THE LM1

In a nutshell, it's a 70's style music synthesizer controlled by a digital step-sequencer. In even simpler terms, it's a looping melody. The LM stands for looping melody.

THE BASIC IDEA

The project is a digitally controlled step-sequencer which loops through sixteen voltage controlled notes generated by an analog voltage controlled oscillator. The oscillator is driven by a linear voltage to exponential current circuit. Because the oscillator is analog, there's no worry about aliasing. But because the step-sequencer is controlled digitally, the user has total control over the tempo - how fast the step-sequencer loops through the sixteen different notes of the melody.

Here's a video of what it might sound like. But the schematics will be completely different. And the digitally controlled, user defined tempo will also be totally different than this example. This is just a video we found that gives a feel for what it might sound like:

https://youtu.be/RCtgHEUoXKc?t=81

Our implementation will be different physically in the sense that the schematic as well as the layout and design will be entirely our own. Additionally, these types of instruments are generally very over-priced and ours will cost much less than anything out there on the market.

This is what it might look like in the end. Please keep in mind that this is a rough sketch made in Illustrator by hand with a mouse.

Artist Rendition
**BLOCK DIAGRAM**

Here’s a simple block diagram of the three main parts - the processor, the counter / analog mux and the voltage controlled oscillator / waveshapers. Not included in the block diagram are the potentiometers which set the voltages on each mux channel. Also not included in the block diagram are any amplifier stages after the wave shaper section and before the output to the speakers.

![Block Diagram for Overall System](image)

**THE STEP-SEQUENCER**

The step-sequencer is composed of microprocessor stage followed by a TTL stage. For the microcontroller, we would like to use the NXP LPC1114 ARM IC.

The tempo, corresponding to how fast the melody will be played, will be input by the user. This input will be processed by the microcontroller, which will then generate a square wave at the corresponding frequency. This square wave will then feed into a counter IC. The counter in turn will control which channel of the sixteen channel analog mux is sent through to the voltage controlled oscillator. Each channel will be one of the sixteen voltages applied by the user with potentiometers on the front of the synthesizer.

As an example, here’s a video of a step-sequencer Justin made last spring break using an analog mux controlled by a 555 timer fed into a counter controlling the mux.

[https://drive.google.com/open?id=0B5a_ciY0REledHV5ekpQUmNNZW5](https://drive.google.com/open?id=0B5a_ciY0REledHV5ekpQUmNNZW5)

In this case, the tempo is generated by the 555 timer. For our 445 project however, we will be using the microcontroller to have total control over the tempo. Another thing to keep in mind while watching this video is that the oscillator in this case is NOT voltage controlled but resistance controlled - it’s just a simple schmitt trigger combined with eight separate potentiometers and the mux switches between the different resistances. Our project on the other
hand will have a voltage controlled oscillator. But at least this video serves as an example of the step-sequencer part of the overall design.

The above step-sequencer video is just the basic idea. Also in the above example, the notes are totally random which is why it sounds somewhat unpleasant and non-musical.

Here are the connections between IC’s for the TTL stage of the step-sequencer.

The counter is driven by the microcontroller based on the user tempo input. The counter feeds into the two 8:1 analog muxes as well as the two 3:8 decoders. The analog muxes sweep through each of the sixteen steps in the sequence. Likewise, the decoders sweep through sixteen LED’s corresponding to each of the sixteen steps.

**THE VOLTAGE CONTROLLED OSCILLATOR**

The VCO is actually composed of two stages. The first stage is the actual VCO and the second stage is for shaping the VCO sawtooth into a square and triangle waves. This way the user can choose between one of the three waveforms for output.

Basically, it works like this: when a potentiometer turns through one volt, the frequency doubles - so it's linear voltage to exponential frequency. Because we hear sounds exponentially, the analog oscillator has to be linear voltage to exponential frequency. The audible range is roughly 20Hz to 20kHz so if we had a way of sweeping through about 20V to 20kV, then we wouldn’t need the linear to exponential converter. But using 20kV for a synthesizer would be crazy! And even if we could do that, the control would be exponential to exponential and that isn’t what we’re used to in terms of instruments like the piano. And the main reason for voltage control is so that you can feed the VCO with another low-frequency oscillator on top of the voltage controlled note in order to provide frequency modulation (vibrato).
Here is the circuit for the actual VCO. The design was done in Eagle. The VCO works however it needs to be fine-tuned.

Voltage Controlled Oscillator Circuit

The first circuit is for the control voltage. The second is the exponentiator, which takes a linear voltage from the previous circuit and converts it into an exponential current. The third circuit is an integrator followed by a comparator. When the comparator is tripped, a JFET shorts the capacitor, which resets the comparator. This is how the sawtooth is generated.

The second section is the wave shaping stage. Here is the circuit schematic done in Eagle.

Wave Shaping Circuit

The first circuit in the wave shaping section takes the sawtooth output from the VCO and brings it to a rail-to-rail amplitude. The second circuit makes a square wave from the sawtooth by using a basic comparator followed by a complementary emitter follower for rail-to-rail output. The third circuit generates a triangle wave by full-wave rectifying the sawtooth.

Here are some images of the linear voltage to exponential current controlled oscillator that Justin was working on over winter break.

https://drive.google.com/open?id=0B5a_ciY0REleQTNFX2Z2N110WVV2bU9sYzg2TFdzbmN6ZC1N

https://drive.google.com/open?id=0B5a_ciY0REleNVhfa1FncFBLLXcyekpFbUV3YjNfMnFjVlRn

The oscillator section could use a lot of fine tuning. Analog Devices sent Justin ten matched
BJT’s for audio applications (the MAT12 dual-matched NPN transistor), which is the at the heart of the voltage controlled oscillator.

**POWER**

The final piece of the puzzle is fitting the two different power supplies together so that there is only one power supply for the entire system. The VCO section requires plus-minus ten volts (so twenty volts from top to bottom but really twenty-four volts from top to bottom which will then be precisely scaled down to twenty volts top to bottom with a DC-DC converter).

The final product should be plug-and-play which means there can only be one power supply to the whole thing. We would like to make a power supply circuit for the system based on a power supply lab we both did in ECE 342.

**OVERALL**

Overall, there are three sections to our project: The step-sequencer composed of a microcontroller and analog mux, the VCO composed of a linear voltage to exponential current driven oscillator and a power supply circuit which integrates the two sub-circuits onto one system.

Based on the preliminary leg work, we feel that this is a difficult yet achievable goal within a semester’s time and more importantly, the final product will be a really cool instrument to play!