The FrankenPipe:
A Bagpipe MIDI Controller with RC Car Control

ABSTRACT
The FrankenPipe is an attempt at converting a traditional Highland Bagpipe into a MIDI Controller unlike any Bagpipe MIDI Controller ever created. To do this, the Chanter is outfitted with photoresistors (CDS Photoconductive Cells) underneath each hole, so as to give a full range of MIDI values with each finger and a natural feel. A pressure sensor is also implemented in the bag to give another element of control with only a few values. The limits of the final product are due to the slow reaction speed of all the elements combined, but there is much room for improvement. In addition, an RC Car Transmitter is modified to respond to MIDI messages sent from the FrankenPipe to create an original performance aspect.

Keywords
MIDI, Bagpipe (referring to the Great Highland Bagpipe unless otherwise mentioned), BASIC Stamp 2SX, Microcontroller, MAX 1270, Photoresistor, Chanter.

1. INTRODUCTION
1.1 The Inspiration
The premise of this project revolves around my personal love for, and the advancement of the traditional Highland Bagpipe. It is an ancient instrument that has changed very little over the past 2000 years and is severely limited in it's capabilities to co-mingle with instruments and performance styles of the modern world. Although this is part of the mysticism of the Bagpipe, it has been a personal frustration of mine for many years.

I started playing bagpipes at the age of 9 and since then I have competed with a Pipe Band in two World Championships, Two USA West Coast Championships, and many other competitions around the Pacific North West winning first, second, or third place prizes in all of them. I have also performed in many Parades, Social Gatherings, Weddings, Funerals, and other events. So I know well the beauty and powerful presence the bagpipe has to offer. But I have also performed with Rock bands, created techno Bagpipe Compositions, and longed to play more with contemporary instruments. This is where my inspiration comes from. To bring the mystic but tonally limited Great Highland Bagpipe into the performance world of the 21st Century, much like what happened with the advent of the electric guitar.

The idea for the RC Car addition stems from my lifelong love of fast cars. I also decided that this is the most practical part of my design. The theory behind it could be applied to many aspects of almost any performance.

1.2 Current Electronic Bagpipes
There are about 5 electronic bagpipes on the market today, all of which use capacitive contacts in place of the holes with only a binary on or off value. These are as follows: the one made by Version MIDI, the DegerPipe, Master Gaita, Fagerstrom's Technochanter, and Ross Electronic Bagpipe. They are all very similar in design but it varies if they have MIDI or not. The Ross and Fagerstrom ones only have an oscillator that sounds like a bagpipe and can be pitch shifted to play in different keys. The Master Gaita is strictly MIDI, and the Version MIDI and DegerPipe have both MIDI and Oscillators. The DegerPipe is probably the best one so far due to the fact that it is reasonably priced ($400 US) and has a MIDI output as well as a dedicated audio output. The DegerPipe can alternate between Highland Bagpipe sound as well as Smallpipe sound and can be pitch shifted through a couple of octaves.

2. LIMITATIONS
2.1 The Acoustic Bagpipe
As stated before, the Highland Bagpipe is a severely limited instrument. It traditionally only plays 9 notes: Low Ab, Low Bb, C, D, Eb, F, G, High Ab, and High Bb, making up the keys of Bb Mixolydian, C Minor, and Eb Major. (In contemporary piping, two additional notes: Db and Gb are played as well.) These notes are played with the fingers on what is called the Chanter and then octaves of the lowest Bb on the chanter are played by the Drones, which go over the piper's shoulder, and the piper generally doesn't touch them while playing. A player can also slur notes if he/she uncovers a hole in an upward or downward motion.

Another very prominent feature of the bagpipe is its harsh timber and complete absence of dynamic range. It is well known that this instrument cannot be turned down. A final restriction of the Highland Bagpipe is that it produces a continuous sound that is difficult for the player to stop and start suddenly. In conclusion, due to the restricted range, constant Bb pedal tone, continuous sound, and the fact that it has one volume level; the bagpipe in this form has a very hard time branching out in performance with other instruments.

2.2 The Electronic Bagpipe

The attempts at creating an electronic bagpipe so far are not very true to form. The only good part about them is that they either have a fairly real sounding bagpipe oscillator, or a MIDI output that can be patched to sound like a bagpipe, or anything else through MIDI manipulation. Other than that they aren't very bagpipe-like. The fingering is the same of course, but the look and feel fall short. Probably the most prominent feature that is missing from them is the bag and drones. Of course the Version MIDI bagpipe has a bag, but no drones and costs $5000 US whereas a top of the line acoustic bagpipe can cost less than $2000. So instead of drones, these instruments just have a synthesized drone sound that can be turned On/Off, volume Up/Down, and that's it. The fact that these electronic pipes use capacitive contacts is a huge limitation. A small round piece of metal, where there is normally a larger concave hole, seems very unnatural to pipers. Plus there is no possibility to bend notes like on a real bagpipe. Pitch can be altered prior to playing a piece, but it is hard to press the pitch buttons while playing. In essence, the only thing reminiscent of a bagpipe in the electronic pipes on the market is the finger positioning.

Figure 1. Fagerstrom Technochanter isn't very bagpipe like.

3. THE FRANKENPIPE

3.1 Main Concepts

The main focus of the FrankenPipe is to be able to convert a real acoustic Great Highland Bagpipe into one capable of creating sound electronically in less than 5 minutes. It also needs to look and feel as much like a real bagpipe as possible.

The first step in this process is choosing the appropriate sensors for the fingers. I narrowed the decision down to three types: Capacitive contacts, some kind of piezoelectric strip above or below the hole, or photoresistors. I chose to use photoresistors for a couple of reasons. They can be mounted just below the hole on a chanter so that the fingers never even come in contact with them, giving it a natural feel. This is also a good choice because light in this sense can mimic the air traveling through the pipe. The photoresistors also have a full range of values allowing for things like pitch bend if a hole were to be partially uncovered in a slurring motion. This is something that none of the other Electronic Bagpipes are currently capable of.

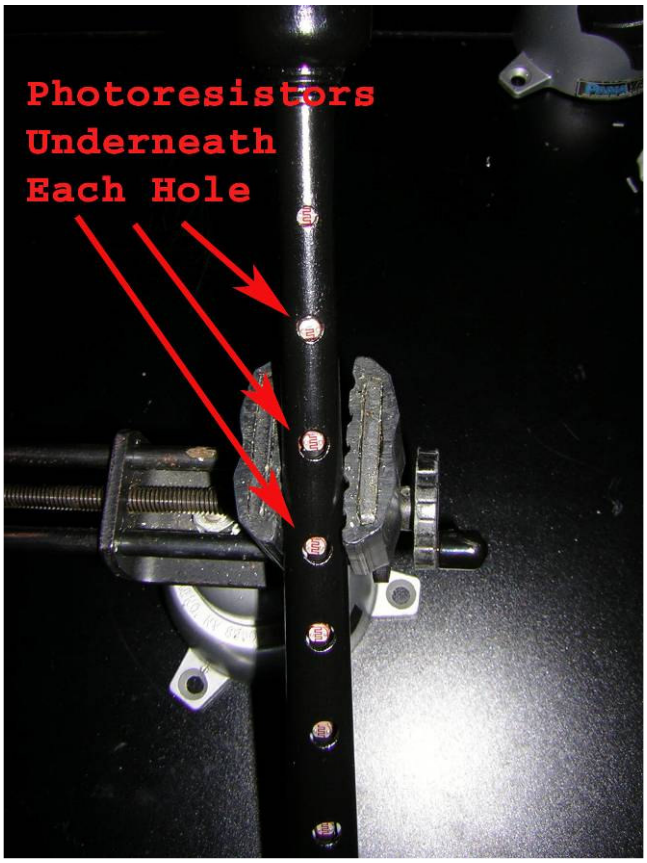

Figure 2. Example of Photoresistors Under Each Hole.

To implement the rest of the bagpipe into the design so it isn't just for looks, I mounted an air pressure sensor on a cork connected to a string which hangs from the bottom of the drone stalk. This allows for the sensor to stay inside the bag while the bagpipe is functioning as an acoustic instrument, and makes it easy to convert it to an electronic instrument. When used electronically the cork is placed in the end of the drone stalk and the other drone stalks plugged as well with regular corks. This allows for the bag to be filled entirely without loss of air, therefore allowing the piper to control the pressure in a natural way with their arm. The voltage supplied by the pressure is sent through the MAX1270 A/D converter and then to the Baisc Stamp 2SX. The values are translated into MIDI and used as pitch shift information. Now when the player squeezes the bag, the bagpipe can modulate to another key. Something that a real bagpipe could never do.

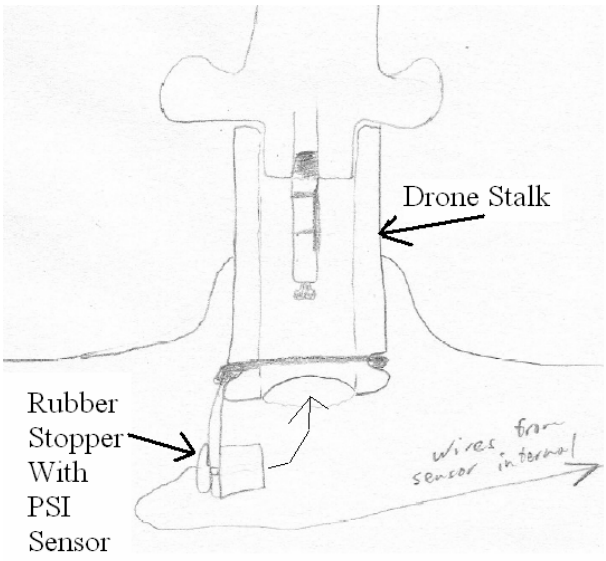

Figure 3. How Air pressure sensor mounted on cork stays in bag awaiting conversion to electronic bagpipe.

Figure 4. At the Right is the before picture with the barbeque skewer and photoresistors ready to be mounted. At the left is the final product complete with 9 pin connector.

3.2 The Chanter Design

This stage in the design is by far the most involved as there are many ways to mount the photoresistors in a chanter. The first approach I decided to try involved making a mold of the inside of the chanter, making a female mold of that, and casting replicas of the space inside the chanter. The idea behind this was that pieces of the cast part could then be carved out and the photoresistors put in their place. I didn't realize though that the air space inside the chanter is extremely small and there is no room for the photoresistors or the wires needed to carry the signal. Eventually I gave up on this idea as I became inspired by a simple barbecue skewer. It was exactly what I needed. A barbeque skewer is stainless steel therefore making it a great conductor. Plus it is very rigid and skinny making it a great candidate to attach one leg of each photoresistor to as a common ground and leave enough room for a very small wire to connect to the other leg. (Unfortunately stainless steel is not prone to being soldered to so for my prototype I just tightly taped each photoresistor to the skewer. This caused problems later as the tape started coming apart. To remedy this problem I used a straight part of a clothes hangar that I could solder to instead. Although it isn't as rigid as a skewer at least I could solder to it.) A ribbon cable is extremely skinny and compact so it proves to be the best lead wire for this sort of application. To make the design more compact, a nine pin D-Subminiature connector is soldered onto the eight ribbon cable leads, leaving one space for the ground. A simple serial cable is then used to connect the chanter to the electronics and convey the signal.

On the other end of the chanter is a circuit board with a MAXIM 1270 eight input A/D converter. The eight inputs go into the converter and a single output is connected to a BASIC Stamp 2SX. The Stamp communicates with the A/D in order to receive values, process them and send them out as MIDI information. The photoresistors have a range of 80Kohm to 5Meg-ohm. In order for the chanter to output the largest range of values possible 470Kohm resistors are connected to form a voltage divider before the input to the MAX1270.

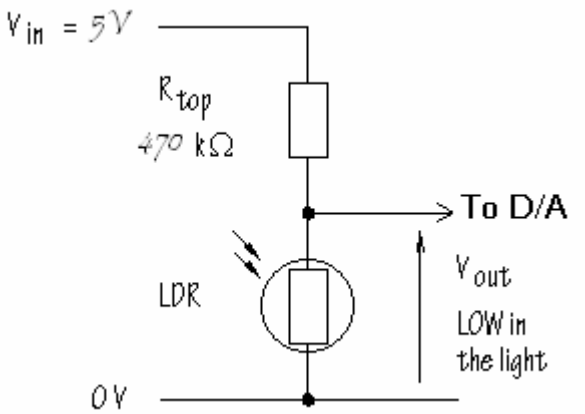

Figure 5. Example of Voltage Divider Circuit

After the voltages are converted to 12 bit binary values, they go to the Stamp to be scaled and processed. The input numbers can range from 1,500 to 2,700 and MIDI of course generally uses values of 0 to 127. Therefore the Stamp has to scale each of the holes separately depending on the light source in the room. A program initiates at startup to scale the values accordingly.

Once the values have been scaled, the Stamp outputs a separate Control Change value for each hole. This is done by use of the SEROUT command in the PBASIC language followed by the MIDI specification bit rate, and the Controller Number, Note Value, and Value of the photoresistive sensor. The Controller Functions are as follows, assigned to holes from bottom to top: Volume, Pan, Portamento, Breath Control, Expression, Foot Pedal, Bank Select, and Effect Control 1. These controllers can be assigned to perform any MIDI function that has a range of values, but these ones seem to be useful. After the value for each separate hole is polled, the Stamp performs 11 IF…THEN routines to decide which note value to send a Note On message to. Generally the Highland Bagpipe plays only 9 notes. The extra two notes correspond to notes that can be created on a bagpipe using false fingering, and are being used more and more in contemporary bagpipe music. These notes are Db and Gb. The IF…THEN routines decide which note to output based on if the right holes to play that note are covered, which it knows if the values of the holes are greater than the value 110. If the holes are less than 110, they are assumed to be open.

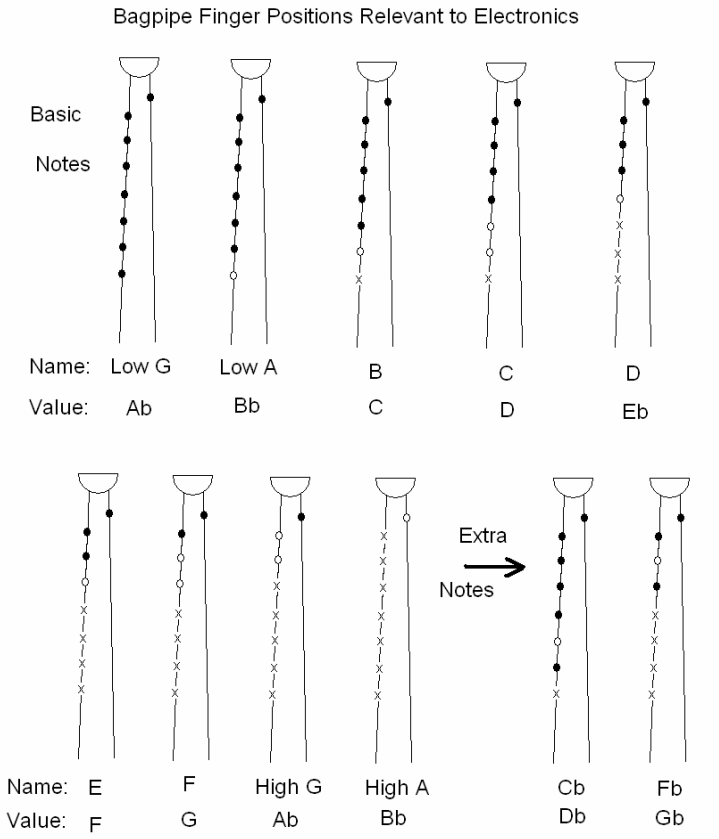

Figure 6. All of the finger positions used in bagpipe music. The x on a hole means it is a logical Don't Care.

4. THE MIDI CONTROLLED RC CAR

4.1 Main Concepts

The broader concept of the MIDI Controlled Car is that any performance can be supplemented by anything that reacts to the instrument being played. Some drummers have lights that are triggered when they hit their drums, but as far as I know, no one has yet tried to connect an instrument to an entirely arbitrary object, play a song, and let it do what it does to add to the performance aspect. Another neat concept is that this can be switched around and the performer can write a song based on how they wan the object to move.

Another application of this is to a guitar. The highest notes on a guitar neck are rarely played. If they were designated to control some other aspect of the performance they could be put to use more often. For example, if a guitar player wasn't needed for a moment, they could play those high notes and make a bunch of lights go off, or cannons of confetti fire rapidly, or drive a car on stage.

4.2 MIDI Controlled RC Car Design

This is by far the simplest of the whole design process. I purchased an RC Car, opened up the transmitter, and found that there were only four different circuits that needed to be grounded in order to move the car Forward and Backward, or turn the wheels Left or Right.

All that is needed is to connect these four circuits to four pins on the basic stamp and use transistors as switches that connect each circuit to ground based on which pins of the Stamp are set to high or low. These four circuits create seven possibilities of motion: Forward and Left, Forward Only, Forward and Right, No Movement, Reverse and Left, Reverse Only, and Reverse and Right. To implement the capabilities of the RC Car into the bagpipe design, each of the original nine notes of the bagpipe are set to cause the car to act in one of the seven movements of the car.

5. RESULTS AND SIMULATIONS

The electronic bagpipe chanter part has some severe problems. The main problem is that the reaction time is too slow. It is most likely a limitation of the photoresistor's response times, but could be that it takes the Basic Stamp to long to poll for values, store them, scale them, and output note values. Some bagpipe music is well known for having extremely fast fingering, and the limits of this project fall well short of being able to play more than 10 notes a second. Hopefully this problem can be remedied by quicker reacting photoresistors or a faster microcontroller, because otherwise my whole innovative idea will be sub par.

Another issue was that the FrankenPipe would constantly resend each MIDI note instead of waiting for a different note to be played. I fixed this problem by adding some code that would recognize if the note previously played was the same as the current one being played. If the two

were equal then there would not be another Note On message.
On the brighter side, the RC Car addition works flawlessly.

6. FUTURE WORK

The FrankenPipe is still far from being finished. The latency from the Photoresistors is much to high. It is possible that a photodiode or other sensor could be used that will have a faster reaction time. Also the scaling of the values is done in code and it would be easier to do it analog.
I am also currently working on creating a MAX patch that will use the bagpipe as a controller of a wave-table. I will attempt to trigger actual sounds recorded from my acoustic bagpipe with the FrankenPipe. With MAX and programs similar to it there are almost endless possibilities.
As for the Car concept, one use for this sort of control is that a song could be written at a certain tempo causing the car to follow a very specific path that could be easily recreated and followed by another performer as long as he/she were performing the same piece at the same tempo.

7. WORKS CITED

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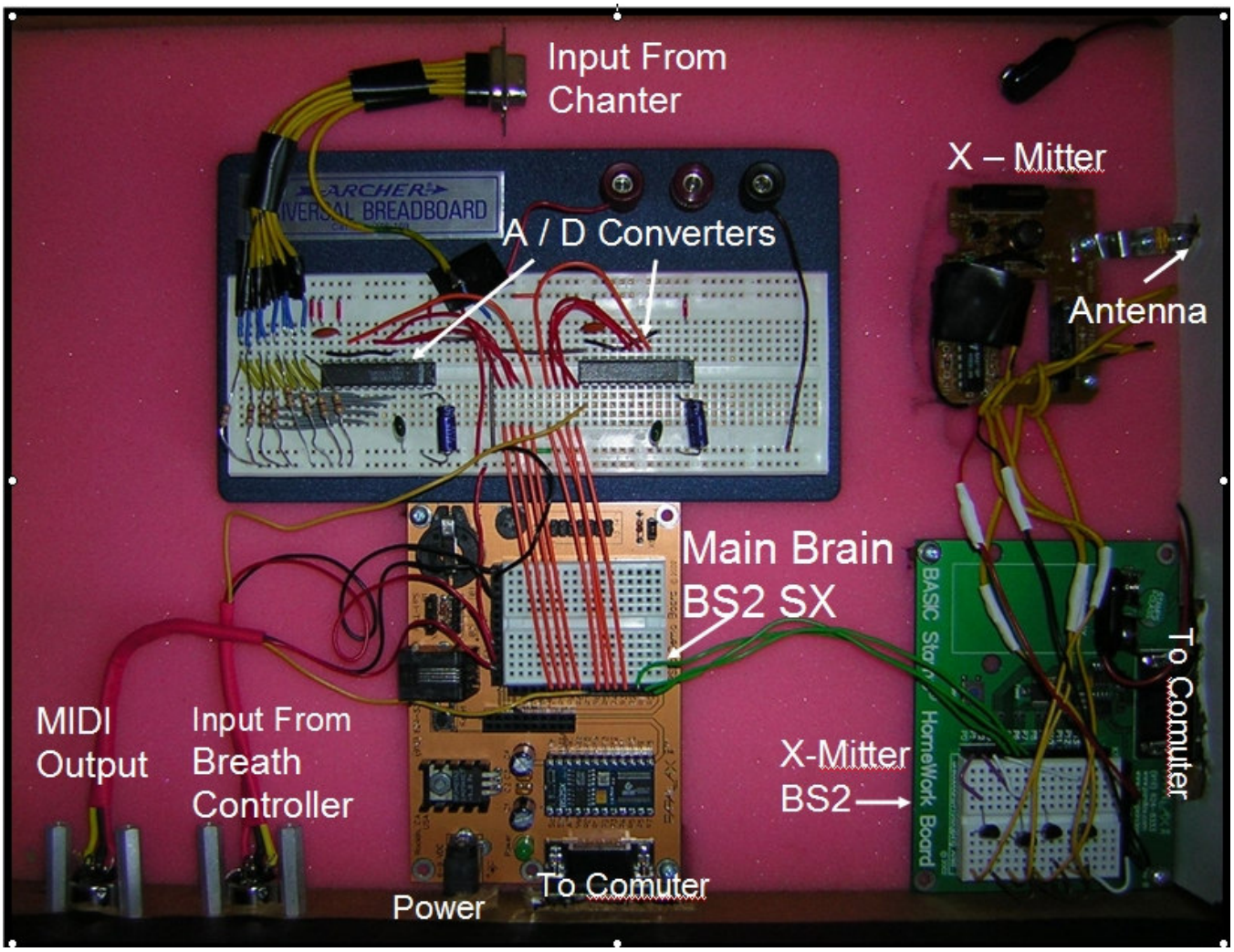
Input From
Chanter
X – Mitter
A / D Converters
Antenna
Main Brain
BS2 SX
To Comuter
MIDI
Output
Input From
Breath
Controller
X-Mitter
BS2
Power
To Comuter