EEL 4924 Electrical Engineering Design
(Senior Design)

Preliminary Design Report

January 27, 2011

Project Title:

Gator Distortionator

Team Name:

The Screamers

Team Members

Jeffrey Caldwell and Quinn Martin

Project Abstract:

Our project consists of several analog music effect (distortion and compression) circuits with digital control. It will allow a user to switch between several analog circuits in real time and control them from the same interface. Users will also be able to recall and save their favorite settings as presets, and automate or remotely control settings using MIDI commands.

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Project Features

- One analog compression effect stage first in the signal path
- Four switchable analog distortion effects second in the signal path
    - Three based on classic analog circuits
    - One designed from scratch
- Settings can be permanently saved as "patches" containing:
    - The current setting of the compression knobs (Sustain and Level)
    - Whether the compressor is active or bypassed
    - The current setting of the distortion knobs (Gain, Tone, Level)
    - Whether the distortion stage is active and, if so, which distortion circuit is selected
- Current settings will be displayed on a large LCD screen.
- Each stage can be bypassed or activated by foot switches for added control while playing the guitar. Patches can also be scrolled by foot switches.
- All patch parameters will be remote controllable and automatable by MIDI commands.
- A 9 V power output can power other guitar effect pedals.

Technical Objectives

The primary objective of this project is to create a digitally-controlled distortion effect with a completely analog audio signal path. There is also a power component of this project to create a power supply capable of delivering the necessary voltage levels needed. The digital, analog, and power components are detailed in the following sections along with the software component.

Hardware Digital Component

The product will be controlled digitally by an Atmel XMEGA microcontroller. This will be used to capture inputs from push buttons and potentiometers wired to the analog to digital channels.

The microcontroller will be used to drive a character LCD screen to provide user feedback on which compression and/or distortion circuit is selected.

The analog signal path will be controlled by analog MUXes, which will be controlled digitally through parallel I/O. These I/O lines will be connected to GPIO pins on the microcontroller.

The analog circuitry will also contain several digital potentiometers. They will be controlled digitally through the SPI serial protocol. The data and clock lines will be connected to a hardware SPI port on the microcontroller and the chip select lines will be connected to GPIO pins on the microcontroller.

The onboard EEPROM in the microcontroller will be used save user settings so that they can be preserved when the device is not powered.

In addition a UART port on the microcontroller will be used to accept MIDI commands from a computer or other MIDI device.

A block diagram of the Digital Component is pictured below in Figure 1.

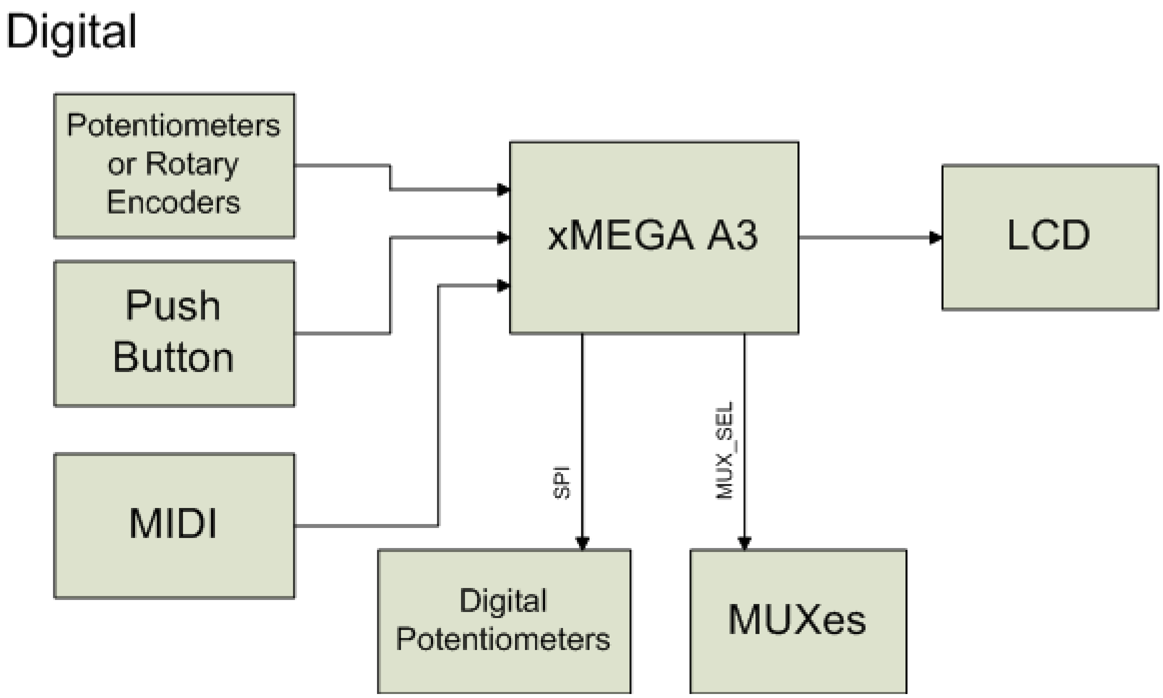

Figure 1 - Digital Block Diagram

Hardware Analog Component

From the primary objective of having a purely analoug signal path, only analog distortion and compression circuits will be implemented. The signal path is pictured in a block diagram in Figure 2.

The design includes one compression circuit that may be bypassed followed one of four distortion circuits (or a bypass). The switching between distortion circuits will be accomplished by analog multiplexers (MUXes).

The compression circuit and three distortion circuits will be based on classic analog circuits. However all of the circuits will have to be modified to use digital potentiometers. The design will aim to closely matching the sound and performance of the original circuits.

The fourth distortion circuit will be a unique design from scratch based around the values of the available digital potentiometers. The circuit will designed to have acceptable sound quality.

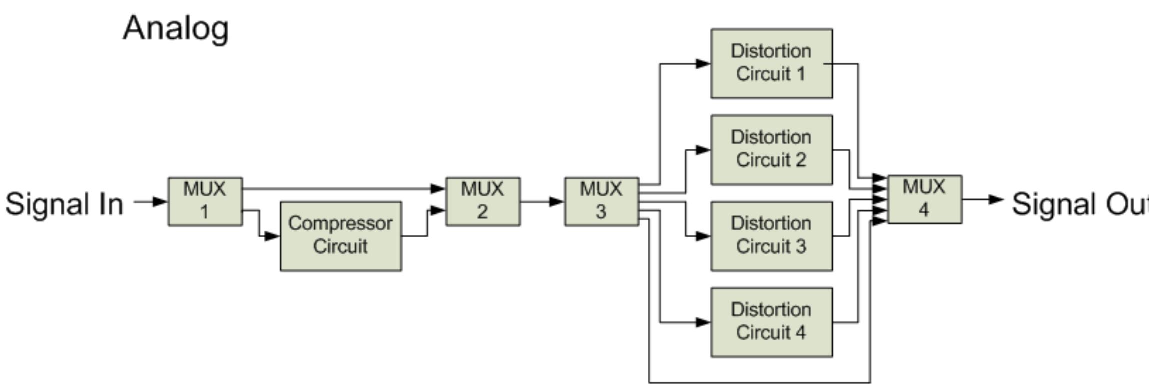

Figure 2 - Analog Block Diagram

Hardware Power Supply Component

This project will also have an onboard power supply capable of delivering the necessary voltage levels needed. A block diagram of the onboard power supply is shown in Figure 3.

The power supply will be implemented by using an AC wall wart transformer to step down the voltage offboard. Then, using half-wave rectification, +/– 12 VDC will be generated. From the +/- 12 V, linear regulators will be used to step sown the voltage to +9 V, -9 V, and 3.3 V supplies. The +/- 12V levels are needed for the analog MUXes and digital pots. The +/- 9V levels are needed for the analog distortion circuits and the compression circuit. The 3.3V level is used for the microcontroller.

The +9V supply and ground will be routed to a power out jack to provide external power to any other components that the user might have that use +9V.

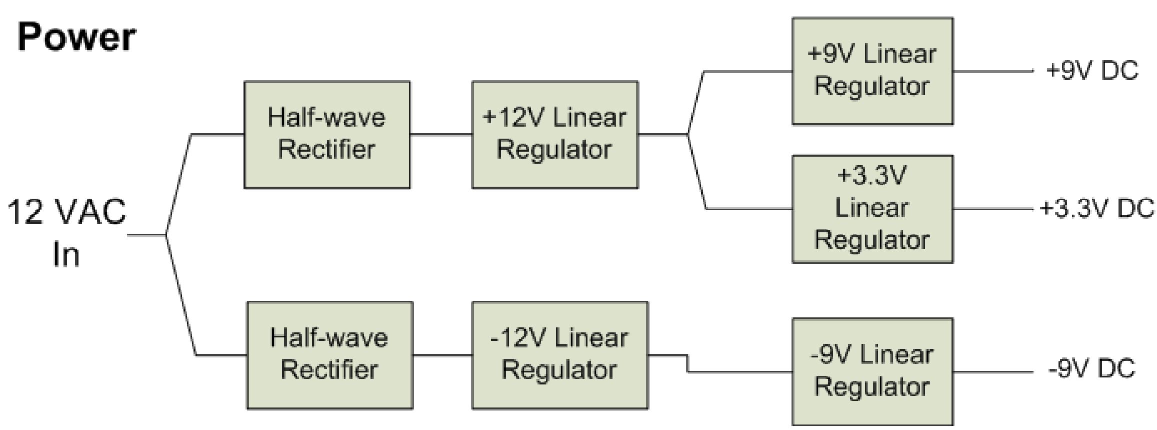

Figure 3 - Power System Block Diagram

Software Component

The project will be designed to be user friendly with useful software. The A/D channels will always be on to detect any change from a user and will update the digital pot to the new valve and output the change in real-time to the LCD.

Software will also detect if a button has been pressed to save to current pot setting to memory. Another set of buttons will be monitored in software that will control advancing to the next preset, advancing to the previous preset, bypassing the compression circuit, or bypassing the distortion circuit.

MIDI commands will be accepted and interpreted to control the system remotely.

Cost Objectives

A main goal of integrating many analog circuits into one box is to reduce cost. In a distortion pedal, most of the cost is the PCB, assembly, enclosure, potentiometers, and jacks. From our previous experience, the cost to build one small analog distortion effect pedal is $50-$70. We expect the price of one Gator Distortionator to be around $200, not including the labor to assemble and test it. If a run of 10-25 units were made, a reasonable selling price might be $300 per unit.

Technology Selection

Choice of analog circuits and components: The analog circuits were chosen because they represent several approaches to musical clipping with different levels of circuit complexity. Additionally, each of these circuits is highly sought after for its sound. Original components for the circuits were used where possible and when important to the performance of the circuit.

- The Fuzz Face was chosen as a simple circuit employing transistor clipping. It uses two germanium transistors, one of which is poorly biased, to clip the signal. We opted to purchase the original germanium parts because although germanium devices behave similarly to silicon in their linear region, they have a softer clipping characteristic.

- The Distortion+ is an op-amp based circuit using shunt diode clipping. Here, we also chose to use the original 1n270 germanium diodes because of their different distortion character. Also, the germanium diodes clip at .3V vs. .7V for silicon, so using silicon diodes would lessen the amount of distortion unless the circuit were redesigned.

- The Tube Screamer is an op-amp based circuit that uses diodes in the op-amp feedback path. Unlike the previous two circuits, it also includes a tone control. This is implemented with an active filter.

- The most complex circuit is the Ross Compressor. It uses the CA3080 operational transcoductance amplifier to control the base current of a transistor to form a voltage controlled amplifier (VCA).

Floor-based form factor: We chose to incorporate all of the electronics into a box that operates like a large guitar effect pedal. This form factor has been the standard for guitar effects for over 50 years because it allows the guitarist control of the effect while playing guitar with both hands. This also allows guitarists to incorporate the device into their existing pedal boards.

Custom-designed bipolar power supply: We chose to design a custom power supply for several reasons. We wanted to use a +/- 12V supply to ensure that the digital potentiometers and analog MUXes would not distort the signal. Bipolar power supplies are not available as inexpenisive wall warts, so it is more practical to design a simple one from scratch using a 12 VAC wall wart.

Digital Potentiometers (AD5290): These are the only commonly available digital potentiometers that accept a supply over 5V. They are much more expensive than others, but redesigning the distortion circuits to use smaller supplies would dramatically change the sound (because of the op-amp performance, diodes clipping at a fixed voltage, etc.), which conflicts with our design objectives. These digital pots allow us to digitally control the circuits in the least invasive way possible.

Dual 8-to-1 Analog MUXes (DG407BDJ): We selected these MUXes because it was easy to obtain samples in DIP form and they offer very low on-state resistance. Like the potentiometers, they are capable of running on +/- 12 V supplies. They also help to minimize the number of I/O lines needed because they switch both MUXes in the package with the same select lines, switching the input and output of the effects in tandem. The main drawback of these components in a high price, so this selection is subject to change if we find a cheaper solution that will maintain high performance.

ATxMega Microcontroller: We chose the ATxMega192A3 microcontroller because we are familiar with it and find it easy to use. It has abundant parallel I/O for the MUXes and LCD, many A/D channels for the potentiometers, SPI for the digital potentiometers, UART for MIDI receive, and EEPROM to store the patches.

Division of Labor

Quinn Martin is responsible for:

- Design of analog compression circuit
- Design of 4 analog distortion circuits
- Design power supply
- Integration of MIDI to microcontroller

Jeff Caldwell is responsible for:

- Integration of character LCD to microcontroller.

- Integration of potentiometers and button inputs to microcontroller.
- Integration of the MUXes and SPI for the digital potentiometers to microcontroller
- Software for EEPROM use in the microcontroller

Both teammates are responsible 50/50 for:

- PCB board design
- Mechanical design
- Software design
- Component selection
- Design reports and presentations
- Updating lab notebook
- Keeping each other informed of progress and setbacks

Project Timeline

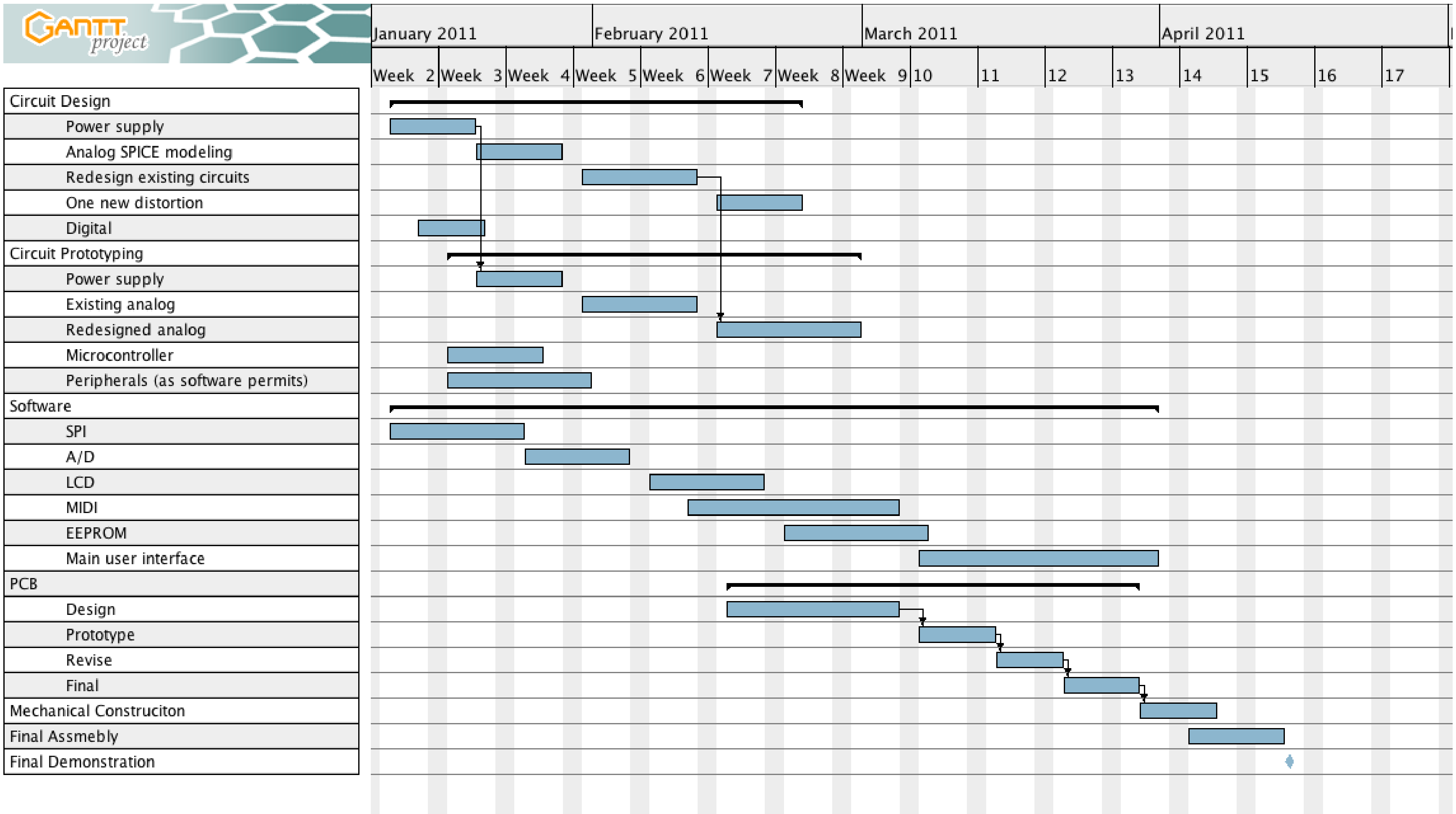

Figure 4 - Gantt Project Timeline