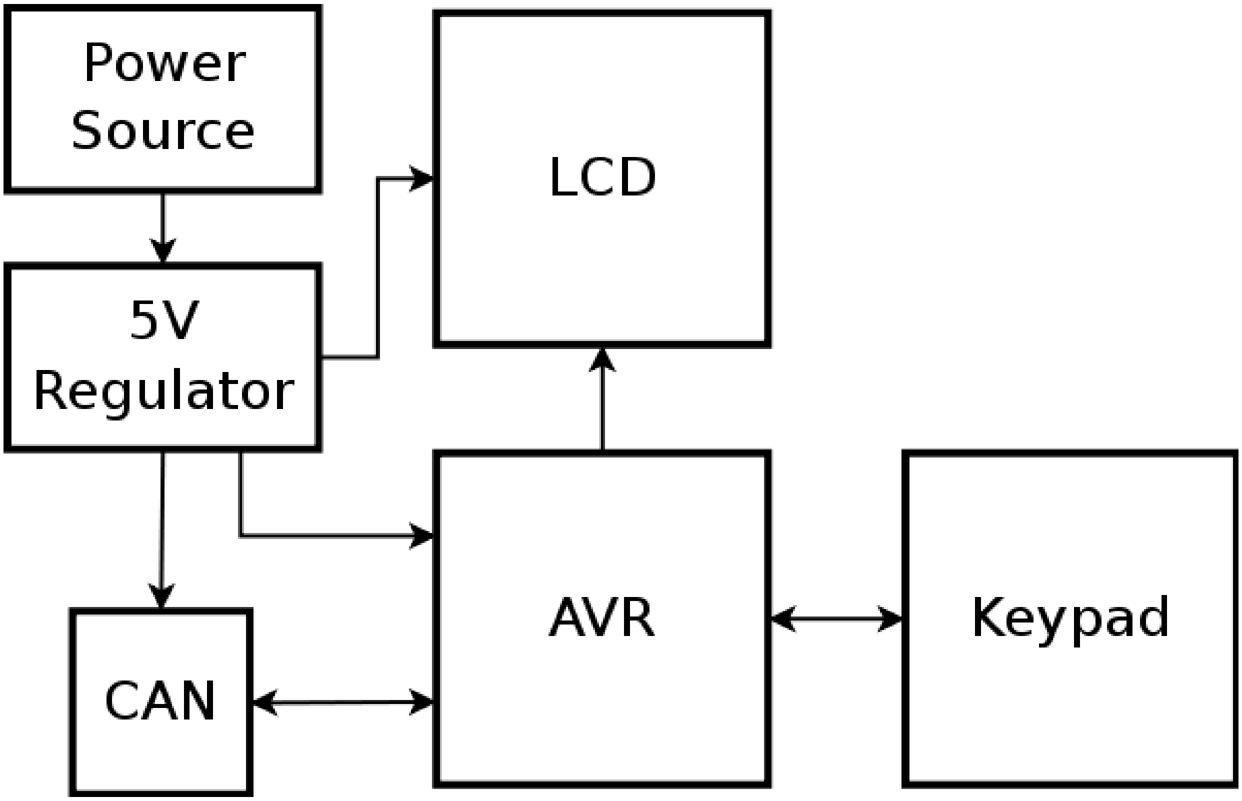


Figure 3: Block Diagram

3.2 Software and Hardware requirements

As with any computing device, there are two facets to the design. In one hand lies the physical hardware and in other the software that makes the hardware run. Each facet must be adequately planned for to effectively design and build any computer system. In the following sections the basic requirements for each area of the project will be laid out. Each requirement refers to both hardware and software, as they must act together to provide the required functionality.

3.2.1 Input

The OBD-II simulator must provide a basic power switch to allow the user to turn the device on and off. The device must also provide a user interface, which includes an LCD and keypad. The LCD, while technically being an output component, is a part of the user input functionality and is thus included in the input definition. The keypad allows the user to easily navigate various informative and interactive screens that will be displayed on the LCD, as well as to enter data for programming the various PIDs.

3.2.2 Output

The output section includes only the CAN BUS interface hardware since the LCD has been defined as part of the input. The purpose of the CAN BUS hardware is to provide an interface with a CAN network, which is commonly used by automobiles for communication between various subsystems and is also used by diagnostic devices to communicate with those same automobile systems and subsystems.

3.2.3 Processing

The processing section includes the microcontroller. The microcontroller handles two distinct tasks. The first to to tie everything, all of the inputs and outputs, together into a cohesive unit. The second is to provide a program platform with which to create the bulk functionality of this project.

3.2.4 Power

The final element of this device is its power supply. The power section is responsible for providing each other element with the electricity necessary for them to operate. All of the digital components in this project require a 5V power supply, which makes the power element fairly simple. A 12V power supply may also be necessary depending on the diagnostic tools used, but is not required.

4.0 Component Selection

Once the basic requirements for the hardware has been laid out, we can turn to the search for specific components to meet those requirements. The search begins by laying out specific criteria for each of the hardware requirements that need to be met. Once the criteria for each component is determined, components that best match those criteria can be selected.

4.1 Criteria

The hardware components for this project include a keypad, LCD screen, CAN interface, microcontroller, and power system. Each component has a corresponding set of criteria that must be met by whatever parts are ultimately purchased. Those criteria are described in detail in the following sections.

4.1.1 Keypad

Keypads are fairly standard components, with few variations between the different models that have any bearing on this project. The primary criterion that has to be considered is simply how many buttons are needed on the keypad. Keypads are wired into a matrix of rows and columns, thus each row and column a keypad has constitutes an I/O line that will have to be connected to the microcontroller. A keypad with a larger number of buttons, and thus columns and/or rows, will require more microcontroller I/O real estate, and will likely come at a cost premium. On the other hand, since keypads are connected by column and row directly, any keypad can be used as a keypad with fewer buttons by merely not connecting one or more of the rows and/or columns. In that way, a more functional keypad is also more versatile.

This project requires at the very least the ability to input numeric data, and at least two other buttons for other functions, including acknowledgment and input clearing.

4.1.2 LCD

LCDs typically come in two flavors, character and pixel based displays. Obviously all LCDs are based on pixels, but the two flavors differ in how the user interacts with them. A character LCD has a set number of character rows and columns and usually includes some internal font table. The user sends commands to the LCD telling it to display a certain character; how that is accomplished in terms of the screen's pixels is handled by the LCD itself. Pixel LCDs expose the full pixel array to the user. A pixel LCD requires the user to send it a data array specifically indicating whether each pixel is on or off. A pixel LCD is more versatile, able to display virtually anything imaginable. A character LCD is far more limited in capability, but is much easier to use, as it does not require arduously programming code for displaying characters on the pixel display.

This project does not require the use of images or graphics on the LCD display; it only needs to display characters.

4.1.3 CAN

There are two ways to provide CAN BUS access to a microcontroller project. The first is to use a microcontroller that has a CAN interface built in, usually an automotive variant. The second is to use an external CAN controller chip. Using a microcontroller with built in CAN functionality is easier, but increases the cost of the microcontroller and is usually provided at the expense of other features, reducing the versatility of that microcontroller. Using an external chip via the Serial Peripheral Interface (SPI) is more complicated both in hardware and software, but allows the use of a generic microcontroller that includes additional functionality (such as an SPI interface) and leaves more I/O pins open for other components.

This project requires a large number of microcontroller I/O pins, thus solutions that provide more versatility in hardware layouts are preferred.

4.1.4 Microcontroller

Unlike the other components, microcontrollers are not easily divided into a small number of categories; there are many different companies building microcontrollers based on many different architectures. Even within a single company and a single architecture, there are often dozens of choices that vary in features.

This project calls for a microcontroller that has a number of specific features. The microcontroller must come in a DIP package so that it can be used with a solderless breadboard. It must have as many I/O pins as possible. Those

I/O pins must include a large number of general purpose I/O pins and an SPI interface. It must be easily programmable without having to invest in expensive programming hardware. The microcontroller must be well known and used so that it will have a robust user community from which to draw support.

4.1.5 Power Source

All of the digital components of this project will need a steady 5V supply. There is the potential for a 12V supply to be used in order to provide a simulated car battery source to a diagnostic tool that cannot power itself. Thus this project should be able to handle a variety of power input scenarios, including battery power for mobility and ease of use in development, and a grid based 12V supply for full functionality.

4.1.6 Voltage Regulator

Providing a steady 5V power source is easily accomplished with a voltage regulator. The regulator for this project must provide a 5V output and accept at least up to 12V of input.

4.2 Hardware Choices

After the specific criteria for each hardware component are determined, real parts can be matched up to those criteria. The following sections identify the specific component selections that were chosen to meet the criteria laid out in the previous sections. Datasheets for these components can be found in the bibliography.

4.2.1 Keypad

For the keypad it was decided that selecting a more versatile 4x4, 16 key model was the right choice. A 4x4 keypad provides 16 buttons with 4 row and 4 column pins for a total of 8 I/O pins needed. It can, however, be configured to use fewer buttons by simply not using one or more of the row and/or column pins. For example, if we choose to only use three of the four available columns, we essentially have a 3x4 'telephone' keypad in terms of functionality. The 4x4 model can act as a 12 button 3x4 model and is also expandable to a full 16 buttons, resources permitting. A Grayhill Series 96 4x4 16 button non-backlit keypad was purchased from Digikey to meet this component requirement; these have a unit cost of $14.30.

Figure 4: Grayhill Series 96 4x4 Keypad

4.2.2 LCD

A character LCD display was chosen as more appropriate for this project over a pixel display. Character LCD displays come in flavors that usually differ in how many rows and columns they provide. The maximum size that is typically available is 80 characters in either a 2x40 or a 4x20 row and column configuration. It was decided that a 4x20 character display would best suit this project by providing both the maximum number of characters available in displays of this sort, 80, and also providing the versatility of four rows. To satisfy this requirement a Hitachi HD44780U based 4x20 80 character display was chosen. This display can be purchased individually for $15, but was purchased as part of a microcontroller kit from Nerdkits Inc. for a kit cost of $80.

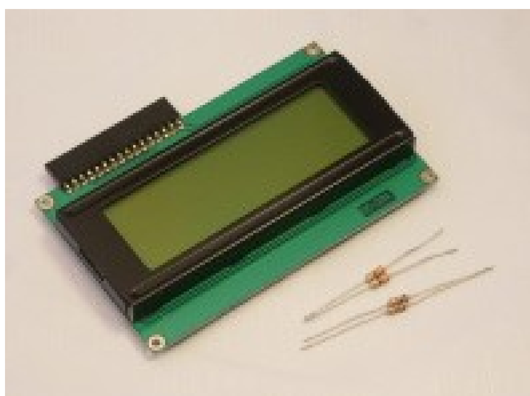


Figure 5: HD44780 Based LCD

4.2.3 CAN

In order to ensure that the maximum number of I/O pins were available for other functions, it was decided that an external CAN controller should be used instead of purchasing a microcontroller with built in CAN functionality. The CAN controller must interface with the microcontroller via the SPI. The Microchip

MCP2515 was originally purchased for this purpose at a cost of $1.98 from Digikey, but it turned out that this part alone was not sufficient to provide a CAN interface for the project. A complete CAN to SPI adapter was purchased from mikroElektronica for $25 to provide a CAN interface for this project instead. This complete adapter includes a Microchip MCP2515 in addition to a CAN BUS driver and a dedicated oscillator required by the MCP2515.

Figure 6: CANSPI Development Board

4.2.4 Microcontroller

Finding a specific microcontroller for this project was particularly difficult given the endless choices and options available. The Atmel ATmega168 was chosen. The ATmeg168 is a rather large DIP packaged chip with a full 28 pins, including 23 for various I/O purposes. The ATmega168 is one of Atmel's popular AVR class of microcontrollers and thus has a robust hobby and support community available online. This chip supports the SPI interface necessary to connect the CAN adapter and has about as many I/O pins as needed. The ATmega168 can be purchased separately for $2.78 from Digikey but was purchased as part of a microcontroller kit from Nerdkits Inc. for a kit cost of $80.

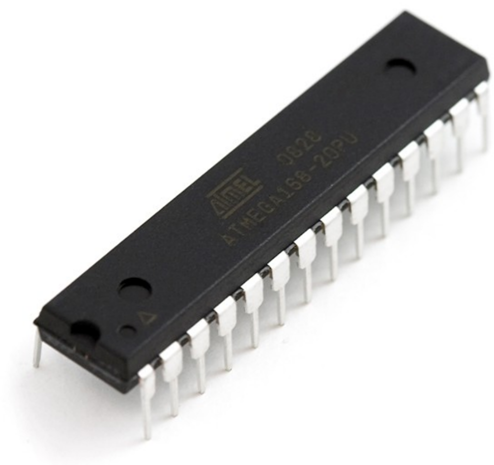


Figure 7: ATmega168 Microcontroller

4.2.5 Power

Power is provided by an L7805 voltage regulator, which receives input from a standard 9V battery. The L7805 can be purchased from Digikey for under $1, but was included with the microcontroller kit from Nerdkits Inc.

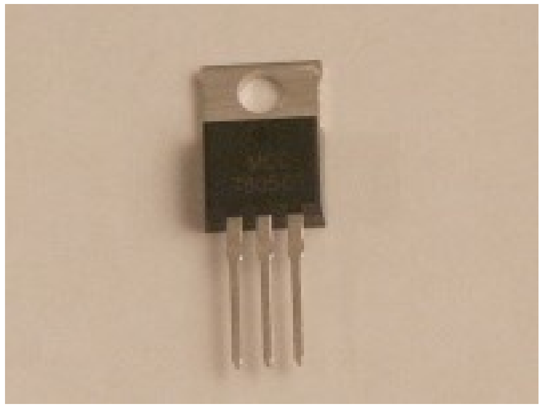


Figure 8: L7805 Voltage Regulator

5.0 Hardware Construction

The construction of all of the hardware that was purchased must be done in a particular order to make verification of operation easier. The microcontroller and power elements must come first, as they are the heart of the system. The LCD should logically follow as it provides an excellent way to easily test all of the other hardware by providing visual responses to stimuli. All other components should then follow. The details of how each component is assembled and integrated with the system are included in the following section.

5.1 Microcontroller

The microcontroller is an Atmel ATmega168, a part of their AVR line of products. The version being used for this project is a 28pin DIP package for usage in a solderless breadboard development environment. The ATmega168 includes 23 pins of I/O space, of which two are required for an external oscillator to drive the chip's clock signal. A 14.7465MHz crystal is being used in this project, running the microcontroller at the same frequency. The pin definitions of the ATmega168 are shown in Figure 9. The crystal is connected to pins 9 (TOSC1) and 10 (TOSC2) of the microcontroller. Pin 7 (VCC) is connected to the +5V rail and provides the microcontroller with the power needed for its operation. Separate voltage sources exist to power and reference the analog to digital converter (ADC) present on the chip on pins 20 (AVCC) and 21 (AREF) respectively. Since the ADC is not being used for this project, both pins are simply connected to the +5V rail. Pins 8 (GND) and 22 (GND) are the ground pins for the chip and the ADC and are both connected to the ground rail. Pin 1 (RESET) is the reset pin and will trigger a reset of the microcontroller when held low for a sufficiently long time. A power cycle was found to provide a sufficient reset capability for this project. The reset pin is held high by connecting it directly to the +5V rail. The remaining 20 I/O pins are available for other functions, as shown in the following sections.

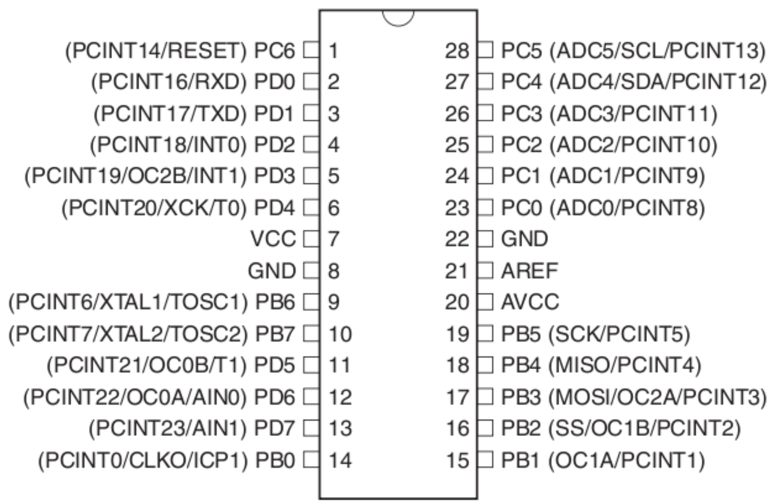


Figure 9: ATmega168 Diagram

5.2 LCD

The LCD is a Hitachi HD44780U based four row by twenty column (4x20) 80 character display. The LCD has 16 I/O pins that are used to support its various capabilities; including data transmission, contrast adjustment, and backlight illumination. Table 1 includes the pin definitions for the LCD. Pins 1 (GND) and 2

(VCC) connect to the ground and +5V rails respectively, providing power for the LCD circuitry. Pin 3 (Contrast) is the contrast control pin. Contrast is controlled by varying the resistance present between pin 3 and ground. A potentiometer can be used to provide adjustable contrast, but this project does not require adjustable contrast and thus a simple 1kΩ resistor is used to set a static contrast level. Pin 4 (Data/Command) is the data mode indicator pin and is connected to pin 13 (PD7) of the microcontroller. When pin 4 is set high, the LCD will interpret incoming data as being information to display and when it is set low, the LCD will interpret incoming data as being commands for the LCD to process. Pin 5 (GND) is another ground connection and is connected to the ground rail. Pin 6 (Data Ready) tells the LCD when a new nibble or byte of data is ready to be read from the data bus and is connected to pin 12 (PD6) of the microcontroller. When pin 6 is driven high, the LCD will automatically read all data present on the data bus. Pins 7-10 are the lower four bits of the LCD's 8bit data bus and are unused in this project. Pins 11-14 are the upper four bits of the LCD's 8 bit data bus and are connected to microcontroller pins 4 (PD2), 5 (PD3), 6 (PD4), and 11 (PD5) respectively. This LCD can be operated in either 4bit mode or 8 bit mode. In 8bit mode the LCD reads and writes a full byte of data at a time, and in 4bit mode it must read or write two sets of 4bits (a nibble) to achieve the same result. The advantage of 4bit mode is an I/O savings of 4 pins on the microcontroller, and as microcontroller I/O pins are scarce for this project, 4bit mode is the preferred method of operation. Pins 15 (BL VCC) and 16 (BL GND) are the backlight power and ground pins, respectively.

Pin #	Function
1	GND
2	VCC
3	Contrast
4	Data/Command
5	GND
6	Data Ready
7	DATA
8	DATA
9	DATA
10	DATA
11	DATA
12	DATA
13	DATA
14	DATA
15	Backlight VCC
16	Backlight GND

Table 1: LCD Pinout

5.3 Keypad

The keypad is a Grayhill Series 96, 16 button 4x4 non-backlit pad. The rows and columns of the keypad form a wire matrix that enables us to determine which button or buttons are being pressed, as shown in Figure 10. The keypad has 8 pins, 4 corresponding to each row, and 4 corresponding to each column. Keypad pins 1-4 correspond to the rows, starting from the top, and pins 5-8 correspond to the columns, starting on the left. When a button is pressed, it creates a connection between the row and column wires that meet at that button. For example, if the first button is pressed, the first row becomes electrically connected to the first column, connecting pins 1 and 5 together. Thus, if we drive a signal down the first column on pin 5, we can detect if button

1 has been pressed by monitoring the level of pin 1. For this project, due to an insufficient number of I/O pins on the microcontroller, the keypad is used in 3x4 mode by simply not connecting the fourth column. Pins 5-7, corresponding to columns 1-3, are connected to pins 26 (PC3), 27 (PC4), and 28 (PC5) of the microcontroller respectively. Pins 1-4, corresponding to rows 1-4, are connected to pins 15 (PB1), 23 (PC0), 24 (PC1), and 25 (PC2) respectively.

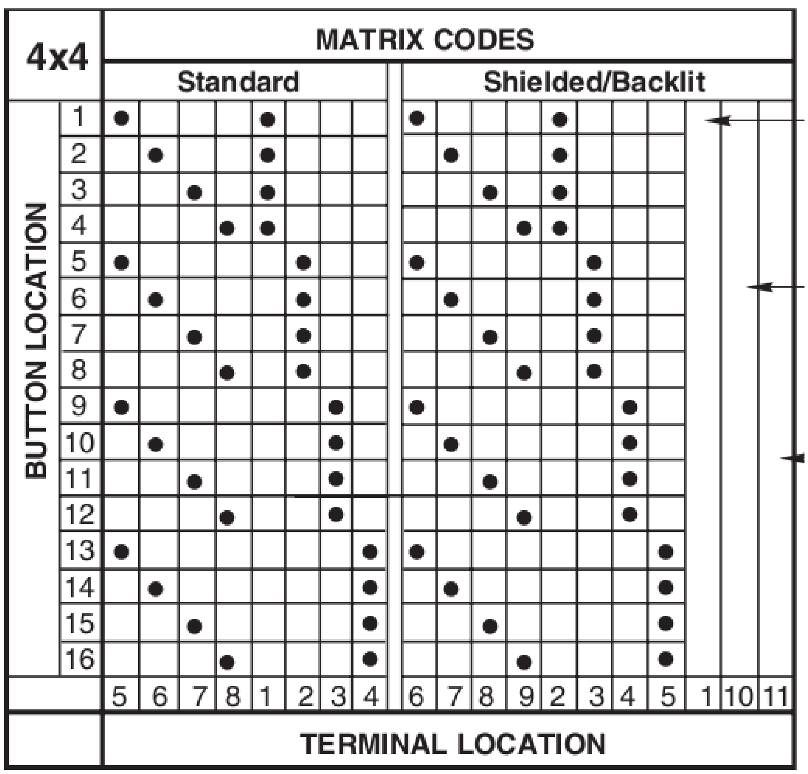


Figure 10: Keypad Codes

5.4 Power

As mentioned before, all of the digital components in this project require a +5V source to operate. To provide a steady +5V supply, a standard L7805 voltage regulator is being used. This regulator provides a 5V output given an input between about 8V and 35V. For prototype purposes, the input power to the voltage regulator is being provided by a standard 9V battery, but a final version would be expected to use a 12V DC wall supply.

5.5 Programming Cable and Switch

The biggest advantage to purchasing the microcontroller kit is that the ATmega168 that comes with the kit is pre-flashed with a bootloader and thus does not require an expensive programming unit to make it usable. All that is required to load code onto the chip is a special USB cable provided with the kit. This cable contains an internal USB to serial adapter that enables any USB capable computer to connect to the microcontroller. The cable has four leads, two data leads and two power leads. The two data leads are connected to pins 2 (RXD) and 3 (TXD) of the microcontroller. The power leads source power from the USB hub of a computer and are not connected, except for the ground lead. The USB cable can be used to provide the +5V source necessary for this project, but it would only be useful during development and loses in versatility compared with the 9V battery.

5.6 CAN-SPI

The CAN Bus interface being used is a packaged solution from mikroElektronica. This package combines the Microchip MCP2515 CAN controller with a CAN Bus driver chip and a crystal oscillator necessary for a complete CAN to microcontroller communication device. Unfortunately mikroElektronica changed the model of this device shortly after purchase and the original schematics are no longer available. It was not possible to discern the pin associations of the 10pin header that is used on the device, thus it could not be connected to the project.

6.0 Software Implementation

The programming for this project is divided into several parts. All of the code is written in C and is compiled for the microcontroller using an AVR specific build of the GNU C Compiler (GCC). All development is done on a PC running a distribution of the GNU/Linux Operating System (OS), Arch Linux. The main program, which includes all OBD-II PID functionality and everything the user sees on the screen, lies in the main C file and is executed in the main loop. The other major code portions are implemented as separate libraries and include all functions for using and interacting with the LCD and the keypad. Source code for this section can be found in Appendix B. This section will discuss how various functionalities are implemented, but will not include verbose code declarations.

6.1 Subcomponents

Each subcomponent library is a collection of functions that make using the associated hardware easier. Once some common function has been achieved, packaging it up for easy use in the future is a standard programming practice and allows large, complex problems to be solved incrementally. Each library includes an initialization function that sets up the hardware, readying it for use, and other functions that abstract the difficulties of the hardware away. Each initialization function must perform two tasks; the first is to setup the I/O pins and parameters on the microcontroller to correctly interface with the peripheral, and the second is to send the relevant commands to the peripheral to bring it into a usable state.

6.1.1 LCD

As indicated in the hardware section, the LCD is connected to the microcontroller using microcontroller pins PD2 through PD7, which are the top six of eight total pins assigned to the microcontroller's PORT D 8bit I/O port. The LCD is always a data sink and never a source, that is, we are always sending information to it and never reading information from it. This means that all of the pins that interface with the LCD will need to be set as output pins. Setting pins PD2 through PD7 to output is accomplished by setting the corresponding bits in the PORT D data direction register, DDRD, to high. To set DDRD to high for the bits we want, and leave the other bits alone, we perform a bit-wise OR operation of the register with 0xfc (1111 1100) which will change bits 2-7 to 1 regardless of their current state and will leave the current state of bits 0 and 1 alone. Once the microcontroller pins are setup for the right direction, we can write data directly to the LCD. Initialization continues by switching into command mode (more on that in the next section) and sending the appropriate codes to enable the LCD and configure it for 4bit operation, setup the font size (5x8 pixels in our case), and set the cursor.

In addition to the initialization function, there are a number of other useful functions for dealing with the LCD. The LCD operates in one of two modes, command and data. In command mode the LCD treats all data it receives on the data bus as a command code and performs the associated function. In data mode the LCD treats all data it receives on the data bus as a character code, and displays it at the current cursor position. We need to be able to switch into either mode and as the mode is determined by the status of a single pin, setting microcontroller pin PD7 high or low puts the LCD in data or command mode respectively.

As mentioned before, the LCD is being used in 4bit mode to save I/O pin space on the microcontroller, which means we need functions that make it easy to write full bytes. Writing a byte is as simple as writing two 4bit nibbles in succession. First the high nibble (bits 7 through 4) is placed on the data bus, then the data ready pin of the LCD is driven high by setting microcontroller pin PD6 high, which tells the LCD that data is ready to be read and causes the LCD to store the nibble and wait for a complete byte to be sent. The data ready pin is then returned low, the lower nibble is placed on the data bus, and the data ready pin cycle is repeated. Once the LCD has a full byte, it handles it appropriately.

Other useful features for the LCD include string and character writing functions. To write a character to the LCD, the LCD needs to be placed into data mode and a byte code corresponding to a character in the font table, which corresponds to ASCII for most basic characters, needs to be written to the LCD. The character will appear at the current cursor location and the cursor location will be automatically incremented. To write multiple characters, representing a string, each character of the string is simply written one at a time, the auto-incrementing feature of the LCD makes string writing seamless.

Being able to write arbitrary characters and strings anywhere on the screen easily is the ultimate goal of the LCD programming. The final feature then, must be functions to handle the location of the cursor. The cursor can be moved to any position on the screen by entering command mode and issuing the cursor position command, 0x80, bit-wise OR'd with the new location desired. This can be packaged into a row function that sets the cursor at the start of a given LCD row and allows easy setting of the desired LCD row. By breaking the LCD programmatically into rows, the LCD is broken up into four distinct areas, allowing four pieces of information to be displayed at once. The LCD character positions pose a bit of challenge, however, as they are not implemented in serial order. Each character space follows a somewhat orderly and somewhat random arrangement that is shown in Table 2 below. With the given functions, it is possible to write any character or string to any position on the LCD desired, thus full functionality is achieved.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103

Table 2: LCD Character Position Map

6.1.2 Keypad

The keypad is connected to the microcontroller using pins PC0 through PC5 and also PB1. However, unlike the LCD, the keypad requires both the reading and writing of data. The basic operation of the keypad is fairly simple.

For example a column is driven low and checked to see which rows have been pulled low. A low-pulled row indicates that that row has been electrically connected to the driven column, revealing exactly which button has been pressed. Initially, the keypad's microcontroller ports have to be configured. Microcontroller ports PC3 through PC5 are set as outputs in the same fashion as described with the LCD, the corresponding register will have those bits set high. These pins are connected to the three usable columns of the keypad. Microcontroller ports PB1 and PC0 through PC2 are connected to the four rows of the keypad and their direction registers are set low for those bits to indicate that they are inputs.

The full functionality of the keypad includes being able to discern which key is being pressed when a key is pressed. To start off, the first column of the keypad, PC3, is driven low by writing a zero to bit 3 of PORT C. The values present on all four of the rows are read in. If any of the rows read as set, then the function returns the value of the button detected, if no buttons are detected, then the next column is driven and the process is repeated for all columns. The keypad code checks for button presses many times a second, and will not register a press unless it has detected a sufficient number of non-presses. This extra feature sufficiently protects against a phenomenon known as bounce that causes a button press to be registered many times due to the physical bouncing of the button.

6.2 Main Program

The main program leverages the LCD and keypad and implements the full functionality of the OBD-II simulator. The program begins by initializing the LCD and keypad, making them both available for use. It continues by setting up all of the variables that are needed, including the default values for the stored OBD-II Parameter IDs (PIDs). The first part of the program the user will see then follows, a display of the start up and welcome screen. The welcome screen prompts the user the press the '#' key on the keypad to begin. Once this button is pressed, the program enters into listening mode. The OBD-II simulator has two primary functions from the perspective of a user. First, it operates in a listening mode, waiting for an external diagnostic device to send a request for information to which it may reply. Second, it provides a programming interface by which a user may change the values of any of the parameters the simulator supports.

The program operates as a loop that is constantly checking for incoming information from the SPI connected CAN controller. If information is detected, the program determines which PID is being requested and returns the information or a not implemented code if the requested PID is either not implemented or not valid. Once the PID request has been handled, the program continues listening for additional requests. If at any time the user presses the '#' button, the program leaves listening mode and enters programming mode.

In programming mode, the user is able to modify the stored values of each PID, changing how the simulator will respond to a request for those PIDs. When programming mode is activated, each PID is displayed individually. The top line of the LCD displays the name of the parameter being modified, the second line displays the range of values which are valid for that parameter, the third line shows the current value, and the last line is an input field that shows the user what they've entered in on the keypad so far. Pressing any numeral on the keypad results in that number being appended onto the input field. Pressing '*' clears the input field, allowing the user to correct mistakes. Pressing '#' saves the new value and moves on to the next PID. If nothing is entered, or if everything in cleared, and then the '#' key is pressed, no new value is stored and the previous value is retained. Once every PID has been confirmed, the simulator enters listening mode with the new values.

7.0 Project Results

Below the full schematic and image of the final project result can be found:

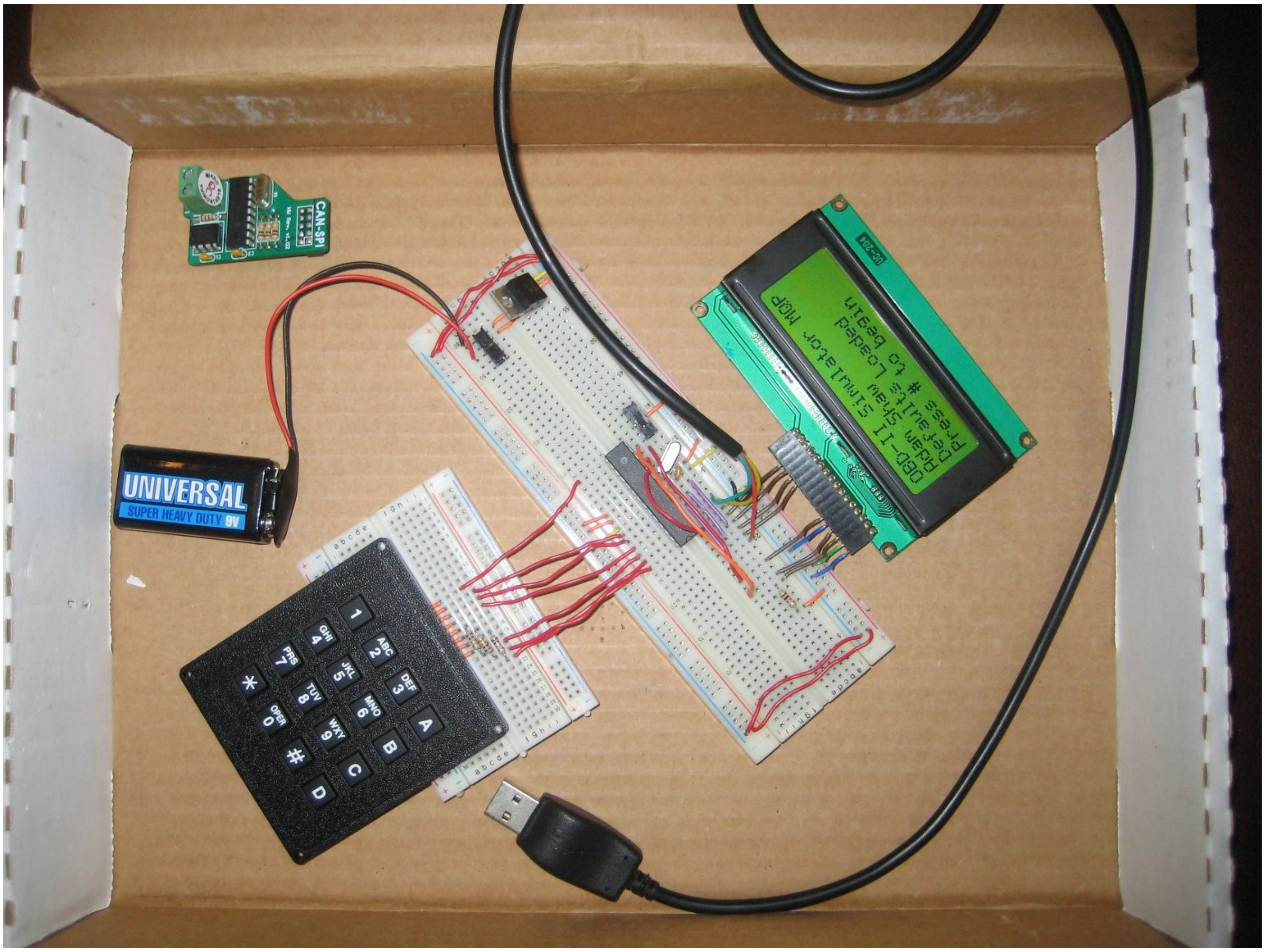


Figure 11: Project Photograph

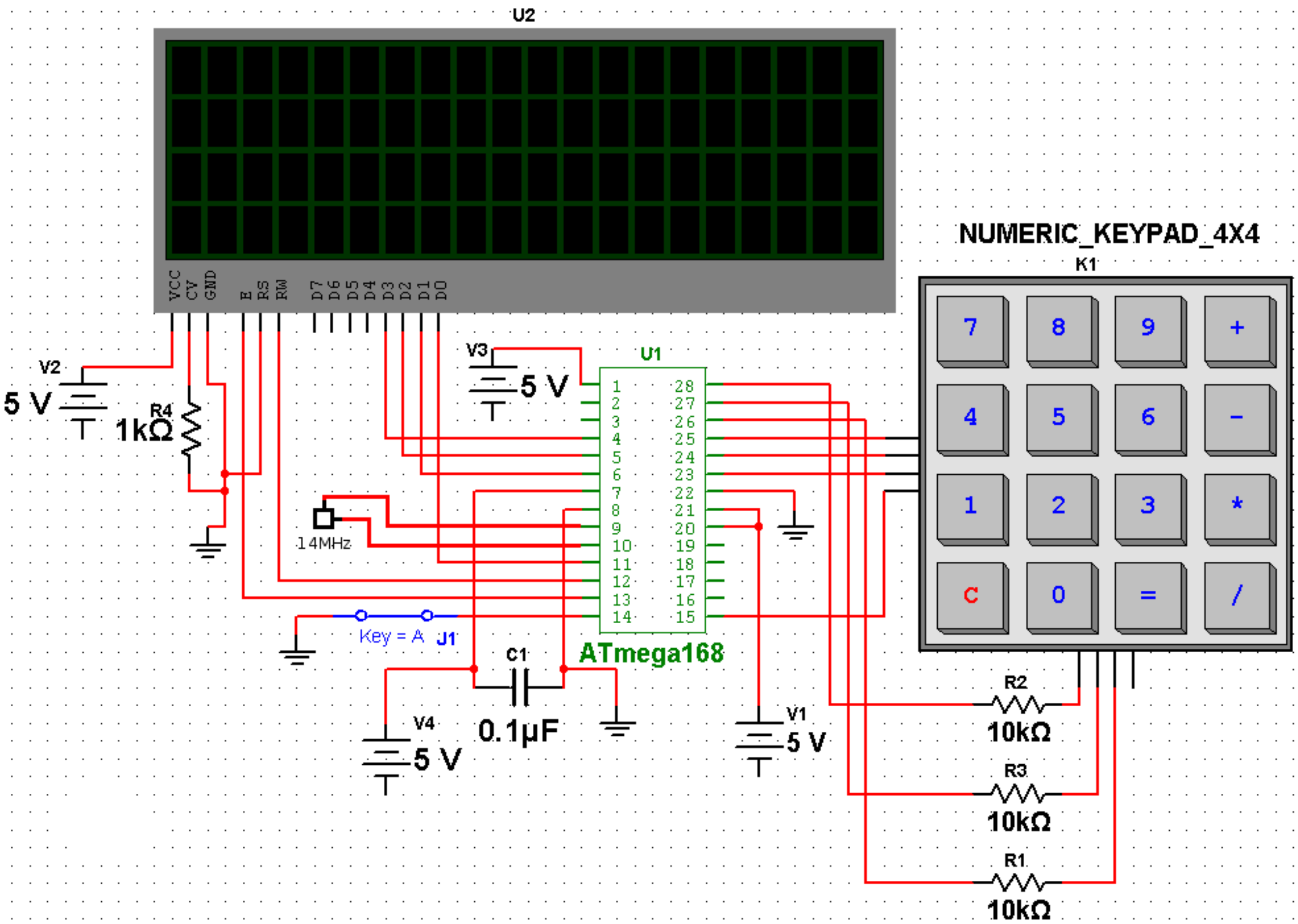


Figure 12: Final Schematic

8.0 Cost Analysis

Part	Quantity	Unit Price	Total	1000ct Price	Total
ATmega168 AVR Microcontroller	1	$4.43	$4.43	$2.51	$2,510.00
HD44780U based LCD	1	$15.00	$15.00	$15.00	$15,000.00
Grayhill 96 Series 4x4 keypad	1	$14.34	$14.34	$7.74	$7,740.00
Mikroe CANSPI board	1	$25.00	$25.00	$25.00	$25,000.00
10k 1/4W Resistor	3	$0.08	$0.24	$0.02	$20.00
14.74MHz Crystal Oscillator	1	$0.40	$0.40	$0.26	$260.00
L7805 Voltage Regulator	1	$0.60	$0.60	$0.21	$210.00
0.1 µF Capacitor	1	$0.24	$0.24	$0.07	$70.00
SPDT Switch	2	$0.50	$1.00	$0.50	$500.00
9V Battery	1	$2.37	$2.37	$0.95	$950.00
TOTAL			$63.62	$52.26	$52,260.00

Table 3: Cost Analysis

The total cost of buying all of the parts used individually comes to $63.62, and buying those same parts in quantities of a thousand brings the unit price down to about $52.26, or $11.36 less than the singular cost. These prices are for purchasing the parts separately instead of in a kit as was done here. This cost comes in well below the nearest competitor's $250 price and leaves a large margin for both profit and further development needed to make this project marketable. Even if we assume that the unit cost for thousand quantities was to rise to $150, the product could still be sold competitively at $200 for a profit of $50,000 per thousand.

9.0 Recommendations

As this project was unsuccessful in meeting all of the original objectives, the primary recommendation to any future effort is to complete those objectives. The ATmega168 microcontroller turned out to be ill-suited for this project in its stock configuration due to its lack of I/O pins. Future efforts should consider either using a microcontroller with more I/O space, or looking into methods of expanding the I/O space of a DIP AVR microcontroller such as the ATmega168. Automotive versions of the AVR line of microcontrollers exist that include a CAN interface. Those microcontrollers were not considered for this project because they were not available with a preloaded bootloader and thus required expensive programming hardware. If any future effort could afford or possess a proper programmer, more suitable options would likely be available.

The LCD is limited in what it can display due to the 80 character limit. While it is certainly possible to work within this limit, it requires some creativity and ultimately tough decisions regarding what can and cannot be displayed on the screen. A larger LCD, perhaps a pixel based one instead of the character based one used here, might better suit this project. The keypad, on the other hand, was well suited and provided all of the buttons that were necessary. The only issue regarding the keypad was the fact that the microcontroller could not handle the full 16 buttons due to I/O pin limitations. If the I/O space of the AVR microcontroller is expanded or if a microcontroller with more I/O space is used, the keypad issues would be rendered moot.

The CAN interface proved to be too ambitious for this project, any future effort would want to ensure that ample time and effort is spent on that element, and to not underestimate the task. Much of the documentation and information regarding the actual automotive standards and implementations are locked up in standards that are expensive to gain access to. If that access can be afforded, the task of designing and building the automotive interfaces and related systems could be greatly simplified.

This project is operated off of a 9V battery for development convenience, but uses a voltage regulator to provide for versatility. The original design called for a 12V wall adapter that could also serve power to a connected scanning tool, simulating the ability of an actual car to provide that power. Also, the +5V power required by all of the components can be supplied via USB and in fact is capable of being used as such during programming with the USB programming cable. Any future effort may want to explore these or other options in powering the device.

10.0 Conclusion

Most of the project and most of the progress towards meeting the goals of this project were achieved. Specific problems, however, prevented all of the objectives from being met. A device designed for automotive diagnostic simulation was constructed and provided a relatively good level of simplicity and ease of use. Hardware limitations prevented the project from being as easy to use as intended. The CAN subsystem proved to be too ambitious to complete, thus the interface with a scan tool could not be constructed and full functionality of the project was unable to be achieved. Despite the problems that were encountered, this project has been a tremendous learning opportunity that afforded a hands on and in depth experience with both the hardware and software of designing an embedded class system, as well as attempting to design a product that interfaces with existing standards and hardware. Ultimately this project was not what it could have been due to being worked on by only a single student with limited resources; a more robust team effort would likely have achieved more.

Bibliography

"ATmega48/88/168 Datasheet." Atmel Corporation. July 2009.

<http://www.atmel.com/dyn/resources/prod_documents/doc2545.pdf>

"ATmega168." Atmel Corporation. 24 August 2010.

<http://www.atmel.com/dyn/products/product_card.asp?part_id=3303>

"HD44780 Datasheet." Hitachi, Ltd. 24 August 2010.

<http://www.nerdkits.com/accounts/downloads/get/NK003USB/HD44780.pdf>

"L7805 Datasheet." STMicroelectronics. 24 August 2010.

<http://www.nerdkits.com/accounts/downloads/get/NK003USB/L7805C.pdf>

Evans, Humberto, and Michael F. Robbins. "The Nerdkits Guide." 2009.

<http://www.nerdkits.com/accounts/downloads/getpdf/NK003USB__4527n6443w67c6s99e99 .pdf>

"Nerdkits." 24 August 2010.

<http://www.nerdkits.com/>

"Standard Keypads Series 96 Datasheet." Grayhill Inc. 24 August 2010.

<http://lgrws01.grayhill.com/web/images/ProductImages/Series%2096%20Standard %20Keypads.pdf>

"MCP2515 Datasheet." Microchip Technology Inc. 24 August 2010.

<http://ww1.microchip.com/downloads/en/DeviceDoc/21801e.pdf>

"MCP2515 Development Tool." mikroElektronika. 24 August 2010.

<http://www.mikroe.com/eng/products/view/129/canspi-board/>

"On-board diagnostics." Wikimedia Foundation Inc. 19 August 2010.

<http://en.wikipedia.org/wiki/On-board_diagnostics>

"OBD-II PIDs." Wikimedia Foundation Inc. 24 July 2010.
<http://en.wikipedia.org/wiki/OBD-II_PIDs>

"ECUsim 5100 Multiprotocol OBD-II ECU Simulator." ScanTool.net LLC. 24 August 2010.
<http://www.scantool.net/ecusim.html>

"CAN Bus ECU Simulator." OBD2Cables.com. 24 August 2010.
<http://www.obd2cables.com/products/obdii-equipment/can-bus-ecu-simulator-with-12vdc-power-supply.html>

Appendix A: Source Code

LCD.c

```
#include <avr/io.h>
#include <avr/pgmspace.h>
#include <inttypes.h>

#include "lcd.h"
#include "delay.h"

void lcd_set_type_data() {
  PORTD |= (1<<PD7);
}

void lcd_set_type_command() {
  PORTD &= ~(1<<PD7);
}

void lcd_write_nibble(char c) {

  PORTD &= ~(0x0f << 2);
  PORTD |= (c&0x0f) << 2;

  PORTD |= (1<<PD6);
  delay_us(1);
  PORTD &= ~(1<<PD6);
  delay_us(1);

}

void lcd_write_byte(char c) {
  lcd_write_nibble( (c >> 4) & 0x0f );
  lcd_write_nibble( c & 0x0f );
  delay_us(80);
}

void lcd_clear() {
```

```
  lcd_set_type_command();
  lcd_write_byte(0x01);
  delay_ms(50);
  lcd_write_byte(0x02);
  delay_ms(50);
}

void lcd_write_data(char c) {
  lcd_set_type_data();
  lcd_write_byte(c);
}

void lcd_write_int16(int16_t in) {
  uint8_t started = 0;

  uint16_t pow = 10000;

  if(in < 0) {
    lcd_write_data('-');
    in = -in;
  }

  while(pow >= 1) {
    if(in / pow > 0 || started || pow==1) {
      lcd_write_data((uint8_t) (in/pow) + '0');
      started = 1;
      in = in % pow;
    }

    pow = pow / 10;
  }

}

void lcd_write_string(const char *x) {
  while(pgm_read_byte(x) != 0x00)
    lcd_write_data(pgm_read_byte(x++));
}
```

```
void lcd_goto_position(uint8_t col) {
  lcd_set_type_command();
  lcd_write_byte(0x80 | col);
}

void lcd_row(char row){

  if(row == 2)
    lcd_goto_position(40);
  else if(row == 3)
    lcd_goto_position(20);
  else if(row == 4)
    lcd_goto_position(84);
  else
    lcd_goto_position(0);
}

void lcd_init() {
  // PD7,PD6, and PD2-5 as outputs
  DDRD |= 0xfc;

  // wait 100msec
  delay_ms(100);
  lcd_set_type_command();

  // do reset
  lcd_write_nibble(0x03);
  delay_ms(6);
  lcd_write_nibble(0x03);
  delay_us(250);
  lcd_write_nibble(0x03);
  delay_us(250);

  // write 0010 (data length 4 bits)
  lcd_write_nibble(0x02);
  // set to 2 lines, font 5x8
  lcd_write_byte(0x28);
```

```
  // disable LCD
  //lcd_write_byte(0x08);
  // enable LCD
  lcd_write_byte(0x0c);
  // clear display
  lcd_write_byte(0x01);
  delay_ms(5);
  // enable LCD
  lcd_write_byte(0x0c);
  // set entry mode
  lcd_write_byte(0x06);

  // set cursor/display shift
  lcd_write_byte(0x14);

  // clear
  lcd_clear();
}
```

LCD.h

```
#ifndef __LCD_H
#define __LCD_H

void lcd_set_type_data();
void lcd_set_type_command();
void lcd_write_nibble(char c);
void lcd_write_byte(char c);
void lcd_clear();
void lcd_write_data(char c);
void lcd_write_int16(int16_t in);
void lcd_write_string(const char *x);
void lcd_row(char row);
void lcd_goto_position(uint8_t col);
void lcd_init();

#endif
```

Keypad.C

```
#include <avr/io.h>
#include <avr/pgmspace.h>
#include <inttypes.h>

#include "keypad.h"
#include "delay.h"


void keypad_init(){
// Set PC3, PC4, and PC5 to output
  DDRC |= 0b00111000;
// Set PB1, PC0, PC1, and PC2 to input with pullups
  DDRB &= 0b11111101;
  PORTB |= 0b00000010;
  DDRC &= 0b11111000;
  PORTC |= 0b00000111;
}

// keypad_getbutton returns the currently pressed key

char keypad_getbutton(){
    //column 1 - PC3
    delay_ms(5);
    PORTC &= 0b11110111;
    delay_ms(5);

    if(bit_is_set(PINB, 1) == 0)
      return 1;
    if(bit_is_set(PINC, 0) == 0)
      return 4;
    if(bit_is_set(PINC, 1) == 0)
      return 7;
    if(bit_is_set(PINC, 2) == 0)
      return 10;

    delay_ms(5);
    PORTC |= 0b00111000;
```

```
delay_ms(5);

//column 2 - PC4
delay_ms(5);
PORTC &= 0b11101111;
delay_ms(5);

if(bit_is_set(PINB, 1) == 0)
  return 2;
if(bit_is_set(PINC, 0) == 0)
  return 5;
if(bit_is_set(PINC, 1) == 0)
  return 8;
if(bit_is_set(PINC, 2) == 0)
  return 0;

delay_ms(5);
PORTC |= 0b00111000;
delay_ms(5);

//column 3 - PC5
delay_ms(5);
PORTC &= 0b11011111;
delay_ms(5);

if(bit_is_set(PINB, 1) == 0)
  return 3;
if(bit_is_set(PINC, 0) == 0)
  return 6;
if(bit_is_set(PINC, 1) == 0)
  return 9;
if(bit_is_set(PINC, 2) == 0)
  return 11;

delay_ms(5);
PORTC |= 0b00111000;
delay_ms(5);
return 12;
```

```
}

// Main keypad function: Poll for user input; print all numbers entered, clear all
entered numbers if * is pushed, save entered numbers if # is pressed.

int16_t keypad_main(int16_t current){

  char button = 12;
  char lastbutton = 12;
  char input = 0;
  int16_t x = 0;
  int16_t y = current;

  while(button != 11){
    lastbutton = button;
    button = keypad_getbutton();

    if( lastbutton == 12){
      if(button == 0){
        // Print '0' to the screen
        lcd_write_string(PSTR("0"));
        // Store and update
        x = (10*x);
        input = 1;
      }
      else if(button == 1){
        // Print '1' to the screen
        lcd_write_string(PSTR("1"));
        // Store and update
        x = (10*x) + 1;
        input = 1;
      }
      else if(button == 2){
        // Print '2' to the screen
        lcd_write_string(PSTR("2"));
        // Store and update
        x = (10*x) + 2;
        input = 1;
      }
```

```
else if(button == 3){
  // Print '3' to the screen
  lcd_write_string(PSTR("3"));
  // Store and update
  x = (10*x) + 3;
  input = 1;
}
else if(button == 4){
  // Print '4' to the screen
  lcd_write_string(PSTR("4"));
  // Store and update
  x = (10*x) + 4;
  input = 1;
}
else if(button == 5){
  // Print '5' to the screen
  lcd_write_string(PSTR("5"));
  // Store and update
  x = (10*x) + 5;
  input = 1;
}
else if(button == 6){
  // Print '6' to the screen
  lcd_write_string(PSTR("6"));
  // Store and update
  x = (10*x) + 6;
  input = 1;
}
else if(button == 7){
  // Print '7' to the screen
  lcd_write_string(PSTR("7"));
  // Store and update
  x = (10*x) + 7;
  input = 1;
}
else if(button == 8){
  // Print '8' to the screen
  lcd_write_string(PSTR("8"));
```

```
        // Store and update
        x = (10*x) + 8;
        input = 1;
      }
      else if(button == 9){
        // Print '9' to the screen
        lcd_write_string(PSTR("9"));
        // Store and update
        x = (10*x) + 9;
        input = 1;
      }
      else if(button == 10){
        // * is pressed, clear entered values
        x = 0;
        input = 0;
        // clear the screen
        lcd_row(4);
        lcd_write_string(PSTR("                    "));
        lcd_row(4);
      }
    }
  }

  if(input == 0){
    return y;
  }
  else{
    return x;
  }
}
```

Keypad.h

```
#ifndef __KEYPAD_H
#define __KEYPAD_H

void keypad_init();
char keypad_getbutton();
```

```
int keypad_main(int current);

#endif
```

Delay.c

```
#include <inttypes.h>
#include "delay.h"

inline void delay_us(uint16_t us) {
  uint16_t i;
  for(i=0; i<us; i++) {
    NOP;
    NOP;
    NOP;
    NOP;
    NOP;
    NOP;
    NOP;
    NOP;
    NOP;
  }
}

void delay_ms(uint16_t ms) {
  uint16_t i;
  for(i=0; i<ms; i++)
    delay_us(1000);
}
```

Delay.h

```
#ifndef __DELAY_H
#define __DELAY_H

#include <inttypes.h>

#ifndef NOP
```

```
#define NOP __asm__ __volatile__ ("nop")
#endif

void delay_us(uint16_t us);
void delay_ms(uint16_t ms);

#endif
```

Main.c

```
#define F_CPU 14745600

#include <avr/io.h>
#include <avr/pgmspace.h>
#include <inttypes.h>

#include "../libs/lcd.h"
#include "../libs/keypad.h"
#include "../libs/delay.h"

int main() {
  // Setup the hardware
  lcd_init();
  lcd_clear();
  keypad_init();

  // Initialize the variables
  char button = 12;
  char lastbutton = 12;
  char loopstop = 0;
  int16_t pid_04 = 0; // Calculated engine load value (0-100)%
  int16_t pid_05 = 250; // Engine coolant tempterature (233-488)K
  int16_t pid_06 = 50; // Short Term Fuel % trim - Bank 1 (0-200)
  int16_t pid_07 = 50; // Long Term Fuel % Trim - Bank 1 (0-200)

  // Display the starting screen
  lcd_row(1);
  lcd_write_string(PSTR("OBD-II Simulator MQP"));
```

```
lcd_row(2);
lcd_write_string(PSTR("Adam Shaw"));
lcd_row(3);
lcd_write_string(PSTR("Defaults Loaded"));
lcd_row(4);
lcd_write_string(PSTR("Press # to begin"));

while(button != 11){
  lastbutton = button;
  button = keypad_getbutton();
}
button = 12;

// Main Program

while(1){
  while(button != 11) {
    lastbutton = button;
    button = keypad_getbutton();

    if(loopstop == 0){
      lcd_clear();
      lcd_write_string(PSTR("Listening Mode"));
      lcd_row(2);
      lcd_write_string(PSTR("Press # to Program"));
    }
    loopstop = 1;
    // Check for PID on SPI
    // Respond to PID request if necessary
  }
  button = 12;
  loopstop = 0;

  // Clear the display
  lcd_clear();

  // Programming Mode
  lcd_write_string(PSTR("Programming Mode"));
```

```
 delay_ms(1000);
 lcd_clear();

// ### PID 0x04 - Calculated engine load value 0-100%

 lcd_clear();

 lcd_write_string(PSTR("Engine Load Value"));
 lcd_row(2);
 lcd_write_string(PSTR("Range: 0% - 100%"));
 lcd_row(3);
 lcd_write_string(PSTR("Current: "));
 lcd_write_int16(pid_04);
 lcd_row(4);

 pid_04 = keypad_main(pid_04);

 // ### PID 0x05 - Engine Coolant Temperature

 lcd_clear();

 lcd_write_string(PSTR("Coolant Temp"));
 lcd_row(2);
 lcd_write_string(PSTR("Range: 233K - 488K"));
 lcd_row(3);
 lcd_write_string(PSTR("Current: "));
 lcd_write_int16(pid_05);
 lcd_row(4);

 pid_05 = keypad_main(pid_05);

 // ## PID 0x06 - Short Term Fuel % Trim - Bank 1

 lcd_clear();

 lcd_write_string(PSTR("Short Term Fuel Trim"));
 lcd_row(2);
 lcd_write_string(PSTR("Range: 0 - 200"));
```

```
    lcd_row(3);
    lcd_write_string(PSTR("Current: "));
    lcd_write_int16(pid_06);
    lcd_row(4);

    pid_06 = keypad_main(pid_06);

    // ## PID 0x07 - Long Term Fuel % Trim - Bank 1

    lcd_clear();

    lcd_write_string(PSTR("Long Term Fuel Trim"));
    lcd_row(2);
    lcd_write_string(PSTR("Range: 0 - 200"));
    lcd_row(3);
    lcd_write_string(PSTR("Current: "));
    lcd_write_int16(pid_07);
    lcd_row(4);

    pid_07 = keypad_main(pid_07);

    // Put further PIDs here once CAN functionality is working
  }
  return 0;
}
```

Appendix B: OBD-II PIDs

PID (hex)	Bytes returned	Description	Min value	Max value	Units	Formula
0	4	PIDs supported [01 - 20]				Bit encoded [A7..D0] == [PID 0x01..PID 0x20]
1	4	Monitor status since DTCs cleared. (Includes malfunction indicator lamp (MIL) status and number of DTCs.)				Bit encoded.
2	2	Freeze DTC				
3	2	Fuel system status				Bit encoded.
4	1	Calculated engine load value	0	100	%	A*100/255
5	1	Engine coolant temperature	-40	215	°C	A-40
6	1	Short term fuel % trim—Bank 1	-100 (Rich)	99.22 (Lean)	%	(A-128) * 100/128
7	1	Long term fuel % trim—Bank 1	-100 (Rich)	99.22 (Lean)	%	(A-128) * 100/128
8	1	Short term fuel % trim—Bank 2	-100 (Rich)	99.22 (Lean)	%	(A-128) * 100/128
9	1	Long term fuel % trim—Bank 2	-100 (Rich)	99.22 (Lean)	%	(A-128) * 100/128
0A	1	Fuel pressure	0	765	kPa (gauge)	A*3

PID (hex)	Bytes returned	Description	Min value	Max value	Units	Formula
0B	1	Intake manifold absolute pressure	0	255	kPa (absolute)	A
0C	2	Engine RPM	0	16383.75	rpm	((A*256)+B)/4
0D	1	Vehicle speed	0	255	km/h	A
0E	1	Timing advance	-64	63.5	° relative to #1 cylinder	A/2 - 64
0F	1	Intake air temperature	-40	215	°C	A-40
10	2	MAF air flow rate	0	655.35	g/s	((A*256)+B) / 100
11	1	Throttle position	0	100	%	A*100/255
12	1	Commanded secondary air status				Bit encoded.
13	1	Oxygen sensors present				[A0..A3] == Bank 1, Sensors 1-4. [A4..A7] == Bank 2...
14	2	Bank 1, Sensor 1: Oxygen sensor voltage, Short term fuel trim	0 -100(lean)	1.275 99.2(rich)	Volts %	A * 0.005 (B-128) * 100/128 (if B==0xFF, sensor is not used in trim calc)
15	2	Bank 1, Sensor 2: Oxygen sensor voltage, Short term fuel trim	0 -100(lean)	1.275 99.2(rich)	Volts %	A * 0.005 (B-128) * 100/128 (if B==0xFF, sensor is not used in trim calc)

PID (hex)	Bytes returned	Description	Min value	Max value	Units	Formula
16	2	Bank 1, Sensor 3: Oxygen sensor voltage, Short term fuel trim	0 -100(lean)	1.275 99.2(rich)	Volts %	A * 0.005 (B-128) * 100/128 (if B==0xFF, sensor is not used in trim calc)
17	2	Bank 1, Sensor 4: Oxygen sensor voltage, Short term fuel trim	0 -100(lean)	1.275 99.2(rich)	Volts %	A * 0.005 (B-128) * 100/128 (if B==0xFF, sensor is not used in trim calc)
18	2	Bank 2, Sensor 1: Oxygen sensor voltage, Short term fuel trim	0 -100(lean)	1.275 99.2(rich)	Volts %	A * 0.005 (B-128) * 100/128 (if B==0xFF, sensor is not used in trim calc)
19	2	Bank 2, Sensor 2: Oxygen sensor voltage, Short term fuel trim	0 -100(lean)	1.275 99.2(rich)	Volts %	A * 0.005 (B-128) * 100/128 (if B==0xFF, sensor is not used in trim calc)
1A	2	Bank 2, Sensor 3: Oxygen sensor voltage, Short term fuel trim	0 -100(lean)	1.275 99.2(rich)	Volts %	A * 0.005 (B-128) * 100/128 (if B==0xFF, sensor is not used in trim calc)
1B	2	Bank 2, Sensor 4: Oxygen sensor voltage, Short term fuel trim	0 -100(lean)	1.275 99.2(rich)	Volts %	A * 0.005 (B-128) * 100/128 (if B==0xFF, sensor is not used in trim calc)
1C	1	OBD standards this vehicle conforms to				Bit encoded.

PID (hex)	Bytes returned	Description	Min value	Max value	Units	Formula
1D	1	Oxygen sensors present				Similar to PID 13, but [A0..A7] == [B1S1, B1S2, B2S1, B2S2, B3S1, B3S2, B4S1, B4S2]
1E	1	Auxiliary input status				A0 == Power Take Off (PTO) status (1 == active) [A1..A7] not used
1F	2	Run time since engine start	0	65535	seconds	(A*256)+B
20	4	PIDs supported 21-40				Bit encoded [A7..D0] == [PID 0x21..PID 0x40]
21	2	Distance traveled with malfunction indicator lamp (MIL) on	0	65535	km	(A*256)+B
22	2	Fuel Rail Pressure (relative to manifold vacuum)	0	5177.27	kPa	(((A*256)+B) * 10) / 128
23	2	Fuel Rail Pressure (diesel)	0	655350	kPa (gauge)	((A*256)+B) * 10
24	4	O2S1_WR_lambda(1): Equivalence Ratio Voltage	0 0	2 8	N/A V	((A*256)+B)/32768 ((C*256)+D)/8192
25	4	O2S2_WR_lambda(1): Equivalence Ratio Voltage	0 0	2 8	N/A V	((A*256)+B)/32768 ((C*256)+D)/8192

PID (hex)	Bytes returned	Description	Min value	Max value	Units	Formula
26	4	O2S3_WR_lambda(1): Equivalence Ratio Voltage	0 0	2 8	N/A V	((A*256)+B)/32768 ((C*256)+D)/8192
27	4	O2S4_WR_lambda(1): Equivalence Ratio Voltage	0 0	2 8	N/A V	((A*256)+B)/32768 ((C*256)+D)/8192
28	4	O2S5_WR_lambda(1): Equivalence Ratio Voltage	0 0	2 8	N/A V	((A*256)+B)/32768 ((C*256)+D)/8192
29	4	O2S6_WR_lambda(1): Equivalence Ratio Voltage	0 0	2 8	N/A V	((A*256)+B)/32768 ((C*256)+D)/8192
2A	4	O2S7_WR_lambda(1): Equivalence Ratio Voltage	0 0	2 8	N/A V	((A*256)+B)/32768 ((C*256)+D)/8192
2B	4	O2S8_WR_lambda(1): Equivalence Ratio Voltage	0 0	2 8	N/A V	((A*256)+B)/32768 ((C*256)+D)/8192
2C	1	Commanded EGR	0	100	%	100*A/255
2D	1	EGR Error	-100	99.22	%	(A-128) * 100/128
2E	1	Commanded evaporative purge	0	100	%	100*A/255
2F	1	Fuel Level Input	0	100	%	100*A/255
30	1	# of warm-ups since codes cleared	0	255	N/A	A
31	2	Distance traveled since codes cleared	0	65535	km	(A*256)+B

PID (hex)	Bytes returned	Description	Min value	Max value	Units	Formula
32	2	Evap. System Vapor Pressure	-8192	8192	Pa	((A*256)+B)/4 (A is signed)
33	1	Barometric pressure	0	255	kPa (Absolute)	A
34	4	O2S1_WR_lambda(1): Equivalence Ratio Current	0 -128	2 128	N/A mA	((A*256)+B)/32768 ((C*256)+D)/256 - 128
35	4	O2S2_WR_lambda(1): Equivalence Ratio Current	0 -128	2 128	N/A mA	((A*256)+B)/32768 ((C*256)+D)/256 - 128
36	4	O2S3_WR_lambda(1): Equivalence Ratio Current	0 -128	2 128	N/A mA	((A*256)+B)/327685 ((C*256)+D)/256 - 128
37	4	O2S4_WR_lambda(1): Equivalence Ratio Current	0 -128	2 128	N/A mA	((A*256)+B)/32768 ((C*256)+D)/256 - 128
38	4	O2S5_WR_lambda(1): Equivalence Ratio Current	0 -128	2 128	N/A mA	((A*256)+B)/32768 ((C*256)+D)/256 - 128
39	4	O2S6_WR_lambda(1): Equivalence Ratio Current	0 -128	2 128	N/A mA	((A*256)+B)/32768 ((C*256)+D)/256 - 128
3A	4	O2S7_WR_lambda(1): Equivalence Ratio Current	0 -128	2 128	N/A mA	((A*256)+B)/32768 ((C*256)+D)/256 - 128
3B	4	O2S8_WR_lambda(1): Equivalence Ratio Current	0 -128	2 128	N/A mA	((A*256)+B)/32768 ((C*256)+D)/256 - 128

PID (hex)	Bytes returned	Description	Min value	Max value	Units	Formula
3C	2	Catalyst Temperature Bank 1, Sensor 1	-40	6513.5	°C	((A*256)+B)/10 - 40
3D	2	Catalyst Temperature Bank 2, Sensor 1	-40	6513.5	°C	((A*256)+B)/10 - 40
3E	2	Catalyst Temperature Bank 1, Sensor 2	-40	6513.5	°C	((A*256)+B)/10 - 40
3F	2	Catalyst Temperature Bank 2, Sensor 2	-40	6513.5	°C	((A*256)+B)/10 - 40
40	4	PIDs supported 41-60				Bit encoded [A7..D0] == [PID 0x41..PID 0x60]
41	4	Monitor status this drive cycle				Bit encoded.
42	2	Control module voltage	0	65.54	V	((A*256)+B)/1000
43	2	Absolute load value	0	25700	%	((A*256)+B) *100/255
44	2	Command equivalence ratio	0	2	N/A	((A*256)+B)/32768
45	1	Relative throttle position	0	100	%	A*100/255
46	1	Ambient air temperature	-40	215	°C	A-40
47	1	Absolute throttle position B	0	100	%	A*100/255

PID (hex)	Bytes returned	Description	Min value	Max value	Units	Formula
48	1	Absolute throttle position C	0	100	%	A*100/255
49	1	Accelerator pedal position D	0	100	%	A*100/255
4A	1	Accelerator pedal position E	0	100	%	A*100/255
4B	1	Accelerator pedal position F	0	100	%	A*100/255
4C	1	Commanded throttle actuator	0	100	%	A*100/255
4D	2	Time run with MIL on	0	65535	minutes	(A*256)+B
4E	2	Time since trouble codes cleared	0	65535	minutes	(A*256)+B
51	1	Fuel Type				From fuel type table see below
52	1	Ethanol fuel %	0	100	%	A*100/255
53	2	Absoulute Evap system Vapour Pressure	0	327675	kpa	1/200 per bit

Appendix C: Weekly Updates

Week 1 Work Summary

Work Planned

Given that this is the first week of the project, scheduled work mostly includes basic research topics and high level planning. Research topics include an analysis of the current market for OBD-II simulators, specifically regarding the state of products currently available; a patent search to attempt to determine the licensing viability of an ODB-II simulator; and detailed information on the OBD-II protocols and standards. Other work for this week includes defining the inputs and outputs for the project and creating a high level sketch of the different components to facilitate hardware design and component selection in the next week.

Work Accomplished

Market Research

In searching for available products similar to this project, I came across three different offerings both directly and often mentioned on discussion boards by people looking for an OBD-II simulator class device. These three devices are the 'ECUsim 5100 Multiprotocol OBD-II ECU Simulator,' the 'CAN Bus ECU Simulator (and protocol variants),' and the 'Xtreme OBD 2.' These products are detailed below:

ECUsim 5100 Multiprotocol OBD-II ECU Simulator
http://www.scantool.net/ecusim.html

As it's name implies, the ECUsim 5100 supports all of the OBD-II protocols, enabled by the use of plug in modules. The unit itself has five knobs to adjust the values of various parameters as well as a USB port for further configuration on a PC. The ECUsim 5100 costs $549.00 for the base unit and one plug in module and an additional $99 for each of up to two more plug in modules.

CAN Bus ECU Simulator
http://www.obd2cables.com/products/obdii-equipment/can-bus-ecu-simulator-with-12vdc-power-supply.html

The CAN Bus ECU simulator is similar in design to the ECUsim 5100 and also includes five knobs to adjust common parameters. Unlike the ECUsim 5100, it does not include any alternative methods to provide for further configuration and only supports a small subset of the standard OBD-II PID spec. This particular device specifically targets the CAN Bus protocol. There are corresponding versions for each of the OBD-II protocols, but each one supports only a single protocol. The CAN Bus ECU simulator and all of it's corresponding versions cost $179.95 each.

Xtreme OBD 2
http://www.immensehardware.com/electronics/xtreme-obd-2.html

The Xtreme OBD 2 is a software based simulator, meaning that the device itself simply interfaces software on a standard PC with and OBD-II scanner. This product is configured entirely within a provided software package and supports the ten more common OBD-II PIDs, the fewest of all products I found. The Xtreme OBD 2 supports two of the five OBD-II protocols, including CAN Bus and ISO 9141-2. The Xtreme OBD 2 costs $169.00.

Patent Research

I was not able to find any patents for OBD-II simulators nor did any of the products I found during market research include any patent numbers.

OBD-II Information

On Board Diagnostics II (OBD-II) is the current standard in automotive diagnostic systems. OBD-II defines a standard connector and pinout, signaling protocols and protocol message formats that all compliant devices must use. There are five signaling protocols currently in use by OBD-II vehicles including SAE J1850 PWM, SAE J1850 VPW, ISO 9141-2, ISO 14230 KWP2000 and ISO 15765 CAN. The CAN protocol is popular outside of the US, and as of 2008 is required to be supported by all vehicles sold in the US.

ODB-II works using Parameter IDs (PIDs). A scanning or diagnostic device sends a message to the vehicles Engine Control Unit (ECU) containing the operating mode and the ID of a parameter that is being requested. The vehicle (or simulator) returns the requested information.

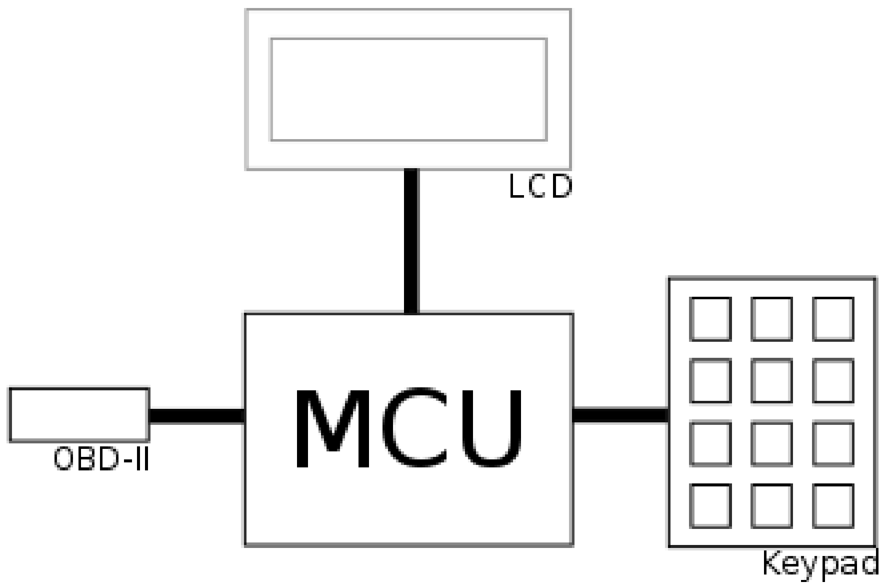
OBD-II defines a set of standard PIDs that vehicles may implement in addition to manufacturer specific ones. Given that the licensing costs of obtaining manufacturer specific codes is prohibitive, I intend to implement only these standard codes. Furthermore, since most of the other signaling protocols, excluding CAN, are typically specific to manufacturers, and since CAN is now mandated on all US vehicles, I also intend to implement CAN only initially and will revisit the other protocols after everything else is complete, time permitting.

Inputs and Outputs

OBD-II Female 16 pin J1962 Connector
LCD Screen
Keypad
Potentiometer(s) (Potentially)
DC Power (Likely 12V)

Reset Switch

High Level Sketch



Problems Encountered

There are standards documents available for all of the standards involved in the OBD-II system, but each of them costs in excess of $50 to obtain, so I do not think it will be feasible to access those documents. Currently I'm not sure if not being able to access those documents will significantly affect this project, but it is something I will keep in mind.

Schedule Status

I believe that I am currently on schedule. I intend to begin looking for the hardware components that I will be using as my next order of business, followed by implementing them in schematic form before purchase.

Week 2 Work Summary

Work Planned

During this second week of the project, scheduled work included beginning the search for hardware components and beginning the hardware design based on the core components selected.

Work Accomplished

Components

There are four primary components involved in this project. The first two comprise the primary user interface and include an LCD and a Keypad. The other two components are the micro controller and a CAN bus controller chip that will provide the interface to the OBD-II scanning device. Below each main component is listed along with an explanation of the criteria being used to identify a suitable candidate for use in this project. All components are being sought in a DIP format for easy integration onto a prototype board and are also being sought for the lowest available price that meets all the necessary criteria.

LCD

The LCD in this project will be tasked with displaying only alphanumeric characters. Any LCD capable of displaying a sufficient number of alphanumeric characters is a suitable candidate. Looking over the kinds of data that will need to be displayed on the LCD, it has been determined that an 80 character display is best suited for this application. Apart from those requirements, an 8bit parallel interface is preferred, due to previous experience with such an LCD.

Keypad

The keypad will only be required to enter numeric information, as well as perform confirmation and deletion of information. As such, a standard “telephone” 3x4 keypad seems to be a good choice.

CAN Controller

Browsing the inventory of electronics component supplier Digikey has yielded a number of CAN controller chips that support the latest in CAN standards. All of these chips make use of the SPI serial bus for communication.

Micro controller

I have narrowed down my search of micro controllers to the Atmel AVR family of chips. The AVR chips have a wide and robust community of hobbyist and professional level users, which provides a rich environment for support and information. The AVR devices are also programmable using a relatively cheap programmer, which is often not the case for similar competing products. The micro controller that is ultimately chosen will have to support the SPI serial bus in order to interface with the CAN controller chip, as well as at least 12 general purpose data lines to be able to make full use of both the LCD and Keypad.

Problems Encountered

Narrowing down the choice of micro controller has proven far more difficult than I had imagined it would be. The number of choices and options available is simply mind boggling, and the issue of programming the chip is not trivial and requires as much, if not more consideration that the selection of the chip itself. More time will be necessary to be able to come to a final decision, and to ensure that the hardware can be programmed and used.

Schedule Status

The unforeseen difficulty in component selection has resulted in an unexpected hold up of a full hardware design, delaying the schedule somewhat.

Week 3 Work Summary

Work Planned

The goal for this week was to take a step back, layout the objectives and requirements for this project, design a block diagram for the project, and use this information to choose parts for purchase.

Work Accomplished

Objectives

The objectives of this project are to create a microcontroller driven OBD-II simulator device that allows a user to simulate working on an automobile from the perspective of an electronic diagnostic scanner; to provide a visual programming interface that works completely without the aid of a personal computer; to support the full range of OBD-II generic Parameter Ids (PIDs); and to be easy enough to use and affordable enough to be competitive or to at least provide the building blocks to reach that goal if the projected continued beyond its known scope.

Requirements

Input

The OBD-II simulator must provide the user with a way to power on, power off, and reset the device. More importantly, he or she must be able to enter in numerical values for each of the Parameter Ids to input sensor values or bit encoded conditions. The user must also be able to navigate through the various programmable PIDs.

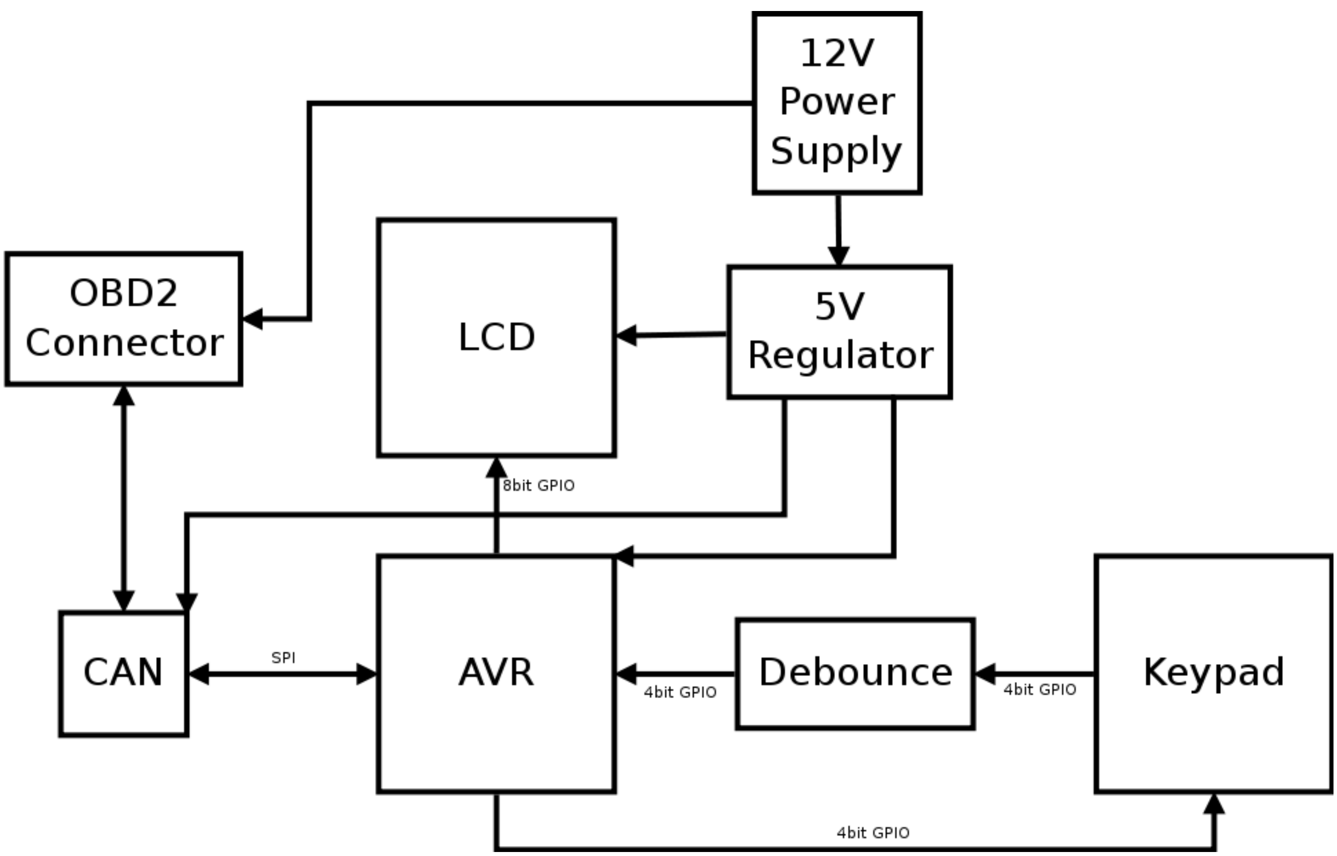
Output

The OBD-II simulator must be able to display the currently selected PID and it's current value to the user visually. The device must be able to listen for PID requests on a CAN BUS and output the appropriate information to the CAN bus in response. Finally, the simulator must provide a 12V output in order to drive scanning tools that assume a car battery will be present to power them through the OBD-II port.

Power

The digital components of the project, including the AVR microcontroller, the LCD screen, the Keypad, and other digital chips all require a 5V power supply, which should be provided by stepping down the voltage of a 12V source, which is needed to provide power output to external scanning devices as previously mentioned. Due to the fact that the simulator may be required to power such external devices, it should be tethered to a wall source and not powered by battery.

Block Diagram



Parts

I have located an AVR hobbyist kit that contains an Atmel AVR ATmega168 microcontroller, a 20x4 LCD that is perfectly suitable for this application, programming tools, and various other components needed by the microcontroller for proper operation, including an oscillator crystal. I intend to purchase this kit, along with an extra microcontroller, the Atmel ATmega328P, which is the double code memory version of the ATmega168 in case the original one proves to have insufficient space. I will also be buying a 4x4 16 key keypad for input. A 4x3 12 key one may suffice, but the 16 key version allows for added functionality, and mitigates unforeseen issues with input. Finally I will be purchasing an SPI based CAN BUS controller and OBD-II connector.

Problems Encountered

No serious problems were encountered this week.

Schedule Status

I am still a bit behind the original schedule, but I am now ready to purchase components and begin assembling and programming this project so that I can get back on schedule.

Week 4 Work Summary

Work Planned

The goal for this week was to assemble and debug the hardware and begin the basic programming and software setup for the project.

Work Accomplished

Hardware

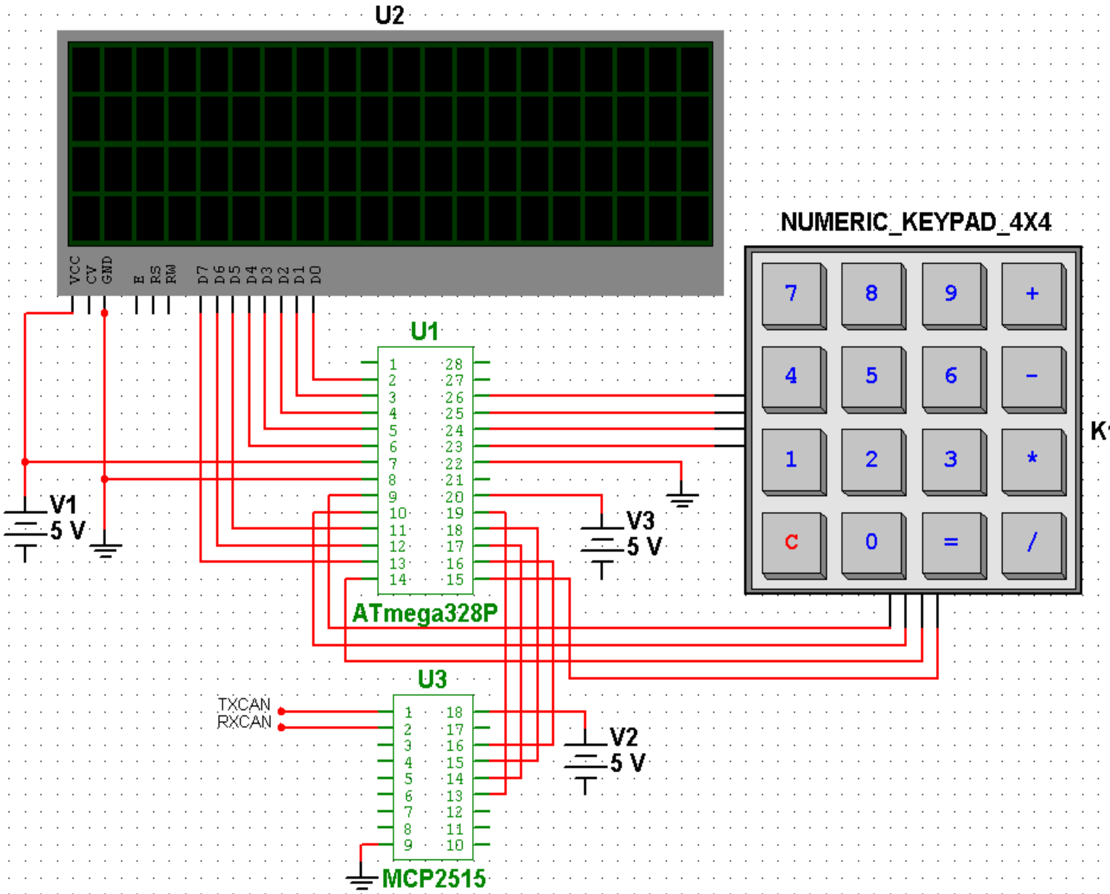


Illustration 1: Hardware Schematic

None of the hardware components have arrived yet, so construction of the hardware has not begun, instead I have started building the hardware schematic so that I will be ready to begin assembling the hardware immediately upon receipt. This schematic is shown below:

Currently included in this schematic are the four largest components: LCD, Keypad, and the two ICs. The Atmega328P IC shown is the microcontroller in a 28pin DIP package, and the MCP2515 IC shown is the CAN controller chip in an 18pin DIP package. The LCD is connected to the microcontroller via PORT-D, an 8bit bidirectional data port. The MCP2515 is connected to the microcontroller via the SPI bus, which is a four pin serial interconnect. Since there isn't another 8bit port free for the Keypad, it's being configured to use the remaining bits of PORT-B, the others of which are using for the SPI bus, to drive the columns, and the lower four bits of PORT-C, a 7 bit bidirectional data port, to read in the status of each row. Below you'll find images of both ICs for easy pin reference:

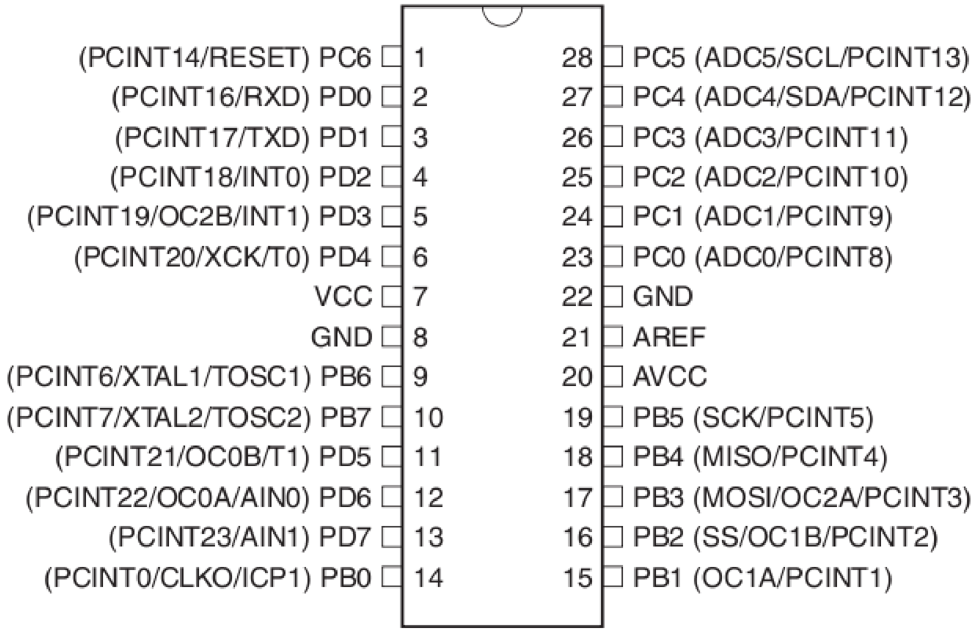


Illustration 2: Atmega328P Microcontroller

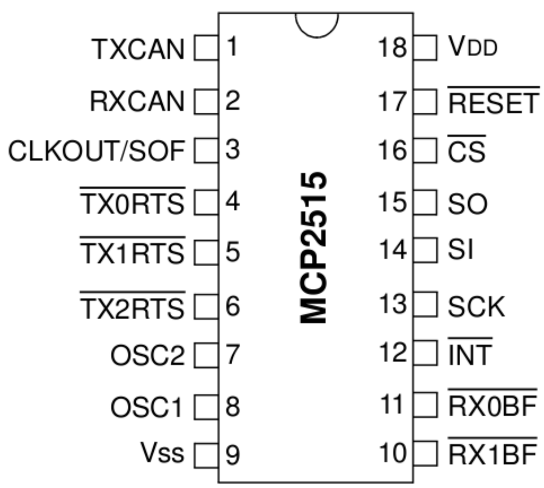
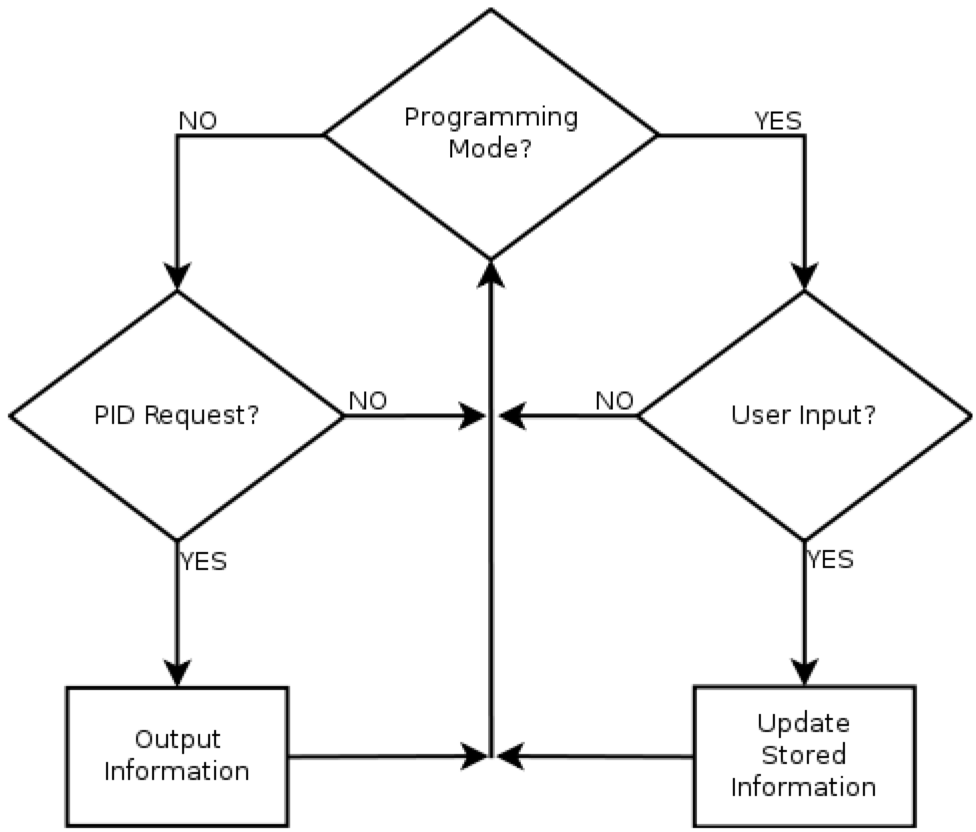


Illustration 3: MCP2515 CAN Controller

Software

The start of any programming endeavor should begin with a good overview of what the program is supposed to accomplish, and a broad flowchart of that activity. The software for this project will have to contend with two separate modes of operation. The first is the programming mode, where the user will be able to enter in the specific status of each parameter he wants the simulated engine to have. The second is the operational mode, where the device will expect to receive requests for information from a scanning or diagnostic tool, and will then respond to those requests with the appropriate information. The basic flow is shown below in chart form:



Once the hardware has arrived, I can tackle more specific programming problems, including functions and loops to write to the LCD, check for user input, check for messages on the CAN BUS, etc.

Problems Encountered

My original schedule did not include any time for the shipping of components, so the most significant problem encountered this week was simply not having the parts I assumed I would have.

Schedule Status

Since the original schedule did not account for shipping or processing times for component purchase, I am a bit behind where I wanted to be at the moment. Hopefully parts will arrive shortly and I can make up for lost time.

Week 5 & 6 Work Summary

Work Planned

The goal for this week was to assemble and debug the hardware and begin the basic programming and software setup for the project.

Work Accomplished

Hardware

This week I assembled most of the hardware that I've purchased. Unfortunately shipping turned out to be exceptionally slow and I've only had the microcontroller for about a week and the other parts for just two days as of this writing. Both the LCD and keypad hardware have been assembled, and the core programming functions have been written. The CAN controller chip is all that's left to wire up, but it only requires a four bit bus for SPI. I'll connect that when I'm ready to make use of it. It turns out that I am using every single pin available on the Atmega168 microcontroller, and I've even had to cut my 4x4 keypad down to a functional 3x4 keypad due to a lack of I/O pins.

Software

Peripheral setup and initialization routines, and core LCD and keypad functions have been written. I'm ready to start tackling the main program and interfacing with the CAN bus now.

Problems Encountered

Once again I've spent a good amount of time simply waiting for parts to arrive, delaying my progress. As previously mentioned I've encountered a lack of I/O pins for my peripheral devices, but I have been able to mostly mitigate this by using the LCD in 4bit mode instead of the full 8bit mode, which does not reduce functionality, and only using 12 of the available 16 buttons on my keypad, which shouldn't present any issues as the extra buttons are not needed.

Schedule Status

Shipping times have set me back quite a bit, but I've made good progress on the hardware in the short time I've had it available to me, so I am not concerned about finishing by the end of summer.

Week 8 Work Summary

Work Planned

The goal for this week was to continue working on any hardware and software that required work and to begin writing the project report.

Work Accomplished

Hardware

I am still waiting for the new CAN Bus interface hardware I ordered to arrive, all other hardware is complete.

Software

Almost all the main functionality is complete, all that remains is to implement additional PIDs, which is not difficult since the necessary structures and templates for PIDs has been made. I am waiting for the CAN Bus interface hardware to come in so that I can easily test it with a few working PIDs before I implement the rest of the PIDs and create headaches for myself. Software relating to the CAN Bus interface is also awaiting hardware.

Report

I've completed a detailed outline of the report and I've started working on the initial sections. Many of the other sections are complete or well developed elsewhere and will be easily added to the report shortly. By the time of our meeting next week I expect a full draft of the entire report to be complete.

Problems Encountered

As I noted above, the largest problem I encountered this week was discovering that my CAN controller chip was not sufficient for actually building a CAN bus interface.

Schedule Status

All hardware and software components should be finished by the end of July as long as the new parts I ordered arrive in a timely fashion, leaving early August for focusing entirely on writing a report. If parts take longer than expected, I will have to deal with that scenario at that time.

Week 9 Work Summary

Work Planned

The goal for this week was to continue working on any hardware and software that required work and to continue writing the project report.

Work Accomplished

Hardware

I am working on getting the CAN to SPI adapter I purchased functioning.

Software

I've been working on making improvements to the software, hopefully I will be able to get the CAN interface working shortly so I can finish the programming for it.

Report

I've complete additional sections regarding the high level design and component selection parts of this project.

Problems Encountered

An unexpected power outage and difficulties with the CAN to SPI chip.

Schedule Status

The rest of the report draft will be complete before our next meeting, hopefully a revised edition that includes full figures and tables will also be available by then. I will do what I can to get the CAN interface working, but my confidence in being successful in that endeavor in waning.