BARTON MUSICAL CIRCUITS

BMC035. Bytewise Operator

Last updated September 15th, 2015

I. Features

WHAT IT DOES

The bytewise operator is a microcontroller based synth module that creates a voltage output based on two voltage inputs. The output can be derived by performing one of four operations between the two voltages, XOR, AND, summing and difference. In addition to the voltage output, there is an expander for the module which provides direct access to the individual bits of of the voltage output as gates.

If you're unfamiliar with them, XOR and AND are each logic operations which compare single bits of information. The voltages on the input are converted digitally into binary numbers (a series of 1s and 0s). These operations ignore the actual voltages that these series of 1s and 0s represent and instead only focus on the each individual bit. The logic behind the operations is this:

1 XOR'd with 1 = 0	1 AND'd with 1 = 1
1 XOR'd with 0 = 1	1 AND'd with 0 = 0
0 XOR'd with 1 = 1	0 AND'd with 1 = 0
0 XOR'd with 0 = 0	0 AND'd with 0 = 0

Below is a table showing an example of voltage inputs/outputs for the different operations used. The digital representation is shown in both binary and decimal form to help illustrate how the different functions use the numbers. The XOR and AND interact only at the individual bits of the binary representation, while the Sum and Difference is more easily understood when looking at the decimal representation.

NAME	Voltage	Binary	Decimal
X Input	+4.009V	1100110101	821
Y Input	+4.902V	1111101100	1004
XOR Output	+1.045V	11011001	217
AND Output	+3.925V	1100100100	804
Sum Output	+3.911V	1100100001	801
Difference Output	+0.894V	10110111	183

It may seem odd that the Sum is actually lower than each of it's individual parts, but this oddity is actually what seperates it from an analog summer. Because the output is only 10 bits of resolution the largest number in decimal form it can represent is 1024. When adding 821 and 1004 we get 1825 which is 801 more than 1024.

CONTROLS/INPUTS/OUTPUTS

CONTROLS

1. Input Voltage Attenuator Knobs – One of these is present for X and Y inputs.
2. Voltage Offset Knobs – This offsets the input voltage or acts as a manual voltage for X and Y.
3. Operation Select Switches – These two switches select which operation is performed to find the output voltage. “OS1” selects whether XOR/AND or SUM/DIFFERENCE is selected, and then “OS2” selects which of the two selected by switch one is used.

4. Y Update Denormalization Switch – This is an optional switch to undo the normalized connection to +5V on the Y update input. This allows for the manual Y Update button to be used.
5. Manual Y Update Button – This optional control allows the Y voltage to be updated by pressing a button instead of constantly updating or needing an external gate. By only sporadically updating Y voltage, the X voltage can be tracked at a higher rate, which gives better results when processing fast moving inputs.

INPUTS

1. Voltage Inputs – These are repeated for each X and Y. By adjusting the the Attenuation and Offset controls, these inputs can be of most any typical synthesizer voltage range.
2. Update Inputs – This is repeated for X and Y. When +5V is present at these inputs, the microcontroller reads the respective voltage input. These jacks are normalized to +5V so the module normally reads both inputs at all times.

OUTPUTS

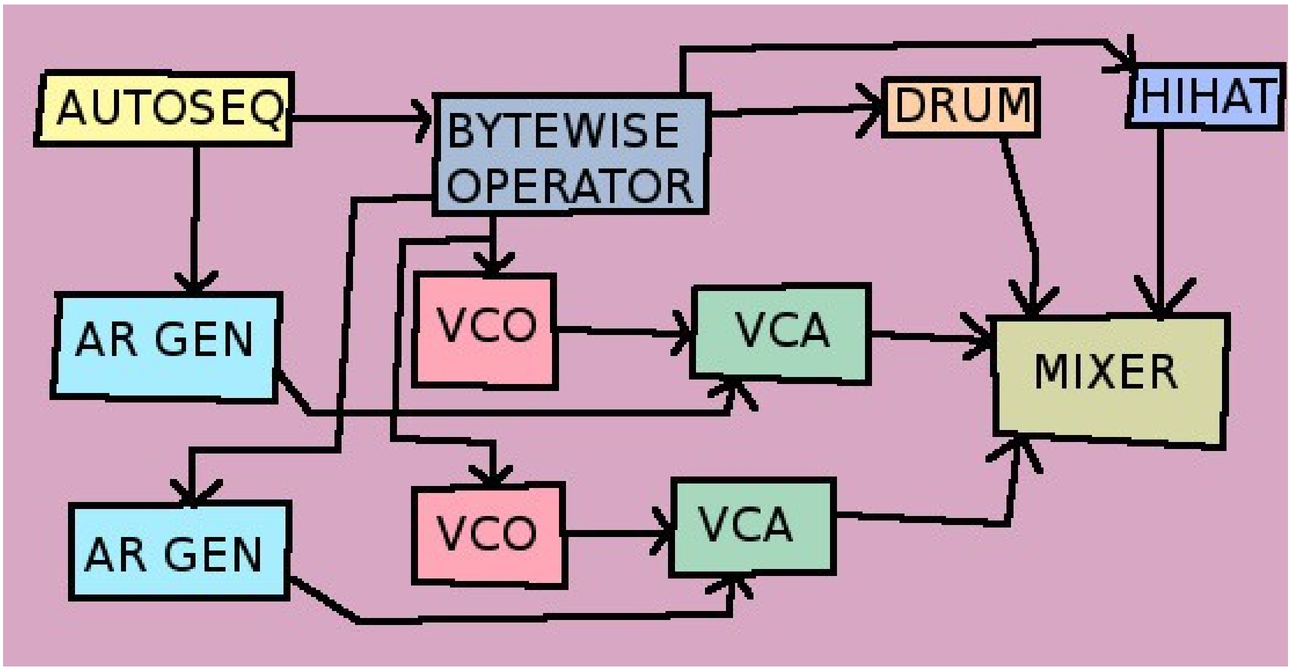
1. +5V/-5V Output – This outputs is DC coupled with a range of -5V to +5V
2. +5V/0V Output – This output is DC coupled with a range of 0 to +5V

DEMOS

There are two youtube videos showing this module. They can be found here and here.

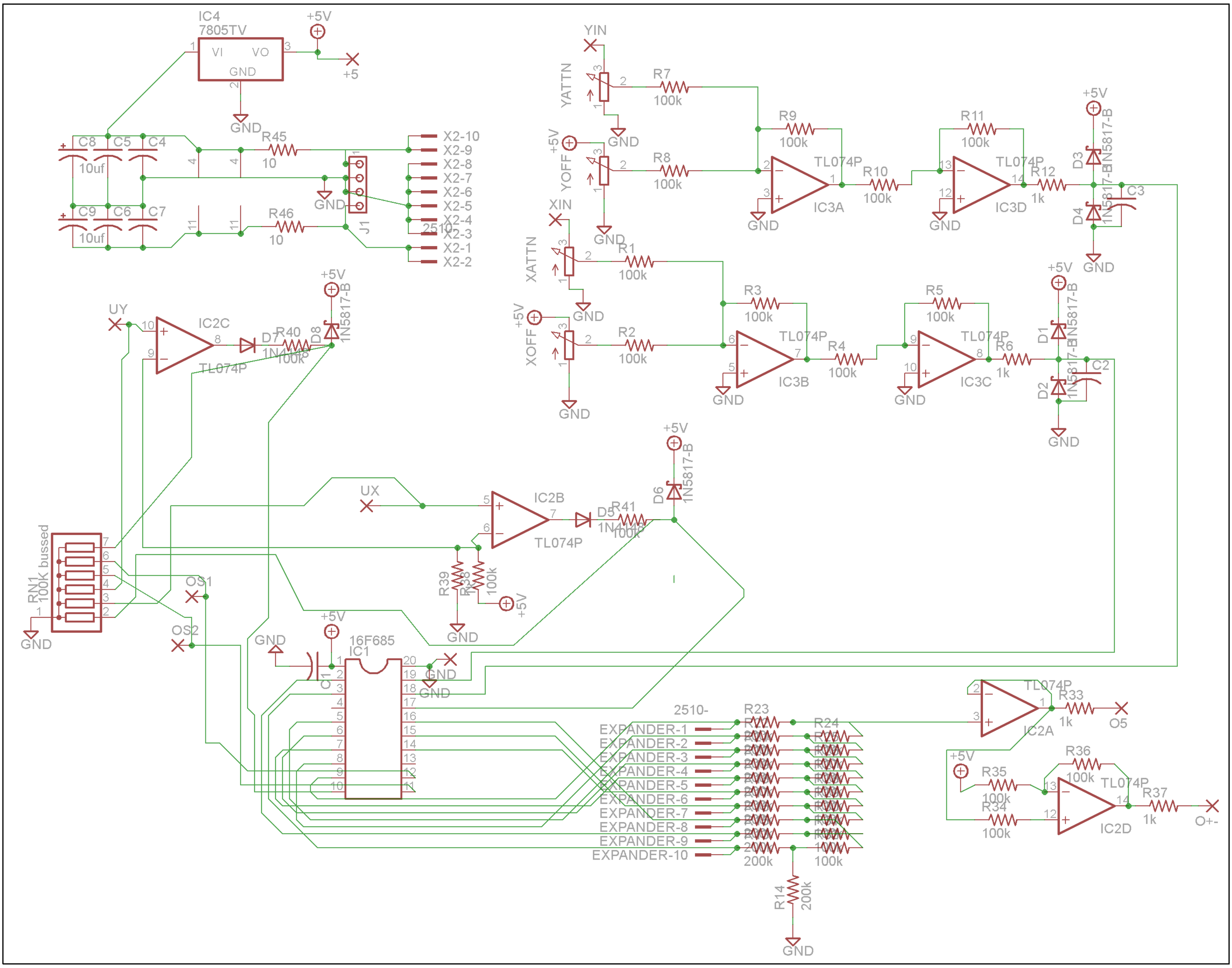
The patch used in the second video is presented in a diagram below. I also recorded MP3s of adjusting the Y input on this patch.

The first MP3 is with the module in XOR mode and the second is of the module in AND mode.



II Schematics

MAIN SCHEMATIC



The above schematic shows everything other than the expander module. All of the individual parts of the module are simple to understand on their own, so I'll only briefly describe the circuit. At the top left is the power section, the 10 ohm resistors and 10uf capacitors filter noise from the power rails and additional .01uf capacitors are at each power pin of each IC to reduce noise further.

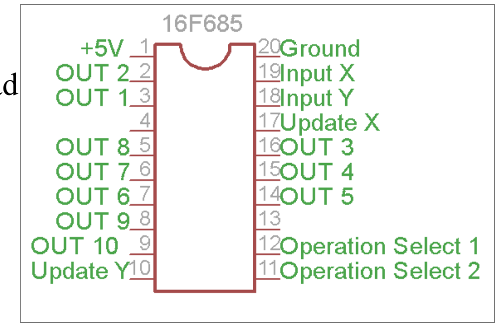
To the right of the power section is the analog input section. Inverting mixers sum the input with it's offset voltage and then a unity gain inverting amplifier corrects the polarity. This is then followed by a network of schottky diodes which limit the voltage to 0 and +5V in order to protect the microcontroller. Finally a .01uf capacitor filters the voltage before going to the microcontroller.

The UY and UX inputs are each fed into a comparator with a very low threshold, their outputs are then reduced to the 0/+5V range by networks of diodes in order to protect the microcontroller. A bussed array of 100K resistors is used on the inputs of these comparators and also on the pins of all the digital inputs of the microcontroller (the update controls and operation select switches).

The output pins of the microcontroller are directly connected to the header which attaches this module to it's expander. These pins are then connected to an R/2R network which converts the digital outputs to an analog voltage. This voltage is buffered and then sent to the +5V output. The +5V output is then sent to a non-inverting gain stage with an offset in order to achieve a +/-5V output.

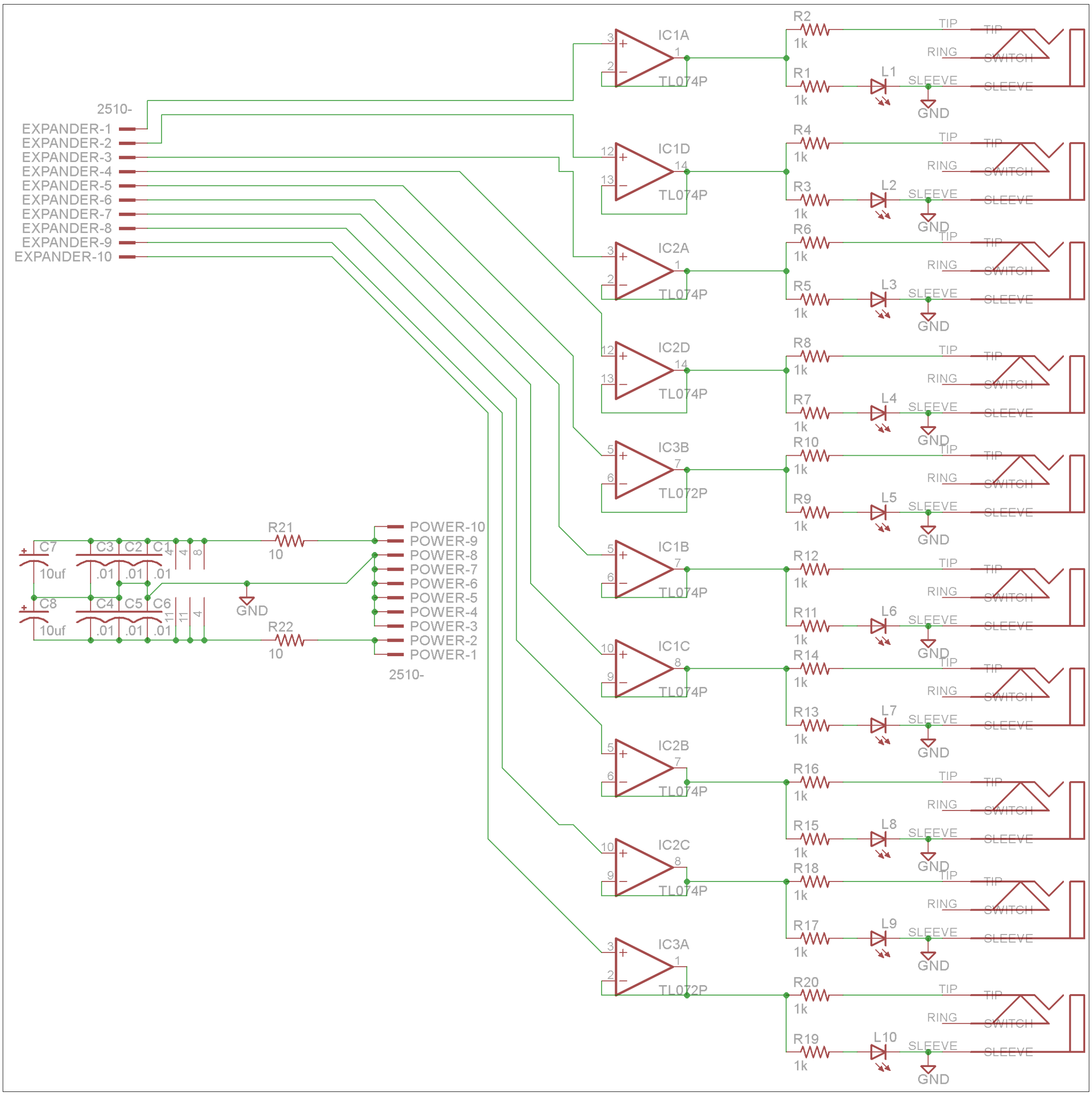
PINOUT

To the right is the pinout of the microcontroller. Because of all the connections to it, it may be difficult to read this section of the main schematic.



EXPANDER

Below is the schematic for the expander. It is composed of 10 op amp buffers, each of which goes to an output jack and an LED.



III. Construction

MAIN PCB Parts List

Semiconductors

Value	Qty	Notes
16F685	1	Should have come with your PCB
TL074	2	DIP packaging, any quad op amp should be fine
Switching diode	2**	1N4148 or similar
Schottky Diode	6	BAT42 or similar
7805 Voltage Regulator	1	

Resistors

Value	Qty	Notes
10 ohm	2	1/4W Metal Film
1K	5	1/4W Metal Film
100K	25	1/4W Metal Film
100K Bussed Array	1	7 Pin, or make your own with 6 more 100K resistors *
200K	11	1/4W Metal Film
B100K Pot	4	16mm PCB mounted

Capacitors

Value	Qty	Notes
10uf	2	Electorlytic 5mm
.01uf	7	Ceramic disc. 2.5mm lead spacing

Other

Value	Qty	Notes
Power Connecter	1	Eurorack or MOTM style
Expander Connecter	1	Same as Eurorack power connecter. 2.54 spacing 10 pin two rows.
14 Pin DIP Socket	2	
20 PIN DIP Socket	1	
Knob	4	
Jack	6	Switching type
Toggle Switch	2**	On-On Type

To learn how to make an array, visit this poorly drawn page.

**** If including the optional De-Normalization switch and manual Update Y, add one more switching diode, one more toggle switch and a (ON) – OFF type pushbutton.**

EXPANDER PCB PARTS LIST

Semiconductors

TL074	2	DIP Packaging, any quad op-amp is fine.
TL072	1	DIP Packaging any dual op-amp is fine
LED	10	3mm

Resistors

10 ohm	2	1/4W Metal Film
1 K ohm	20	1/4W Metal Film

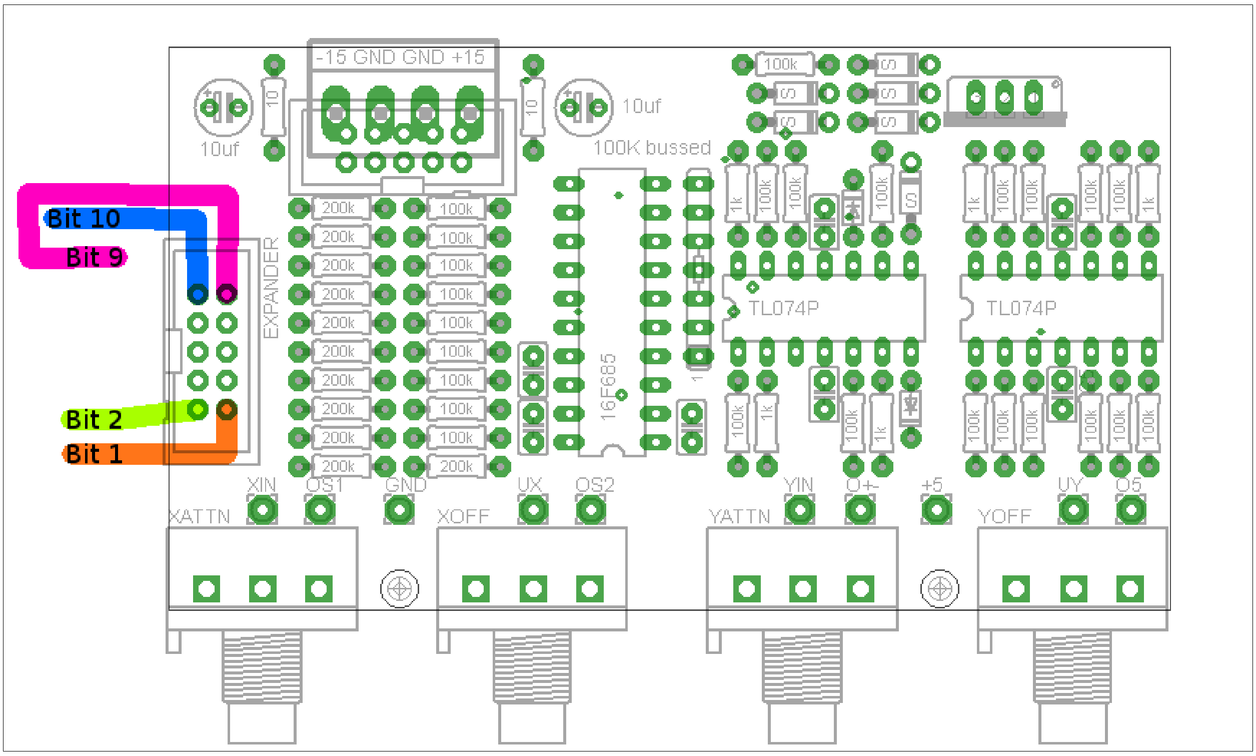
Capacitors

.01 uf	6	Cheap ceramic disc
10 uf	2	Electrolytic 12V rating or higher

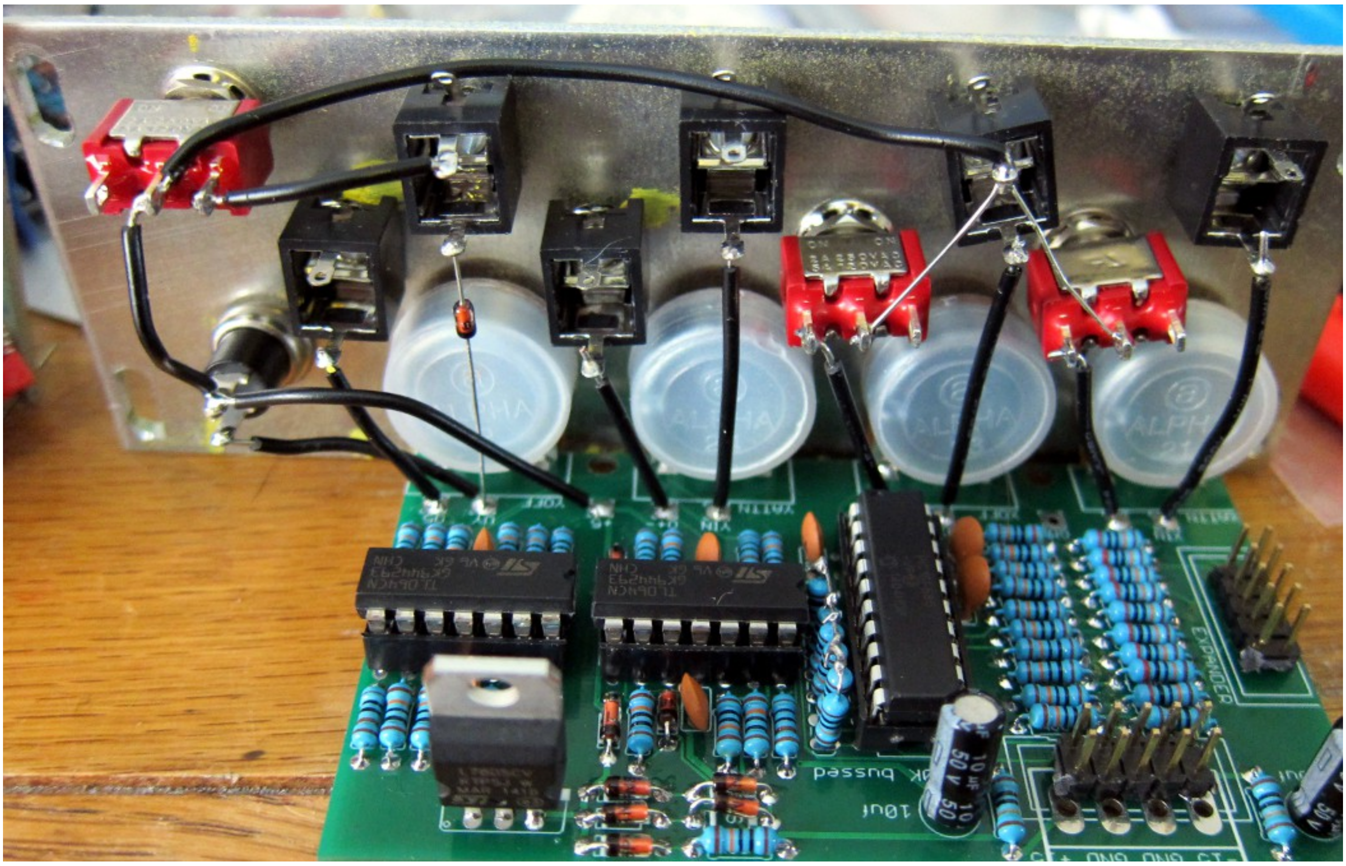
Other

Eurorack Power Connecter	2	
3.5mm Jack	10	[I use these.](#)

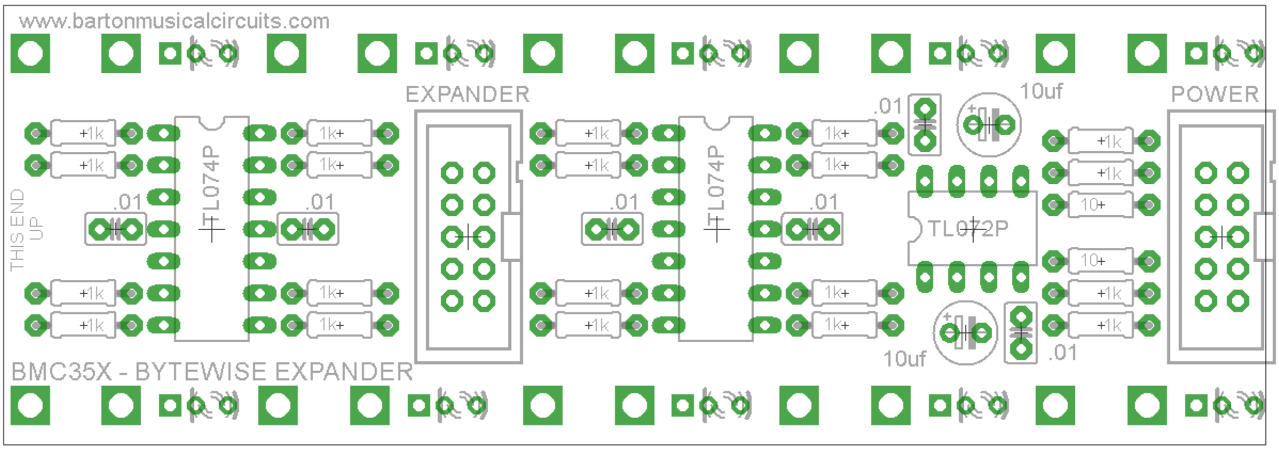
PCB INFORMATION



Above is the Main PCB for this module. On the left is the pinout for the expander header. The PCB's dimensions are 3.475” X 1.9625.” The mounting holes are provided for those who don't want to use PC mounted pots. They are 1.875” apart. The pots are spaced 15/16” apart.



Above is a photo of my wiring for the main PCB. I have installed the optional denormalization circuitry for Update Y.



Above is the image for the top of the expander PCB. The PCB is 3.95” x 1.375”. The jacks are spaced .775” apart vertically and 1.1” apart horizontally. It is designed to be attached parallel to an 8HP Eurorack panel.