Design of MIDI Audio Synthesizer Module for Musical Applications

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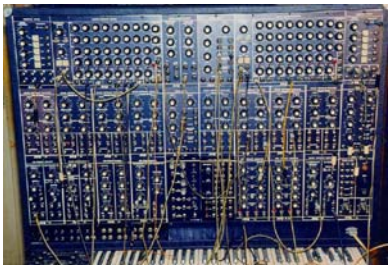
Senior Design Instructor: Professor Paul Lin

History

- 1963 Robert Moog (VCO, amplifier, keyboard) inspired by Herbert Deutsch
- 1970 Minimoog
- 1976 First digital synthesizer
- 1983 MIDI introduced



Project Blocks:

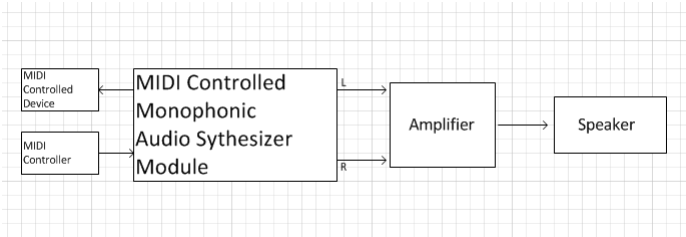
- VCO (Voltage Controlled Oscillator)
- VCA (Voltage Controlled Amplifier)
- System Integrated Circuitry (Op-Amps)
- MIDI (Musical Instrument Digital Interface) [Incomplete]

Purpose of this Project

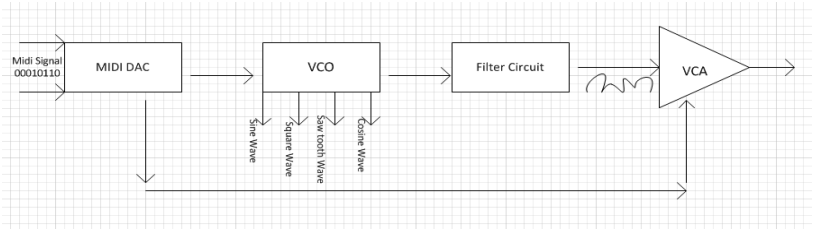
- Produce a Functioning Synthesizer Module for low cost
- Provide basic synthesizer functions
- Explore aspects of MIDI code
- Make noise

Top Level Diagram

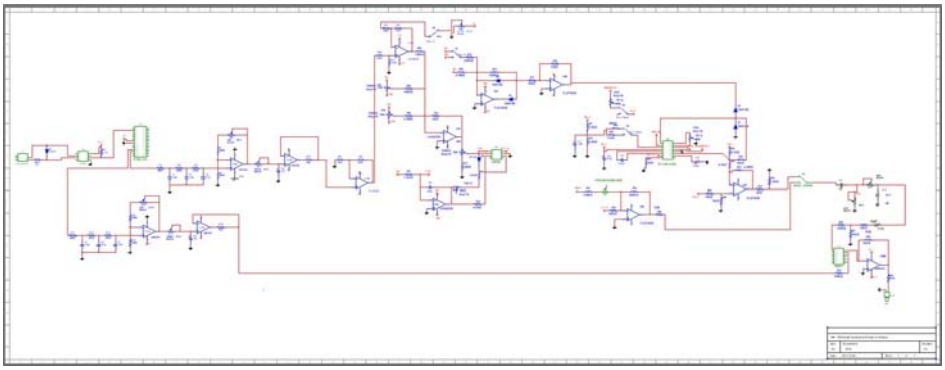
- The block labeled MIDI Controlled Monophonic Audio Synthesizer Module contains the components in this project.



Synthesizer Module Block Diagram

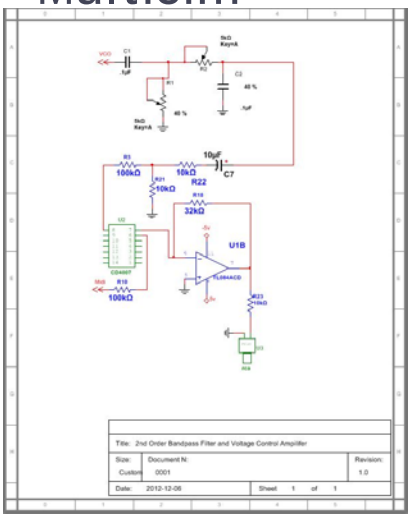


MultiSim



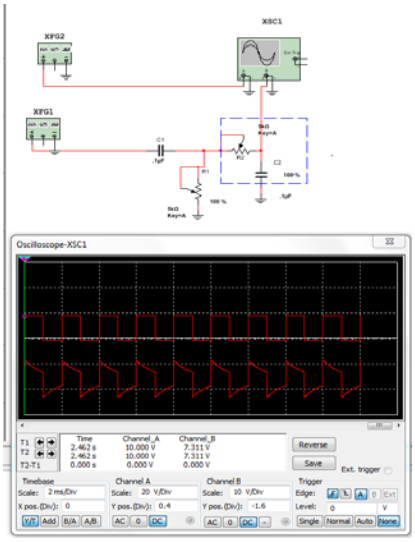
- System Circuit

MultiSim

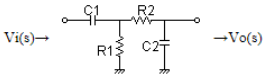


- 2nd Order Band Pass Filter
- 1st Order High Pass Filter
- 1st Order Low Pass Filter
- Adjustable Pot to change filter

MultiSim Simulation Of the Filter



- Band Pass Filter



Transfer function:

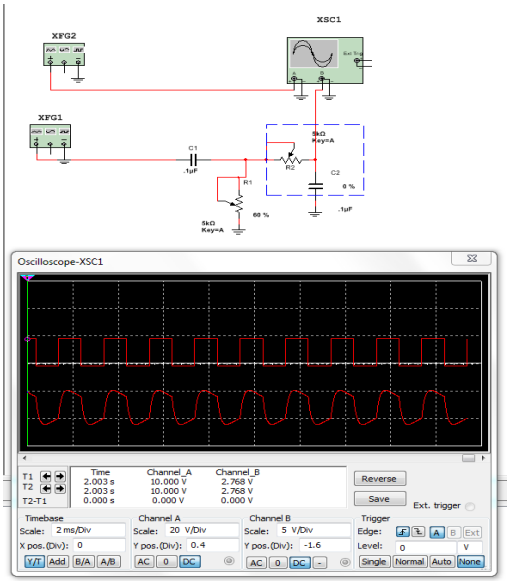
$$G(s)=\frac{2000s}{s^2+6000s+4000000}$$

Center frequency
fc = 318.309886184[Hz]

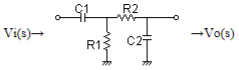
Q factor
Q = 0.333333333333

http://sim.okawa-denshi.jp/en/CRCRkeisan.htm

MultiSim Simulation Of the Filter



- High Pass Filter



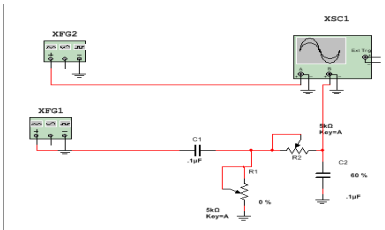
Transfer function:

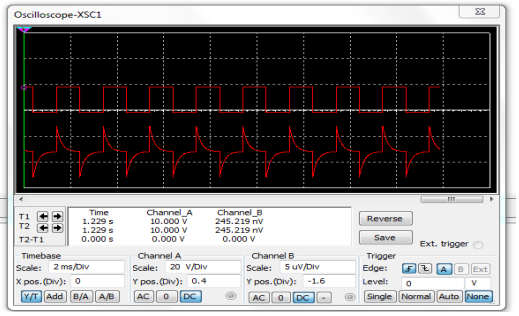
$$G(s)=\frac{10000000s}{s^2+20003333.3333s+33333333333.3}$$

Center frequency
fc = 29057.5841566[Hz]

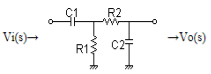
Q factor
Q = 0.00912718809374

MultiSim Simulation Of the Filter





- Low Pass Filter



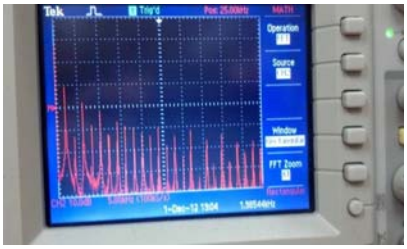
Transfer function:

$$G(s)=\frac{3333.33333333s}{s^2+10006666.6667s+33333333333.3}$$

Center frequency
fc = 29057.5841566[Hz]

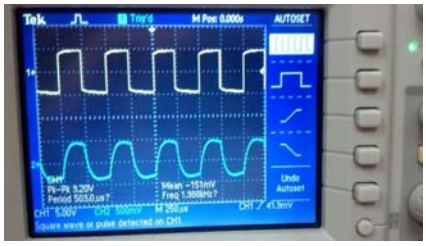
Q factor
Q = 0.0182452550801

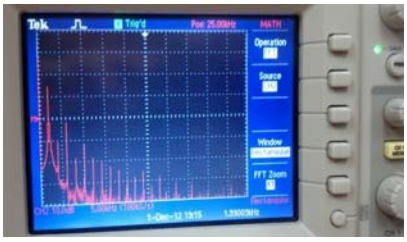
Filter Measurement



Operation of Band Pass Filter

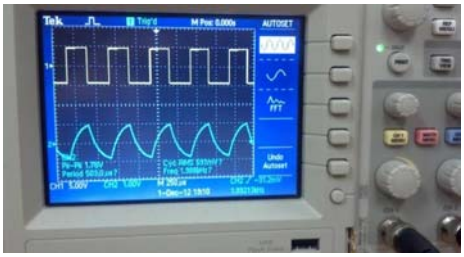
Filter Measurement

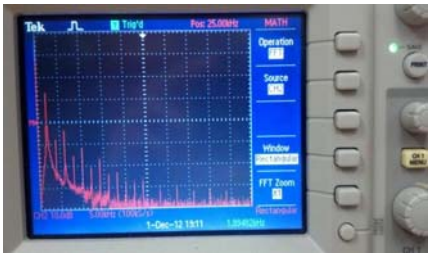




Operation as High Pass Filter

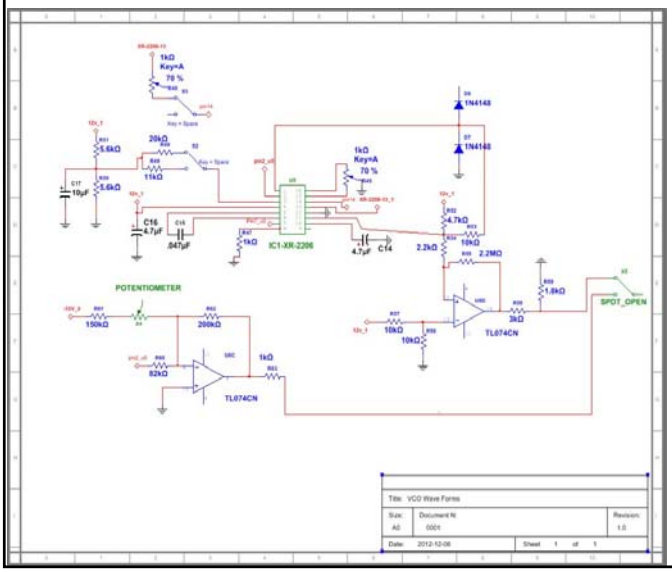
Filter Measurements





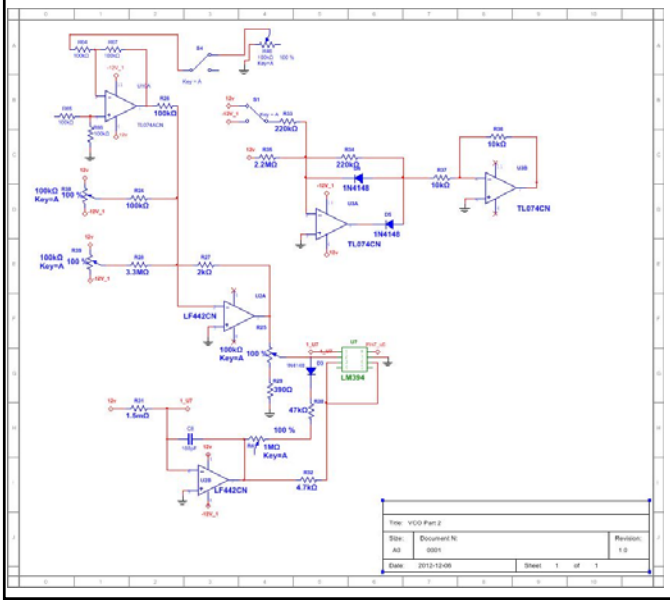
Operation of Low Pass Filter

MultiSim



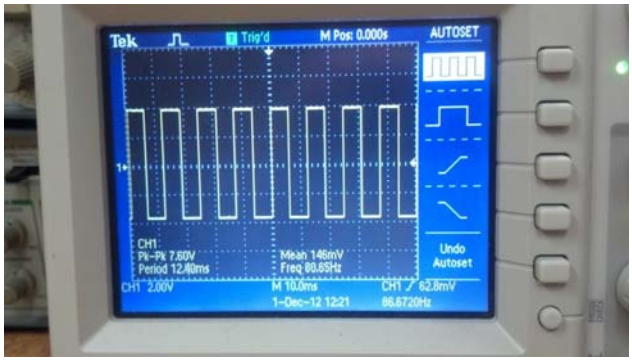
- VCO pg. 1

MultiSim

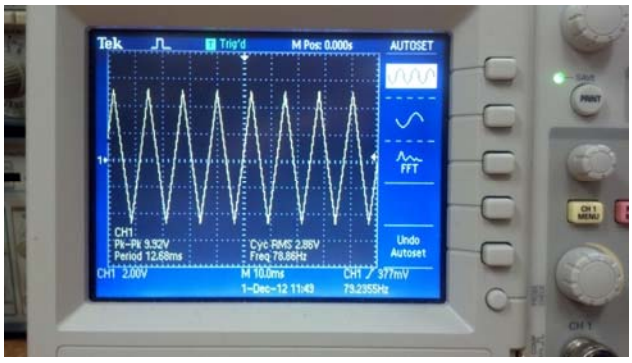


- VCO pg 2

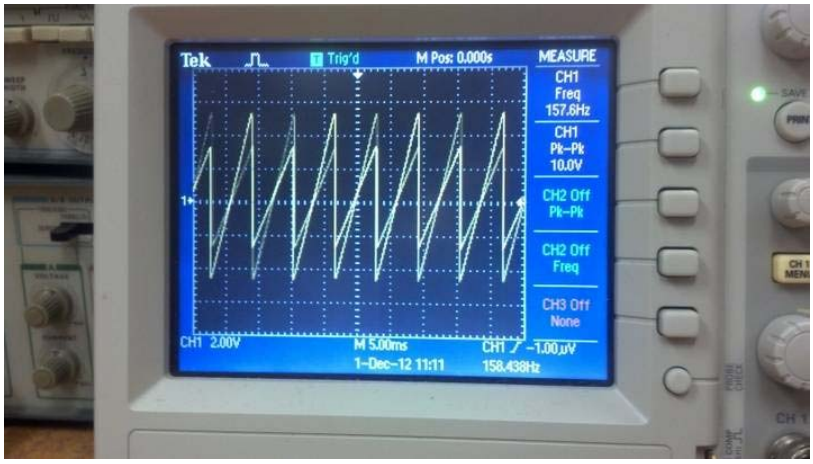
VCO Square Wave



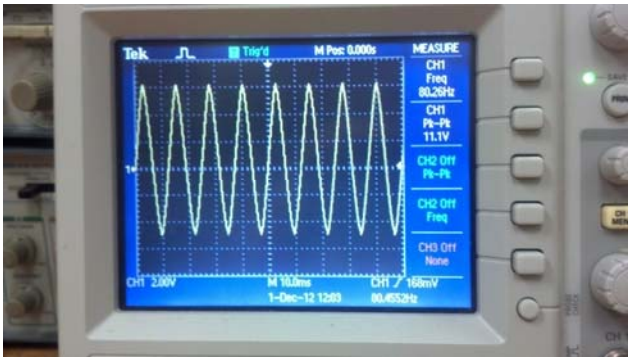
VCO Triangle Wave



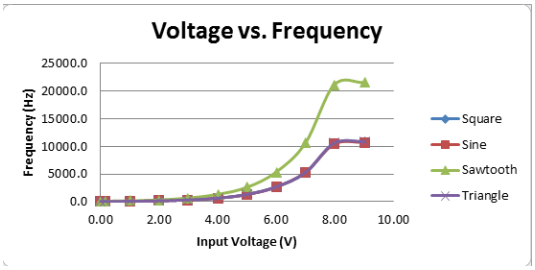
VCO Sawtooth Wave



VCO Sine Wave

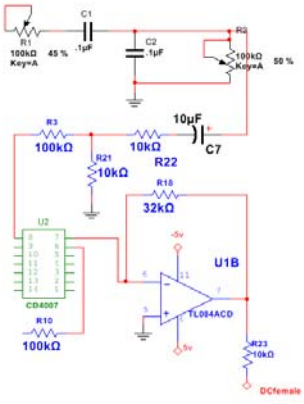


VCO Measurments



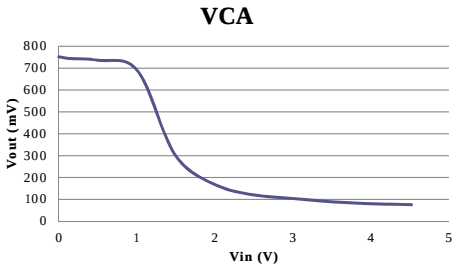
Input Voltage (V)	Square	Sine	Sawtooth	Triangle
0.00	40.3	39.8	77.4	40.0
0.15	44.9	44.5	88.0	44.8
1.00	79.9	80.7	160.0	79.1
1.99	160.3	160.4	322.0	160.3
2.97	318.9	324.7	653.0	320.5
4.01	654.5	646.8	1340.0	631.3
5.00	1309.0	1295.0	2620.0	1333.0
5.99	2675.0	2660.0	5360.0	2695.0
6.99	5251.0	5314.0	10620.0	5291.0
7.97	10490.0	10450.0	21140.0	10610.0
9.00	10910.0	10740.0	21560.0	10870.0

VCA Multisim



VCA Measurements

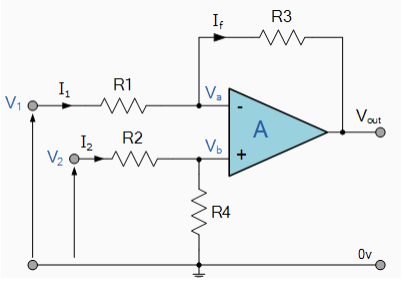
Vin (V)	Vout (mV)
0	752
0.14	744
0.51	736
1.01	688
1.49	304
2.00	168
2.51	120
3.00	104
3.54	88
4.01	80
4.52	76



Op-Amp for Sawtooth

- Difference Op-Amp
- V2 comes from MIDI DAC
- V1 set to 1.00 V
- Saw tooth is 2 times the f at any give voltage, so decreasing by 1.00 gives the same output

$$V_{OUT} = \frac{R_3}{R_1}(V_2 - V_1)$$

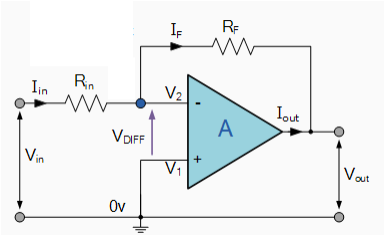


http://www.electronics-tutorials.ws/

Op-Amp for Output

- Inverting Op-Amp
- From filter to VCA
- Attenuates filter to not overdrive audio amplifier
- -Gain does not matter because waveform flipped simply sets signal 180° out of phase

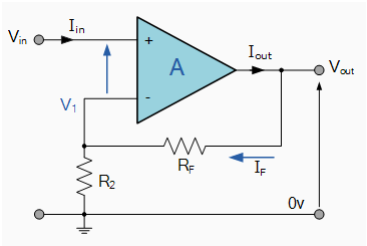
$$\text{Gain (Av)} = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$



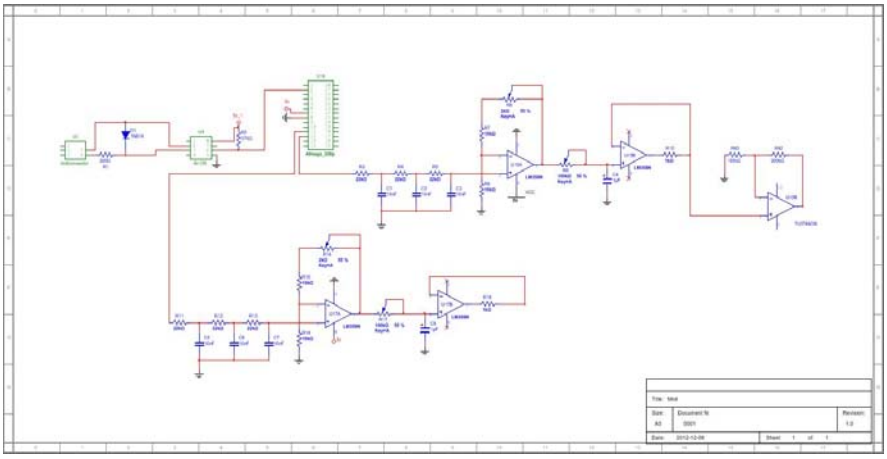
Op-Amp for VCO input

- Non-Inverting Op-Amp
- From MIDI DAC to VCO
- Amplifies DC voltage from 0-4.5V range to 9V range

$$A_{(v)} = 1 + \frac{R_F}{R_2}$$

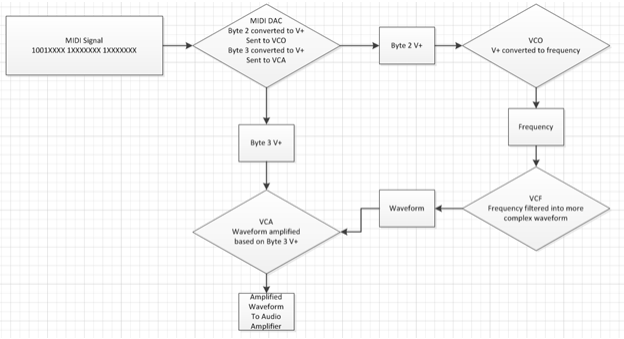


MultiSim



- MIDI DAC

MIDI Software flowchart



Arduino Pros

- Arduino offers a variety of projects and support online
- Arduino's website offered its own MIDI.h header file which makes for easy coding
- The cost of the programmer was inexpensive ($30.00)
- Free Integrated Development Environment (IDE) software

Arduino Cons

- The chip used (ATmega328) cost $5.00 (whereas PIC options are much cheaper)
- Arduino does not actually utilize DAC, the coding is based off of filtering a Pulse Width Modulation (PWM) output
- No prior experience with using Arduino products

Cost

COSTING OF PROJECT			
DATE	SUPPLIER	PRODUCT	COST
7/29/2012	MOUSER	269-ASSORTED COMPONENTS	$59.92
8/24/2012	MICHAELS	5-ORGANIZER CASE	$10.65
8/24/2012	WALMART	LABEL MAKER	$33.98
8/28/2012	RADIO SHACK	2-PROTOTYPE BOARD	$29.98
9/17/2012	JAMECO	3-XR2206CP IC, 15-POTENTIOMETER	$38.52
9/18/2012	MOUSER	65-ASSORTED COMPONENTS	$55.68
9/18/2012	MOUSER	102-ASSORTED COMPONENTS	$48.10
10/7/2012	MOUSER	105-ASSORTED COMPONENTS	$37.50
10/7/2012	JAMECO	8-ASSORTED COMPONENTS	$42.34
11/18/2012	RADIO SHACK	2-PROTOTYPE BOARD	$32.98
11/20/2012	RADIO SHACK	2-PROTOTYPE BOARD	$19.98
11/26/2012	MOUSER	110-ASSORTED COMPONENTS	$107.81
11/30/2012	RADIO SHACK	JUMPER CABLES	$7.69
12/1/2012	RADIO SHACK	PROTOTYPE BOARD, CAPACITORS	$25.74
	VARIED	MISCELANEOUS SUPPLIES *	$100.00
TOTAL			$650.87

* INCLUDES WIRES, BOOKS, CABLES, AND LAST MINUTE CHANGES

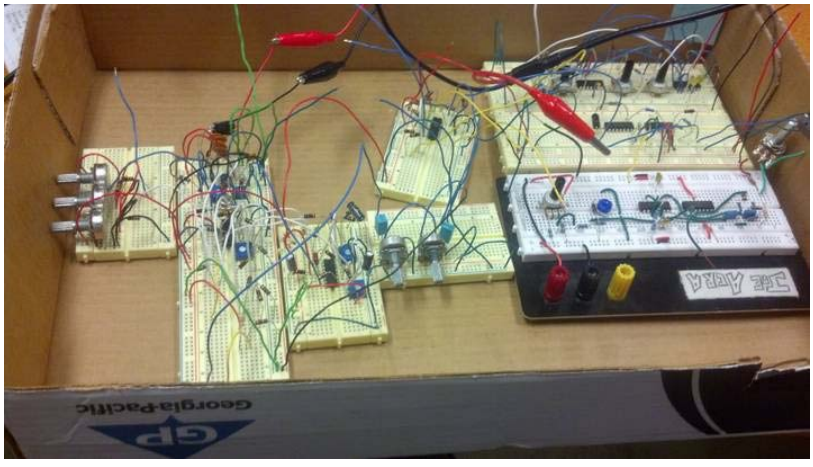
Problems

- Scope of the Project
- Reverse Engineering (VCF, VCA modifying, VCO modifying)
- Coding
- Power Sources
- Obsolete Parts (LM 394)

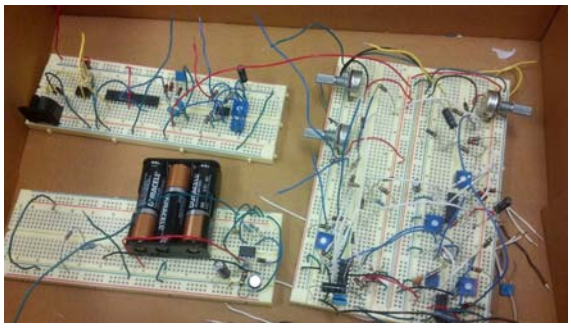
Improvements

- Working MIDI DAC
- True Sawtooth Waveform
- Active Bandpass filter (Greater Q Value)
- Power Supply

Final Product



Testing Circuits



References

- REFERENCES
- [1] D. M. Huber, *The Midi Manual*, 3rd ed. Burlington, MA: Focal Press, 2007, ch. x, sec. x, pp. 15,76.
- [2] L. Tan, *Digital Signal Processing*, Burlington, MA: Academic Press, 2008, ch. x, sec. x, pp. xxx-xxx.
- [3] W. D. Stanley, *Transform Circuit Analysis for Engineering and Technology*, 5th ed. Upper Saddle River, NJ: Prentice Hall, 2003, ch. x, sec. x, pp. xxx-xxx.
- [4] F Welsh, *Welsh's Synnthesizer Cookbook Vol. 1 & 2*, 3rd ed. Xxxx city, ST, PUBLISHER, 2006, ch x, sec. s, pp. xxx-xxx.
- [5] T Censi, A Gordon Jr., *Labolida Synthesizers* [Online], Available FTP: http://www.sdiy.org/labolida/index.htm
- [6] B. S. Blanchard, *System Engineering Management 3rd ed.* Hoboken, NJ: John Wiley and Sons Inc., 2004. ch xx sec. x, pp. xxx-xxx.
- [7] http://www.midi.org
- [8] http://www.digikey.com/Web%20Export/Supplier%20Content/api-technologies-1171/pdf/api-ptc-engineering.pdf?redirected=1
- [9] http://zebu.uoregon.edu/~rayfrey/431/notes9.pdf
- [10] http://tams-www.informatik.uni-hamburg.de/applets/cmos/

Questions

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